GBMINERALS LTD

FARIM PHOSPHATE PROJECT

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

VOLUME 4 – TECHNICAL SUPPORTING DOCUMENTS

Knight Piésold CONSULTING

VOLUME 4 – TECHNICAL SUPPORTING DOCUMENTS

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FARIM PHOSPHATE PROJECT, GUINEA-BISSAU

Mine Component Environmental and Social Baseline Studies

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1.0 ENVIRONMENTAL AND SOCIAL BASELINE STUDIES

1.1 Background Information

1.1.1 Introduction

Golder Associates has been commissioned by GB Minerals Ltd to undertake environmental baseline studies to inform an Environmental and Social Impact Assessment (ESIA) for the Farim Phosphate Project (the Project) in Guinea-Bissau. The Project is located in the central northern part of Guinea-Bissau, and consists of a high grade sedimentary phosphate deposit which extends over a known surface area of approximately 40 km^2. The life of mining operations is expected to be 25 years.

It is planned to develop the Project as an open pit mining operation to supply a processing plant with an annual production of 1 Mtpa of phosphate rock concentrate product. Significant positive effects are expected from this Project, especially in economic terms at both national and local levels. It is expected that there will be potential adverse impacts on the environment and on the lives of local communities. The overall aim of the ESIA is to identify and assess these potential environmental and social impacts that may be a consequence of the Project. The ESIA will determine if these potential adverse impacts can be avoided, reduced or offset, to the extent practicable, as part of the Project design. This is an iterative process during the Project design and requires the engineering, environmental and social specialists involved to have a regular dialogue.

The proposed mine design has developed during the course of the baseline studies and the location of prposed mine facilities identified on plans may vary.

1.1.2 Scope of Work

Baseline field studies for the physical, biological, human and socio-economic environments were completed in 2013. These studies included field studies and desk top reviews of available information describe the baseline conditions of the Project area. Surveys were conducted over a period of one year for some specialist studies to record variations between the dry and wet seasons.

Public consultation on the Project commenced in April 2011 when high level meetings took place with government departments and a meeting of village leaders (Golder, 2011). Consultation is an ongoing process and two further rounds of consultation took place in March 2012 and December 2013 at national, regional and local levels, with representatives from the Guinea-Bissau Government, local authorities, and stakeholders from communities in the local study area.

1.2 Legal and Institutional FrameworkNational Environmental and Social Policy

The Constitution of Guinea-Bissau establishes sovereign rights for the Republic of Guinea-Bissau for the preservation or exploitation of living and non-living natural resources. GB Minerals is committed to adhering to national constitution and regulations of Guinea Bissau. In addition, GB Minerals will apply international and industry best practice guidelines relating to extractive industries to the development of the Project.

1.2.1 National Regulatory Authorities

The key national regulatory authorities involved in permitting and environmental management of extractive industries are the Ministry of Natural Resources and Energy, Industry, & Natural Resources, in collaboration with the Secretary of State of Environment and Tourism.

The Ministry of Natural Resources and Energy is the government agency responsible for regulating the mineral industry in Guinea Bissau. The Ministry has a function to prepare and implement mining policy and regulation, promote exploration and develop geological studies and maps. This ministry issued the Mining Agreement (May 2009), which provides the necessary permits for development and exploitation activities for the Project.

The Secretary of State for the Environment and Tourism is responsible for Guinea-Bissau's environmental policy. The Directorate General of Environment includes three services:

- Service Branch of the Urban Environment;
- The Directorate of Operations Department of Natural Resources; and

- Service Management of Protected Areas.

The Secretary of State of the Environment and Tourism reviews the ESIA for the Project, and makes a recommendation to the Ministry of Natural Resources and Energy regarding the implementation of the Project. This recommendation is based on the determination of the lead authority, Célula de Avalição de Impacte Ambiental (CAIA). This department was founded in 2005, with the following responsibilities:

- Create a legal framework for environmental impact assessments in Guinea-Bissau;
- Ensure that all development projects initiated in the country are analysed for their potential environmental and social impacts before the existence of a national law for the sector; and
- Ensure that proposed measures to mitigate the impacts of development projects are implemented.

CAIA, under the terms of its decree, advises the Prime Minister and Secretary of State of Environment and Tourism on environmental issues and is tasked with providing:

- Support to the establishment of a procedure for environmental impact assessment;
- Ensure, in collaboration with relevant institutions, monitoring of mitigation of environmental impacts;
- Ensure the compliance of the environmental assessment process and advise on studies/environmental study reports; and
- Seek and take into account the technical advice of the authorities in charge of the environment.

It is acknowledged that further national and regional regulatory agencies may be active in monitoring the Mine's performance against their requirements (such as, wildlife and forestry, workplace health and safety, work permits).

1.2.2 National Legislation and Regulation

Further to the constitution, a number of laws related to environmental protection and management have been passed. The National Environmental Management Plan (NFSP; 2004), outlines the national policy on environmental conservation and sustainable development based on principles of equality and equity, environment and development, precaution, preservation, protection, and valuation of natural and built heritage.

The NFSP focuses on strengthening institutional capacity for environmental management, managing land degradation, land use, water resources and water supply, renewable energies, information management, education and environmental awareness, research, rational use of mineral resources, and monitoring of multilateral agreements related to the environment.

The legislation most relevant to the Project is summarised below.

1.2.2.1 Mining and Minerals Law

Law 1/2000 (the Mining and Minerals Law) regulates all issues related to the exploration and commercial production of mining substances that exist in the soil or subsoil and in the territorial waters, with the exception of oil. All mining resources in Guinea-Bissau belong to the State and property rights and the issuing of licenses/permits is the sole responsibility of the government. The Mining and Minerals Law sets out the procedures which enable individuals and entities (national or foreign) to be issued with mining leases, licenses, and rights. The law also establishes:

- The application process, timeframes for consideration, and method of notification;
- Conditions to be met for the issue of or an extension to mining leases or mining rights;
- Grounds on which the minister can reject application, suspend mining rights, or investigate suspected infractions;
- The duration of mining leases, licences, and rights;
- Requirements to install markers at the boundary of mining lease area;

- Requirements regarding records to be kept on-site and records to be handed over at the end of a mining lease;
- Requirements to assess and manage any environmental impacts, including restrictions on the proximity between operations and residential or agricultural properties, and the requirement to develop an Environmental Plan;
- Obligations should mining operations be suspended or halted;
- Fees and taxes to be paid for applications, extensions, and income gained from the sale of minerals; and
- Sanctions for infractions against the regulations.

1.2.2.2 Basic Law on the Environment

Guinea-Bissau has developed a framework law on the environment that lays the foundation for environmental policy and environmental assessments. Law No 1/2011 of 2 March 2011 approves the Basic Legislation on the Environment. This law defines the basic concepts, norms, and principles related to the protection, preservation and conservation of the environment. It aims to improve quality of life through the management and rational use of natural resources, to achieve the sustainable use of such resources.

1.2.2.3 Regulation of Environmental Impact Assessment

Law 10/2010 (the Environmental Assessment Law) regulates environmental and social impact assessment in Guinea-Bissau. It identifies environmental assessment as the fundamental preventative tool of environmental policy, and is an important component of the government's overarching policy of sustainable development.

The Environmental Assessment Law sets out the types of projects for which an ESIA is required and the categorisation of these projects is in line with the IFC's categories:

1. **Category A projects** have high risks of having several very negative impacts with significant effects on the environment and human health, and sometimes irreversible with large scale effect;
2. **Category B projects** are likely to have on population and environmental less sever negative impacts than the previous category and are generally impacts of local nature with possibilities of having special mitigation measures;
3. **Category C projects**: negative impacts on the environment and on human health are considered insignificant or nil. After prior analysis, no other measure of environmental assessment is required for projects in this category.

In line with IFC guidelines, the Farim Phosphate project is classified as a Category A project due to the size of the operation. As such, a full ESIA is required for the Project.

The Law details the ESIA processes to be followed, requirements for public consultation and disclosure, the components of the studies to be undertaken and resulting reports, and the government agencies that will be involved in the assessment process. Requirements are set for environmental and social management plans, which must present recommended mitigations, monitoring, capacity building, and a schedule and cost estimate to implement the mitigation measures.

The ESIA will be considered by a committee appointed by the environmental authority. If the committee approves the report, the authority will issue an environmental licence: either a compliance declaration that gives the project proponent one year to implement initial management measures, or a compliance certificate that gives the proponent a licence to operate for one to five years. The law further establishes the government's authority to conduct environmental audits (at the expense of the proponent) to check compliance with the conditions of the environmental license.

The National Strategy and Action Plan for Biodiversity (2004) sets out national guidance on conservation and sustainable use of biological diversity.

1.2.2.4 Additional Legislation

A summary of additional available legislation relevant to the Project is provided in Table 1-1, although this list is not exhaustive.

Table 1-1: Summary of Relevant Guinea-Bissau Regulation (titles translated from Portuguese)

Name of Law, Code, or Article	Date Adopted	Description
Decree-Law No. 11/2011 creating the National Institute of Meteorology of Guinea-Bissau	2011	Approves the creation of the National Institute of Meteorology of Guinea-Bissau (INM-GB), which is responsible for implementing national policy, collection and analysis of data, delivering the weather forecast and dissemination of information, research on climate change and potential impacts on local populations.
Decree-Law No. 10/2011 approving the Basic Fishing Legislation	2011	Regulates fishing and fishery resources, including licensing requirements, processing, and hygiene controls. It also establishes fishery inspections and fines to be paid for illegal fishing activity.
Decree No. 24/2011 approving the Regulation on Artisanal Fisheries	2011	Regulates artisanal fishing within inland waters and territorial sea to enable sustainable exploitation. It specifies fishing zones and requirements for fishing vessels, licenses, gear and methods. It also prescribes inspections, controls and fines to be paid for illegal artisanal fishing activities.
Decree-Law No. 8/2011 regulating economic activities in industry, trade and tourism sector	2011	Regulates economic activities in industry, trade and the tourism sector. It also specifies requirements for authorisation to perform economic activities related to: human health, environmental preservation, human or goods safety, and natural resource protection.
Order of 21 March 2011 creating the Environmental Impact Assessment Institution (CAIA)	2011	Creates the Environmental Impact Assessment Institution (CAIA) aimed at supporting enterprises and institutions in environmental impact assessment, guarantees the monitoring of mitigation measures and gives advice on research related to this sector.
Decree-Law No. 5-A/2011 establishing the legal framework of protected areas	2011	Establishes the legal framework for protected area, including the classification and declassification of protected areas, and sets out the authorities responsible for the protection of natural ecosystems, fauna and flora, including promotion of its sustainable development. It classifies protected areas as follows: National park; Integral Natural Reserve; Wild Heritage Area; Natural Monument; Area managed for its habitat and species; Protected natural or marine heritages; Protected managed area of natural resources; Community protected areas and forests and sacred sites.
Decree-Law No. 5/2011 approving the New Forestry Law	2011	The Forestry Law aims to promote sustainable exploitation of forestry resources, achieving improved quality of life (including socio-economic and cultural development) through the promotion and rationall exploitation of forestry resources. Establishes the requirements for authorised forest exploitation activities, public and private forest management, tree logging authorization/prohibition and wood sale, and establishes forestry protection measures in order to avoid forest fires and sanctions for offenders.

Name of Law, Code, or Article	Date Adopted	Description
Decree No. 10/12 creating the Institute of Biodiversity and Protected Areas (IBAP)	2005	Establishes the composition, duties and responsibilities of the Institute of Biodiversity and Protected Areas. Its role is to propose, coordinate and implement policy and other activity related to biodiversity and protected areas, to promote and preserve local ecosystems, and promote the socio-economic and sustainable use of natural resources, including water resources in continental and marine areas.
Decree-Law No. 2/2004 establishing the basic norms for protection, promotion and exploitation of Wildlife	2004	Establishes the basic norms for protection, promotion and exploitation of wildlife. It specifies requirements for activities related to wildlife: endangered animal species protection, authorised wild animals to be caught, hunting areas, authorized methods and seasons. It also regulates hunting licence requirements, controls and sanctions for illegal activity.
Law No. 1/2000 approving the Mining Act	2000	The Mining Act regulates any geological and mining activity and in particular: geological research, investigation, finding and classification of minerals, characterization, assessment, exploitation, commercialisation, and use of existing mineral resources in the soil, underground, except for oil and hydrocarbons products. It establishes the provisions regulating rights related to National mineral resources exploitation and competencies for implementation and control of established objectives for prospection, mining exploration, treatment and commercialization of minerals within the territory of Guinea-Bissau.
Land Act No. 5/98	1998	Regulates land-use planning and rational exploitation of land. Land is property of the Government of the Republic of Guinea-Bissau, its exploitation is allowed only under concession or authorization granted by the Government. This Law lays down the requirements to be satisfied in order to obtain a land concession.
Decree-Law No. 3/97 approving the Legal Regime for Protected Areas	1997	Approves the legal regime for protected areas and specifies the requirements for protected areas to preserve natural ecosystems, to protect flora, fauna and biological diversity, and promote the rational and sustainable economic use, including water courses, lakes, sea, which can be classified by Decree as National or natural parks, sanctuary, protected areas or sacred forests.
Legal Framework on Protected Areas	1996	Establishes the basic legislation on protected areas, specifying the requirements to be satisfied in order to preserve flora and wildlife ecosystems and to manage forestry resources. It concerns protected areas classification and creates the Protected Areas' Council. It lays down the conditions to be satisfied in order to obtain an authorisation for forest exploitation. Sanctions and penalties are prescribed for unauthorized activities
Decree No. 52/92 creating the National Committee on Water (CNA)	1992	Creates the National Committee on Water (CNA) and its composition, duties and responsibilities to: design policy on water resources, control public and private water exploitation, under the supervision of the Inter-ministerial Committee of Waters (CIMA).

Name of Law, Code, or Article	Date Adopted	Description
Decree-Law No. 5-A/1992 establishing the Water Code	1992	Establishes the Water Code and its objectives: defining the legal regime of all activities relevant with water management, defining the institutional framework to implement national policy on water rights, guaranteeing the control and management of water resources, regulating water uses, guaranteeing the protection of the water quality in order to avoid freshwater pollution or its waste.

1.2.3 International Guidance Framework

Guinea-Bissau is a member of the African Union, Economic Community of West African States, Organisation of Islamic Cooperation, the Latin Union, Community of Portuguese Language Countries, La Francophonie and the South Atlantic Peace and Cooperation Zone.

Guineas Bissau is a party to numerous international environmental and social development agreements which include:

- Agreement On The Conservation Of African-Eurasian Migratory Waterbirds;
- Cartagena protocol on biosafety to the convention on biologicall diversity;
- Kyoto Protocol to the UN Framework Convention on Climate Change;
- United Nations Convention on Biological Diversity;
- United Nations Framework Convention on Climate Change;
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES);
- Convention on the conservation of migratory species of wild animals (Bonn Convention); and
- Constitution of the Food and Agriculture Organisation of the United Nations.

For projects in developing countries, leading industry practice suggests the use of international standards and guidelines. Their use can be required in order to gain project funding from international lenders, but can also be implemented in cases where national legislation is not well defined. International standards and guidelines originated within financial institutions which were seeking to identify and manage environmental and social risks associated with projects they were funding. These standards have since been widely adopted and can be used by project proponents to give confidence (to regulators and shareholders) that the project conforms to leading international practice. Other international guidance used to complement national legislation includes:

- IFC Performance Standards, including Environmental Health and Safety (EHS) Guidelines;
- Equator Principles; and
- Good International Industry Practice (GIIP) that helps to define leading industry practices, such as the International Council of Mining and Metals (ICMM).

PHYSICAL ELEMENTS

2.0 CLIMATE AND AIR QUALITY

2.1 Introduction

Golder was commissioned by GB Minerals Ltd to undertake an air quality and climate baseline study to allow the characterisation of atmospheric conditions surrounding the proposed Farim Phosphate Project (the Project). A characterisation of existing baseline conditions is required to enable an appropriate assessment of the Site's potential contribution to local and regional air quality concentrations.

This chapter presents the baseline air quality and climate data. A meteorological station was installed in Farim in December 2011. Meteorological data are presented for the complete year of 2012 (January 2012 to December 2012).

2.1.1 Climate

Local meteorological conditions need to be considered in order to characterise the existing and future dispersion of air quality parameters from project-derived sources. As very little historical meteorological data exist in the Farim region, a meteorological monitoring station was installed in Farim to obtain localised data.

Public documents describe the highest point of elevation in Guinea-Bissau as 300 m amsl (above mean sea level). The land area is considered to be mostly savannah and the coastline is plain with swamps and mangroves. The climatic and seasonal variations are very distinct in Guinea-Bissau and follow the conditions of a general West African climate. The climate is described as tropical and is generally hot and humid all year round. It experiences a wet season (June to October), during which rainfall is high and the predominant wind direction is southwesterly. During the dry season (November to May) northeasterly harmattan winds are experienced, which introduces dry, dust-laden air (Web 1, 2013).

2.1.2 Air Quality

Five air quality monitoring stations were installed during October 2011. These stations were located to characterise the existing air quality in and around the proposed mine pit areas. Air quality data are presented for a non-continuous period of 8 months between November 2011 and October 2012; data loss occurred during a period of political instability in the country (May to July 2012). These results are the focus of this baseline report.

Additional investigative air quality monitoring stations were also installed along potential transport route options (roads, ports, pipelines) during October 2011 and September 2012. The transportation option was yet to be finalised at the time of writing and the data are presented in Appendix A1.

The objective of the baseline study was to monitor existing environmental conditions and parameters of concern at the proposed Project mine site. This allows quantification of potential changes in air quality associated with the construction and operations phases of the Project. This baseline information is intended to be incorporated within a future environmental and social impact assessment (ESIA) which will assess in detail the potential impacts from the Project.

2.2 Study Area

The local study area (LSA) was based on the spatial extent of the project footprint and an associated buffer zone expected to contain the majority of the air quality effects.

The LSA is defined as the area contained within a 10 km radius of Saliquenhe and at least 500 m from the nearest emission source including local villages and identified cultural heritage sites, covering a total area of approximately 100 km^2. The LSA was also used as the extent for the model domain area.

2.3 Climate Methods

2.3.1 Air Quality Standards and Guidance

Baseline air quality parameters are required to characterise existing concentrations of key parameters without the mine development. The predicted development emissions combined with the monitored baseline concentrations allow direct comparison with the Project AQS.

2.3.1.1 Guinea-Bissau Air Quality Legislation and Standards

No suitable Air Quality Standards (AQS) or applicable guidance was found relating to air quality within Guinea Bissau. Therefore, in the absence of specific local AQS, international standards and guidelines are identified to assess baseline air quality data. This comparison is used to provide an understanding of current air quality levels in the area.

2.3.1.2 Other International Guidance

The International Finance Corporation (IFC) guidance document for air quality together with the South African National Dust Control Regulations (2004) was adopted for this project. The project AQS are presented in Table 1.

2.3.2 Guinea-Bissau Regional Meteorological Data

The Bissau Port station lies 80 km southwest of Farim and the Bafata station is situated approximately 94 km northeast of Bissau and 65 km southeast of Farim.

Monthly average wind data were supplied by the Instituto Nacional de Meteorologia da Guinea-Bissau (INMGB) for the Bissau Port and Bafata Region stations. The data provided cover approximately 20 years' worth of wind speed data for both the Bissau Port station (1962 to 1981) and the Bafata Region station (1962 to 1984). More recent data provided from the Bissau Port station also included some limited data parameters for 2006 and 2011. No long-term temperature or rainfall data was provided for analysis. Where data was not available for 2011 data was supplemented with 2006 data, particularly for the wind direction data.

Data supplied consists of monthly or daily observed parameters, making the data difficult to analyse for diurnal or seasonal patterns. Some of the data supplied by the INMGB also prompt questions of quality control and it is suspected that some sensors were of limited functionality. However wind analysis is provided for 2011 data from the Bissau Port only. This data is presented below where it is compared with other regional data to provide context.

2.3.3 Farim Metereological Station

The Farim meteorological station is located at the rear of the Police station within Farim, at coordinates 12°29.046'N, 15°13.233'W, 8 m elevation. This location was chosen based on a number of key criteria, namely station security, minimal building and object interference of prevailing wind speed and land ownership. Images A to F show the Farim station installation.

Image A - facing north

Image B - facing south east towards Farim Port

Image C - facing directly south towards Farim Town

Image D - facing directly east

Image E - the rain gauge station

Image F - the lowered tower facing north

The siting of the meteorological monitoring station was chosen away from the significant influence of nearby buildings. The specific area chosen was identified and supported by GB Minerals Ltd and any nearby vegetation was cleared to prevent them affecting station readings.

2.3.3.1 Farim Station Measurement Parameters

The Farim station was installed on 18 December 2011 by Golder. The following instrumentation and sensors were installed on the tower:

- CS300 Apogee Pyranometer at 5 m;
- RM Young 05103 Anemometer at 10 m;
- Campbell Scientific (CS215) temperature / RH probe sensor at 2 m;
- ARG100 rain gauge with 0.254 mm tipping buckets at 1 m;
- CR800 data logger, 10 W solar panel at 5 m;
- 12 V backup battery; and
- Logger Control Box.

To log data, the sensors are connected to a Campbell Scientific CR800 data logger and the station is powered by a 70 W solar panel connected to a 90 Amp-hr backup battery. Further detail on the instruments installed on the Farim tower and parameters measured are given below.

The data logger was programmed using PC400 software to record a number of parameters. Statistics for these parameters are recorded in three data output tables and include 10 minute, hourly, and daily recorded data. The following parameters were measured:

- Battery voltage; and
- Average temperature (°C) at 2 m;
  - Sample relative humidity (%);
  - Total solar radiation (kJ/m^2);
  - Average solar radiation (W/m^2);
  - Average wind speed (m/s);
  - Wind direction mean unit vector relative to true north (°); and
  - Total precipitation (mm).

Precipitation

Precipitation is an important parameter in air quality assessments due to the damping effect it has on parameter concentrations such as particulate matter and dust. Precipitation is measured at the Farim meteorological station using an ARG100 rain gauge with 0.2 mm tipping buckets. The sensor/logger will count a tip each time the bucket is filled with the equivalent of 0.2 mm of rainfall and the tips are totalled over ten minute, hourly and daily intervals to give the total rainfall measured (mm) for each time period. The rain gauge has an operational range of between 0 and 500 mm/hr.

Temperature and Relative Humidity

Temperature is critical to air quality assessments and is used in calculating many of the factors used within air dispersion algorithms. Temperature at the Farim meteorological station is measured using a standard Campbell Scientific temperature / relative humidity CS215 sensor. The logger records the mean temperature in degrees Celsius (°C) over ten minute, hourly and daily intervals. In the daily interval, the logger also records the reading (°C) and timestamp for the minimum and maximum temperatures measured at 2 m above ground level.

Relative humidity is a temperature and pressure dependent term used to describe the amount of water vapour in a mixture of air and water vapour and is used to characterise rates of evaporation.

Solar Radiation

Incoming solar radiation is important in air quality due to the potential of sunlight to react with other atmospheric parameters to produce other parameter species and also the photo degradation of various parameter species. For example, tropospheric ozone (O_3) is formed when nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) react in the atmosphere in the presence of sunlight.

The Farim meteorological station is equipped with a Campbell Scientific CS300 Apogee Pyranometer which measures incoming solar (shortwave) radiation. The sensor measures incoming solar radiation in the spectral range of 0.3 to 1.1 µm and between intensities of 0 to 2000 W/m^2. The logger records the mean solar radiation (W/m^2) over ten minute, hourly and daily intervals. The logger also records the total solar radiation (kJ/m^2) over the three time intervals. In the daily interval, the logger records the reading (W m^{-2}) and timestamp for the minimum and maximum solar irradiances.

Wind Speed and Direction

Wind measurements are essential in air quality assessments as these data will provide the information needed to determine how far and in which direction air parameters will be predominantly dispersed. To measure wind speed and direction, the meteorological station is equipped with an R M Young 05103 Wind Monitor. The sensor measures wind direction between 0 to 360° and wind speed between 0 to 100 ms^{-1}.

The logger records the mean wind direction unit vector degree relative to true north (°) and also the standard deviation of this unit vector (°) over ten minute, hourly and daily intervals. The logger also records the mean and maximum wind speed readings over these intervals. In the daily interval, the logger additionally records the timestamp at which the maximum wind speed was measured.

2.3.3.2 Farim Meteorological Station Audit

Golder performed a sensor audit of the Farim station in September 2012, nine months after the initial installation. The audit consisted of lowering the folding tower and comparing each of the station sensors with calibrated instrumentation.

The equipment used for the audit (and corresponding sensors tested) is given in Farim Meteorological Station Audit below:

Table 2.1: Farim Meteorological Audit Equipment and Corresponding Sensors

Audit Equipment		Corresponding Sensor(s)		Method
R M Young Rain Gauge Calibrator Model 52260		ARG100 Rain Gauge		■ The calibrator is filled with a known volume of water; this volume is converted by calculation into the number of tips (and therefore mm rainfall) expected from the 0.2 mm buckets in the ARG100. ■ The water is then slowly emptied by the calibrator into the ARG100 and the number of tips counted. The tip count is then back calculated to give a rainfall depth in mm which is compared with the calibrator calculation in mm. ■ The allowed tolerance of error is ≤± 10%.
Fisher Scientific Traceable Hygrometer model 4185 with probe		Campbell Scientific CS215		■ The CS215 sensor is removed from the aspirated radiation shield and the cap removed, the cap is also removed from the traceable hygrometer (in order to improve responsiveness). ■ The CS215 and traceable hygrometer sensor tips are held in close proximity and the values for temperature are recorded simultaneously from both the handheld hygrometer unit and the direct readout form the laptop connected to the CR800. ■ The same process is carried out for relative humidity. ■ The allowed tolerances are: ■ 1 Temperature ≤ ± 0.50 °C; and ■ 2 Relative Humidity ≤ ± 10% per test point. ■ The traceable hygrometer and are compared in a similar way but due to differences in the sensors responsiveness, the temperature readings are used as a sensibility check only.
Kipp & Zonen METEON hand-held display unit with calibrated SP Lite2 radiometer		CS300 Apogee Pyranometer		■ The calibrated SP Lite2 is attached to the supporting arm of the CS300 and the arm is rotated to ensure that all sensors are level (using the built in spirit level of the sensors). ■ The SP Lite2 is connected to the METEON, and the meteorological station CR800 logger readout for the CS300 is displayed in real time on a laptop – readings are taken simultaneously from both and are entered into a calibration spreadsheet which calculates the error and also the slope, intercept and correlation coefficient of the calibration curve.

Audit Equipment		Corresponding Sensor(s)		Method
				■ The allowed tolerances are; ■ 1 Slope = 1.0 ± 0.05; ■ 2 Intercept ≤1% of full scale (2000 W m2); ■ 3 Correlation Coefficient ≥ 0.995; and ■ 4 Error per test point = ± 5% of METEON readout.
R M Young Vane Angle Bench Stand Model 18112		R M Young 05103 Wind Monitor (Wind Direction)		■ The Wind Monitor is removed from the mast and attached to the vane angle bench stand (on a level surface) at the correct orientation (using a designated notch) and held stationary using the vane support. ■ The Wind Monitor is then rotated at 30° increments (increments of 10° are marked on the vane angle bench stand) and held in place whilst the reading is recorded from the CR800 laptop readout. ■ The process is repeated for both clockwise and anti-clockwise. ■ The allowed tolerance is ≤ ± 3°.
R M Young Vane Torque Gauge Model 18331		R M Young 05103 Wind Monitor (Wind Direction)		■ The vane support is removed from the vane angle bench stand to allow the 05103 to rotate freely. ■ The vane torque gauge is then placed on top of the 05103 near the propeller. ■ When stationary and sheltered from the wind, the 05103 is gently rotated from a stationary position by pulling the attachment on the vane torque gauge at an angle perpendicular to the orientation of the 05103 body. ■ The reading is taken as the increment the attachment is aligned with at the point where the 05103 begins to rotate and is repeated for both clockwise and anti-clockwise. ■ The allowed tolerance of this starting torque threshold is ≤ 40 g cm.
R M Young Anemometer Drive Model 18802		R M Young 05103 Wind Monitor (Wind Speed)		■ The vane torque gauge and propeller are removed and the vane support re-attached, the anemometer drive support is attached to the 05103 body and the rubber drive shaft placed over the propeller shaft. ■ The speed is set in rpm using the handheld control and when stabilised the wind speed readings are taken from the CR800 laptop readout. ■ The process is repeated for both clockwise and anti-clockwise. ■ The values are entered into the audit spreadsheet (which has the corresponding velocities for the rpm increments). ■ The allowed tolerances are: ▪ 1 Windspeed input of ≤5 ms-1; ≤ ±0.2 ms-1. ▪ 2 Windspeed input of > 5 ms-1; ≤ ± 5% of input speed.

Audit Equipment		Corresponding Sensor(s)		Method
R M Young Torque Disk Model 18310		R M Young 05103 Wind Monitor (Wind Speed)		■ The anemometer drive is removed and the torque disk is placed on the propeller shaft of the 05103. ■ Bolts are added in increments (starting with 1 x 0.1 g bolt moving out from the innermost screw hole) until the disk rotates 90° under the weight/torque of the bolt. ■ The bolt positions and weights are compared with the look up diagram to determine the torque acting on the propeller shaft and noted down. ■ The process is repeated for both clockwise and anti-clockwise. ■ The allowed tolerance is of the starting torque threshold is ≤ 3.8 g cm.

Following the audit, data were quality checked to determine that all sensors are operating within the allowed tolerances and as such some data may be removed where uncertainty is present.

2.3.4 Limitations

The following limitations have been identified with respect to the baseline monitoring and the data presented in this section:

- Complete meteorological data are available for Farim for a 12 month period only providing little inter-annual variability; and
- Historic meteorological data analysis was limited due to the quality of data available, as no long-term trends could be determined to analyse if the baseline data is representative of a typical year or is extreme.

2.4 Climate Results and Discussion

2.4.1 Guinea-Bissau Regional Meteorological Data

2.4.1.1 Bissau Port Rainfall 2011

The average annual rainfall for Guinea-Bissau is almost entirely accounted for during the wet season between June and October. From December to May, the country experiences very little rainfall. Monitored rainfall data provided by the INMGB for 2011 indicate an annual total rainfall of 1,412 mm (Table 2.2).

Table 2.2: Rainfall - Bissau Port (2011)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	0.0	0.0	0.0	0.0	0.0	81.0	434.0	503	301	92	0.0	0.0	1,412

2.4.1.2 Bissau Port Temperature (T) and Relative Humidity (RH) 2011

Guinea-Bissau is warm all year around and there is little fluctuation in average temperature. Temperature data provided by the INMGB indicate that temperatures at the Bissau monitoring station range between 16.6°C and 38.6°C, with the maximum temperature recorded in March and the minimum in December (Table 2.3).

In respect of average monthly Relative Humidity (RH, calculated from daily average data), the most humid months are June to November (77.9% to 72.0%) which coincides with the transition and arrival of the wet season in Guinea-Bissau (Table 2.3).

Table 2.3: Temperature and Average Relative Humidity – Bissau Port (2011)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min Temp (°C)	18.0	18.0	19.4	21.2	20.4	21.0	22.4	21.6	22.1	22.2	21.4	16.6
Max Temp (°C)	33.4	36.2	38.6	36.5	36.4	36.4	32.8	31.6	32.2	33.7	34.2	34.0
Average RH (%)	50.6	45.8	57.5	62.3	65.7	77.9	82.6	85.0	82.9	77.7	72.0	50.5

2.4.1.3 Regional and Historic Wind Direction and Speed Data 1996

Bissau Port Station Regional

Monthly wind roses for the Bissau Port station are shown in Figure 2.1 and Figure 2.2 for the year 1996. However these wind datasets are reported to have had a sensor failure; therefore these data should be used for reference only and no further comparison is made.

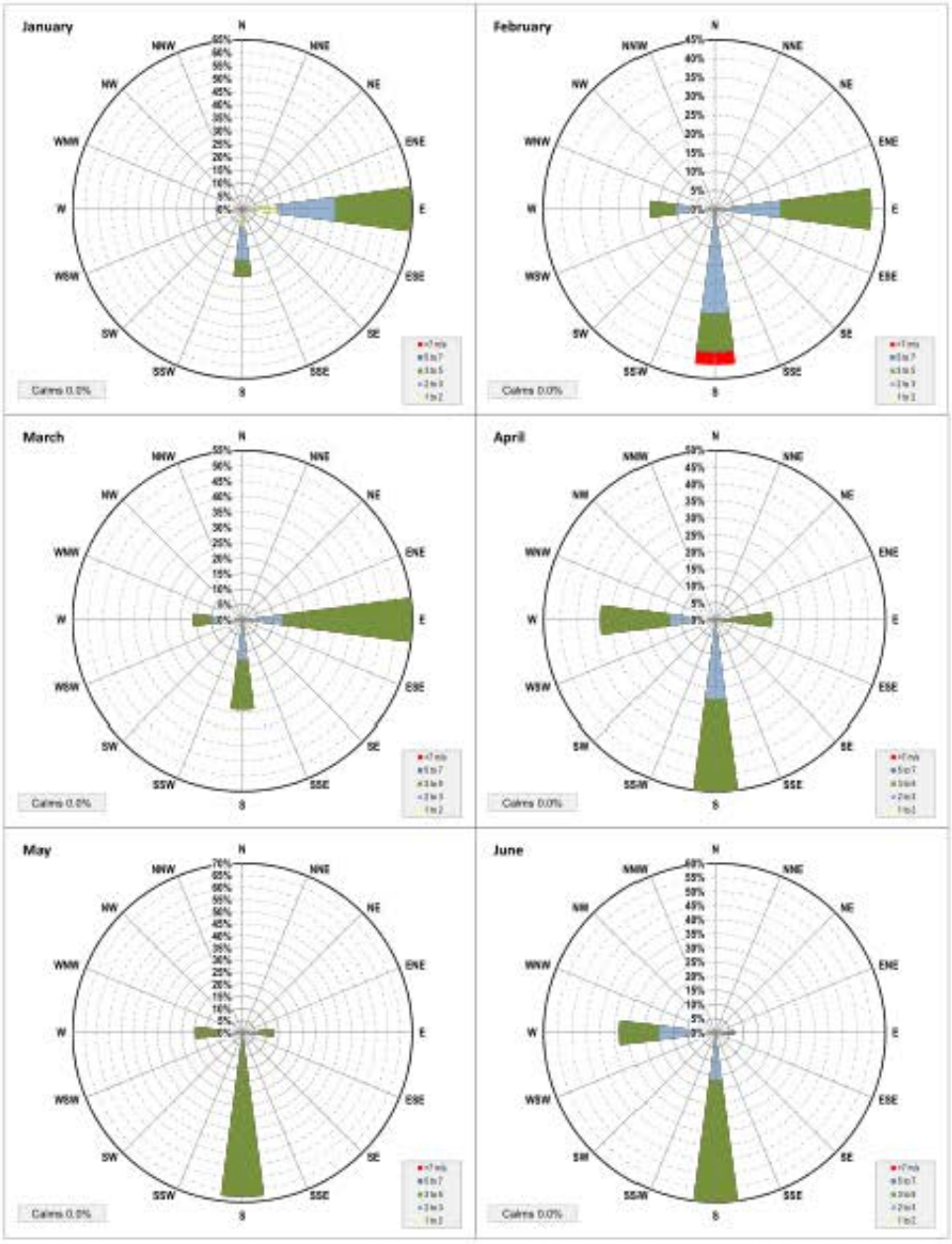


Figure 2.1: Monthly Wind Roses generated from Wind Speed and Direction Data supplied by the Bissau Meteorological Office for the Bissau Port Station for the period of January to June 1995

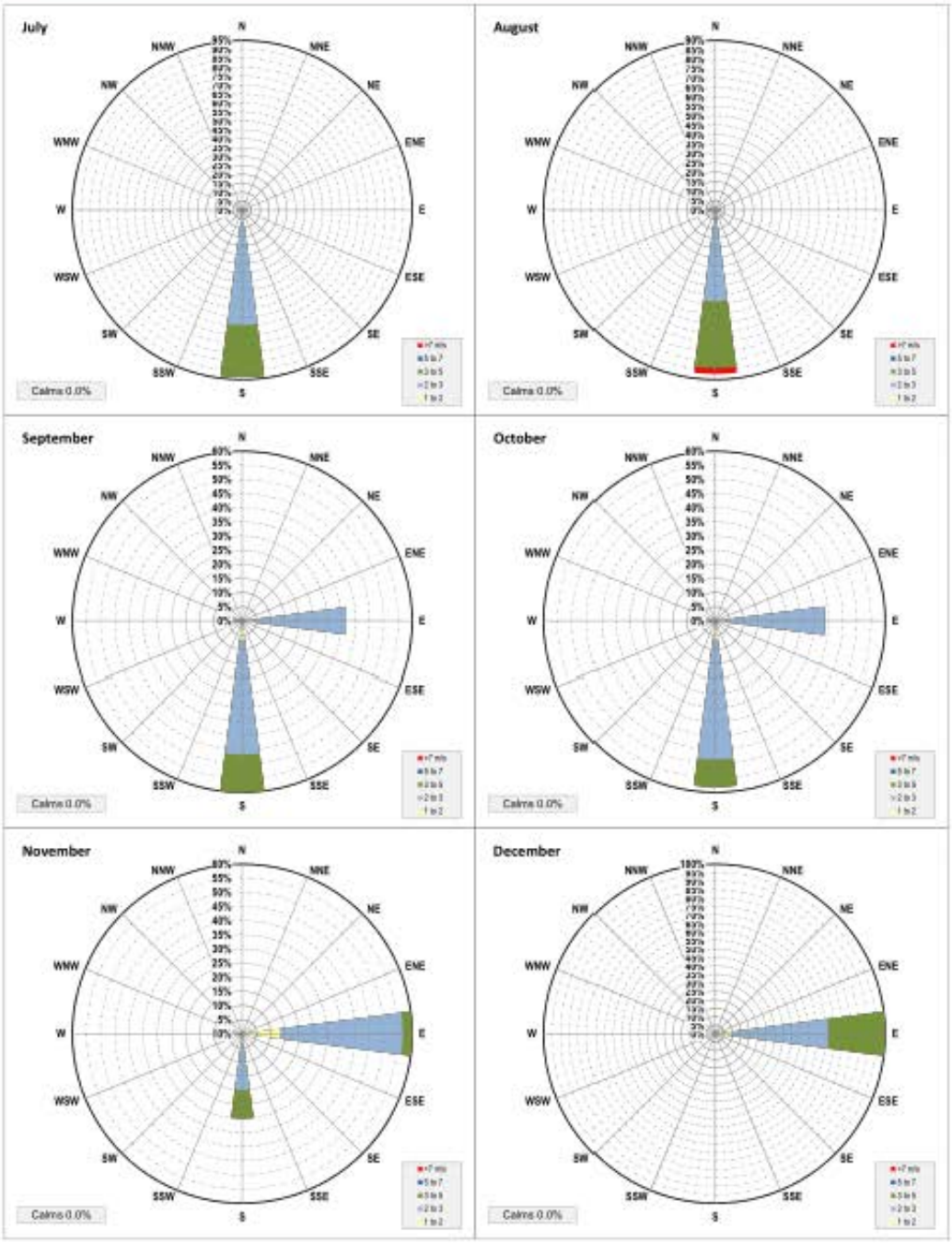


Figure 2.2: Monthly Wind Roses generated from Wind Speed and Direction Data supplied by the Bissau Meteorological Office for the Bissau Port Station for the period of July to December 1996

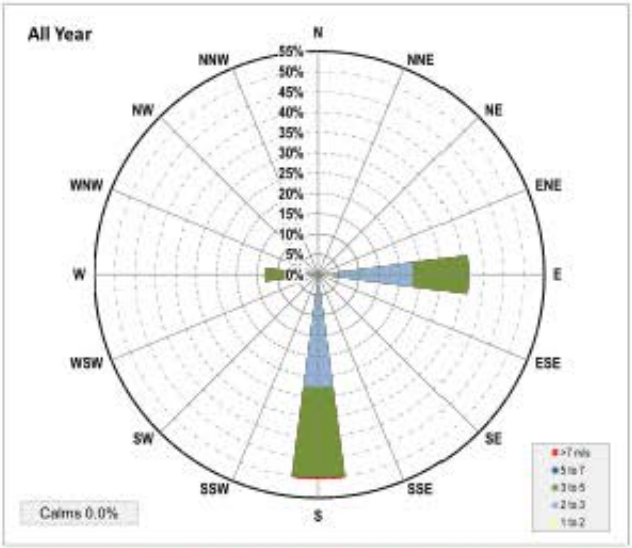


Figure 2.3: Annual Wind Rose data generated from Wind Speed and Direction Data supplied by the Bissau Meteorological Office for the Bissau Port Station for the period of 1996

2.4.2 Farim Meteorological Monitoring Station 2012 Data

The data collected from the Farim monitoring station were analysed for the period 1 January 2012 to 31 December 2012. A summary of the ten minute data is presented in Table 2.4 and the achieved data collection for 2012 was 98%. Highlighted data is referred to in the text below.

Table 2.4: Summary of 2012 Farim Data

Parameter/Month		Temperature	Relative Humidity	Solar Radiation	Wind Speed	Rainfall
		°C	%	Wm^{-2}	m/s	mm
January	min	**9.77**	9.09	0	0.00	0.00
	max	36.80	**100**	983	4.68	0.00
	avg	**21.88**	54.5	221	0.87	0.00
February	min	11.41	5.66	0	0.00	0.00
	max	40.33	97.6	893	4.83	0.00
	avg	24.13	**40.9**	203	1.04	0.00
March	min	13.47	5.2	0	0.00	0.00
	max	41.00	**100**	941	4.43	0.00
	avg	27.27	49.3	215	1.02	0.00
April	min	15.96	7.34	0	0.00	0.00
	max	**42.30**	97.7	1002	4.97	0.00
	avg	**29.18**	48.2	**255**	1.28	0.00
May	min	19.62	17.7	0	0.00	0.00
	max	41.39	99.6	939	5.72	1.20
	avg	28.93	61.6	240	1.64	0.00
June	min	20.70	23.5	0	0.00	0.00
	max	39.01	**100**	1109	5.70	14.60
	avg	28.58	70.3	228	1.65	0.05
July	min	20.87	54.5	0	0.00	0.00

Parameter/Month		Temperature	Relative Humidity	Solar Radiation	Wind Speed	Rainfall
		°C	%	Wm^{-2}	m/s	mm
	max	34.04	**100**	1153	6.17	18.60
	avg	26.01	89.5	192	1.02	0.09
	min	20.68	59.1	0	0.00	0.00
August	max	33.85	**100**	**1203**	6.03	21.60
	avg	25.91	91.2	193	1.12	0.13
	min	21.53	56.8	0	0.00	0.00
September	max	34.94	**100**	942	4.95	15.00
	avg	25.89	**91.5**	143	0.93	0.07
	min	20.30	51.2	0.00	0.00	0.00
October	max	35.48	**100**	914	4.21	9.20
	avg	27.12	88.7	168	0.73	0.02
	min	17.21	41.1	0.00	0.00	0.00
November	max	35.51	**100**	772	3.47	4.00
	avg	26.06	86	156	0.67	0.00
	min	10.40	19.4	0	0.00	0.00
December	max	35.18	**100**	720	4.26	0.20
	avg	21.32	67.7	157	0.89	0.00
	min	**9.77**	5.2	0	0.00	0.00
Whole year	max	**42.30**	**100**	**1203**	6.17	21.60
	avg	26.02	70	198	1.07	0.03

Analysis of the data collected has been performed and the current performance of the meteorological station to output representative data has been assessed as reliable, based on data quality assurance procedures and sensor audits completed in 2012 and 2013.

An audit performed during September 2012 indicates that all sensor values are within the specified operating range for the installed weather sensors. During the most recent audit, the solar radiation sensor required replacing due to it marginally falling out of the calibration tolerance limits.

2.4.2.1 Farim Temperature Analysis

Over the course of the 12 month monitoring period during 2012, monthly average temperatures varied between 21.32°C in December and 29.18°C in April. The maximum temperature of 42.30°C was recorded in April 2012 and the minimum temperature of 9.77°C was recorded in January 2012.

The regional minimum and maximum temperature data supplied by the INMGB for 2011 have been compared with 10 minute average data collected from the Farim station during 2012 (Figure 2.4). The two datasets illustrate a very similar seasonal trend between the two years. The average 10 minute temperature for Farim during 2012 also shows good correlation, sitting between the minimum and maximum temperature recorded in Bissau 2011 and corroborates the two monitored datasets.

Figure 2.5 displays the 10 minute average temperature for 2012. The plot illustrates that the range in temperatures is greater during the dry season and is reduced during the wet and transition seasons.

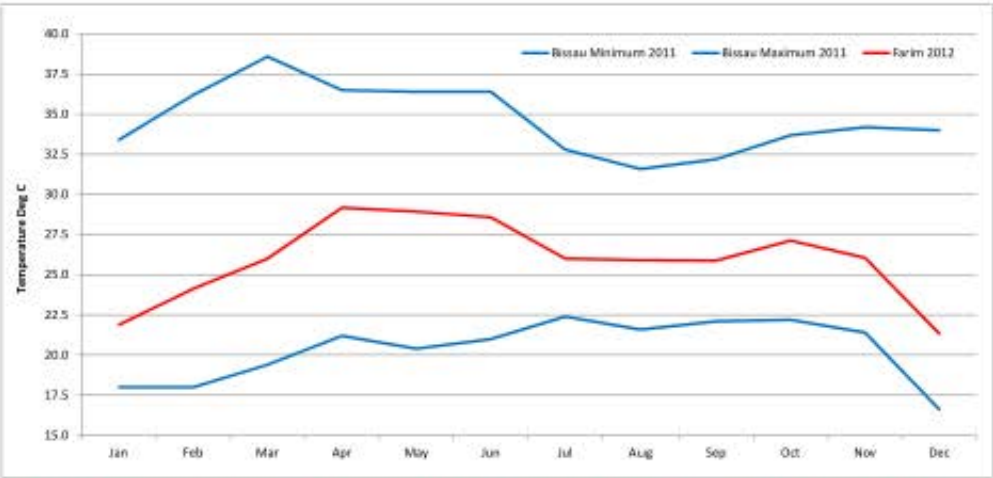


Figure 2.4: Minimum and Maximum Temperature Data from the Bissau Port Station (2011) compared with Farim average data (2012)

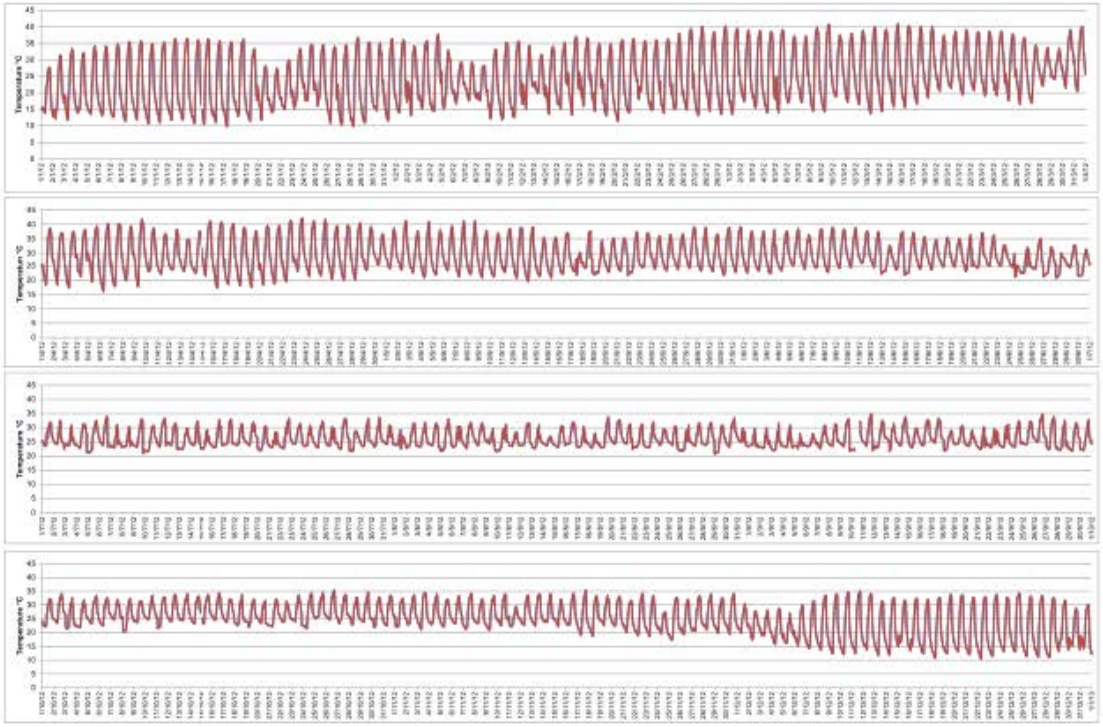


Figure 2.5: Temperature data from the Farim Station for the period 01 January 2012 to 31 December 2012

2.4.2.2 Farim Relative Humidity Analysis

Figure 2.6 shows that the most humid month recorded in Farim on average was September 2012 (mean 91.5%). The least humid month was February with an average relative humidity of 40.9%. The maximum relative humidity of 100% was monitored during most months during the 2012 monitoring period. The lowest relative humidity recorded was of 5.2% in March 2012.

Relative humidity data supplied by the INMGB for 2011 are compared with data collected from the Farim station during 2012 in Figure 2.6 and show a good correlation of monthly trends between the two stations.

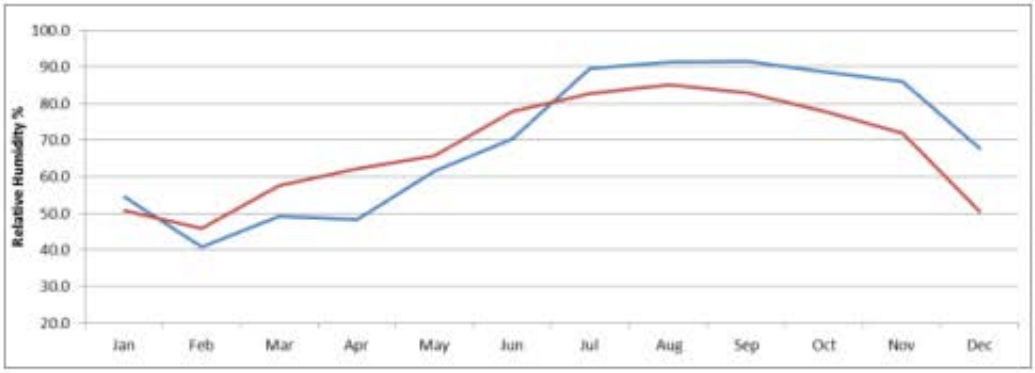


Figure 2.6: Bissau Port Relative Humidity % 2011 (red line) compared with Farim 2012 (blue line)

Figure 2.7 displays the 10 minute average relative humidity for 2012. The plot illustrates that the range in relative humidity is greater during the dry season and is smaller during the wet and transition seasons. During the wet season (July to October), relative humidity is seen to be approximately 60% at the start of the day and frequently rises to 100% by the end of the day. Conversely, during the dry season (December to June) the range in humidity is much greater: relative humidity levels are often 10% at the start of the day and frequently increase to 100% by the end of the day.

Consistently high relative humidity during the wet season is due to evaporation of water from the ground surface following rainfall.

Conversely, during the dry season there is less water available and once evaporated it is transported away rapidly during the day, resulting in low amounts of water vapour in the air. At night when temperatures are cooler, the relative humidity is high as the transport mechanisms by which water is transferred to the atmosphere are slowed down.

Dew point (the temperature at which a volume of humid air must be isobarically cooled for water vapour to condense into a liquid form) is generally high during the wet season. A higher relative humidity results in a greater likelihood of condensation forming and so the dew point is closer to the air temperature.

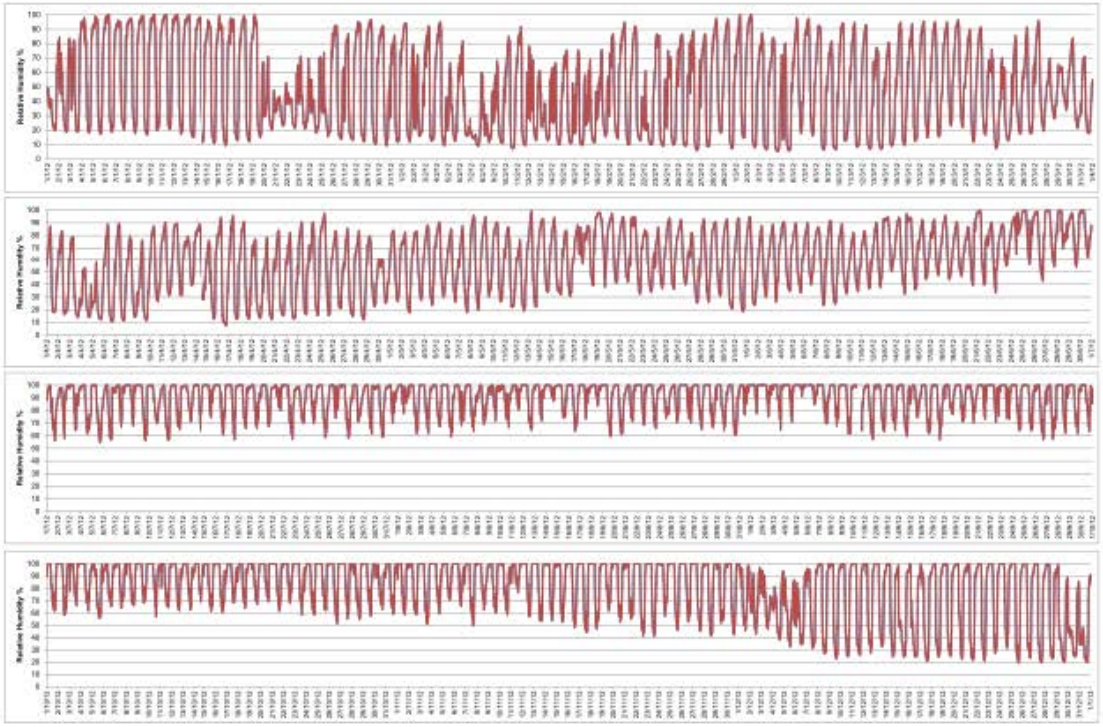


Figure 2.7: Relative Humidity Data from the Farim Station for the period 01 January 2012 to 31 December 2012

2.4.2.3 Farim Solar Radiation Analysis

The maximum solar radiated from the sun was recorded in August 2012 measuring 1203 W/m^2 and coincides with the month of highest rain fall. The highest monthly average solar radiation was recorded during April at 255 W/m^2 and coincides with the monthly maximum temperature recordered during 2012.

The plotted solar radiation data in Figure 2.8 show peaks and troughs of sunlight intensity throughout the day during the different seasons of the year. During the first quarter of 2012 (January to March), solar radiation shows a high number of clear sky days with little cloud cover during the morning. The cloudiest event was recorded in early February where solar radiation peaked at approximately 400 W/m^2. In contrast, solar radiation for most other days during this period typically reached 800 W/m^2.

During the second quarter of the year (April to June), clear sky days appear to be present for the majority of April while cloudy conditions become more prevalent towards May and June, with noticeable cloud interrupting sunlight throughout the day. These conditions are typical of the transition from dry season to wet season. July to September, most days appear to be interrupted by cloud, coinciding with the peak of the wet season. The month of August displayed the most intense solar radiation reading (1,203 W/m^2) within a ten minute period. These short periods of high intensity irradiance readings coupled with periods of low intensity irradiance readings indicate a mixture of clear and cloudy conditions during the third quarter of 2012.

Records for October to December 2012 show that solar radiation during this period is less intense, with a maximum peak of approximately 900 W/m^2, occurring in early October. On average during this period, solar radiation is approximately 600 W/m^2. Towards the end of the year, solar radiation indicates clear sky days, which coincides with the transition to the dry season.

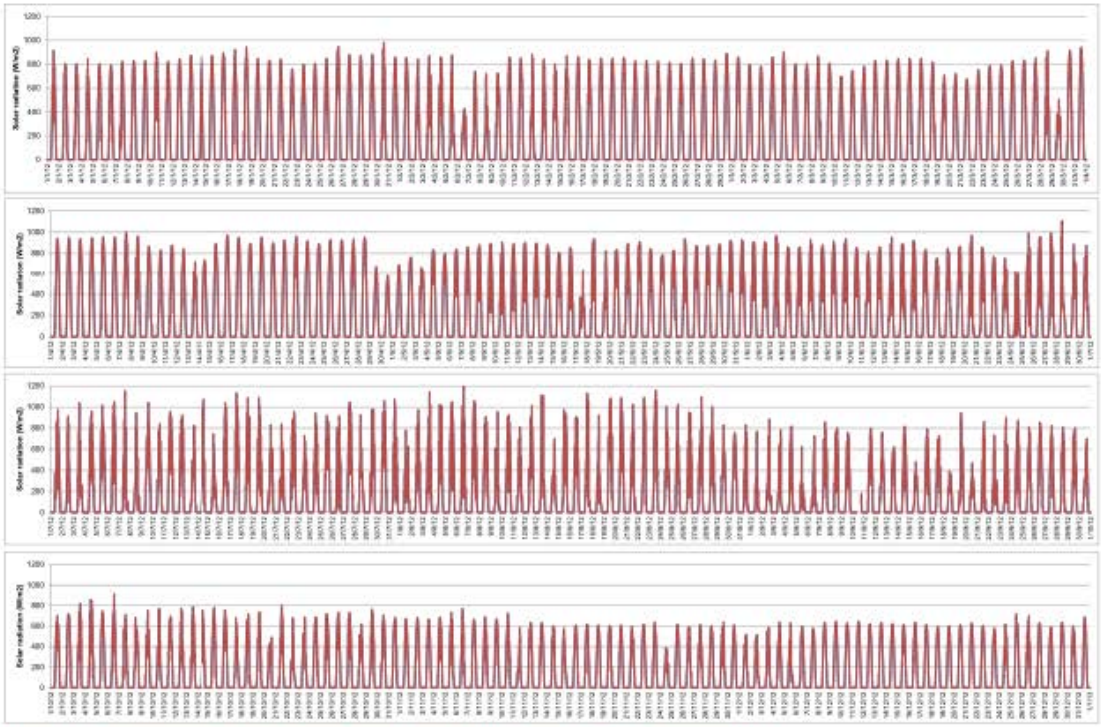


Figure 2.8: Solar Radiation Data from the Farim Station for the period 01 January 2012 to 31 December 2012

2.4.2.4 Farim Wind Direction and Wind Speed Analysis

Figure 2.9 to Figure 2.11 displays the monthly and annual wind roses generated from the wind speed and direction data gathered at the Farim station during 2012.

The annual wind rose indicates that the dominant wind direction is predominantly from a southeasterly direction and wind speeds are generally light all year round with wind speeds less than 5 m/s.

During January to March, the wind direction appears to partly transition from an easterly wind direction towards a southwesterly wind direction. From April to October 2012, the south westerly wind direction is dominant, coinciding with some of the strongest winds and the peak wet season. As the wet season transitions to the dry season, the wind speeds decrease and the wind direction changes towards a north and northeasterly direction again.

The highest average wind speed recorded was 1.65 m/s in June 2012. The highest ten minute average wind speed was experienced in July 2012 (6.17 m/s). The average wind speed for the year is recorded as 1.07 m/s.

Regional wind speed and direction data analysed for the Bissau Port during 2006 were also found to have a seasonal trend. Wind speeds peak around May to August, which corresponds with the transition to the wet season, reducing again from September onwards until the transition from the wet season to the dry season. Wind data collected at each of the Farim and Bissau Port stations indicate that wind directions patterns are different. Wind roses for Bissau suggest a more south and east dominant direction compared to Farim where winds are southwest dominant. These different patterns in wind direction are likely to be influenced by the Bissau Port's coastal location.

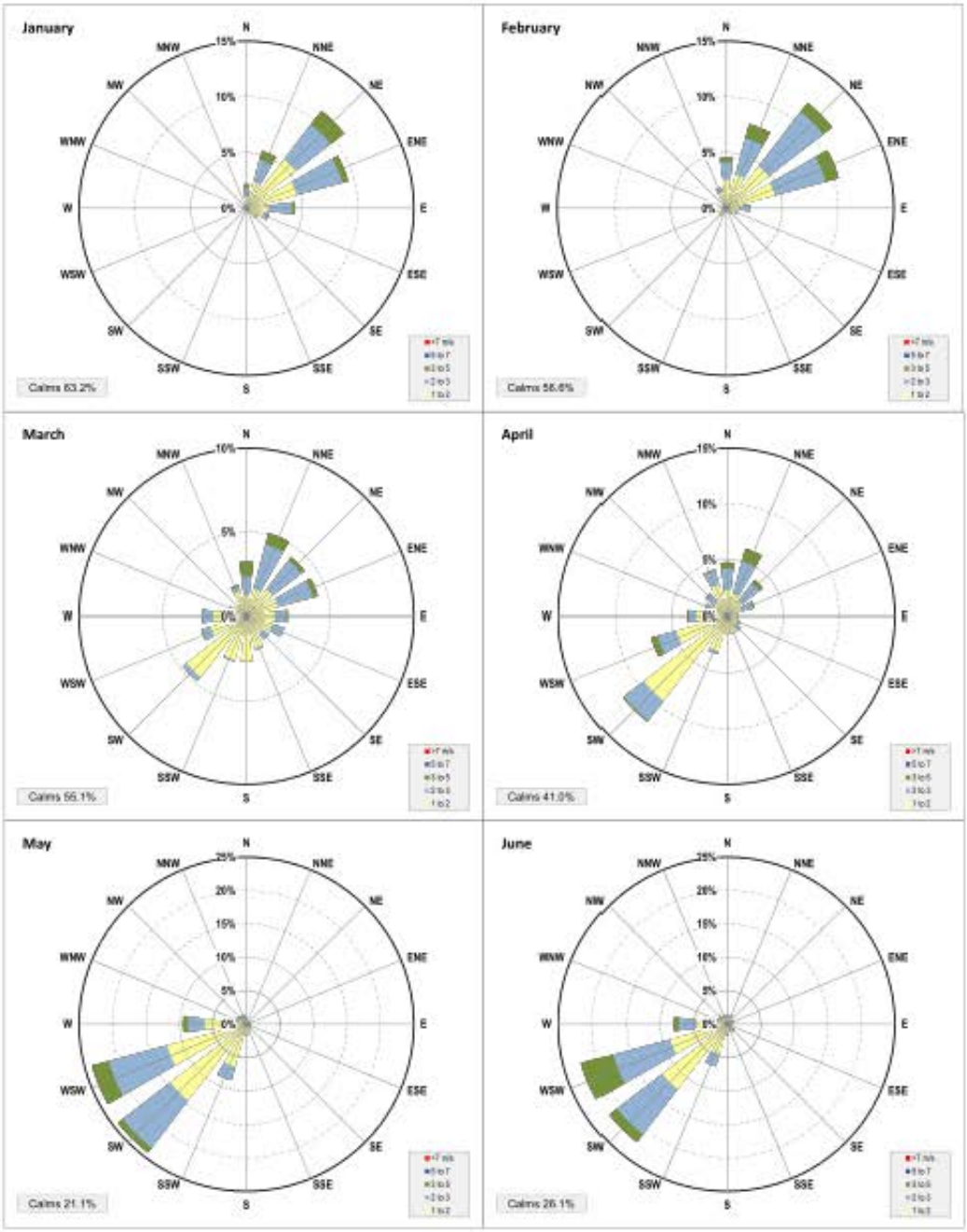


Figure 2.9: Monthly Wind Roses generated from Wind Speed and Direction Data collected from the Farim Station for the period from January 2012 to June 2012

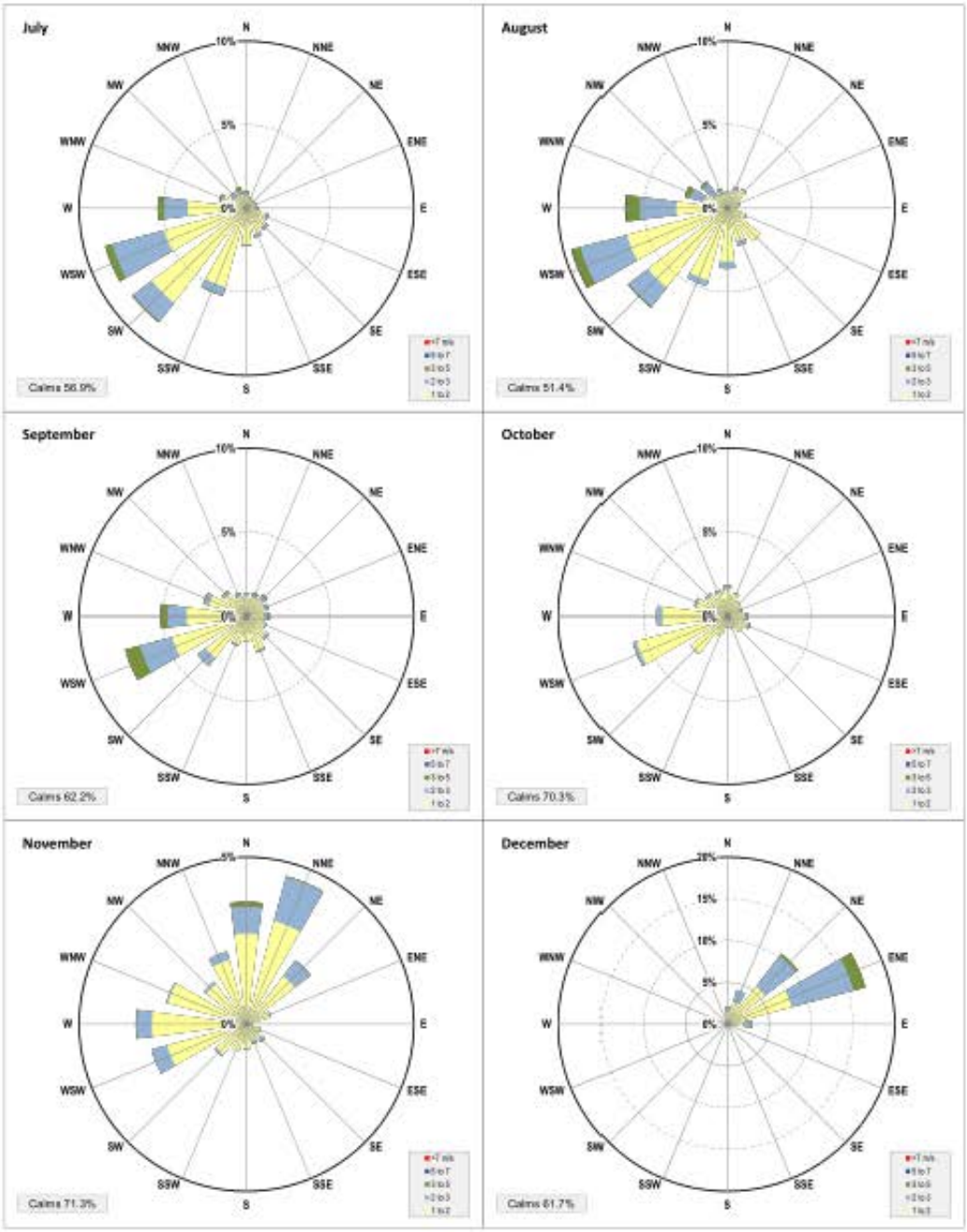


Figure 2.10: Monthly Wind Roses generated from Wind Speed and Direction Data collected from the Farim Station for the period from July 2012 to December 2012

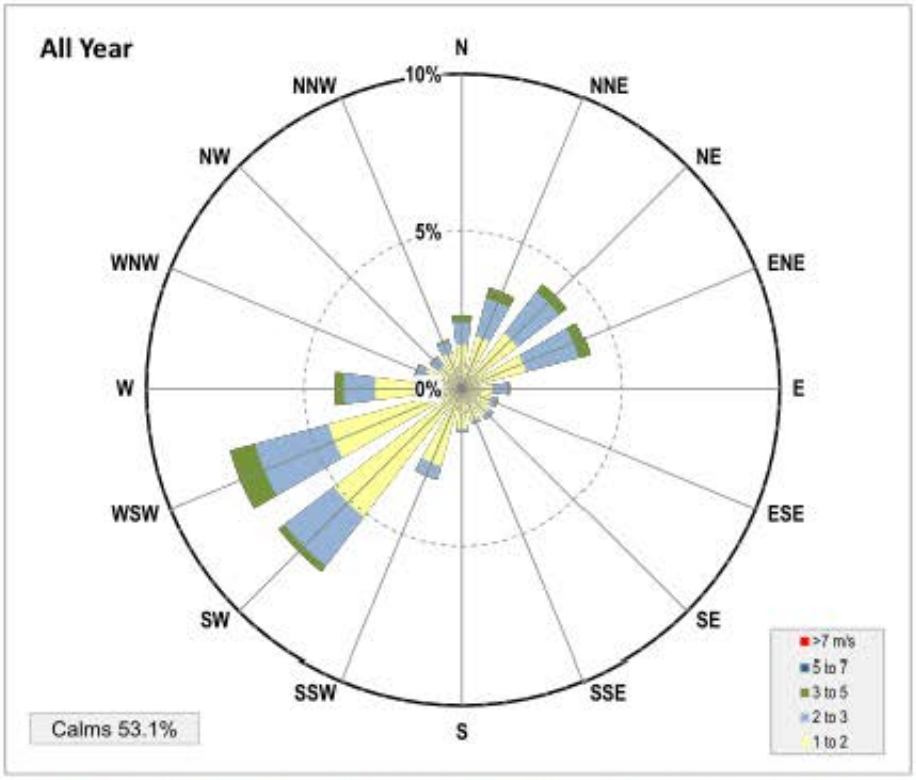


Figure 2.11: Annual Wind Rose data generated from Wind Speed and Direction Data collected from the Farim Station for the year 2012

2.4.2.5 Farim Rainfall Analysis

Table 2.5 indicates that the wet season is between June and October, with a dry period starting between October and November and going through until May. Figure 2.12 shows the monthly total rainfall during 2012. The height of the wet season was August with a total rainfall of 572.4 mm. The station demonstrated a dry period between the months of December and April. The total rainfall recorded at the station was approximately 1,594 mm (1.6 m) which is considered typical for the Guinea-Bissau climate.

Table 2.5: Farim Total Monthly Rainfall Data (2012)

Month	Rainfall (mm)
January	0.0
February	0.0
March	0.0
April	0.0
May	11.6
June	213.6
July	400.6
August	572.4
September	276.0

Month	Rainfall (mm)
October	105.4
November	11.0
December	3.2
Total	**1594**

Rainfall data supplied by the INMGB for the Bissau Port station in 2011 were compared with data collected at the Farim station during 2012 (Table 2.5). This comparison shows a good correlation of monthly trends between the two datasets. Rainfall recorded in Farim shows a uniform rise in rainfall until the peak of the wet season in August, followed by a steady decline into November. Monthly rainfall from Bissau shows a slower rise in rainfall at the start of the wet season, with a steep increase observed between June and July. Peak rainfall for both stations was recorded in August and a similar rate of decline in rainfall is observed between the two datasets. Farim had a slightly higher total annual rainfall than that recorded in Bissau.

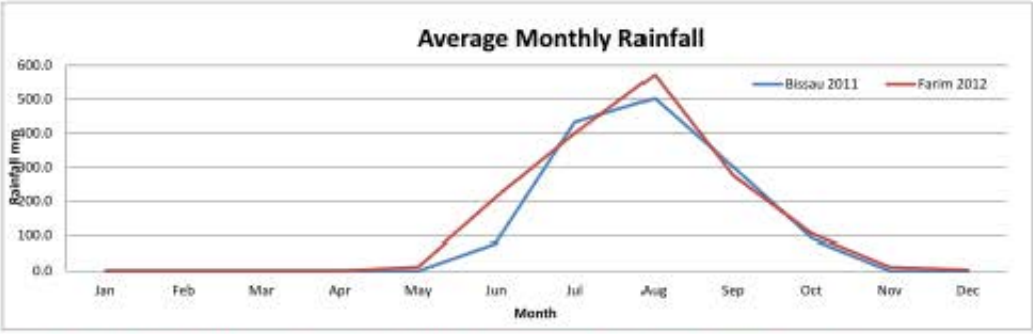


Figure 2.12: Bissau Port Monthly Rainfall Data (2011) compared with Farim Monthly Rainfall (2012)

Rainfall Intensities

Figure 2.13 displays the 10 minute rainfall totals for the Farim Station per quarter. Rainfall intensity is high during the peak rainfall months as would be expected. It is also apparent that the majority of rainfall events are short duration and high intensity, although during the wetter months (August and September 2012) rainfall duration is more prolonged, sometimes displaying several peaks in intensity during a single rainfall event. Early August had the most intense rainfall period for the year, with a total of 21.60 mm recorded at the station in one 10 minute period. This coincides with August being the wettest month monitored during 2012 at this station.

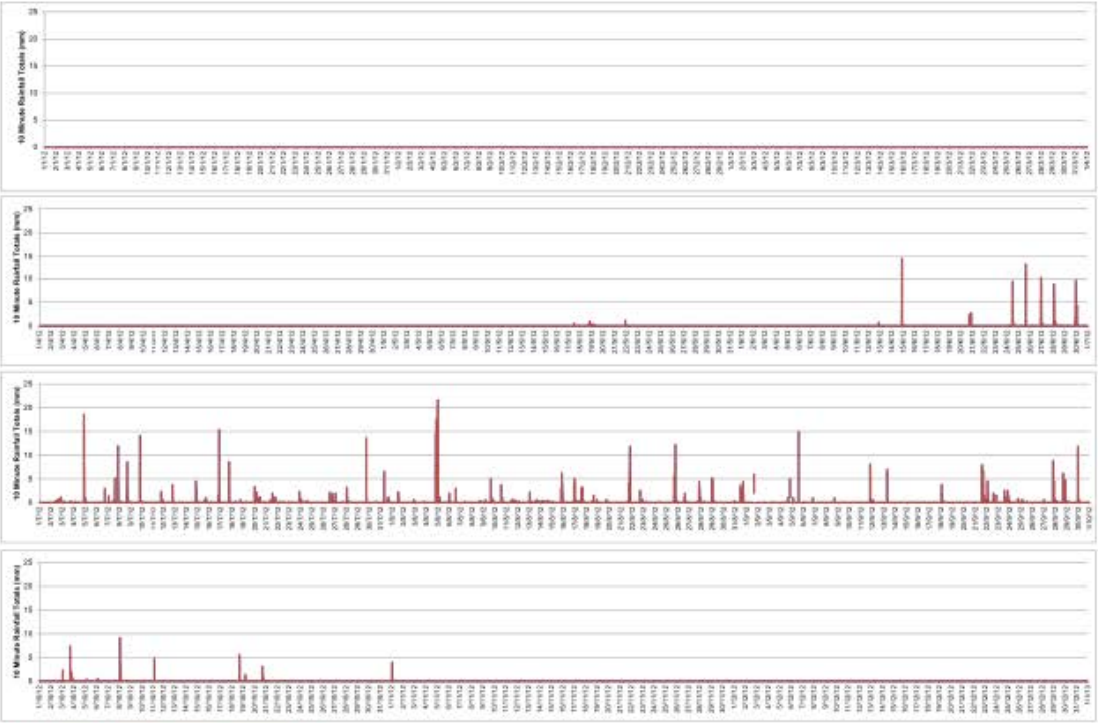


Figure 2.13: Farim 10 minute Rainfall Intensities 2012

Rainfall Polar Plots Analysis 2012

Rainfall and wind speed/direction data from Farim were analysed together in order to determine which winds brought certain rainfall intensities.

The first rain of the 2012 wet season in Guinea-Bissau arrived in May with only a small number of rainfall events occurring during a transient easterly wind. During June and July, more significant rainfall occurred when a stronger easterly wind was prevalent. During the height of the wet season (August), a shift in wind direction was recorded and significant amounts of rainfall were experienced under a westerly-dominated wind direction, which then becomes more sporadic during September and October when the wet season begins transitioning to the dry season.

Rainfall polar plots give an indication as to the direction from which local precipitation events originate (Figure 2.14 to Figure 2.16). These events may be due to secondary rainfall events occurring when fallen rain has been evaporated and transported a distance before falling again over the land mass. Many of the heavier rainfall events originate from the west, and due to the position of Bissau (i.e. no land mass to the west or south).

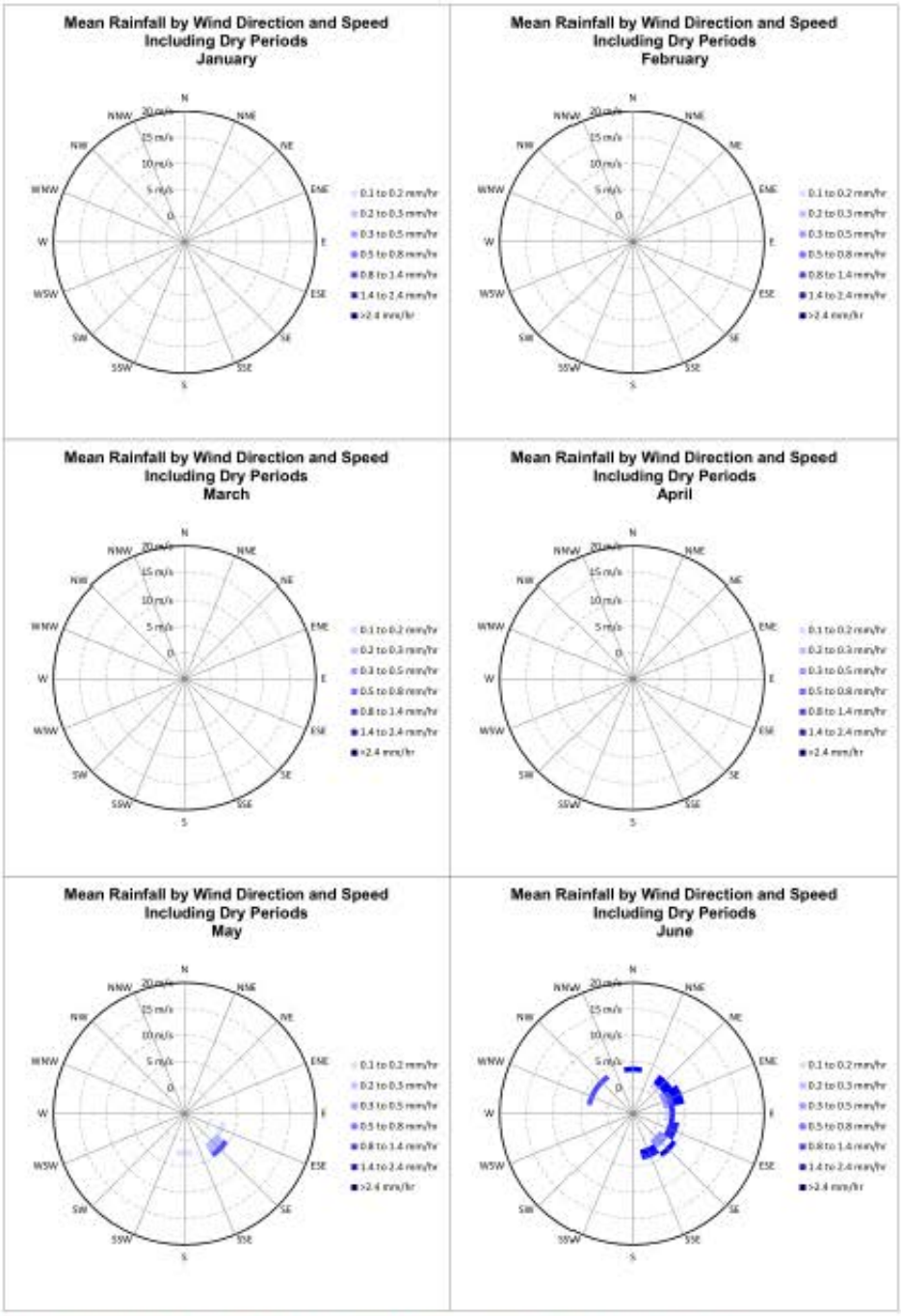


Figure 2.14: Rainfall Polar Plots from the Farim Station for the period January 2012 to June 2012

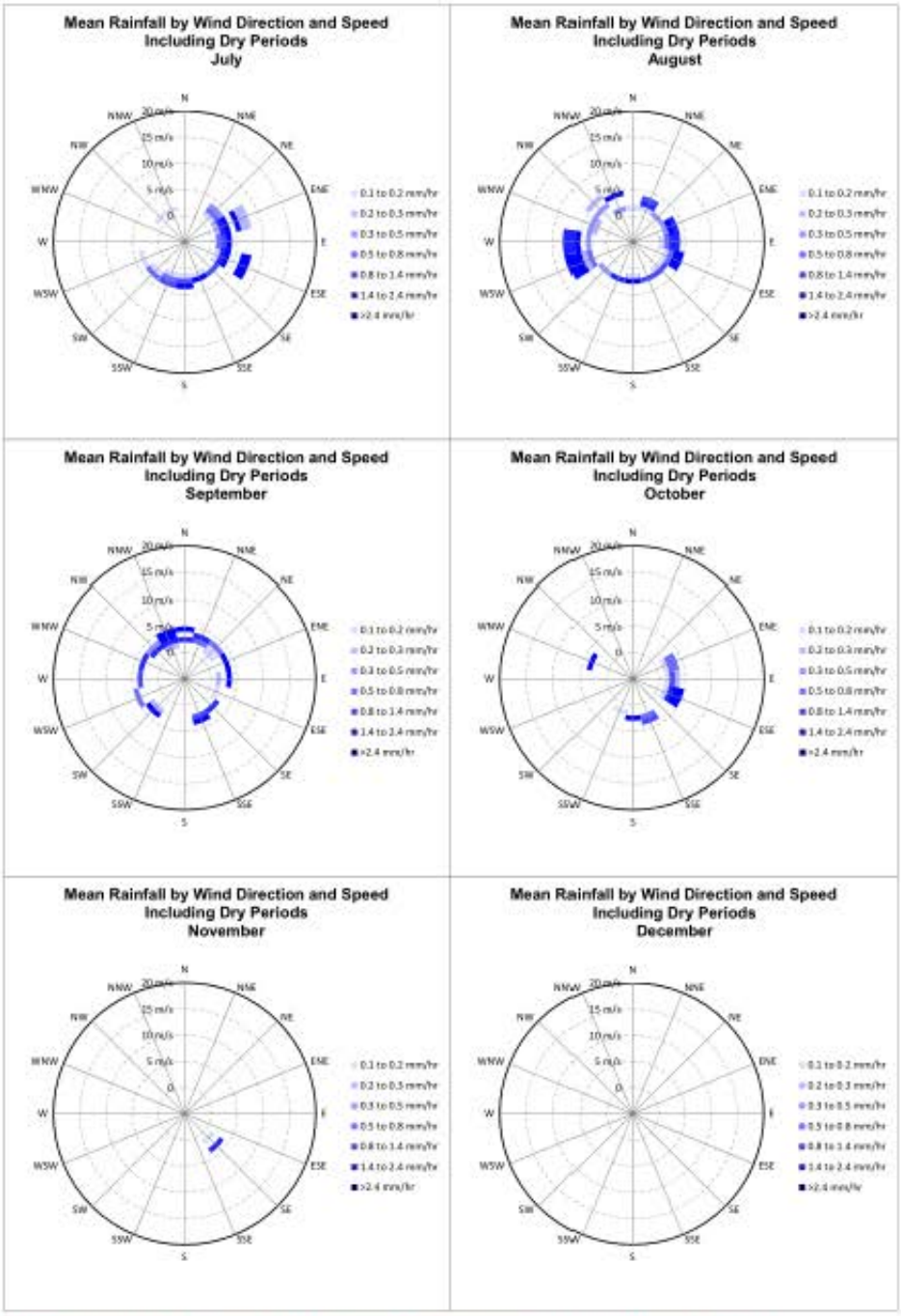


Figure 2.15: Rainfall Polar Plots from the Farim Station for the period July 2012 to December 2012

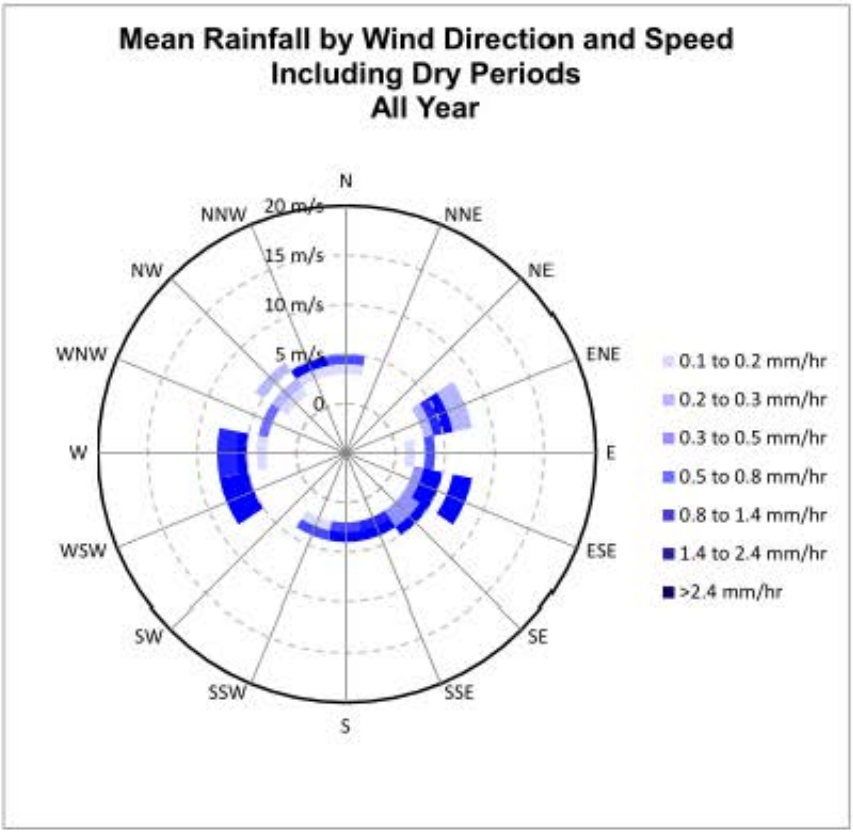


Figure 2.16: Annual Rainfall Polar Plots from the Farim Station for the year 2012

2.4.3 Summary of Minimum and Maximum Conditions

Table 2.6 provides a summary of meteorological ranges, where applicable.

Table 2.6: Summary of Parameter Extremes between January and December 2012

Parameter	Month	Value	Unit
Driest Months	January - April 2012	n/a	Month
Wettest Month	August 2012	572.4	mm/month
Highest Average Rainfall Rate	August 2012	21.6	mm (in 10 minutes)
Highest Temperature	April 2012	42.3	°C
Lowest Temperature	January 2012	9.77	°C
Highest Average Humidity	September 2012	91.5	%
Lowest Average Humidity	February 2012	40.9	%
Most Intense Solar Radiation	August 2012	1203	W/m^2
Highest Wind Speed	July 2012	6.17	m/s

2.5 Air Quality

Five air quality monitoring stations were installed during October 2011. The objective of the baseline study was to monitor existing environmental conditions and parameters of concern at the proposed Project mine site. This allows quantification of potential changes in air quality associated with the construction and operations phases of the Project. This baseline information is intended to be incorporated within a future environmental and social impact assessment (ESIA) which will assess in detail the potential impacts from the Project.

2.5.1 Parameters of Concern

For the purposes of this baseline report the definition of a parameter is assumed to be a chemical compound or representative air quality pollutant that may cause harm to human health.

According to the World Health Organisation (WHO), air pollution is an internationally recognised risk to human health and the environment.

Industrial or commercial processes can be a significant source of degraded air sheds that can affect local air quality and therefore human health. Degradation of air quality can also cause long-term damage to sensitive environmental habitats. It is generally accepted that mining operations can reduce air quality during the construction, operation and closure phases. Emissions generally include combustion emissions, primarily generated by vehicle engines and generators, and fugitive emissions associated with mechanical rock extraction, processing and movement of materials.

A summary for each key parameter that represent air quality are described below including their individual specific risks to human health and the environment.

2.5.1.1 Nitrogen Oxides (NOx) including Nitrogen Dioxide (NO_2)

NO_x emissions are formed as a product of combustion. NO_x is a generic term for mono-nitrogen oxides, namely NO (nitric oxide), and NO_2 (nitrogen dioxide). They are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. NO_x is also central to the formation of tropospheric ozone (O_3) and is known to inhibit the natural growth rate of plants (WHO, 2005).

A form of natural NO is produced during thunderstorms due to the extreme heat of lightning, causing the splitting of nitrogen molecules. This in turn can result in the production of acid rain, if NO forms compounds with water molecules.

NO_2 typically arises via the oxidation of NO in air. The main effect of breathing NO_2 is the increased likelihood of respiratory problems. NO_2 is found to cause inflammation of the lungs and can reduce immunity to lung infections. This can cause respiratory problems such as wheezing.

Increased levels of NO_2 can affect people with asthma, causing more frequent attacks. Children with asthma and older people with heart disease are most at risk. Scientific studies have shown that symptoms of bronchitis and asthma in children increase in association with long-term exposure to NO_2 (WHO, 2005).

2.5.1.2 Sulphur Dioxide (SO_2)

SO_2 is a by-product of burning fuel that contains sulphur, such as coal and petroleum. Excessive exposure to elevated concentrations of SO_2 is known to affect the human respiratory system and inhibit the function of the lungs. Inflammation of the respiratory tract causes coughing, aggravation of asthma, chronic bronchitis and makes people more prone to infections of the respiratory tract (WHO, 2005).

When SO_2 combines with water, it forms sulfuric acid (H_2SO_4); this is the main component of acid rain which can result in loss of plants and deforestation (WHO, 2005).

2.5.1.3 Ozone (O_3)

Excessive or elevated O_3 levels in the air can have implications for human health. O_3 has the potential to cause breathing problems, trigger asthma attacks, reduce lung function and cause lung diseases. Several

European studies have reported that daily mortality rises by 0.3% and likelihood of heart diseases by 0.4%, per 10 µg/m^3 increase in ozone exposure (WHO, 2005).

2.5.1.4 Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are gases emitted from a wide range of solids or liquids materials. VOCs include a variety of chemicals, some of which may have short and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors (USEPA 2012 Web source). VOC's have the potential to be emitted from all aspects of mining operations and although no direct assessment standards are available, baseline VOC's are monitored purely to establish baseline (USEPA 2012 Web source). No standards are available for assessing ambient VOCs to establish the quality or condition of a project baseline.

2.5.1.5 Deposited Dust

The term 'dust' refers specifically to particle sizes of dust measuring between 10 and 75 microns in size. It should be noted that there are no internationally agreed standards for assessing the effects of deposited dust. Dust particles generally travel significant distances from the generated source and dust is generally perceived as being a nuisance (when a deposit accumulates and rapidly soils a surface), rather than being considered a significant risk to human health.

Deposited dust is generally not associated with human health issues, but is considered a nuisance due to loss of amenity. Elevated dust levels may however affect visibility and thus cause a health and safety issue. Dust can also have effects on plant and their growth patterns. Deposited dust can settle on the surface of the plant leaves and reduce the intake of sunlight, inhibiting the natural process of photosynthesis with the potential to result in stunted growth.

As such, mean rates of dust deposition (based upon gravimetric values) are generally used to indicate any potential nuisance impact. The South African National Dust Control Regulations (2004) suggest deposited dust concentrations below 600 mg/m^2/day for residential receptors is acceptable and a maximum of 1,200 mg/m^2/day related to light commercial areas. This guidance is considered the most appropriate regional guidance on which to assess dust effects considering the local climates are similar, and are therefore adopted for the project. These are also included in **Table 2.8**. However it should also be considered that the level at which dust soiling becomes a nuisance is highly subjective and can be dependent on the sensitivity of surrounding receptors.

2.5.1.6 Particulate Matter (PM_{10} and $PM_{2.5}$)

The health effects from particulate matter can occur at levels of exposure currently being experienced by most urban and rural populations in both developed and developing countries. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer (WHO 2005). Particulates are internationally recognised as harmful to human health and the wider population.

2.5.2 Project Adopted Air Quality Standards

The IFC guidance document for air quality (IFC, 2007) recommends the use of the World Health Organisation (WHO) Ambient Air Quality Guidelines for projects with significant sources of air emissions and potential for significant impacts to ambient air quality.

Further to this, a South African National Standard (SANS, 2011) for dust deposition was also adopted for this assessment to quantify the impact of deposited dust on nearby settlements as this standard was most representative of the region considered in the absence of international AQS.

The adopted project AQS are presented in Table 2.7 and those for dust deposition in Table 2.8.

Table 2.7: Summary of Air Quality Concentration Guidelines Adopted for the Project

Parameter	Project Air Quality Standard		Source
	Averaging period	Concentration (µg/m^3)	
Nitrogen dioxide (NO_2)	1 year	40	IFC, 2007
	1 hour	200	
Sulphur dioxide (SO_2)	24 hour	20	IFC, 2007
	10 minute	500	
Particulate matter (PM_{10})	1 year	20	IFC, 2007
	24 hour (99 %ile)	50	
Particulate matter ($PM_{2.5}$)	1 year	10	IFC, 2007
	24 hour (99 %ile)	25	

All concentrations are reported at the 100 %ile unless otherwise stated.

Table 2.8: Summary of Dust Deposition Guidelines Adopted for the Project

Parameter	Time Weighted Average	Deposition (mg/m^2/day)	Source
Deposited Dust	30 days	600	SANS, 2011

2.6 Air Quality Method

The objective is to measure key baseline parameters at selected stations to quantify the quality of the air quality baseline. The following parameters were monitored:

- Nitrogen Dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3); and
- Particulate matter (PM_{10} and $PM_{2.5}$).

Additional parameters such as nitrogen oxides (NO_x), Volatile Organic Compounds (VOCs) and deposited dust were also monitored for the following reasons:

- Baseline NO was also monitored alongside NO_2, to allow the calculation of total NO_x for consideration of potential habitats effects on sensitive vegetation;
- Baseline VOCs were monitored during the wet and dry season. These data are not comparable to any AQS but provide a baseline against which measurements taken during mining operations can be compared; and
- Baseline deposited dust was monitored for the consideration of potential amenity loss to sensitive areas and effects on sensitive habitats and vegetation (including analysis of metal content during the transition wet (September-October) and dry seasons (January).

International guidance indicates that baseline air quality monitoring should be sufficient to represent significant changes in season or to represent the period of the proposed development operations. The monitoring programme collected gaseous and deposited dust data over a non-continuous 8 month period between November 2011 to April 2012 covering largely the dry season, and September to October 2012 incorporating the end of the wet season and its transition in to the dry season (see Section 5). Fine particulate monitoring was undertaken for five 24 hour periods during September 2012 and September 2013.

2.6.1 Gaseous NO, NO2, SO2, and O3 Monitoring

Passive air quality monitoring was used for the gaseous data collection of key parameters due to the non-industrialised environment and the need to cover a wider spatial area with many monitoring stations. The use of passive diffusion tube samplers allowed for long-term monitoring of large areas without the need for significant capital investment, infrastructure or provision of a continuous power supply.

Passive monitoring tubes were exposed and co-located with dust deposited gauges for approximately one month intervals over a non-continuous 8 month period. Passive diffusion tube monitoring techniques are known to have a +/-25% uncertainty associated with the analysis method depending on the parameter being monitored (AEA, 2008). For NO, NO2, SO2 and O3, substance specific diffusion tubes were deployed. NOx is calculated by the sum of the results from a pair of NO2 and NO diffusion tubes.

All samples were couriered and analysed by Gradko International Ltd, which is accredited by United Kingdom Accredited Service (UKAS).

2.6.1.1 Passive Volatile Organic Carbons (VOC) Monitoring

During the wet and dry season, VOC absorbent tubes were deployed on each monitoring station for a period of approximately four weeks in tandem with the gaseous diffusion tubes. The exposed tubes were then analysed to determine the key ambient VOC concentrations deposited in the atmosphere during each significant seasonal period.

2.6.1.2 Deposited Dust Monitoring

Deposited dust samples were collected monthly alongside the passive air quality tubes using the Frisbee deposit dust gauge collection method. As no international statutory assessment standards are available for this commonly utilised monitoring technique, gauges were deployed in accordance with the manufacturer's recommendations.

The Frisbee system collects dust over an aluminium surface with a known surface area. Rain water washes the deposited dust into a water bottle. Dust samples are collected and changed once the bottles were full of rain water, to reduce over filling in the wet season. A new sample is started once the diffusion tubes were changed in next the months monitoring period. This method was chosen to be appropriate based on the amount of rain experienced in periods during the wet seasons.

The water and particulates in the water bottle are analysed to determine total deposited dust by sample drying, weighing and performing dust metallic analysis using inductively coupled plasma (ICP) techniques).

The metals analysis on the deposited dust samples were performed to identify atmospheric concentrations of metals that may be mobile in the atmosphere. All samples were couriered and analysed by Environmental Scientifics Group (a United Kingdom Accreditation Service (UKAS) accredited laboratory in the United Kingdom). The metallic dust suite selected for analysis includes aluminium, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium and zinc.

2.6.1.3 Particulate Monitoring

Fine particulate monitoring was undertaken using a Turnkey Optical Scattering Instantaneous Respirable Indication Sensor (OSIRIS) particulate monitor. The monitor uses a light scatter technique with a heated inlet to establish particulate concentrations. The OSIRIS is accredited for measuring continuous particulate matter concentrations and is endorsed for use by the United Kingdom Environment Agency. It is therefore considered suitable for monitoring airborne particulates in the project area.

Short-term 24 hour fine particulate monitoring was conducted between 6 and 7 September 2012 and 24 to 27 September 2013 in Farim. Monitoring was undertaken to identify baseline particulate concentrations in and around the proposed mine open pits. Monitoring was completed over 24 hour periods to allow direct comparison with the short-term project AQS. Figure 1 shows the OSIRIS particle monitor and meteorological monitoring station which is located in Farim. Further monitoring is recommended during the dry season to characterise baseline particulate concentrations.

Figure 2.17: Fine Particulate Monitoring in Farim

2.6.2 Baseline Monitoring

2.6.2.1 Baseline Air Quality Monitoring Period

Golder initially visited the Site in July 2011 to scope the air quality monitoring locations likely to be required to produce a comprehensive baseline study. Golder then returned to Site between the 28 October and 5 November 2011 to install air quality stations at the previously identified locations.

Due to political instability within Guinea-Bissau between the months of May and August 2012, the baseline survey was postponed and some air quality samples were subsequently lost in transit or destroyed during this period. Data collection resumed in September 2012 for a period of two months (September and October 2012) before the data collection was discontinued. Therefore baseline data collected are non-continuous over an 8 month period which is dominated by the dry and transitional wet seasons (September to October) and so are likely to be representative of worst-case conditions, particularly with respect to dust levels. Baseline data for the wet season are expected to be most closely represented within

the September 2012 data collection period. Table 2.9 details the parameters monitored during the data collection periods.

The short-term data were collected largely during the dry season and is expected to be worst-case of atmospheric conditions. For the purpose of this assessment, data relevant to the mine area is presented below and additional investigative monitoring covering the potential transportation routes is provided in Appendix A1.

Table 2.9: Air Quality Monitoring Periods 2011 to 2012

Month	Start Month	Analysis	
		Gaseous Air Quality	Deposited Dust
1	November 2011	NO_2, NO_x, SO_2 and O_3	Standard Dust
2	December 2011	NO_2, NO_x, SO_2 and O_3	Standard Dust
3	January 2012	NO_2, NO_x, SO_2 and O_3 Dry / wet season VOC analysis	Standard Dust and ICP Metals suite
4	February 2012	NO_2, NO_x, SO_2 and O_3	Standard Dust
5	March 2012	NO_2, NO_x, SO_2 and O_3	Standard Dust
6	April 2012	NO_2, NO_x, SO_2 and O_3	Standard Dust
7	May 2012	No data	No data
8	June 2012		
9	July 2012		
10	August 2012		
11	September 2012	NO_2, NO_x, SO_2 and O_3 Dry/wet season VOC analysis	Standard Dust and ICP Metals suite
12	October 2012	NO_2, NO_x, SO_2 and O_3	Standard Dust

2.6.2.2 *Baseline Air Quality Monitoring Locations*

Table 2.10 describes the air quality monitoring locations surrounding the mine area. A plan of the monitoring locations is provided in Appendix A5.

Table 2.10: Mine Area Baseline Air Quality Monitoring Stations

Location	Description	Comments
Location GB 1	Censenhe 12°27'39.55"N 15°18'18.49"W	West of the deposit and downwind of operations. Situated 165 m to the rear of residential buildings in an open area between the village and the proposed mining area.
Location GB 2	Saliquenhe/Box Cut 12°29'23.66"N 15°16'14.49"W	Located between the two mine deposits within the secure Box Cut area. The station is elevated to approximately 2 m upon a hard standing and is situated away from any direct plant emissions, 1,000 m north of the Saliquenhe.
Location GB 3	Proposed Plant Area 12°30'15.20"N 15°13'59.94"W	Upwind of the proposed mine operations within a cleared area approximately 65 m from the access road. The station is located on agricultural grassland.
Location GB 4	Farim 12°29'4.52"N 15°13'14.82"W	East of the proposed mining operations, located behind the police station within the area of the proposed meteorological station. The station is located on grassland, situated approximately 40 m from the main through road in Farim.

Location	Description	Comments
Location GB 5	Saliquenhedim 12°28'2.18"N 15°13'18.42"W	South of river crossing and representative of additional vehicle traffic entering Farim and construction traffic. The station is situated in an open area on agricultural land, located approximately 20 m away from the main road.

GB 1 (Censenhe)

GB 2 (Saliquenhe / Box Cut)

GB 3 (Proposed Plant Area, Farim)

GB 4 (Farim Police Station)

GB 5 Saliquenhedim

Figure 2.18: Air Quality Stations GB 1 to GB 5

2.7 Air Quality Results and Discussion

2.7.1 Summary of Baseline Air Quality Data

2.7.1.1 Gaseous Data

Table 2.11 presents the summary of gaseous monitoring results for the baseline data collected within the mine area. GB 4 was a quality assurance station where gaseous parameters were monitored in triplicate. Reported concentrations for GB 4 are an average of all three samples for each parameter.

Table 2.11: Summary of Gaseous Results

Location	8 Month Value	NO_X	NO_2	SO_2	O_3
		µg/m³			
GB 1 Censenhe^	average	4.66	2.59	1.20	61.48
	minimum	**1.67**	0.89	**0.39**	45.46
	maximum	8.55	5.66	2.02	83.77
GB 2 Saliquenhe/Box Cut^	average	4.92	2.76	1.49	76.17
	minimum	2.48	1.12	1.03	47.17
	maximum	8.43	5.28	2.20	**120.60**
GB 3 Proposed Plant Area^	average	4.89	2.23	1.07	56.75
	minimum	1.55	**0.38**	0.84	**30.60**
	maximum	**10.35**	4.58	1.44	89.49
GB 4 Farim^	average	7.08	4.94	1.57	63.85
	minimum	4.86	1.71	1.07	40.69
	maximum	9.89	8.16	3.13	91.19
GB 5 Saliquenhedim^	average	5.60	3.13	1.33	58.70
	minimum	2.00	0.64	0.45	31.73
	maximum	9.05	5.61	2.39	98.02

^ Result based on 6 monthly datasets averaged over 6 months

***Bold** indicates results used in text*

The minimum and maximum monitored NO_x and NO_2 concentrations were 1.67 and 10.35 µg/m³ and 0.38 and 8.24 µg/m³ (maximum tube in February), respectively as detailed in Table 2.11. The maximum NO_x and NO_2 concentrations were recorded at the GB 3 and GB 4 stations within Farim.

The average minimum and maximum monitored SO_2 concentrations were 0.39 and 4.12 µg/m³ (maximum tube in November 2011) as detailed in Table 2.11 and Table 2.12. The minimum and maximum monitored O_3 concentrations were 30.60 and 120.60 µg/m³. Ozone concentrations are thought to be naturally occurring and therefore higher due to lightning occurrences. The maximum SO_2 and O_3 concentrations occurred at the GB 2 and GB 4 stations within Farim.

The single triplicate GB 4 monitoring results are presented in Table 2.12.

Table 2.12: Summary of Triplicate Gaseous Results

GB – 4 Location	Value	NO_X	NO_2	SO_2	O_3
		µg/m³			
November 2011	1	5.54	5.99	2.34	45.47
	2	4.22	5.80	2.92	54.03
	3	4.81	4.60	**4.12**	52.47
December 2011	1	5.22	4.75	0.88	63.41
	2	4.84	4.86	0.92	55.39
	3	5.13	5.27	1.41	59.04
January 2012	1	6.02	5.74	0.98	67.65
	2	6.29	6.46	1.27	66.85
	3	6.27	6.21	1.54	60.42
February 2012	1	6.54	8.02	1.87	35.71
	2	9.72	**8.24**	1.12	39.86
	3	10.47	8.22	1.07	46.51

GB – 4 Location	Value	NO_X	NO_2	SO_2	O_3
		µg/m³			
March 2012	1	9.64	7.90	1.47	59.48
	2	9.89	8.12	1.68	70.02
	3	9.84	8.12	1.70	68.51
April 2012	1	5.57	2.25	0.82	82.51
	2	5.01	2.58	1.48	88.86
	3	4.56	2.14	LOD	102.19
September 2012	1	6.01	1.75	LOD	79.10
	2	9.71	1.43	LOD	65.35
	3	4.87	1.95	LOD	71.08
October 2012	1	6.13	2.77	1.44	60.18
	2	12.41	2.84	LOD	71.21
	3	11.14	2.58	LOD	67.2

***Bold** indicates results referred to in text*

2.7.2 Passive VOC Monitoring Data

Passive VOC monitoring data were collected for locations GB 1 to GB 4 within the mine area during both the dry and transition wet seasons. A summary of the top 5 (by concentration) VOC concentrations during both the dry and transition wet seasons is provided in Table 2.13. The laboratory results are provided in Appendix A4.

Table 2.13: Summary Top Dry and Transition Wet VOC's Results

Dry Season VOC's	GB1	GB2	GB3	GB 4 Average
	µg/m³			
Heptane, 2,2,4,6,6-pentamethyl-	83.00	65.31	107.00	71.96
2,4-Dimethyl-1-heptene	33.50	30.06	39.00	34.32
Dodecane	20.11	16.56	22.02	20.70
Decane	19.40	18.38	21.85	18.79
Tridecane	14.8	-	16.59	16.02
Transition Wet Season VOC's				
Ethylebenzene	50.00	46.00	51.00	49.00
2,4-Dimethyl-1-heptene	48.00	42.00	33.04	35.23
Dodecane	25.85	28.15	19.47	29.97
Decane	25.57	26.02	19.05	28.19
m/p-Xylene	40.00	38.00	41.00	26.23

The VOC monitoring has identified that the top 5 compounds (by concentration) identified are largely consistent at all monitoring locations within the mine pit areas (GB1–4).

The compounds Heptane, 2,2,4,6,6-pentamethyl and Ethylebenzene were found to be present in the highest concentrations during the dry and transition wet season monitoring periods. Ethylebenzene was found to be present during the wet season only across all monitoring stations.

A number of compounds identified by the monitoring are thought to be attributable to petroleum based products, such as petrol.

2.7.2.1 Deposited Dust Data

Table 2.14 presents the summary of the deposited dust monitoring results for the baseline data collected within the mine area.

Table 2.14: Summary of Deposited Dust Results

Location	8 Month Value	Deposited Dust
		mg/m²/day
GB 1 Censenhe^	average	94
	minimum	17
	maximum	255
GB 2 Saliquenhe/Box Cut^	average	77
	minimum	13
	maximum	159
GB 3 Proposed Plant Area^	average	85
	minimum	4
	maximum	213
GB 4 Farim^	triplicate average	143
	minimum	25
	maximum	245
GB 5 Saliquenhedim^	average	100
	minimum	33
	maximum	228

^ Result based on eight monthly datasets averaged over eight months
***Bold** indicates numbers used in text*

The minimum and maximum monitored deposited dust concentrations were 4 and 255 mg/m²/day, recorded at the GB 1 and GB 3 monitoring stations respectively.

2.7.2.2 Short-term 24 Hour Fine Particulate Monitoring Data

Table 2.15 and Table 2.16 detail the average 24 hour fine particulate monitoring results collected during site visits in September 2012 and September 2013.

Table 2.15: Summary of 24 Hour Fine Particulate Data (September 2012)

Location	Date	24 Hour Value	Fine Particulate PM_{10}	Fine Particulate $PM_{2.5}$
			µg/m³	
GB 4 Farim	6 September 2012	average	20.00	4.00
GB 4 Farim	7 September 2012	average	19.00	4.00

***Bold** indicates numbers used in text*

Table 2.16: Summary of 24 Hour Fine Particulate Data (September 2013)

Location	Date	24 Hour Value	Fine Particulate PM_{10}	Fine Particulate $PM_{2.5}$
			µg/m³	
GB 4 Farim	24 September 2013	average	100.07	20.05
GB 4 Farim	25 September 2013	average	123.41	23.90
GB 4 Farim	26 September 2013	average	85.48	16.68

***Bold** indicates numbers used in text*

Fine particulate monitoring undertaken in Farim during 2012 and 2013 indicate a wide range of concentrations for both PM_{10} and $PM_{2.5}$. Short-term 24 hour average PM_{10} concentrations ranged between 19 and 123 µg/m^3. Short-term 24 hour average $PM_{2.5}$ concentrations ranged between 4 and 24 µg/m^3. Monitoring was undertaken during the transition period between wet and dry seasons, and significant rainfall was experienced during some of the measurement events in 2012 which may have contributed to the wide range of concentrations recorded. The maximum monitored average PM_{10} and $PM_{2.5}$ concentrations of 123 and 24 µg/m^3 were recorded on a hot dry day and are considered more typical for the West African dry season climate.

2.7.2.3 Missing Data

Data capture was generally successful although some data gaps occurred due to incorrect labelling of tubes, loss of tubes during exposure in the field, damage to the tube, or due to the sorbent gauze being soiled. In January 2012, the SO2 and O3 tube for location GB 3 was lost from the station for a one month period before being replaced.

2.7.3 Baseline Results Interpretation

2.7.3.1 Gaseous Air Quality

Monthly data for each monitoring location were averaged and used to represent long-term annual background concentrations. Results were compared to the project AQS and the current contribution towards these standards are assessed.

To allow the comparison between monthly data and project AQS based on short-term averaging periods (*i.e. 24 hour, 1 hour and 10 min*), the United Kingdom Environment Agency guidance (Environment Agency, 2010) is used the Ontario Ministry of the Environment, Canada (2008) methodology to calculate the 10 minute average period, was used. The long-term annual average concentration is taken as the mean of the monthly monitored data. The following assumptions were applied:

- The annual average concentration x 2 = hourly average concentration;
- The hourly average concentration x 0.59 = 24 hour average concentration;
- The hourly average concentration x 0.7 = 8 hour average concentration; and
- The hourly average concentration x 1.65 = 10 minute average concentration.

For example:

- The monitored annual average SO_2 concentration at GB 1 for the baseline monitoring period was 1.20 µg/m^3;
- Therefore the hourly average SO_2 concentration was estimated to be 2.40 µg/m^3 (i.e., 1.20 µg/m^3 x 2);
- 24 hour average concentration = 1.42 µg/m^3 (i.e., 2.40 µg/m^3 x 0.59); and
- 10 minute average concentration = 3.96 µg/m^3 (i.e., 2.40 µg/m^3 x 1.65).

Table 2.17 to Table 2.21 compare the monitored long-term average concentrations to the Project AQS. Any parameter concentration which is greater than the relevant AQS is highlighted in bold.

Table 2.17: GB 1 Background Monitored and Estimated Gaseous Concentrations

Parameter Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	2.59	2.59	6%	40
NO_2 1 hour	2.59	5.18	3%	200
SO2 10 minute	1.20	3.96	1%	500
SO_2 24 hour	1.20	1.42	7%	20
O_3 8 hour daily max	61.48	86.07	86%	100

Table 2.18: GB 2 Background Monitored and Estimated Gaseous Concentrations

Parameter Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	2.76	2.76	7%	40
NO_2 1 hour	2.76	5.51	3%	200
SO2 10 minute	1.49	4.93	1%	500
SO_2 24 hour	1.49	1.76	9%	20
O_3 8 hour daily max	76.17	106.63	107%	100

Table 2.19: GB 3 Background Monitored and Estimated Gaseous Concentrations

Parameter Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	2.23	2.23	6%	40
NO_2 1 hour	2.23	4.46	2%	200
SO2 10 minute	1.07	3.51	1%	500
SO_2 24 hour	1.07	1.26	6%	20
O_3 8 hour daily max	56.75	79.45	79%	100

Table 2.20: GB 4 Background Monitored and Estimated Gaseous Concentrations

Parameter Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	4.94	4.94	12%	40
NO_2 1 hour	4.94	9.88	5%	200
SO2 10 minute	1.57	5.20	1%	500
SO_2 24 hour	1.57	1.86	9%	20
O_3 8 hour daily max	63.85	89.40	89%	100

Table 2.21: GB 5 Background Monitored and Estimated Gaseous Concentrations

Parameter Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	3.13	3.13	8%	40
NO_2 1 hour	3.13	6.26	3%	200
SO2 10 minute	1.33	4.40	1%	500
SO_2 24 hour	1.33	1.57	8%	20
O_3 8 hour daily max	58.70	82.18	82%	100

The results indicate that the majority of parameters monitored at the air quality monitoring stations within the mine area are significantly below the Project AQS, with the exception of the following:

- 8-hour O_3 concentrations at the GB 2 station were estimated to be greater than the Project AQS.

The laboratory analysis reports are provided in Appendix A2.

2.7.3.2 Fine Particulate Monitoring Results

Short-term fine particulate monitoring was undertaken at the GB 4 monitoring station (Farim) using an Optical Scattering Instantaneous Respirable Indication Sensor (OSIRIS) fine particulate monitor for two 24 hour periods during September 2012 and three periods during 2013. Table 2.22 compares the maximum 24 hour average concentrations against the project AQS, based on the five short-term measurements undertaken.

Table 2.22: GB 4 Background Monitored and Estimated Fine Particulate Concentrations

Parameter Average Period	Monitored Maximum	Period Average	Project AQS	% of AQS
	µg/m³			
PM_{10} Annual	123.41	123.41	20	**617%**
PM_{10} 24 Hour	123.41	123.41	50	**247%**
$PM_{2.5}$ Annual	24.00	24.00	10	**240%**
$PM_{2.5}$ 24 Hour	24.00	24.00	25	96%

Fine particulate data collected at the GB 4 station indicate that concentrations are close to or are greater than both the annual and 24-hour Project AQS. However concentrations are considered to be typical considering the regional climate of Guinea-Bissau and West Africa.

2.7.3.3 Deposited Dust Monitoring Results

Table 2.23 presents the results for deposited dust monitoring. The average monthly concentrations are assumed to represent annual average concentrations and are compared to the project AQS. The laboratory dust and metallic analysis reports are provided in Appendix A3.

Table 2.23: Baseline Deposited Dust Concentrations

	GB 1	GB 2	GB 3	GB 4	GB 5
Average	94	77	85	143	100
Min	17	13	4	25	33
Max	255	159	213	245	228
% of AQS (600 mg/m²/day)	16%	13%	14%	24%	17%

The deposited dust concentrations recorded display a large range of values as indicated by the minimum and maximum values.

The deposited dust collected from the GB 4 station exhibits the highest average daily dust concentrations over the year (143 mg/m^2/day), representing only 24% of the project AQS. GB 4 station is located within Farim, therefore there is expected to be a higher frequency of disturbances leading to greater deposited dust emissions. Conversely, the lowest average daily dust concentration was recorded at the GB 2 station (77 mg/m^2/day), representing only 14% of the project AQS. All stations located within the mine area were significantly below the recommended guideline of 600 mg/m^2/day for deposited dusts in residential areas.

2.7.4 Baseline Condition

Within the air quality ESIA, existing concentrations will be required to be assessed. For example, a detailed air quality assessment using air dispersion modelling (ADM) will predict a modelled process contribution (PC) which will be combined with the existing air quality concentrations (background) to give a total predicted environmental concentration (PEC). The PEC will then be compared to the relevant project AQS.

The data has been combined for the mine area only (GB 1 to GB 5 stations) and the maximum concentrations for each parameter at each location are used to derive the combined gaseous, dust and fine particulate concentrations for the mine area (Table 2.24).

Table 2.24: Proposed Baseline Concentrations for Development Areas

Parameter / Development Area	NO_2	SO_2	O_3	PM_{10}	$PM_{2.5}$	Deposited Dust
	µg/m3					mg/m^2/day
FPM Area (GB 1 to GB 5)	5.86	2.24	96.61	123.41	23.90	220

2.7.5 Limitations

The following limitations have been identified with respect to the baseline monitoring and the data presented in this section:

- Complete meteorological data are available for Farim for a 12 month period only providing little inter-annual variability; and
- Historic meteorological data analysis was limited due to the quality of data available, as no long-term trends could be determined to analyse if the baseline data is representative of a typical year or is extreme.

2.8 Glossary

Air Quality Standards	Air Quality Standards are the concentrations of pollutant parameters in the atmosphere which can broadly be taken to achieve a certain level of environmental quality. The Standards are based on assessment of the effects of each parameter on human health, including the effects on sensitive sub-groups
Ambient Air	The air (or concentration of parameter) that occurs at a particular time and place outside of built structures
Average	The result obtained by adding several amounts together and then dividing this total by the number of amounts; the mean.
Background Concentration	Estimated existing concentration of parameter
Data Capture	Data capture is the term given to the percentage of measurements for a given period that were validly measured

Diffusion Tube Samplers	Passive diffusion tube samplers that collect nitrogen dioxide and other parameters by molecular diffusion along an inert tube to a chemical absorbent. After exposure for a known time, the absorbent material is chemically analysed and the concentration calculated
Diurnal	Daily; of each day
Exceedance	An exceedance defines a period of time during which the concentration of a parameter is greater than, or equal to, the appropriate air quality criteria. For Air Quality Standards, an exceedance is a concentration greater than the Standard value. For Air Pollution Bandings, an exceedance is a concentration greater than, or equal to, the upper band threshold
Frisbee Deposit Dust Gauges	Very shallow dish collectors with a low rim used to sample dust. Their low profile reduces both the disturbance to the flow and development of the internal vortex that causes re-entrainment, and their collection efficiency is less sensitive to wind speed
Fugitive emissions	Emission of a chemical to the air that does not occur from a stack, vent, duct, pipe or other confined air stream (e.g., leaks from joints).
Gaseous Air Quality Data	Air quality data referring specifically to gas form parameters
Harmattan Wind	West African trade wind from the Sahara
Long-term	Relating to an extended period of time e.g. one year
Mean	The arithmetic mean; the sum of the values in the set divided by the total number of values in the set
Meteorological Conditions	Conditions concerned with the processes and phenomena of the atmosphere e.g. precipitation, wind and temperature
Parameter	A chemical compound, indicator of the presence or effects of chemical compounds"
Particulate Matter	Airborne Particulate Matter includes a wide range of particle sizes and different chemical constituents. Of greatest concern to public health are the particles small enough to be inhaled into the deepest parts of the lung
Prevailing Wind Direction	The direction from which the wind blows at a particular time period
Respiratory	Relating to organs involved in respiration (breathing); for example, the lungs and throat
Short-term	Relating to a shorter period of time typically less than or equal to 24-hours
Spatial	Relating to space
Volatile Organic Carbons (VOC)	Volatile organic compounds (VOCs) refer to any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions. VOCs are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure.

2.9 Abbreviations and Acronyms

ADM	Air Dispersion Model
AQS	Air Quality Standards

ESIA	Environmental and Social Impact Assessment
IFC	International Finance Corporation
INMGB	Instituto Nacional de Meteorologia da Guinea-Bissau
LSA	Local Study Area
MASL	Meters above Sea Level
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
NO	Nitric Oxide
OSIRIS	Optical Scattering Instantaneous Respirable Dust Indication System
SO_2	Sulphur Dioxide
O_3	Ozone
OSF	Overburden Storage Facility
PEC	Predicted Environmental Concentration
PC	Process Contribution
PM	Particulate Matter
QA	Quality Assurance
RSA	Regional Study Area
Site	Farim Phosphate Mine Area
TMF	Tailings Management Facility
VOC	Volatile Organic Compound
WHO	World Health Organisation

2.10 References

- AEA (AEA Energy and Environment). 2008. Diffusion Tubes for Ambient NO2 Monitoring: Practical Guidance. Prepared for DEFRA and the devolved administrations. Issue 1a, February 2008.
- IFC (International Finance Corporation), 2007. Environmental health and Safety Guidelines for Mining.
- World health Organisation, 2005. Air Quality Guidelines- Global Update 2005.
- Gradko. 2012. *Nitrogen Oxides Technical Data Sheet: TDS 2*. Version 1. Gradko Environmental, Winchester.
- Web 1, 2013. [http://en.wikipedia.org/wiki/Geography_of_Guinea-Bissau].
- WHO (World Health Organisation). 2000. Air Quality Guidelines for Europe. Second Edition. WHO Regional Publications, European Series, No. 91. World Health Organis ation Regional Office for Europe, Copenhagen, Denmark.
- WHO. 2005. Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide. 20 pp. WHO Press, Geneva, Switzerland.

3.0 GEOLOGY

3.1 Introduction

3.1.1 Regional Geology

The Farim phosphate deposit is located within the Middle Eocene Lutetian Unit that forms part of the southern margin of the Mauritania-Senegal-Guinea Cenozoic sedimentary basin (Prian, 1987). The basin extends from Morocco in the north through Mauritania, Senegal, Guinea-Bissau and into Guinea to the south. The Mid-Eocene and particularly the Lutetian of the basin contains known phosphate horizons and hosts a number of important economic phosphate deposits including Bofal in Mauritania and Taïba, Thiès and Matam in Senegal.

The sediments of this basin were formed in the palaeo-gulf of Casamance, which extended from the southeast of Mauritania in a generally southwesterly direction into what is now the Atlantic Ocean.

The regional geology and setting of Farim is shown on Figure 3.1.

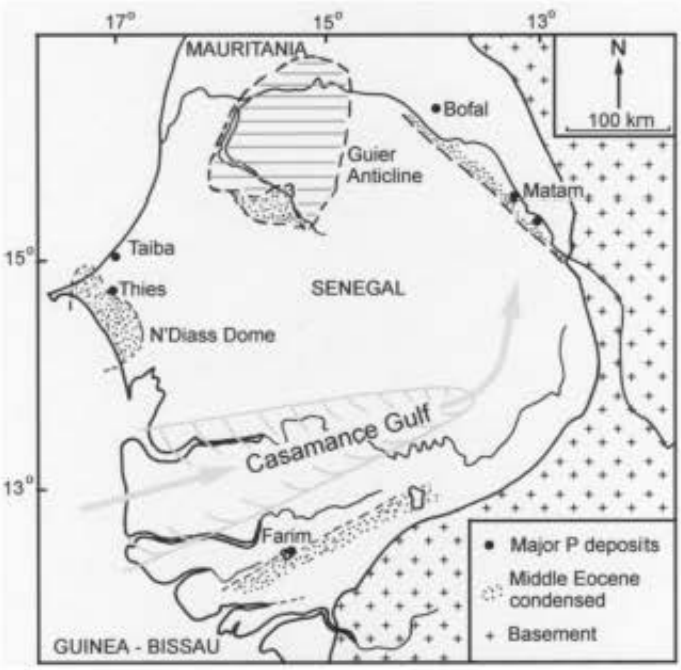


Figure 3.1: Regional geology and setting of Farim

3.1.2 Geology local to the Mine Site

The Farim area forms part of the southern margin of the former Casamance Gulf and is located 60 km northwest of the southern edge of the Senegal-Mauritania-Guinea sedimentary basin in which the Maastrichtian strata unconformably overlies the Devonian pelite sequence (Prian, 1987). The various Mesozoic and Cenozoic Units become thinner and wedge out progressively from northwest to southeast towards the Devonian bedrock. Abrupt condensing and wedging out of the Eocene sedimentary Units occurs in the Farim area around an elevated structure known as the Rio Jumbembem ridge, which gives way southwestwards to the Binta high. The high, rectilinear Rio Jumbembem ridge strikes 050° to 060° and is positioned over a basement flexure. Immediately to the southwest of Farim, between the high points of Rio Jumbembem and Binta, is the smaller Saliquinhé bay, 3 km wide from northwest to southeast and 5 km long

from southwest so northeast, open to the northeast and closed to the southwest. A subsidence zone at the southeast edge of the Casamance Gulf lies to the northwest of this zone of highs, which is marked by sequential condensing and frequent wedging out of the various Palaeocene and Eocene sedimentary Units.

The late Palaeocene occupies an elevated position and forms the greater part of the Rio Jumbembem ridge, in which it is composed of nummulitic limestone, becoming argillaceous and marly towards the Palaeocene subsidence zone to the northwest.

The Eocene is condensed and/or reduced over elevated zones. Boreholes located on the Rio Jumbembem high have all the lithologic Units of the lower to upper Eocene present, but extremely condensed (39 m). The thickness of these Units in the subsidence zone is over 70 m.

Abrupt sequential condensing occurs in the Farim area near the phosphate deposit. This is particularly evident in the calcareous and phosphatic sequence. Only the lower to basal middle Eocene, composed of argillaceous and micritic laminite, is present in the elevated zone. The calcareous-phosphatic middle Eocene and the calcareous-dolomitic upper Eocene are notably absent the Binta high. The middle and upper Eocene are, however, well developed to the north of the high.

Throughout this area of the Senegal-Guinea sedimentary basin, the Eocene, Palaeocene and Maastrichtian are respectively unconformably overlain southeastwards by an Oligo-Mio-Pliocene and Quaternary sandy argillaceous sequence displaying black lignitic clay at the base. This is locally overlain by a greensand sequence, probably Miocene in age, containing thin limestone beds. These Units underlie a sandy-argillaceous sequence assigned to the late Continental. The thickness of post Eocene sandy-argillaceous cover ranges from 15 m to 35 m in the Farim area, and from 50 m to 64 m in the basin subsidence zone.

The local geology beneath the overburden is shown on Figure 3.2.

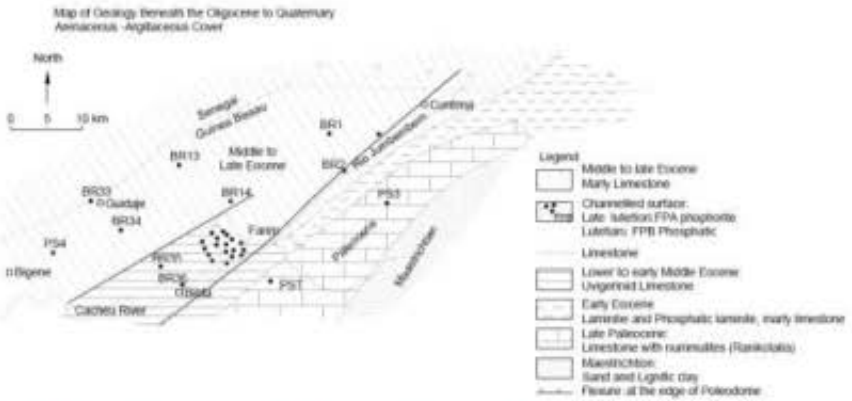


Figure 3.2: Local geology beneath the overburden (reproduced by Golder from Prian, 1987)

Figure 3.3 shows a typical cross section of the Farim deposit together with a lithostratigraphic column (Prian, 1989).

Figure 3.3: A typical cross section of the Farim Deposit with a Lithostratigraphic Column (reproduced from Prian, 1989)

3.2 Previous Work

Phosphate was first discovered in Farim as part of a water survey in 1950. Exploration in and around the Project area has been carried out by several companies from 1973 to the present including:

- BRGM drilled 101 resource drill holes from 1981 to 1985;
- Champion resources drilled 34 drill holes from 1997 to 1999;
- GBMAG drilled an additional 55 resource drill holes between 2008 and 2011;
- Global Geomatics was contracted in 2011 to re-survey all drill hole collars on the Project; and
- Plains Creek Mining drilled 18 drill holes in 2011 to undertake pump tests.

Reports detailing or summarising the previous work are refenced in Section 3.6.

3.3 Methods

3.3.1 Ground Investigation

Ground investigations have been undertaken at the proposed mine site, pipeline route and the port site and comprised geotechnical intrusive and geophysical investigations.

- Boreholes were progressed by conventional rotary open hole and coring techniques;

- Trial pits were undertaken using either a tracked excavator or wheeled backhoe excavator;
- The geophysical investigations comprised:
  - EM 31 survey - to evaluate the resistivity of the cover ground;
  - Seismic refraction survey - to determine the stiffness of the different strata;
  - Multi-Channel Analysis of Seismic Waves (MASW) - to evaluate the elastic condition of the ground; and
  - Resistivity survey - to determine overburden properties.
- Laboratory testing has comprised:
  - Geotechnical properties; and
  - Geochemical characterisation.

The ground investigations are detailed in the 2012 Ground Characterisation – Factual Report (Golder 12514950591.504/B.1, 2013).

3.3.2 Geochemistry

Overburden

A total of 20 composite samples were identified by Golder from different depths in four of the boreholes (BH8, BH10, BH20 and BH23). Two duplicate samples (Sample 10, BH10 30.45-49.7 and Sample 17, BH23 3.0-16.5) were also included in the sampling and testing protocol. Samples were sent to SGS Laboratories in Lakefield, Canada.

Twenty overburden samples (including two duplicates) were dispatched to SGS Canada Inc. ("SGS"), in Lakefield, Ontario for analysis. The samples were received by the laboratory in April 2012, and analyses were conducted in May and June 2012. The analytical programme is summarised in Table 3.1.

Table 3.1: Summary of geochemical assessment analytical programme

Type of Test	Specification	No. of Samples Analysed*
Sample preparation	Crushing to <9.5 mm and further as required for specific analysis	22
Chemical composition	Whole Rock Analyses by XRF (Lithium Metaborate Fusion)	22
	3- acid and microwave assisted digestion followed by metals analysis by ICP-MS & CVAAS	
Mineralogy	Semi-quantitative XRD with Rietveld Refinement	22
Acid Base Accounting	Modified Sobek method used, with analyses for Paste pH, Bulk neutralisation potential (NP), Sulphur species (S_{total}, $S_{sulphate}$, $S_{sulphide}$), Total inorganic carbon (TIC) and Total carbon (TC).	22
NAG pH	Single addition NAG tests with peroxide leach	22
Short-term Leach Tests	Shake flask tests using 4:1 Liquid: Solid ratio	22
	Supernatant analysed for: pH, EC, Major cations, Major anions (including alkalinity), metals and metalloids and CN_{total}	

*Twenty samples were collected and analysed. Two field duplicate samples were also analysed for QA/QC purposes.

Mineral identification and interpretation involved matching the diffraction pattern of the unknown material to patterns of single-phase reference materials using DiffracPlus Eva software and the International Centre for Diffraction Data (ICDD) database. The ICDD database of reference patterns is available on software as Powder Diffraction Files (PDF-2/PDF-4).

Phosphate

Chemical characterisation analyses undertaken by ALS Chemex have been reviewed. Statistics were produced Using OBO v11.02 (Golder Propietary Software).

3.4 Results and Discussion

3.4.1 Mine Site

The geological sequence at Farim displays the following lithological Units from top to bottom:

- Sandy-argillaceous overburden with soft, alternating sandy, clayey and sandy-clayey layers, and a blue, green soft clay at the base;
- Grey, white fine grained sand including phosphatic interval (FPO);
- Upper dolomitic limestone, where present;
- Decarbonised phosphate Unit (FPA), where present;
- Calcareous phosphate member (FPB), where present; and
- White, soft and porous limestone.

The available ground investigation indicates a highly variable ground profile comprised of discontinuous inter-bedded bands of clayey sand, sandy clay, sand and clay overlying marl/weak chalk bedrock. Without relatable strata between the boreholes, the ground profile detailed in below has been inferred on the basis of changes in the engineering properties of the ground with depth. The units vary in thickness and are not always laterally extensive and may occur in repeated sequences. They are:

- Formation MS1. Firm clay Unit;
- Formation MS2. Clayey sand Unit;
- Formation MS3. Hard clay Unit;
- Formation MS4. Fine sand and clay Unit (including FPA Resource); and
- Formation MS5. Bedrock.

The following sections describe the geology encountered across the mine site.

Topsoil

Where present, topsoil generally comprised of moist brown sandy clay with organics including roots and rootlets. The depth of the topsoil varied between 0.3 mbGL and a maximum of 1.5 mbGL observed in BH21.

Formation MS1 – Firm Clay

Formation MS1 is generalised as a firm red brown, often mottled orange clay. Occasional orange fine sand layers and fine laterite gravel was encountered.

This Formation is present in almost all boreholes. The thickness of Formation MS1 varied between 4.5 m (BH02) and 43.0 m (BH03). The firm clay Formation was not encountered in BH11.

Formation MS2 – Clayey Sand

Formation MS1 is generally underlain by a yellow brown mottled orange fine to medium clayey sand with some laminations of red and dark grey sand observed. Occasionally gravel was identified in this Formation. The gravel content is small although not always present. The clay is encountered as small, pale brown lenses.

This layer was normally found inter-bedded with Formation MS3. With an average thickness across the area in excess of 10 m, the thickness of this Formation varied between 2.0 m (BH15) and greater than 20 m (BH25). Formation MS2 was not encountered in boreholes BH29 and BH30, located in the TMF area.

Formation MS3 – Hard Clay

This Formation was normally found inter-bedded with Formation MS2 and consisted of a light grey very stiff to hard clay, often with orange brown mottling and was described as having a medium to high plasticity in the field. Formation MS3 also included laminations of grey sand and occasional fine to medium gravel and cobbles.

Formation MS4 – Fine Sand (Resource)

Where encountered, this Formation was found lying above the bedrock. This Formation consisted of a very dense light grey mottled light brown fine sand with laminations and lenses of black clay and was identified as containing the phosphate resource and occasional black lignite grains. Recovery of this Formation was generally poor due to the granular nature of the layer.

The thickness of the Formation MS4 varied from not being encountered in Borehole BH13 to 10 m in Borehole BH17.

A clay layer was also encountered below the fine sand that contained laminations of the fine sand. This is identified as Formation MS4a for the purposes of this report. The thickness ranged from absent to 10.55 m in BH04.

Formation MS5 – Bedrock

The bedrock was generally described as a very weak to medium strong fractured white, light grey or pale brown dolomite or limestone. In places, the material appeared to have weathered to a sandy or clayey matrix containing gravel or cobbles of intact rock. Sandstone and mudstone bedrock was also noted.

The thickness of the Formation was not proven.

Phosphate

The three phosphate-bearing horizons referred to as FPO, FPB and FPA are described below.

FPO

The FPO is a clayey dolomitic limestone that is weakly phosphatic and has limited economic potential. It comprises laminated green clays and aluminophosphate and is 0.5 m to 1 m thick. At the surface in the higher zones, laterite with a ferruginous cover in places may be found.

FPA

The FPA ore is homogenous and has a grainstone texture, with grains less than 800 µm in size. It is a soft, poorly cemented unit of phosphatic sand, which includes phosphatised shell and bone material, teeth, faecal pellets and crustacean coprolites. There is no calcareous cement and it contains little silica and clay. It is mildly indurated and includes siliceous or pyritised layers 50 to 200 mm thick which comprise an average of 6% of the unit. The FPA layer has a P_2O_5 content of approximately 30% (consistently higher than 25%). The FPA unit is currently considered the potentially economic phosphate horizon. Grades of sedimentary phosphate deposits of worldwide distribution as compiled by Mosier (1986) are in the range of 15 to 32%. The Farim deposit is at the higher end of that range (Champion, May 2000).

The FPA is localised within the Saliquinhé bay sub-basin and is the potentially economic phosphate bed. The sub-basin is bounded to the south and east by carbonate platform rocks against which the FPA wedges out. The northwestern limit of the FPA has not yet been defined. To the north, the Tambato submarine bar, which formed a barrier between the Saliquinhé bay and the deeper Casamance basin, will likely form the northern limited of the FPA unit but this has not been demonstrated by drilling.

The limits of the FPA unit, the hanging and the foot walls, are clearly defined. A mixture of saprolitic fine sand and clays, which are generally unconsolidated, overlies the FPA. The immediate hanging wall to the FPA is 200 to 600 mm thick unconsolidated sand. The hanging wall rocks are oxidised reddish brown to an elevation of about 10 m below sea level. The FPA is grey to beige and brown and lies in a generally reducing environment below the oxidised interval. This is important because iron oxide, which is soluble in sulphuric acid, is a contaminant in phosphate deposits whereas iron sulphide, which is insoluble in sulphuric acid, is not. (Champion, May 2000).

The FPA unit has an average width of about 3 m (in the resource area) and underlies an area of about 60 km^2. In the northern part of the basin, north of the village of Saliquinhé, a northeasterly trending area about 5.5 km long and 1.5 km wide has FPA thickness typically greater than 3.0 m and up to 6.0 m. A smaller area to the south of Saliquinhé, near the Cacheu River, also exceeds 3.0 m in thickness.

FPB

The FPB is a calcareous phosphate unit consisting of alternating soft phosphate strata with carbonaceous gangue and thinner, hard strata of slightly phosphatic bioclastic limestone. The lower grade FPB layer consists of highly carbonated phosphate, generally containing 5-20% P_2O_5 with an average of 13% P_2O_5. The FPB phosphatic limestone is indurated and much harder than FPA.

FPB is located immediately below FPA, but exists under only 50% of the area of FPA. FPB also has a large extent outside of FPA. This horizon is known to extend 20 km north to south and 50 km east to west with thickness variable from 20 to 60 m with an average thickness of about 4 m.

Mine Site Geochemistry

Overburden

The results from the chemical analysis of overburden ar provided in Appendix B1 can be summarised as follows:

- Silica accounts for most of the total oxides (>51% SiO_2 in all samples), with the highest concentration of 94.8% being detected in Sample 12 and the lowest of 51.4% in Sample 2;
- Concentrations of aluminium, as Al_2O_3, range from 1.55% (Sample 12) to 22.6% (Sample 3), with an average of 13.3% being calculated for the sample set;
- Iron concentrations (as Fe_2O_3) range from 1.76% (Sample 12) to 18.9 % (Sample 2), with an average concentration of 6.92% being calculated for the rock samples;
- An average calcium concentration (as CaO) of 0.52% was calculated for the sample set, with the lowest concentration being detected in Sample 1 (<0.01%) and the highest in Sample 15 (6.27%);
- Phosphate concentrations ranged from 0.02 to 4.37% P_2O_5. The highest concentration was measured in Sample 15, which may intercept the FPA phosphate horizon. The second highest concentration was 2.55% P_2O_5 and was measured in Sample 10 from Borehole 10, which does intercept the FPA horizon;
- Significant variability exists in the trace element compositions of the samples; and
- In general, the trace metal concentrations are similar to or below the crustal abundances, with the exception of Ag, As, Mo, Se and U, which exceed 6x crustal abundance in one or more samples. The potential mobility of trace metals highlighted here as being of potential environmental concern was verified through short-term leach testing.

The results from the mineralogical studies are generally consistent with the whole rock results, in particular with respect to the Si-, Al-, and Fe-containing compounds.

The major findings are as follows:

- The samples demonstrate an average quartz concentration of 55.9 wt%;
- Relatively high concentrations of aluminium silicates, kaolinite and halloysite, were detected in the samples;
- The only sulphide mineral detected was pyrite, which occurred in just over a third of the samples, with concentrations ranging from 0.3 wt% (Sample 13) to 3.5 wt% (Sample 20);
- Calcite was detected in one sample (Sample 2) at a concentration of 0.6 wt%;
- The iron carbonate mineral, siderite, was detected in just under a third of the samples, with concentrations ranging from 0.5 wt% (Sample 10) to 11 wt% (Sample 20);
- No dolomite was detected in any of the samples analysed, suggesting that the Upper dolomitic limestone horizon was not intercepted in any of the boreholes sampled; and
- Two phosphate minerals were identified: crandalite in Sample 10 (9.5%), and fluorapatite in Sample 2 (1.8%) and Sample 15 (12%).

Phosphate

Phosphate chemical analyses was undertaken to characterise the phosphate. The results are provided in Appendix B2. A statistical analysis of phosphate sample testing is provided in Table 3.2.

Table 3.2: Summary of Phosphate Chemistry

Analysis	Samples	Min	Max	Mean	Median	Variance	STD DEV	C.V.	Skew
Al_2O_3_%	154	0.32	26.43	3.384	1.81	18.3187	4.28	1.2647	2.9277
CaO_%	154	1.38	54.36	38.933	42.73	125.8637	11.2189	0.2882	-1.4127
Cr_2O_3_%	154	<0.01	0.12	0.045	0.05	0.0003	0.0187	0.4191	0.0825
Fe_2O_3_%	154	0.49	40.98	5.886	4.08	37.577	6.13	1.0414	3.0578
K_2O_%	154	<0.01	0.39	0.065	0.05	0.0037	0.0611	0.9456	2.943
MgO_%	154	0.12	6.58	0.464	0.31	0.3904	0.6248	1.3467	6.6831
MnO_%	154	<0.01	0.81	0.099	0.05	0.0179	0.1338	1.345	3.0141
P_2O_5_%	154	0.73	35.94	22.549	26.235	107.6688	10.3764	0.4602	-0.689
SiO_2_%	154	1.62	79	12.877	8.725	135.5827	11.644	0.9043	2.7591
TiO_2_%	154	<0.01	1.16	0.111	0.07	0.0191	0.138	1.2417	4.0445
LOI_%	154	3.74	40	13.152	8.325	103.1881	10.1582	0.7724	1.446
F_%	102	0.13	3.47	2.162	2.485	0.8503	0.9221	0.4266	-0.8896
C_%	154	0.15	11.25	2.717	1.025	10.6091	3.2572	1.1987	1.4607
Ag_ppm	154	<0.5	30.8	0.738	0.25	6.653	2.5793	3.4966	10.4938
Al_%	154	0.2	10.05	1.711	0.99	3.3861	1.8401	1.0754	2.2622
As_ppm	154	<5	23	9.62	10	19.3411	4.3979	0.4572	0.22
Ba_ppm	154	10	410	48.18	30	2385.01	48.837	1.0136	3.788
Be_ppm	154	<5	26.2	2.944	1.7	12.1674	3.4882	1.1846	3.2289
Bi_ppm	154	<2	25	2.136	1	7.7931	2.7916	1.3067	4.9941

Analysis	Samples	Min	Max	Mean	Median	Variance	STD DEV	C.V.	Skew
Ca_%	154	1.11	35.9	25.24	26.85	53.3527	7.3043	0.2894	-1.2446
Cd_ppm	153	0.6	26.5	6.12	5.9	13.8749	3.7249	0.6087	1.9895
Co_ppm	154	<1	64	11.27	8	124.569	11.161	0.9901	1.8882
Cr_ppm	154	40	744	280.9	304	13458.7	116.01	0.413	0.1162
Cu_ppm	154	3	138	19.81	18.5	213.036	14.596	0.7367	3.8385
Fe_%	154	0.33	28.5	3.881	2.7	16.6312	4.0781	1.0507	3.1759
Ga_ppm	154	<10	<10	5.097	5	0.4775	0.691	0.1356	6.9536
K_%	154	<0.01	0.35	0.057	0.04	0.0026	0.0514	0.8974	2.6259
La_ppm	154	10	240	97.34	100	1894.86	43.53	0.4472	-0.2286
Mg_%	154	0.01	3.55	0.211	0.12	0.1216	0.3488	1.6496	6.3378
Mn_ppm	154	64	5490	694.6	324	882411	939.37	1.3524	3.1053
Mo_ppm	154	<1	8	1.669	0.5	3.1858	1.7849	1.0695	1.6122
Na_%	154	0.02	0.37	0.095	0.08	0.0027	0.0522	0.5499	1.7065
Ni_ppm	154	5	530	69.81	45	5205.1	72.146	1.0335	2.6501
P_ppm	154	3610	>10000						
Pb_ppm	154	<2	2270	19	4	33125	182.00	9.5824	12.285
S_%	154	<0.01	8.36	2.143	1.995	1.8243	1.3507	0.6302	1.5169
Sb_ppm	154	<5	12	3.016	2.5	2.1442	1.4643	0.4855	3.3386
Sc_ppm	154	1	25	5.084	5	10.077	3.1745	0.6244	2.7825
Sr_ppm	154	161	7260	1058	535.5	1897902	1377.6	1.3019	2.9099
Th_ppm	154	<20	40	19	20	34.074	5.837	0.3007	0.3993
Ti_%	154	0.01	0.59	0.06	0.04	0.0045	0.067	1.1458	4.4909
Tl_ppm	154	<10	10	5.7	5	3.18	1.78	0.3101	1.9675
U_ppm	152	<10	200	68.6	70	1084	32.93	0.4801	0.7013
V_ppm	154	25	971	228	210.5	18544	136.18	0.5985	1.48
W_ppm	154	<10	70	5.8	5	29.8	5.46	0.9342	10.675
Zn_ppm	154	18	814	212	192.5	17385	131.9	0.6232	1.1841

Note: When the value was below the detection limit of detection, half the value was used, when above, the statistical analysis was not completed.

3.5 Abbreviations and Acronyms

BH	Borehole
C.V	Coefficient of Variance
ESIA	Environmental and Social Impact Assessment
EM	Electro-magnetic
m asl	metres above mean sea level
MAX	Maximum
MIN	Minimum

ND Not detected, value below detection limit

STD DEV Standard Deviation

3.6 References

- ASCON, 2007. Hydrogeological Analysis Levantamento Topografico – PDF provided contains a location plan and borehole logs. InUnit in Portuguese.
- Bureau de Recherches Geologiques et Minieres, 1986. Troisième phase du projet phosphate Farim (campagne de terrain d'avril à août 1985) simulation prèliminaire de l'exhaure de la future exploitation à ciel ouvert. 86 GNB 049 EAU. Report provided in French.
- BRGM. (1983). Géologie et Réserves du Gisement de Phosphate de Chaux de Farim-Saliquinhe.
- Champion Industrial Minerals Inc, 2000. Farim Phosphate Project Resource Audit.
- GBM, 2011. Technical report on the preliminary economic assessment of the Farim Phosphate Project, Guinea Bissau. An NI 43-101 Report.
- GEEEM, 2008. Field of Phosphate, Farim, Validity of Operation. Google English translation of report provided by GBM.
- GEEEM, 2009. Farim Phosphate Deposit, Pumping Test. InUnit in French.
- Geiger, Albert, 2007, Cacheu River & Estuary Guinea Bissau Marine Survey: Initial Report, Albert Geiger. Geomatics, May 2007.
- Golder Associates (2011). Farim Phosphate Mine: Hydrology and Hydrogeology Desk and Field Study. Report No. 11514950043.510, September 2011.
- Golder Associates (2012). Farim Phosphate Project, Guinea Bissau: Goundwater and Dewatering 1.32 Mtpa Open Pit Feasibility Study Report. Report No. 12514950591.501/B.0, October 2012.
- Golder Associates (2013). Farim Phosphate Project, Guinea Bissau: 2012 Ground Characteristation – Factual Report. Report No. 12514950591.504/B.1, October 2013.
- Prian, J. P, Gama, C, Bourdillon de Grissac, J, and Roger J, 1987. The Eocene Farim-Saliquinhe phosphate deposit (Republic of Guinea Bissau) chron. Rech.min Number 486 p25-54. Paper provided in French.
- Prian, J. P, 1989, The Farim-Saliquinhe Eocene Phosphate deposit Guinea Bissau, West Africa. Chapter 43 of Phosphate Deposits of the World: Volume 2, Phosphate Rock Resources, Ed. A. J. G. Notholt, R. P. Sheldon, D. F. Davidson, Cambridge University Press.

4.0 GEOMORPHOLOGY AND TOPOGRAPHY

4.1 Introduction

The topography in the Project area is relatively flat with an elevation change of approximately 20 m over a distance of 4 km between the Cacheu River and the north western edge of the Farim phosphate mine deposit. The elevation of the wider project varies between 5 m and 50 m.

A baseline study for river morphology and oceanography was developed in consideration of potential physical effects on the River Cacheu and its estuary arising from loading of barges at the mine site, barge traffic on the river, storage of barges near Bolor, and then the transfer of phosphate matrix from barge to ship offshore of Bolor. This is reported in the River Morphology and Physical Oceanography Baseline Study (Golder 13514950220.503/B.0 dated September 2013) and summarised below for the area relating to the mine site.

4.1.1 River Morphology Introduction

The River Cacheu is tidal (semi-diurnal). Farim is about 180 km upstream from the open Atlantic Ocean. The estuary and river width ranges from a maximum of over 10 km near Bolor, over 1,500 m near Cacheu, to about 350 m near Sao Vicente Bridge, whilst it is approximately 150 m near Farim.

The main objective of this baseline assessment is to characterise the river morphology associated with the Project, including water quality and sediment quality. This was completed through the following:

- A literature review of available public data;
- A review of the morphological history of the river system, to aid in understanding potential effects and appropriate mitigation; and
- A summary of data (water quality, sediment quality, river discharges, velocity measurements, site observations) collected during the wet and dry season field visits.

4.1.1.1 Study Area

The study area includes the River Cacheu from Farim approximately 180 kilometres (km) downstream. The study area is shown in Drawing 550-4.1.

The study area was determined considering the following potential effects of the Project:

- Potential erosion of the river banks which could undermine the existing shoreline vegetation; and
- Potential changes in water quality.

4.1.1.2 Study Limitations

The baseline study for river morphology is limited one wet season and one dry season programme. No dredging will be required to provide navigation access to Farim.

Analytes were selected to focus on metals and nutrients that are similar to the key geochemical features of the phosphate product. This allows limited characterisation of water and sediment quality and is considered to provide a good basis to identify potential effects to the river resulting from mine-related activities.

4.1.2 River Cacheu Water Quality and Sediment Quality Standards

Water quality data were evaluated by comparing concentrations of individual select analytes with published acute and chronic water quality guidelines for the protection of aquatic health in marine waters. Acute guidelines protect aquatic organisms from potential short-term lethal effects, while chronic guidelines provide protection from potential long-term sub-lethal effects. For this study, Canadian Council for Ministers of the Environment (CCME) water quality guidelines (CCME 1999) were used in lieu of any specific guidelines for Guinea-Bissau. Whilst other national water quality guidelines are available, and potentially more applicable to tropical, estuarine environments (e.g., ANZECC 2000), the CCME guidelines may be more conservative

for a variety of analytes (e.g., metals). This approach will be reviewed in future monitoring and assessment work.

Similarly, sediment quality data were evaluated by comparing concentrations of individual sediment analytes with values of the Canadian Interim Sediment Quality Guidelines (ISQG) and the probable effects level (PEL) for the protection of aquatic life in marine systems. This ISQG have been derived solely from the threshold effects level (CCME 1999). The threshold effects level represents the concentration below which adverse biological effects are expected to occur rarely, while the PEL represent the concentration above which adverse biological effects are expected to be frequently observed. For this study, Canadian Council for Ministers of the Environment (CCME) sediment quality guidelines (CCME 1999) were used in lieu of any specific guidelines for Guinea-Bissau.

4.2 Previous Work and Existing Data

4.2.1 Topography

A topographic survey was carried out during 2011 by AOC of South Africa using airborne LiDAR, which had a horizontal accuracy of 0.5 m and a vertical accuracy of 0.2 m.

4.2.2 River Morphology

The following information sources were used in the characterisation of the baseline river morphology, water and sediment quality of the study area:

- Literature review and baseline gap analysis of publically available information;
- Preliminary surveys conducted by GBM Minerals Engineering Consultants Limited (GBM MEC) in July 2012;
- Wet season field study conducted by Golder in September 2012 (River Morphology, Physical Oceanography, and Marine Biology);
- Farim Phosphate Project Beneficiation Option Study conducted by in 2012 W.F. Baird and Associates Coastal Engineers Ltd. (Baird 2012);
- Dry season field study conducted by Golder in May 2013 (River Morphology, Physical Oceanography, and Marine Biology); and
- Aerial landsat imagery from 1979 to 2003 (USGS 2013).

4.3 Methods

4.3.1 Preliminary Surveys (July and August 2012)

A river survey, including bathymetric, tidal, and acoustic profile surveys, from Farim to Bolor, and offshore of Bolor, was conducted by GBM MEC in July 2012. Although preliminary, the data illustrated that the river has sufficient depth for barge operations up to Farim, if tidal assistance is used for transit. This survey also noted that there are a number of deep sections of the river (up to 25 m).

Tidal surveys, including current velocities and directional discharge, were recorded by GBM MEC at Binta, Cacheu, and Bolor in July and August, 2012 (wet season). These data were collected under a range of tidal conditions.

An Acoustic Doppler Current Profiler (ADCP) was also deployed at the originally proposed trans-shipment area near Bolor to observe tide levels and currents. As part of the preliminary surveys, an exploratory level hydrographic survey (bathymetry) of the Cacheu River (i.e., the estuary and coastal areas) was conducted by Coastal Consulting and Exploration (CCE) in July 2012. This work supplemented and built upon the existing hydrographic survey completed in 2007 by Albert Geiger Geomatics (AGG), which surveyed the river reach between Canico and to the estuary (mostly along the centreline).

4.3.2 Wet Season Field Study (September 2012)

Golder conducted a wet season reconnaissance river survey (September 17 to 20, 2013) between Farim and Bolor by boat. Physico-chemical water quality surface water field measurements and water column profiles (i.e., temperature and salinity) were conducted at select locations; water and sediment samples were collected for laboratory analysis. The water column profile and water and sediment sampling locations are shown in Drawing 550-4.2.

The methods used for measurements and sampling during the reconnaissance survey were:

- Sediment samples were taken with an Eckman sediment sampler (Photographs 9 and 10). Samples were collected from the river, and seabed, and then placed in plastic bags for shipment to a lab in the UK for particle size analysis. Some of the sediment samples were also assessed for select chemical analytes;
- Salinity and temperature measurements through the water column were taken with a Sontek Castaway-CTD probe (Photographs 11 and 12). The Castaway-CTD measures conductivity, temperature, and pressure continuously as it is lowered through the water column. The probe has an internal GPS sensor and automated wireless data transfer to simplify the data collection and analysis process. Further information about this equipment is available in the Castaway-CTD users' manual (Sontek, 2012);
- *In situ* surface water quality field data measurements (e.g., dissolved oxygen, pH) were collected using a handheld YSI multi-parameter meter and probe' at various locations within the Cacheu River around Farim, which also included nearby inflowing tributaries (i.e., Rio de Bio, Rio de Bunja, and Rio de Cavaras Marinhos). These data were collected under a range of tidal conditions; and
- Filtered water quality samples were collected approximately 30 cm below the surface of the water. A syringe was used to push water through a small filter unit (Millex Filter HV 0.45 µm pore size) and then placed in plastic bottles for shipment to a lab in the UK (Jones Environmental Laboratory) for water quality analysis of selected analytes (Photographs 13 and 14). Prior to sample collection, the syringe and filter unit were flushed with sample water taken directly from the river to charge the syringe and unit for sampling.

4.3.3 Dry Season Field Study (May 2013)

Golder completed a river transit during the dry season field survey (13 to 21 May 2013). Similar to the wet season, salinity and temperature water column profile measurements were collected at 15 locations along the river reach from Farim to Bolor, and water and sediment samples were collected for select analyses. River flow velocity and discharge measurements were taken at various channel cross sections from Farim to the Sao Vicente Bridge. Sampling locations are shown in Drawing 550-4.3.

The key methods used during the reconnaissance survey are outlined as follows:

- Sediment samples were collected using an Eckman sediment sampler (Photographs 9 and 10). Samples were collected from the river and seabed and then placed in plastic bags for shipment to a lab in the UK (Jones Environmental Laboratory) for particle size analysis;
- Salinity and temperature measurements were collected through the water column using a Sontek Castaway-CTD probe (Photographs 11 and 12);
- Velocity measurements using an ADCP which was mounted onto a wood frame and attached to the side of the vessel (Photograph 15). Various straight sections of the river were chosen to conduct river transects (see Photograph 16). The time of the measurements were recorded to correlate to tidal patterns;
- Water levels were measured at Farim and at Sao Vicente Bridge to assist with correlation of the velocity measurements to tide level;

- Filtered water quality samples were collected approximately 30 cm below the surface of the water. Water samples were collected near the surface of the water for safety reasons. A syringe was used to push water through a small filter unit (0.45 µm pore size) and then placed in plastic bottles for shipment to a lab in the UK (Jones Environmental Laboratories) for water quality analysis of selected analytes. Prior to sample collection, the syringe and filter unit were flushed with sample water taken directly from the river to charge the syringe and unit for sampling; and
- Additional to the collection of surface water samples along the river reach, *in situ* salinity, temperature, and dissolved oxygen measurements were collected using a handheld YSI multi-parameter meter and probe. At these locations, Secchi disk depths were also measured.

4.4 Results and Discussion

4.4.1 Topography

A contour plot of the LiDAR survey is presented in Figure 4.1. Within the study area, topographical variation is fairly small, ranging from approximately 8 m above sea level (ASL) in the southwest of the study area to a maximum height of 55 m ASL in the north. The town of Farim is located around the 9 m contour. The main part of the study area is dominated by the flat low-lying valley through which the River Farim meanders in a generally westerly direction. There are a number of shallow side valleys which join the Farim valley, to the west of Farim town. However, these are comparatively shallow and are relatively indistinct features. Throughout the study area the landform is best described as flat to gently undulating. Dense vegetation cover serves to mask landform variation and it is likely that topographical appreciation will be greater during the dry season when there is less vegetation and the hills/valleys are more pronounced.

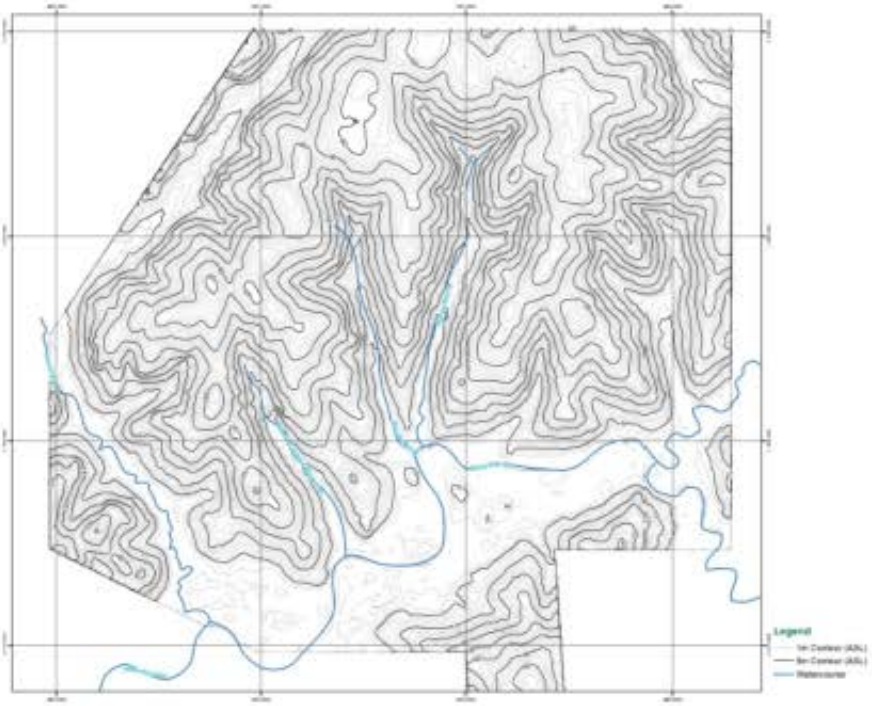


Figure 4.1: Farim Topography

4.4.2 River Morphology

Detailed results are reported in the River Morphology and Physical Oceanography Baseline Study (Golder 13514950220.503/B.0 dated September 2013) and summarised below for the area relating to the mine site.

The baseline characterisation of river morphology, physical oceanography, water and sediment quality within the River Cacheu and its estuary, provides the following findings:

4.4.2.1 Literature Review

- There is little publicly available historical data on the River Cacheu from Cacheu to Farim, and the proposed mine site; and
- Most available information on geomorphological development of the estuary has been generalised for Guinea-Bissau and western Africa.

4.4.2.2 River Cacheu Hydrodynamics

- The River Cacheu in the reach from Farim to Cacheu is strongly influenced by the tidal regime (semi-diurnal); tides extend upstream of Farim even during the wet season, and influences some of the tributaries. Hydraulic analysis results show that the river currents are dominated by tidal conditions rather than runoff from surrounding upland areas; and
- Maximum average velocities in the river range from 1.1 to 1.5 m/s according to simulated hydrodynamic conditions on the River Cacheu for both wet and dry seasons (Baird 2012).

4.4.2.3 River Cacheu Geomorphology

- The River Cacheu estuary is considered to be a flooded river system resulting from a post-glacial sea level rise (over the last 19,000 years BP), drowning the original river channel. Some examples of the drowned river channel are deep areas (up to 25 m) observed in the river channel between Farim and Cacheu;
- In both the wet and dry season the river bed sediments range from silt and clay at Farim to sand-sized particles at the estuary near Bolor. This is consistent with literature and the understanding of the geomorphological development of the estuarine system. Seabed sediments appear to be dominated by fine sand, which most likely were aerially transported from paleo-dunes from northern Senegal;
- The river banks are composed of fine-grained sediments and are well vegetated with mangroves and other vegetation. The fine-grained sediments are exposed at low tides and have the potential to be eroded through the action of waves and currents;
- The river morphology is currently dominated by the transport and deposition of fine-grained (predominantly silt, clay) sediments;
- Historical imagery indicates that no major channel changes (e.g. avulsions, meander cut-offs) have occurred from 1979 to 2012 between Farim and Cacheu; and
- Historical imagery indicates that there has been significant shoreline change on the north side of the estuary. Sandy shoals and cheniers exist off-shore and migrate in the dry season and migrate on an annual basis.

4.4.2.4 Water Quality

- During the wet season survey measurements shows predominately low salinity at Farim which increased in a steady gradient to the expected, near-open ocean levels offshore from the estuary. Salinity levels in the estuary indicate the influence of wet season flows on the river, despite the strong marine tidal influence in the study reach. The salinity in the dry season is much higher than in the wet season (there is dilution of the water in the River Cacheu in the wet season;

- Surface water temperatures are very similar throughout the river in the wet season. In the dry season, the surface water temperatures are approximately 1 to 1.5°C lower;
- The water column throughout the study reach is generally well mixed in both the wet and dry seasons;
- Water quality sampling around Farim (Rio de Caur, Rio de Cavaras Marinhos, River Cacheu) indicate that major ions and nutrient concentrations are lower in the wet season than in the dry season;
- Tributaries between Farim and Binta do no greatly influence the water quality within the River Cacheu;
- In the dry season water quality analytes such as TSS and TDS are approximately 10 times higher in the dry season; and
- For the analytes tested, metal concentrations were within reference water quality guidelines, with one possible exception chromium.

4.4.2.5 Sediment Quality

- No PAH compounds were detected in the wet season sampling event;
- Near Farim metals concentrations within the river sediment remain below marine sediment guidelines;
- For most parameters, (nutrients and metals), an analyte concentration peak occurs at around Binta and then concentrations decrease towards the estuary near Bolor;
- Sediment-nutrient concentrations, including phosphorus, are generally higher upstream than measured in the estuary. Phosphorus within the sediment ranges from approximately 600 mg/kg at the proposed project mine site to about 250 mg/kg at the estuary;
- Metals concentrations, such as iron, zinc, and nickel are also generally higher upstream near Farim, and gradually decrease towards the estuary which is possibly associated with mineralogical influence in these reaches and decrease downstream; and
- Limited analysis of some analytes (particularly nitrates) due to the logistical challenges associated with collecting samples and the hold times between collection and analysis.

4.5 Abbreviations and Acronyms

ADCP	acoustic doppler current profiler
AGG	Albert Geiger geomatics
BP	before present
CCE	coastal consulting and exploration
CCME	Canadian Council for Ministers of the Environment
CAIA	Cellule d'Evaluation des Impacts Environnementaux (Unit for Environmental Impact Assessments)
EHS	Environmental, Health, and Safety
EP	Equator Principles
GBM MEC	GBM Minerals Engineering Consultants Limited
GIIP	good international industry practice
IFC	International Finance Corporation

ISQG	interim sediment quality guidelines
LSA	local study area
NOAA	National Oceanographic and Atmospheric Administration
NEMP	National Environmental Management Plan
PAH	polycyclic aromatic hydrocarbons
PEL	probable effects level
PGBZC-GB	Le Projet Gestion de la Biodiversité et des Zones Côtières en Guinée-Bissau (Project Management of Biodiversity and Coastal Zone of Guinea-Bissau)
PSU	practical salinity units
RSA	regional study area
TDS	total dissolved solids
TSS	total suspended sediment

4.6 References

- Anthony, E. 2006. The Muddy Tropical Coast of West Africa from Sierra Leone to Guinea-Bissau: Geological Heritage, Geomorphology, and Sediment Dynamics. Africa Geoscience Review. Vol 13 (3): 227-237.
- Baird and Associates Coastal Engineers Ltd. (Baird). 2012. Farim Phosphate Beneficiation Option Study prepared for GBM MEC Minerals Engineering Consultants Limited on September 24, 2012. pp 120.
- Barusseau, Giresse, Faure, Lezine, Masse. 1988. Marine Sedimentary Environments on Some Parts of the Tropical and Equatorial Atlantic Margins of Africa during the Late Quaternary. Continental Shelf Research. Vol. 8 (1):1-22.
- Bird. E. 2005. Ria. In Encyclopedia of Coastal Science (Ed. M.L. Schwartz). pp 810-811. Springer, The Netherlands.
- Bird, E. 2010. Encyclopedia of the World's Coastal Landforms. p 1498. ISBN 978-1-4020-8640-3. Springer Science: New York.
- Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life and Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Available at: http://www.ccme.ca/publications/ceqg_rcqe.html. Accessed: 15 July 2012
- Catarino, L., Martins, E., Pinto Baso, M., Diniz, M. 2008. An annotated checklist of the vascular flora of Guinea-Bisseau. Blumea 53:1-222.
- Dean, R.G. and Dalrymple, R.G. 2002. Coastal Processes with Engineering Applications, Cambridge University Press, 475 pp.
- Eastern Atlantic Hydrographic Commission (EAtHC). 2004. Annex D to EAtHC West Africa Action Team Report April-May 2004. Last Accessed Jun 10, 2012 at <http://www.iho.int/mtg_docs/CB/CBA/Technical%20visits/TV03/Guinea_Bissau.pdf>
- Environmental Strategy for the Management of the Coastal Zone.

- Equator Principles, July 2006, derived from the policies and guidelines of the World Bank Group, which includes the IFC.
- Giresse, P. 2008. Tropical and Sub-Tropical West Africa: Marine and Continental Changes During the Late Quaternary. Elsevier. Amsterdam, the Netherlands. pp 395.
- Golder Associates (UK) Ltd, 2013. Farim Phosphate Mine, Guinea-Bissau, River Morphology and Physical Oceanography Baseline Study, dated September 2013. 13514950200.503/B.0;
- Guilcher. 1979. Marshes and Estuaries in Different latitudes. Interdisciplinary Science Review 4:158-168.
- ICMM – Sustainable Development Principals, May 2003.
- IFC Performance Standards on Environmental and Social Sustainability, January 2012.
- Integrated Framework (IF). 2010. Guinea-Bissau, Cashew and Beyond: Diversification through Trade. A diagnostic trade integration study for the enhanced integrated framework for trade-related technical assistance prepared for the Government of Guinea Bissau.
- Jones, Steve. 1997 (updated in 2009). Cruising Guide to West Africa. Prepared for the Royal Cruising Club Pilotage Foundation. Sherborne, Dorset. p. 115.
- Keulegan, G. H. (1967). "Tidal Flow in Entrances: Water-Level Fluctuations of Basins in Communications with Seas," Technical Bulletin No. 14, Committee on Tidal Hydraulics, U.S. Army Engineer WaterwaysExperiment Station, Vicksburg, MS.
- Kyle, Stevens. 2009. Transport, Electricity and Communications Priorities in Guinea Bissau. Cornell University Department of Applied Economics and Management. WP 2009-27.
- McLachlan, A. 2005. Africa, Coastal Ecology. Encyclopedia of Coastal Science (Ed. M.L. Schwartz). Springer, The Netherlands. pp 4–9.
- Mantyla, A.W. 1987. Standard Seawater Comparisons updated. J. Phys. Ocean., 17: 543–548.
- Master Plan of Artisanal Fisheries.
- Master Plan for Water and Sanitation.
- McMaster, R.L. Lachance, T.P., Ashraf, A., de Boer, J. 1971. Geomorphology, Structure, and Sediment of the Continental Shelf and Upper Slope Off of Portuguese Guinea, Guinea, and Sierra Leone. In Delany, F.M. (ed.) The Geology of the East Atlantic Continental Margin. London. pp 109-119.
- Nakayama, E., Suzuki, Y., Fujiwara, K., and Y. Kitano. 1989. Chemical analysis of seawater: recent progress in Japan on clean sampling and chemical speciation of trace elements. Analytical Sciences. 5: 129-139.
- National Environmental Management Plan (NFSP). 2004.
- National Forest Management Plan.
- National Strategy and Action Plan for Biodiversity. 2004.
- NOAA Wavewatch III, 2011. National Weather Service Environmental Modeling Centre. Available at: ftp://polar.ncep.noaa.gov/pub/history/waves/. Accessed 9 June 2012.
- Orme, A.R. 2005. Africa, Coastal Geomorphology. In Encyclopedia of Coastal Science (Ed. M.L. Schwartz). Springer, The Netherlands. pp 10–21.

- Otvos. E.G. 2005. Cheniers. In Encyclopedia of Coastal Science (Ed. M.L. Schwartz). Springer, The Netherlands. pp 233-235.
- Queensland Government. 2006. (minor updates 2007) Queensland Water Quality Guidelines. Prepared by Environmental Protection Agency. Brisbane., Australia.
- Sontek Castaway-CTD User Manual, 2012.
- World Bank Group (IFC) Environmental Health and Safety Guidelines, April 2007.
- Google Earth Pro. 2013. Images obtained from Google Earth Pro. Used under license. Imagery date March 9, 2013. Google Earth image is not to scale and distances are approximate.

5.0 HYDROGEOLOGY

5.1 Introduction

The hydrogeology baseline study focuses on the groundwater within 5 km of the proposed Farim Phosphate Mine (the Project), to develop an understanding of the current hydrogeological regime.

5.2 Study Area

The regional study area for groundwater extends to the surface water catchment of the River Cacheu, since groundwater discharges to this watercourse. .

The extent of the local study area is defined by the groundwater flowing beneath the Project area and surrounding areas estimated to be directly impacted by mine activities. This includes reaches of the following surface watercourses:

- River Cacheu;
- Rio de Bunja;
- Rio de Banim;
- Rio de Caur; and
- Rio de Cavaras.

5.3 Method

Golder undertook a hydrogeological investigation for open pit mining which focused on defining the hydrogeological conditions for mining operations (Golder, 2012a). These data have been used and integrated into the hydrogeological studies for the ESIA. In addition to the hydrogeological investigation, the following tasks have been completed specifically for the ESIA baseline study:

- A desk study;
- A site familiarisation visit;
- A hydrocensus;
- Groundwater level monitoring;
- Groundwater quality sampling; and
- Interpretation and Reporting.

5.3.1 Methods for Assessment of Existing Hydrogeological Baseline

The Scope of Work for the hydrogeological programme included four principal tasks:

- A desk study review of existing hydrogeological information;
- A hydrogeological fieldwork programme undertaken between 2011 and 2013 comprising:
  - Drilling and installing seven deep groundwater monitoring boreholes, nine shallow groundwater monitoring boreholes and two abstraction boreholes;
  - Clearance pumping of all boreholes;
  - Monitoring of groundwater levels (manually, and between February 2012 and September 2013 by using electronic pressure transducers);

- Undertaking two long-duration (minimum ten day) pumping tests (one in each of the two abstraction boreholes), using as many existing boreholes as possible for monitoring groundwater levels during the tests;
- Characterising groundwater water quality by collecting water samples for laboratory analysis; and
- A hydrocensus to establish sources of water used by villagers.

- Interpretation of hydrogeological conditions; and
- Development of a conceptual model.

Due to unforeseen in-country fuel shortages in September 2012, wet season baseline data collection was curtailed after two of the wells included in the hydrocensus had been visited and sampled for groundwater quality.

Additional sampling of the monitoring boreholes installed during the hydrogeological fieldwork programme was carried out in September 2013, to supply data on the groundwater quality during the wet season. The water level of twelve of the hydrocensus wells in the vicinity of the Project area was also recorded during the September 2013 fieldwork.

The following sections present the results and interpretation of data collected over five field visits:

- between 30 June and 16 July 2011;
- between 17 October and 17 December 2011;
- between 20 January and 8 February 2012;
- between 18 and 19 September 2012; and
- between 1 and 11 September 2013.

5.4 Results and Discussion

5.4.1 Summary of Previous Hydrogeological Data

GBM (2011) report that the sandy clay formations of the overburden, the phosphate-bearing layer and the underlying micritic limestones, all contain groundwater.

Two aquifers have been distinguished in previous studies (GEEEM, 2008; GBM, 2011):

- An upper aquifer in the sandy clay overburden formations and the FPA phosphate-bearing layer; and
- A lower aquifer, which corresponds to the micritic limestones.

It has been stated that these two aquifers are separated locally by the FPB layer, which is considered as semi-permeable.

The information gained from the hydrogeological investigation undertaken to define the operational hydrogeological conditions for the proposed open pit area (Golder, 2012a), allowed a conceptual groundwater model to be developed.

The information indicates that there is a multiple aquifer system present at the proposed Mine Site, which can be summarised as:

- An upper aquifer in the overburden formations (that predominantly comprises the superficial deposits of gravels, sands and clays);
- An intermediate aquitard, comprising the grey, blue clay at the base of the overburden and where present, potentially the FPB layer; and

- A lower aquifer, which corresponds to the micritic limestones and the FPA phosphate-bearing layer.

5.4.1.1 Monitoring Boreholes

Sixteen monitoring boreholes were drilled during 2011. Seven pairs of boreholes were drilled (MW01A and B; MW02A and B; MW03A and B; MW04A and B; MW05A and B; MW07A and B; and MW08A and B). Two shallow boreholes (MW06 and MW09) were drilled in the southern part of the mine area. The locations of the monitoring boreholes are shown on Drawing 550-5.1.

Boreholes MW01-MW04 were drilled in locations suitable for groundwater monitoring; they are located outside of the proposed active mine areas. Borehole MW05 was drilled down-gradient of a proposed tailings management facility in a location no longer part of the proposed Project area. Boreholes MW06 to MW09 were installed as observation points for the pump tests.

The shallow monitoring boreholes were drilled to depths of 25 m and 37 m below ground level (m bgl) (MW01B, MW02B, MW03B, MW04A, MW05A, MW06, MW07B, MW08B and MW09), in the overburden. The deep monitoring boreholes (depths between 48 m and 74 m bgl; (MW01A, MW02A, MW03A, MW04B, MW05B, MW07A and MW08A) are installed either within the limestone or within the phosphate and the limestone. The potential FPB phosphate layer (calcareous phosphatic unit) was previously interpreted as an aquitard. The presence of the FPB phosphate layer was not confirmed during the drilling.

5.4.1.2 Abstraction Boreholes

Two abstraction boreholes were drilled in 2011, for the long-duration pumping tests. Pumping well PW1 was drilled in the southern open pit area, and PW2 was drilled in the northern open pit (and existing box-cut) area Drawing 550-5.1.

Pumping well PW1 was screened in the limestone, with pumping well PW2 screened in the limestone and the phosphate. The gravel pack for both pumping wells extended up into the overburden section.

Boreholes installed at the site historically (DW1-DW9, F1, F2, P1-P4 shown on Drawing 550-5.1) have been screened across the hydrogeological layers (overburden, phosphate and limestone).

5.4.1.3 Groundwater Elevations

Manual Dip Measurements

Manual dip measurements of the groundwater levels in the monitoring boreholes have been made by GEEEM and Golder between August 2009 and September 2013. All the boreholes were surveyed to a local (mean sea level) datum in November and December 2011, which has allowed groundwater elevations, in metres above sea level (m asl), to be calculated from the water level depths measured. Table 5.1 contains a summary of the baseline groundwater elevations, which have been measured manually between August 2009 and September 2013.

Minimum baseline groundwater elevations in the monitoring boreholes (PW1, MW01, MW02, MW03, MW06, MW09, F1, F2, and P1 to P4) are reported as below the mean sea level datum; they are near the River Cacheu. These are taken to be genuine elevations, and not associated with recovery following drilling or well purging. Groundwater elevations were not monitored manually during the wet season in 2012, and as such the maximum elevations shown in Table 5.1 are missing the peak of the groundwater levels.

Table 5.1: Summary of Groundwater Elevations recorded from manual measurements between August 2009 and September 2013

Borehole ID	Screened Horizon	Horizons with Gravel Pack	Ground Elevation (m asl)	Groundwater Elevation (m asl)			Groundwater Range (m)	Number of Monitoring Rounds	Monitoring Period
				Minimum	Maximum	Mean			
DW1	Phosphate and Limestone	Overburden, Phosphate and Limestone	9.18	3.57	4.63	3.90	1.07	15	22/06/11 – 11/09/13
DW4	Limestone	Overburden, Phosphate and Limestone	11.06	3.52	4.61	3.82	1.09	16	22/06/11 – 11/09/13
DW5	Limestone	Overburden, Phosphate and Limestone	7.90	3.48	4.57	3.77	1.10	14	22/06/11 – 11/09/13
DW6	Limestone	Overburden, Phosphate and Limestone	8.04	3.44	4.53	3.74	1.09	15	22/06/11 – 11/09/13
DW7	Limestone	Overburden, Phosphate and Limestone	12.79	3.45	4.55	3.75	1.10	15	22/06/11 – 11/09/13
DW8[1)]	Limestone	Overburden, Phosphate and Limestone	14.45	1.47	4.56	3.61	3.09	16	22/06/11 – 11/09/13
DW9	Limestone	Overburden, Phosphate and Limestone	10.66	2.96	4.58	3.75	1.62	15	04/07/11 – 11/09/13
MW01A	Phosphate and Limestone	Clay at base of Overburden, Phosphate and Limestone	7.80	-0.62	-0.01	-0.20	0.61	11	24/11/11 – 07/09/13
MW01B	Overburden	Overburden	7.81	-0.81	-0.01	-0.27	0.80	12	20/11/11 – 07/09/13
MW02A	Limestone	Phosphate and Limestone	2.42	-0.52	0.30	-0.03	0.82	12	23/11/11 – 09/09/13
MW02B	Overburden	Overburden	2.58	-0.88	0.28	-0.19	1.16	13	23/11/11 – 09/09/13

Borehole ID	Screened Horizon	Horizons with Gravel Pack	Ground Elevation (m asl)	Groundwater Elevation (m asl)			Groundwater Range (m)	Number of Monitoring Rounds	Monitoring Period
				Minimum	Maximum	Mean			
MW03A	Limestone	Limestone	10.86	-0.10	0.79	0.19	0.89	12	11/11/11 – 06/09/03
MW03B	Overburden	Overburden	10.68	-0.27	-0.02	-0.11	0.25	12	11/11/11 – 06/09/13
MW04A	Overburden	Overburden	16.97	0.46	1.88	1.58	1.42	18	14/07/11 – 11/09/13
MW04B	Phosphate and Limestone	Phosphate and Limestone	17.04	0.68	1.94	1.54	1.26	19	14/07/11 – 07/09/13
MW05A	Overburden	Overburden	33.62	5.33	8.51	6.18	3.18	17	06/08/11 – 10/09/13
MW05B	FPO and Dolomitic Limestone	FPO and Dolomitic Limestone	33.50	5.08	8.31	5.89	3.23	15	06/08/11 – 10/09/13
MW06	Overburden	Overburden	4.95	-0.81	0.32	-0.07	1.13	16	11/11/11 – 09/09/13
MW07A	Limestone	Limestone	21.68	3.61	4.58	3.79	0.97	11	11/11/11 – 08/09/13
MW07B	Overburden	Overburden	21.63	3.40	3.45	3.43	0.05	10	11/11/11 – 05/02/12
MW08A	Limestone	Limestone	25.46	3.90	4.01	3.97	0.11	11	11/11/11 – 08/02/12
MW08B	Overburden	Overburden	25.48	4.09	4.46	4.29	0.37	10	11/11/11 – 08/02/12
MW09[2]	Overburden	Overburden	5.33	-0.81	0.22	-0.22	1.03	12	02/12/11- 09/09/13

Borehole ID	Screened Horizon	Horizons with Gravel Pack	Ground Elevation (m asl)	Groundwater Elevation (m asl)			Groundwater Range (m)	Number of Monitoring Rounds	Monitoring Period
				Minimum	Maximum	Mean			
PW1	Limestone	Overburden, Phosphate and Limestone	4.30	-0.80	0.40	-0.08	1.20	12	11/11/11 – 07/02/13
PW2	Sandy clay/silt and Limestone	Overburden, Phosphate and Limestone	20.85	3.72	4.57	3.84	0.85	18	29/10/11 – 08/09/13
F1	Phosphate (FPA, FPB) and Limestone	Overburden, Phosphate and Limestone	1.83	-1.10	0.30	-0.26	1.40	16	26/08/09 – 06/09/13
F2	Phosphate (FPA, FPB) and Limestone	Overburden, Phosphate and Limestone	2.84	-1.13	0.42	-0.24	1.55	16	26/08/09 – 06/09/13
P1	Phosphate (FPB) and Limestone	Overburden, Phosphate and Limestone	2.60	-1.05	0.47	-0.17	1.51	16	26/08/09 – 06/09/13
P2	Phosphate (FPA) and Limestone	Overburden, Phosphate and Limestone	4.91	-1.12	0.46	-0.20	1.58	16	26/08/09 – 06/09/13
P3	Phosphate (FPA, FPB) and Limestone	Overburden, Phosphate and Limestone	2.12	-1.04	0.38	-0.20	1.41	16	26/08/09 – 06/09/13
P4	Phosphate (FPB) and Limestone	Overburden, Phosphate and Limestone	1.44	-0.91	0.28	-0.22	1.18	17	26/08/09 – 06/09/13

(1) Borehole DW8 has been pumped to supply water for drilling during the baseline monitoring.
(2) The information given for MW09 is based on the use of the surveyed ground elevation for the original borehole drilled.

Measurements Made By Electronic Pressure Transducer

Electronic pressure transducers were installed in twelve of the monitoring boreholes in February 2012 following the completion of the second long term pumping test (MW01A, MW01B, MW02A, MW02B, MW03A, MW03B, MW04A, MW04B, MW05A, MW05B, MW06 and MW09). The transducers were downloaded in March and September 2013, with the exception of borehole MW02B, where the transducer was lost.

The elevations recorded were compensated using the barometric pressure data collected by the transducer installed in borehole MW04A, before being converted to an elevation above mean sea level using the elevation calculated from the manual dip measurement recorded. Table 5.2 provides a summary of the groundwater elevations recorded by the transducers with groundwater hydrographs provided in Figure 5.1 to Figure 5.7.

The data recorded by the pressure transducers show that the groundwater elevations start rising once the wet season begins. In 2012 this was at the end of June or beginning of July, while in 2013, it was at the end of July or beginning of August. The maximum groundwater elevations during the period monitored were generally recorded in September or October 2012, towards the end of the 2012 wet season. The peak in the borehole pair MW05, located north of Farim, is the exception, where the peak is not reached until December 2012.

The boreholes recording the lowest groundwater elevations are located close to the River Cacheu or the associated surface water courses (MW01, MW02 and MW03).

The levels recorded in the boreholes installed in the overburden show a seasonal increase in groundwater elevation of between 3.49 m (MW01B) and 5.89 m (MW03B), while those installed in the limestone have a seasonal increase of between 2.76 m (MW02A) and 5.99 m (MW03A).

Table 5.2: Summary of Groundwater Elevations Recorded by Electronic Pressure Transducer between February 2012 and September 2013

Borehole ID	Screened Horizon	Ground Elevation (m asl)	Full Data Set				Year Data Set (1 March 2012 – 28 February 2013)				
			Minimum Groundwater Elevation (m asl)	Maximum Groundwater Elevation (m asl)	Range (m)	Monitored Dates	Minimum Groundwater Elevation (m asl)	Maximum Groundwater Elevation (m asl)	Mean Groundwater Elevation (m asl)	Standard Deviation (m)	Range (m)
MW01A	Phosphate and Limestone	7.80	-1.27	3.76	5.03	08/02/12 to 02/09/13 - data gap 30/03/13 to 16/05/13	-1.27	3.76	0.51	1.51	5.03
MW01B	Overburden	7.81	-1.39	2.10	3.49	08/02/12 to 02/09/13 - data gap 30/03/13 to 16/05/13	-1.39	2.10	0.05	1.18	3.49
MW02A	Limestone	2.42	-0.96	1.81	2.76	07/02/12 to 02/09/13 - data gap 30/03/13 to 16/05/13	-0.96	1.81	0.29	0.93	2.76
MW03A	Limestone	10.86	-1.24	4.75	5.99	08/02/12 to 02/09/13 - data gap 30/03/13 to 16/05/13	-1.24	4.75	1.07	1.92	5.99
MW03B	Overburden	10.68	-1.47	4.43	5.89	08/02/12 to 02/09/13 - data gap 30/03/13 to 16/05/13	-1.47	4.43	0.84	1.95	5.89
MW04A	Overburden	16.97	0.36	4.10	3.74	07/02/12 to 01/09/13 - data gap 30/03/13 to 15/05/13	0.36	4.10	2.14	1.43	3.74

Borehole ID	Screened Horizon	Ground Elevation (m asl)	Full Data Set				Year Data Set (1 March 2012 – 28 February 2013)				
			Minimum Groundwater Elevation (m asl)	Maximum Groundwater Elevation (m asl)	Range (m)	Monitored Dates	Minimum Groundwater Elevation (m asl)	Maximum Groundwater Elevation (m asl)	Mean Groundwater Elevation (m asl)	Standard Deviation (m)	Range (m)
MW04B	Phosphate and Limestone	17.04	0.79	4.25	3.46	07/02/12 to 01/09/213 - data gap 30/03/13 to 15/05/13	0.79	4.25	2.44	1.35	3.46
MW05A	Overburden	33.62	5.15	9.41	4.26	07/02/12 to 02/09/13 - data gap 30/03/13 to 16/05/13	5.15	9.41	6.97	1.78	4.26
MW05B	FPO and Dolomitic Limestone	33.50	5.03	9.18	4.15	07/02/12 to 02/09/13 - data gap 30/03/213 to 17/05/13	5.03	9.18	6.83	1.75	4.15
MW06[1]	Overburden	4.95	-1.52	3.69	5.20	07/02/12 to 30/03/13	-1.52	3.69	0.20	1.47	5.20
MW09[1]	Overburden	5.33	-1.49	3.82	5.31	07/02/12 to 30/03/13	-1.49	3.82	0.26	1.50	5.31

[1] The pressure transducers installed in MW06 and MW09 were not reset in March 2013.

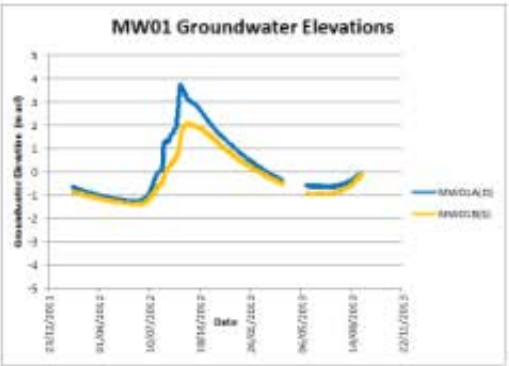


Figure 5.1: MW01 Groundwater Hydrograph

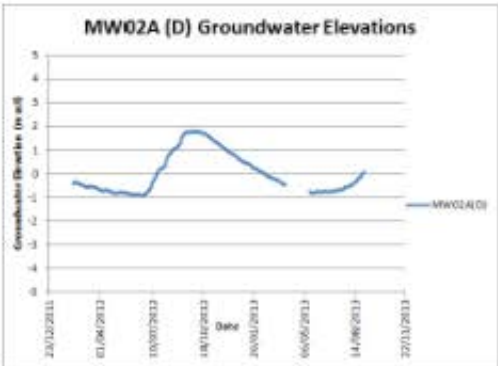


Figure 5.2: MW02A Groundwater Hydrograph

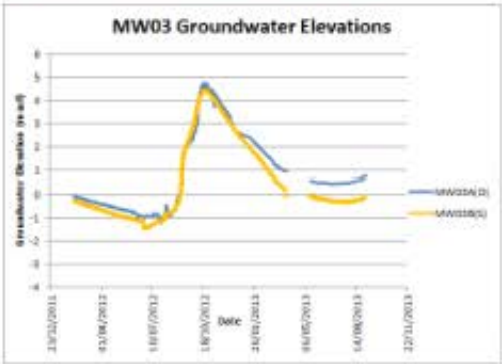


Figure 5.3: MW03 Groundwater Hydrograph

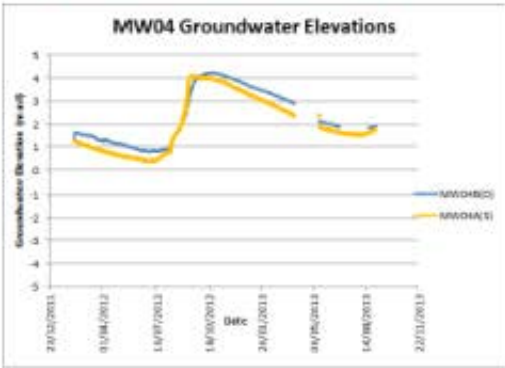


Figure 5.4: MW04 Groundwater Hydrograph

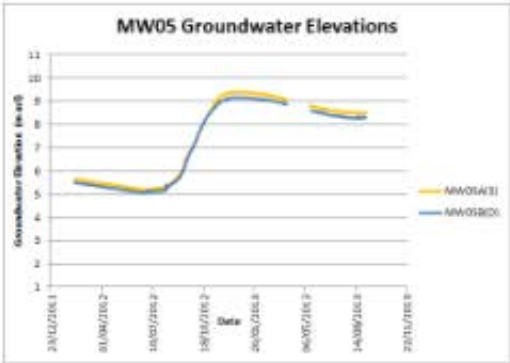


Figure 5.5: MW05 Groundwater Hydrograph

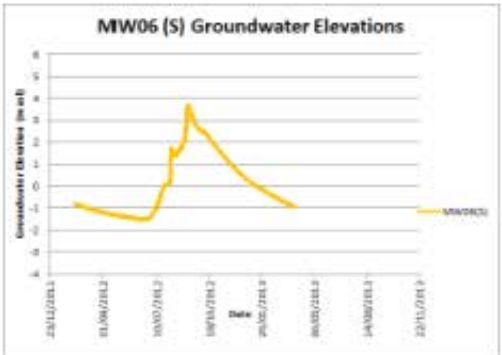


Figure 5.6: MW06 Groundwater Hydrograph

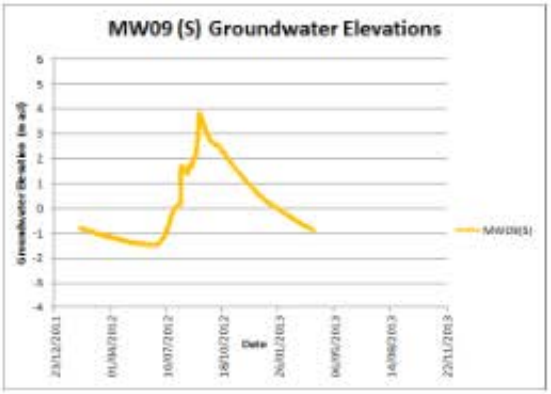


Figure 5.7: MW09 Groundwater Hydrograph

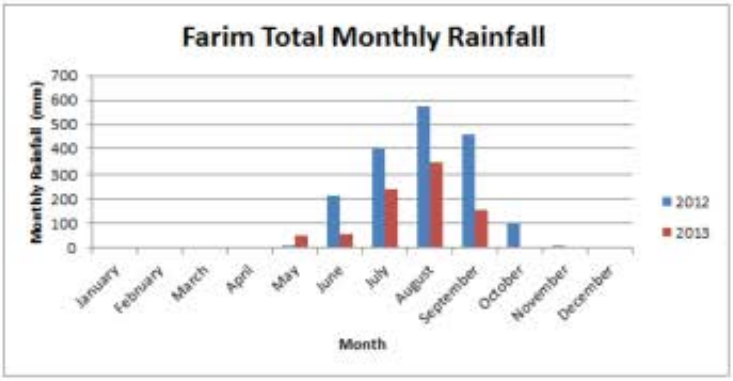


Figure 5.8: Farim Total Monthly Rainfall 2012 to September 2013

5.4.1.4 Groundwater Elevation Variation

Pairs of monitoring boreholes were drilled and installed to allow groundwater elevations within the overburden (shallow aquifer) and within the phosphate and limestone (deep aquifer) to be compared. Table 5.3 provides a summary of the variations of groundwater elevations in the pairs of boreholes for the transducer data between February 2012 and September 2013 and the manual monitoring undertaken between November 2011 and September 2013. Data from shallow borehole MW06 is compared to that collected from P2, which is the closest borehole to it that is screened in the deeper aquifer.

The groundwater elevations observed in the borehole pairs indicate that there is a vertical downward hydraulic gradient from the overburden into the bedrock underlying geology towards the northwest of the Project area. Closer to the River Cacheu and the Rio de Bunja an upward vertical hydraulic gradient rather than a downward gradient is observed.

During the wet season, the water level in the overburden rises and during the wet season of 2012 this resulted in the potential for a downwards vertical flow in the MW02, MW03 and MW04 borehole pairs. In the MW01 borehole pair, located in the southwest of the proposed Project area, the rise in water level did not result in a change in the upward vertical flow.

The water level fluctuation recorded in the overburden boreholes can be used to estimate the amount of recharge reaching the water table through the annual cycle, with the assumption that the amount of available

water in a column of unit surface area is equal to the specific yield times the height of water in the column (Healy, 2010). This uses the following equation:

$$R = S_y \frac{dH}{dt}$$

Where:

- R = Recharge (m/year);
- Sy = Specific yield (taken as the historically quoted value of 1 x10^{-3} for storativity discussed later);
- dH = the change in water level recorded (m) (taken from transducer data collected over the year March 2012 to February 2013); and
- dt = the change in time (years) (taken as one year).

Using the mean water level change from the shallow boreholes in the proposed Project area (MW01A, MW03A, MW04B, MW06 and MW09) of 4.73 m, a recharge of 0.00473 m (4.73 mm) to the overburden is estimated. This is 0.27% of the total precipitation recorded during the time period.

Table 5.3: Summary of Groundwater Elevation Variation

Borehole Pair	Measurement Method	Minimum Groundwater Elevation (m asl)		Maximum Groundwater Elevation (m asl)		Difference in Groundwater Elevation (Shallow – Deep) (m)		Indication of Vertical Groundwater Flow Direction	Months Direction Trend Observed
		Shallow Borehole	Deep Borehole	Shallow Borehole	Deep Borehole	Minimum	Maximum		
MW01	Manual	-0.81	-0.62	-0.01	0.02	-0.01	-0.30	Upward vertical flow	all monitoring
	Transducer	-1.39	-1.27	2.10	3.76	-0.02	-0.234	Upward vertical flow	all monitoring
MW02	Manual	-0.88	-0.57	0.28	0.30	-0.36	0.08	Upward vertical flow	November 2011 to February 2012
								Downward vertical flow	September 2013
MW03	Manual	-0.27	-0.04	0.01	0.79	-0.10	-0.91	Upward vertical flow	all monitoring
	Transducer	-1.47	-1.24	4.43	4.75	-0.894	0.668	Upward vertical flow	February 2012 to June 2012, end of December 2012 – September 2013
								Downward vertical flow	Periods in July to December 2012
MW04*	Manual	0.46	0.68	1.88	1.90	-0.27	0.27	Upward vertical flow	July and August 2011 and September 2013
								Slight downward vertical flow indicated	September 2011 to February 2012
	Transducer	0.36	0.79	4.10	4.25	-0.553	0.921	Upward vertical flow	February 2012 to July 2012, October 2012 to June 2013 and August to September 2013 (comparison between June and Aug 2013 not possible due to transducer error)
								Downward vertical flow	August to September 2012
MW05*	Manual	5.33	5.08	8.47	8.30	0.13	0.25	Downward vertical flow	All monitoring

Borehole Pair	Measurement Method	Minimum Groundwater Elevation (m asl)		Maximum Groundwater Elevation (m asl)		Difference in Groundwater Elevation (Shallow – Deep) (m)		Indication of Vertical Groundwater Flow Direction	Months Direction Trend Observed
		Shallow Borehole	Deep Borehole	Shallow Borehole	Deep Borehole	Minimum	Maximum		
	Transducer	5.15	5.03	9.41	9.18	-0.035	0.252	Slight upward vertical flow	October 2012
								Downward vertical flow	February 2012 – October 2012 and November 2012 to September 2013
MW07	Manual	3.4	3.6	3.45	3.76	-0.18	-0.33	Upward vertical flow	November 2011 to February 2012 (Shallow borehole unusable September 2013)
MW08	Manual	4.09	2.81	4.46	4.01	0.16	1.44	Downward vertical flow	November 2011 to February 2012
MW06/P2	Manual	-0.82	-1.27	0.33	0.27	-0.20	0.21	Upward vertical flow	November 2011 to February 2012
								Downward vertical flow	During the PW1 pumping test in January 2012 and September 2013

** Borehole pairs with manual data from July to September 2011 (wet season).*

5.4.1.5 Daily Groundwater Oscillations

Groundwater elevations in a number of the monitoring boreholes indicate a tidal oscillation from the transmission of tidal fluctuation from the River Cacheu through the underlying geology. Data collected (Golder, 2012a) shows that the boreholes installed in the bedrock (Phosphate and Limestone) show a more distinct tidal oscillation (approximately 1 cm to 5 cm) compared to the boreholes in the overburden (less than 1 cm). Boreholes installed in the bedrock, closer to the River Cacheu (F1, F2, P1, P2, P3, P4 and MW02A) show a tidal response amplitude of between 3 cm and 5 cm, compared to those at a distance (MW07A, MW08A, DW series), which show a tidal response amplitude of around 1 cm.

The amplitude of the tidal range in the River Cacheu recorded at Bissau is around 1.4 m; therefore, the tidal variations in the groundwater are between only 0.7% (in the overburden) and 3.5% (in the bedrock) of the tidal amplitude and as such the scale of the tidal variation is considered negligible compared to the recharge influence even in the locations close to the river.

5.4.1.6 Groundwater Flow Direction

Drawing 550-5.2 displays groundwater flow directions based on groundwater elevations recorded in December 2011.

Groundwater elevations recorded in the both the overburden and the bedrock indicate that groundwater flows from the northwest, towards the River Cacheu in the south. Elevations recorded in both the wet and dry seasons indicate that this pattern persists throughout the year.

Groundwater elevations recorded in the boreholes in the northeast of the Project area (MW07 and MW03) indicate that there is some flow from the northwest towards the Rio de Bunja. Boreholes in the southwest of the Project area (MW04 and MW01) indicate groundwater flow from the northwest towards the south, towards the River Cacheu.

5.4.2 Pumping Tests

Two long term pumping tests were carried out at the site to determine the feasibility of pit dewatering (Golder, 2012a). The first test in December 2011 utilised pumping well PW2 in the area of the northern proposed open pit area; the second test in January and February 2012 utilised pumping well PW1 in the area of the southern proposed open pit area.

The transmissivity values calculated from the pumping tests indicate that the overburden transmissivity values were calculated to be in the range of 3.1×10^{-5} m^2/s to 1.8×10^{-3} m^2/s, while the lower limestone and phosphate aquifer has a transmissivity in the range of 1.7×10^{-4} m^2/s to 3.3×10^{-3} m^2/s. Historically quoted values obtained during the desk study (BRGM, 1986, GEEEM, 2008, GEEEM, 2009) range from 5.8×10^{-4} m^2/s to 1.2×10^{-3} m^2/s for the overburden, while for the limestone, a value of 7×10^{-4} m^2/s was quoted (Golder, 2012a).

The storativity estimated for the lower limestone aquifer was calculated between 1.2×10^{-4} to 1.1×10^{-3} and for the overburden storativity was 8.1×10^{-5}. Historically quoted values for the limestone ranged from 2×10^{4} to 4×10^{-4}, while for the overburden a value of 1×10^{-3} was reported (Golder, 2012a).

During the pumping tests, water-level responses were measured in local village wells. No drawdown effect was observed at any of the observation wells during the pumping tests

5.4.3 Groundwater Quality

Groundwater samples were collected in February 2012 from each of the paired boreholes at MW01, MW02, MW04, MW05 and MW07 and sent for analysis at the Institute Pasteur (Dakar, Senegal). This was to provide a comparison of the water quality in the overburden and the bedrock. Further samples were collected in September 2013 from all but one of the boreholes (MW07B). The samples were sent for analysis at the accredited Jones Environmental Ltd (UK) laboratory. In addition, two water samples have been taken from each pumping borehole (PW1 and PW2) during the long term pump tests, with field parameters taken each day during pumping.

Field parameters were recorded before samples were collected using a hand held water quality probe.

Table 5.4 details the field parameters recorded in the samples taken from the monitoring boreholes in February 2012.

Table 5.4: Results for Field Measurements (February 2012)

Borehole Location	Shallow (Overburden) Boreholes			Deep (Underlying Geology) Boreholes		
	pH (pH units)	Electrical Conductivity (µS/cm)	Temperature (°C)	pH (pH units)	Electrical Conductivity (µS/cm)	Temperature (°C)
MW01	4.68	30	29.2	6.43	480	29.6
MW02	5.89	555	29.1	6.57	998	28.9
MW04	4.81	53	29.6	5.79	205	30.6
MW05	5.12	65	30.3	5.79	205	30.6
MW07	4.92	42	28.4	5.85	222	29.8

The field data collected indicates that the groundwater in the deeper boreholes is slightly less acidic and has a higher electrical conductivity than the groundwater in the shallower overburden boreholes. The groundwater temperature is fairly similar in the borehole pairs.

The deep boreholes located closest to the River Cacheu (MW01 and MW02), have a higher electrical conductivity (EC) and pH than those located further away (approximately 3 km) from the river.

The overburden borehole installed at location MW02, has recorded a much higher EC and pH than the shallow boreholes in other localities. The borehole is located approximately 200 m from the River Cacheu, and 500 m downstream from the inflow of the Rio de Bunja. The groundwater chemistry suggests that the overburden groundwater in this location shows more connection with the tidal surface water courses.

Table 5.5 provides a summary of the field parameters in the two pumping wells through the course of the step test in PW2 and long term pumping tests.

Table 5.5: Summary of Results for Field Measurements taken from Pumping Wells during Pumping Tests

Statistic	PW1 (Southern part of the Project Area)			PW2 (Northern part of the Project Area)		
	pH (pH units)	Electrical Conductivity (µS/cm)	Temperature (°C)	pH (pH units)	Electrical Conductivity (µS/cm)	Temperature (°C)
Minimum	6.31	772	28.8	6.35	407	28.3
Maximum	6.82	849	32.0	6.92	550	31.3
Mean	6.52	808	30.4	6.70	455	29.6
Standard Deviation	0.14	23	1.0	0.16	45	0.7
Range	0.51	77	3.2	0.57	143	3.0

The groundwater abstracted from the pumping well in the southern part of the Project area (PW1) shows a higher electrical conductivity than that taken from the northern part of the Project area (PW2). This is consistent with the PW1 being located closer to the River Cacheu. The other field parameters show less variation, however the pH is less acidic than the groundwater obtained from the deep groundwater monitoring boreholes.

A summary of results from the laboratory analyses are presented in Table 5.6 and Table 5.7. These tables only include data where concentrations were above the laboratory detection limit for any individual determinand. Available Guideline Values for Drinking Water, based on those from the World Health Organisation (WHO, 2011) or from Health Canada Guideline Values (Health Canada, 2012), are included for the purposes of comparison. Where the analytical results have exceeded these guideline values the results have been highlighted to identify potentially elevated concentrations.

Table 5.6: 2012 Dry Season Groundwater Quality Laboratory Results for the Boreholes Samples in the Project Area (Institute Pasteur de Dakar)

			Pumping Well Samples				Deep Groundwater Samples						Shallow Groundwater Samples			
Parameter	Units	Guideline Value[1]	PW2-1	PW2-2	PW1-24	PW1-24	MW01A	MW02A	MW04B	MW05B	MW05B-2	MW07A	MW01B	MW02B	MW04A	MW05A
Date			12/12/11	12/12/11	25/1/12	01/2/12	06/2/12	07/2/12	07/2/12	26/1/12	04/2/12	05/2/12	06/2/12	07/2/12	07/2/12	04/2/12
Alkalinity	mmole/L		2.08	2.08	33.7	30.4	2	2.96	3.04	13.6	7.2	2.94	<0.4	1.26	<0.4	2.4
Ammoniacal Nitrogen	mg/L	1.5 [2]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium	mg/L	-	56	60	72	40	32	48	54	24	24	16	16	24	32	20
Chloride	mg/L	250	6	6	213	39.05	53.25	106.5	35.5	177.5	35.5	53.25	35.5	88.75	35.5	35.5
Conductivity	µS/cm	-	432	438	803	816	503	922	544	190	166.3	41	23.7	480	42	45.9
Dissolved Oxygen	mg/L	-	4.4	4.2	9.5	4.9	NR	NR	NR	7.6	6.9	4.8	NR	NR	NR	4.3
Magnesium	mg/L	-	16.8	14.4	14.4	33.6	14.4	28.8	14.4	9.6	33.6	24	24	28.8	28.8	31.2
pH	pH units	6.5 – 8.5	6.97	6.94	6.88	6.86	7.14	7.03	6.95	6.32	6.27	5.73	5.55	6.5	5.52	5.73
Phosphates	mg/L	-	<0.5	<0.5	<0.05	<0.5	<0.05	<0.05	<0.05	<0.05	<0.5	<0.05	<0.05	<0.05	<0.05	<0.5
Potassium	mg/L	-	<5	<5	<5	<5	2	5.9	1.4	<5	3.9	0.5	<0.5	4.5	0.8	0.5
Sodium	mg/L	200	1.5	1.7	48.4	48.7	9	92.7	6	NR	3.9	7.7	3.5	69.7	5.8	3.6
Sulphate	mg/L	500	20	20	65	73	27	73	<2	<50	<50	<50	<2	68	2	<50
Temperature	°C		22.1	22.2	24.6	24.9	25.6	25.6	26	24.6	23.7	24	25.6	25.7	26	23.7
Total Dissolved Solids	ppm	500	230	233	453	433	268	491	289	99.5	88.1	22	12.6	256	22	24.4
Polyaromatic Hydrocarbons (PAHs)																
Fluoranthene	µg/L		<0.005	<0.005	<0.005	<0.005	<0.005	0.32	<0.005	NR	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phenanthrene	µg/L		<0.005	<0.005	<0.005	<0.005	<0.005	0.017	<0.005	NR	<0.005	<0.005	<0.005	<0.005	<0.005	0.009
Pyrene	µg/L		<0.005	<0.005	<0.005	<0.005	<0.005	0.032	<0.005	NR	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

			Pumping Well Samples				Deep Groundwater Samples						Shallow Groundwater Samples			
Parameter	Units	Guideline Value[1]	PW2-1	PW2-2	PW1-24	PW1-24	MW01A	MW02A	MW04B	MW05B	MW05B-2	MW07A	MW01B	MW02B	MW04A	MW05A
Date			12/12/11	12/12/11	25/1/12	01/2/12	06/2/12	07/2/12	07/2/12	26/1/12	04/2/12	05/2/12	06/2/12	07/2/12	07/2/12	04/2/12
Metals																
Arsenic – Dissolved	µg/L	**10**	<0.5	<0.5	0.7	0.6	0.7	0.6	<0.5	NR	<0.5	1.2	<0.5	0.6	<0.5	1.3
Cadmium – Dissolved	µg/L	**3**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	NR	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium – Dissolved	µg/L	**50**	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NR	<0.5	3.4	0.7	<0.5	0.9	<0.5
Copper – Dissolved	mg/L	**2**	<0.05	<0.05	<0.05	<0.05	0.0062	<0.001	<0.001	<0.05	<0.05	<0.001	0.0013	<0.001	0.0013	<0.05
Iron – Dissolved	µg/L	300	4090	3600	40	30	80	50	<5	3340	30	320	<5	<5	<5	1140
Iron – Total	µg/L	300	4320	3990	50	40	100	70	70	3420	50	430	50	40	80	1200
Lead – Dissolved	µg/L	**10**	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	NR	<0.2	1.3	0.3	<0.2	<0.2	<0.2
Manganese – Dissolved	µg/L	50	280	360	1430	810	610	<10	1480	890	<10	240	<10	208	<10	40
Manganese - Dissolved (from analysis in France))	µg/L	50	NR	NR	NR	NR	100	130	49	NR	NR	NR	13	320	76	NR
Nickel – Dissolved	µg/L	**70**	<0.5	<0.5	0.6	0.7	0.8	3.2	2.8	NR	<0.5	2.9	3.6	2.7	3.1	1.1
Zinc – Dissolved	mg/L	3	0.148	0.12	0.22	0.174	0.0058	0.0021	0.0045	0.714	0.0042	0.0063	0.0037	0.0044	0.0077	0.011
Zinc – Total	mg/L	3	0.18	0.14	0.277	0.183	<0.005	<0.005	0.005	0.803	0.006	0.009	<0.005	0.007	0.008	0.009

[1] Guideline Value taken from lowest quoted value from World Health Organisation Guideline Value or the Health Canada Guideline Value (**bold**). Where a health guideline value does not exist the lowest Aesthetic objective is applied (not in bold).
[2] Taken as lowest reported aesthetic objective for ammonia.
NR = not reported.
– = no guideline value.

Table 5.7: 2013 Wet Season Groundwater Laboratory Quality Results for the Boreholes Samples in the Project Area (Jones Environmental Ltd)

Parameter	Units	Guideline Value[1]	Pumping Well Sample	Deep Groundwater Samples					Shallow Groundwater Samples			
			PW2-1	MW01A	MW02A	MW04B	MW05B	MW07A	MW01B	MW02B	MW04A	MW05A
Date			08/09/13	07/09/13	09/09/13	07/09/13	10/09/13	08/09/13	07/09/13	09/09/13	07/09/13	10/09/13
Total Alkalinity as CaCO3	mg/L	-	250	16	290	306	86	130	240	56	0.16	26
Ammoniacal Nitrogen as N	mg/L	1.5 [2]	0.21	0.22	0.58	0.22	0.43	0.21	0.52	1.01	0.48	0.36
Dissolved Calcium	mg/L	-	83.6	2.3	127.5	98.6	13.9	36	79.6	87.2	2.1	5.6
Chloride	mg/L	250	2.3	2.5	571.9	3.8	7	1.6	3.3	661.9	2.5	3.4
Electrical Conductivity @25C	µS/cm	-	471	42	2280	4774	8732	266	492	2335	1638	1760
Dissolved Oxygen	mg/L	-	10	10	10	9	10	10	9	10	9	10
Dissolved Magnesium	mg/L	-	5.1	0.4	34.5	2.7	7.5	4.7	4.2	30.4	0.8	0.5
pH	pH units	6.5 – 8.5	7.28	5.28	7.05	6.95	6.37	6.58	6.95	6.03	5.41	5.69
Ortho Phosphate as PO4	mg/L	-	<0.03	<0.03	<0.03	0.27	<0.03	<0.03	0.06	<0.03	0.16	0.31
Dissolved Potassium	mg/L	-	1.9	0.4	4.8	0.9	3.7	1.8	1.7	7.4	0.9	0.4
Dissolved Sodium	mg/L	200	1.5	2.6	276	1.8	2.7	6.7	8.3	307.6	3	2.1
Sulphate	mg/L	500	14.66	0.44	58.54	1.13	10.17	2.92	21.03	63.94	0.48	0.88
Total Dissolved Solids	mg/L	500	238	<10	1362	304	86	132	234	1397	<10	<10
Total Suspended Solids	mg/L	-	14	<10	20	25	<10	42	<10	26	<10	<10
Polyaromatic Hydrocarbons (PAH)												

Parameter	Units	Guideline Value[1]	Pumping Well Sample	Deep Groundwater Samples					Shallow Groundwater Samples			
			PW2-1	MW01A	MW02A	MW04B	MW05B	MW07A	MW01B	MW02B	MW04A	MW05A
Date			08/09/13	07/09/13	09/09/13	07/09/13	10/09/13	08/09/13	07/09/13	09/09/13	07/09/13	10/09/13
Acenaphthene	µg/L	-	<0.01	NR	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01
Acenaphthylene	µg/L	-	<0.01	NR	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
Anthracene	µg/L	-	<0.01	NR	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	0.02	<0.01
Benzo(a)anthracene	µg/L	-	<0.01	NR	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)pyrene	µg/L	**0.05**	<0.01	NR	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(bk)fluoranthene	µg/L	-	<0.01	NR	<0.01	<0.01	0.21	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(ghi)perylene	µg/L	-	<0.01	NR	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	µg/L	-	<0.01	NR	<0.01	<0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ah)anthracene	µg/L	-	<0.01	NR	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	µg/L	-	<0.01	NR	<0.01	<0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	µg/L	-	<0.01	NR	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	0.04	<0.01
Indeno(123cd)pyrene	µg/L	-	<0.01	NR	<0.01	<0.01	0.1	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	µg/L	-	<0.01	NR	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	0.05	<0.01
Pyrene	µg/L	-	<0.01	NR	<0.01	<0.01	0.12	<0.01	<0.01	<0.01	<0.01	<0.01
Total PAH	µg/L	-	<0.1	NR	<0.1	<0.1	1.2	<0.1	<0.1	<0.1	0.2	<0.1
Metals												

Parameter	Units	Guideline Value[1]	Pumping Well Sample	Deep Groundwater Samples					Shallow Groundwater Samples			
			PW2-1	MW01A	MW02A	MW04B	MW05B	MW07A	MW01B	MW02B	MW04A	MW05A
Date			08/09/13	07/09/13	09/09/13	07/09/13	10/09/13	08/09/13	07/09/13	09/09/13	07/09/13	10/09/13
Dissolved Arsenic	µg/L	**10**	<0.9	<0.9	1.8	<0.9	1.4	1.7	1.5	18.7	<0.9	1.1
Dissolved Cadmium	µg/L	**3**	0.15	0.08	0.39	0.12	1.26	0.5	0.14	1.23	0.15	0.46
Total Dissolved Chromium	µg/l	**50**	5.2	7.9	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	0.9	<0.2
Dissolved Copper	µg/L	**2**	<3	<3	<3	<3	<3	<3	<3	4	<3	<3
Total Dissolved Iron	µg/L	300	239.5	<4.7	2111	<4.7	4118	3407	879.2	5024	15.6	1192
Total Iron	µg/L	300	239.5	<4.7	2111	<4.7	4118	3407	879.2	5024	15.6	1192
Dissolved Lead	µg/L	**10**	0.8	<0.4	2.2	0.6	1.5	1.2	1.5	<0.4	<0.4	<0.4
Dissolved Manganese	µg/L	50	101.8	13.8	120	105.4	457.9	628.3	81.4	562	54.8	96.4
Dissolved Nickel	µg/L	**70**	3.2	4.1	5.8	1.6	0.7	1.6	<0.2	9.2	3.3	0.7
Dissolved Zinc	µg/L	3000	<1.5	6	1.8	8.7	7.8	23	3.5	21	13.5	10.1
Total Zinc	µg/L	3000	<1.5	6	1.8	10.7	7.8	23	3.5	21	13.5	10.1

(1) Guideline Value taken from lowest quoted value from World Health Organisation Guideline Value or the Health Canada Guideline Value (**bold**). Where a health guideline value does not exist the lowest Aesthetic objective is applied (not in bold).
(2) Taken as lowest reported aesthetic objective for ammonia.
NR = not reported. – = no guideline value.

Generally the water quality in the Project area can be described as having good chemical quality. With the exception of samples taken from boreholes MW02B (shallow borehole) and MW05B (deep borehole) in September 2013, none of the available health guideline values were exceeded. Dissolved arsenic and dissolved copper marginally exceeded the available health guideline values in the sample from MW02B, while benzo(a)pyrene marginally exceeded the available health guideline value in the sample from MW05B.

The salinity of the water measured as EC is between 23.7 µS/cm and 922 µS/cm. From the pumping borehole data it was seen that the EC increased slightly with pumping (430 to 810 µS/cm). The salinity is primarily contributed by dissolved sodium and chloride ions.

The chloride and sodium concentrations reported are generally low, and decrease between samples taken in the dry season (February 2012) and those taken in the wet season (September 2013), indicating a freshwater source. The water quality reported in 2013 (wet season) from the MW02 borehole pair, located close to the River Cacheu and Rio de Bunja, is the exception to this where the chloride, sodium and total dissolved solids concentrations increased compared to those in the dry season and were reported above the aesthetic objectives for drinking water. This indicates the groundwater in the area of this borehole may have an element of recharge from the river water during the wet season.

Of the trace metal elements tested, only the iron and manganese content were identified at concentrations above the aesthetic objectives for drinking water. pH was also identified at concentrations outside the aesthetic objectives range in several of the samples.

Low levels of polyaromatic hydrocarbon (PAH) components were reported in the samples taken from boreholes MW02A and MW05A in 2012 and boreholes MW05B and MW04A in 2013. The concentrations recorded in boreholes MW02A and MW05A in the samples taken in 2013 were below the laboratory detection limit indicating that these are likely attributable to remnants of drilling fluids, as such they do not need to be considered as chemical of concern.

5.4.4 Hydrocensus

The locations of the wells surveyed by Golder during the hydrocensus in February 2012 are shown in Drawing 550-5.3 and the hydrocensus data are provided in Appendix C1.

The objectives of the hydrocensus carried out by Golder in the February 2012 field visit were to:

- Visit each known borehole and well within a 5 km radius of the proposed Farim Phosphate open pit areas;
- Collect information from the local population about the groundwater use; and
- Collect information on groundwater quality in these boreholes and wells.

The main land uses observed during the hydrocensus survey were crop production and livestock grazing. Rice is predominantly grown in paddies in floodplain areas; there are groves of cashews, and small plantations for chillies, potatoes, and cassava. Horses, cattle and donkeys were observed grazing on and around, floodplains.

During the hydrocensus it was found that groundwater is mainly used for potable and domestic purposes (e.g. washing and cooking) and livestock watering. All villages have at least one public well; most villages have several wells, and some houses were observed to have wells for private use (Photographs 6.1 to 6.4).

The water levels measured during the survey were between 4 and 18 m below ground level; the groundwater elevation has been calculated from an approximate measurement of the ground level and a contour plot has been generated (Drawing 550-5.4). Flow is generally towards the River Cacheu from both sides of the river, with a slight depression in water levels in the area of Farim, where a large number of wells are present.

Photograph 6.1: Village Well

Photograph 6.2: Village borehole

Photograph 6.3: Village Well

Photograph 6.4: Village borehole

From the field measurements undertaken during the February 2012 hydrocensus, the electrical conductivity values recorded in the hydrocensus wells are generally between 20 µs/cm to 600 µs/cm. Four wells had recorded values of more than 1000 µs/cm); one in Cansenhe village (W10) and the other 3 in Iribato (southwest of Farim, south side of River Cacheu) (W63, W64, and W65).

Nine samples were collected from hydrocensus wells in February 2012 and sent for analysis at the institute Pasteur (Dakar, Senegal). A further two samples were collected in September 2012 from Cahsenha (W11) and Farim (W52) and sent for analysis at Jones Environmental Ltd (UK).

The major chemical analysis results are given in Table 5.8. None of the major chemical parameters have available health guidelines values for drinking water. Calcium concentrations are below potential taste threshold (100 to 300 mg/L; WHO, 2011). Chloride concentrations are generally below potential taste threshold (250 mg/L, WHO, 2011), except for Sample 1 from W63 near Saliquinhedim.

The trace metals iron, copper, manganese and zinc were also analysed; the results of the analyses are given in Table 5.9. Copper tested below detection for all samples except for samples 1 (W63) and 5 (W52). These results were less than the available guideline value. Both dissolved and total iron values are reported below concentrations that may cause staining (0.3 mg/L, WHO, 2011). All samples tested below concentrations for zinc that may cause unpleasant taste (4 mg/L, WHO, 2011). Most of the samples tested above concentrations for manganese that may cause unpleasant taste and staining of laundry and pipes (0.05 mg/L, Health Canada, 2012).

The two samples taken during the wet season in September 2013 showed slightly higher total dissolved solids, and lower magnesium when compared to those taken in February 2012 during the dry season. The wet season sample taken from W52 in Farim showed a slightly higher chloride and lower calcium concentrations compared to the dry season sample, while the sample taken from W11 in Cansenha showed the reverse. It should however be noted that the wet and dry season samples were analysed in two different laboratories.

Table 5.8: Major Chemical Element Analysis Results for Hydrocensus Water Samples

Sample Number	Well ID	Sample Round	Parameter	pH	Electrical Conductivity	Total Dissolved Solids	Calcium	Magnesium	Potassium	Sodium	Total Alkalinity	Chloride	Sulphate	Phosphate
			Units	pH units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			Guideline Value[1]	-	-	-	-	-	-	200	-	250	500	-
Sample 1	**W63**	Feb 2012		4.38	114.4	609	16	28.80	21.90	NR	6.01	408.25	<2	<0.05
Sample 2	**W70**	Feb 2012		5.8	51.4	274	32	9.6	23.9	NR	32	142	12	<0.05
Sample 3	**W81**	Feb 2012		6.0	11.6	61.9	24	14.4	0.6	NR	<40	71	<2	<0.05
Sample 4	**W41**	Feb 2012		6.1	10.4	55.3	32	4.8	0.7	NR	<40	71	<2	<0.05
Sample 5	**W52**	Feb 2012		5.1	41.6	222	48	19.2	6.8	NR	<40	53.3	<2	<0.05
Sample 5A		Sept 2012		6.86	47.8	332	8.9	4.7	7.2	62.8	34	78.8	0.88	<0.03
Sample 6	**W29**	Feb 2012		5.7	13.3	70.9	24	9.6	<0.1	NR	<40	88.8	<2	<0.05
Sample 7	**W20**	Feb 2012		6.3	14	74.1	24	14.4	1.1	NR	<40	53.3	<2	<0.05
Sample 8	**W19**	Feb 2012		6.2	8.8	46.4	40	24.0	1.7	NR	44	53.3	<2	<0.05
Sample 9	**W11**	Feb 2012		6.3	12.7	67.3	20	28.8	<0.5	NR	41	53.3	<2	0.06
Sample 9A		Sept 2012		7.37	24.9	154	35.3	1.2	5.0	6.1	86	14.3	2.45	0.10

[1] Guideline Value taken from lowest quoted value from World Health Organisation Guideline Value or the Health Canada Guideline Value (**bold**). Where a health guideline value does not exist the lowest Aesthetic objective is applied (not in bold).

Table 5.9: Trace Element Chemical Results for Water Samples

Sample Number	Well ID	Sample Round	Parameter	Copper (total)	Copper (dissolved)	Zinc (total)	Zinc (dissolved)	Iron (total)	Iron (dissolved)	Manganese (dissolved)	Nickel (dissolved)	Chromium (dissolved)	Cadmium (dissolved)
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			Guideline Value[1]	2	2	3	3	0.3	0.3	0.05	**0.07**	**0.05**	**0.003**
Sample 1	W63	Feb 2012		0.01	0.009	0.05	0.049	0.24	0.11	0.48	NR	NR	NR
Sample 2	W70	Feb 2012		>0.005	<0.001	0.02	0.019	0.07	0.01	0.15	NR	NR	NR
Sample 3	W81	Feb 2012		>0.005	<0.001	0.009	0.0086	0.11	0.02	0.09	NR	NR	NR
Sample 4	W41	Feb 2012		>0.005	<0.001	0.006	0.0063	0.18	0.06	0.01	NR	NR	NR
Sample 5	W52	Feb 2012		0.01	0.0091	0.035	0.035	0.1	0.05	0.08	NR	NR	NR
Sample 5A		Sept 2012		NR	0.003	0.052	0.0486	0.0087	0.0065	0.1585	0.0099	<0.0002	<0.00003
Sample 6	W29	Feb 2012		>0.005	<0.001	0.008	0.0078	0.08	0.04	0.12	NR	NR	NR
Sample 7	W20	Feb 2012		>0.005	<0.001	0.007	0.0078	0.06	0.02	0.1	NR	NR	NR
Sample 8	W19	Feb 2012		>0.005	<0.001	0.008	0.0075	0.06	0.02	>0.01	NR	NR	NR
Sample 9	W11	Feb 2012		>0.005	<0.001	0.005	0.0048	0.25	0.13	0.22	NR	NR	NR
Sample 9A		Sept 2012		NR	<0.003	0.0296	0.0224	0.0135	0.0082	0.0115	0.0017	0.0009	0.00005

[1] Guideline Value taken from lowest quoted value from World Health Organisation Guideline Value or the Health Canada Guideline Value (**bold**). Where a health guideline value does not exist the lowest Aesthetic objective is applied (not in bold).

5.4.5 Conceptual Groundwater Model

The information obtained from the desk study, the 2011 to 2012 site investigations, feasibility study (Golder, 2012a) and the baseline data collected up to September 2013 allow a conceptual groundwater model to be developed for the Project area under baseline conditions. Three distinct hydrogeological units that control the groundwater regime in the Project area have been identified. These are as follows:

- An upper aquifer (a permeable formation that contains groundwater) in the overburden formations (that comprises gravels, sands and clays);
- An intermediate aquitard (a low permeability unit that restricts the movement of groundwater), comprising the grey blue clay at the base of the overburden and where present potentially the FPB layer; and
- A lower aquifer, which corresponds to the micritic limestones and the FPA phosphate-bearing layer.

These are discussed further in the sections below, and illustrated on Drawing 550-5.5.

5.4.5.1 Overburden Aquifer

The overburden aquifer consists of lenses of sands and clays that extend across the Project area. A sand lens is present above the grey blue clay in the northern part of the Project area, and this may be the dominant unit for groundwater flow and storage within the overburden in this area. In the southern part of the Project area, a sand lens is also present at depth, with a gravel unit at the ground surface. These two units may provide the majority of the overburden groundwater flow in the south of the Project area.

The analysis of the pumping test data indicates that the overburden aquifer transmissivity (a measure of how much groundwater can be transmitted horizontally) ranges between 3.1×10^{-5} m^2/s and 1.8×10^{-3} m^2/s).

Groundwater elevations recorded by Golder in the overburden aquifer between 2011 and 2013 indicate that in the Project area, the groundwater flows from the northwest, where groundwater elevations are highest (MW08), towards the River Cacheu in the southeast. The groundwater elevations recorded in the overburden ranged between -1.52 m asl and 4.43 m asl during this monitoring period. The groundwater elevations are higher during the wet season, as recharge, estimated by Golder to be approximately 0.27% of the rainfall recorded in Farim over the same monitoring period as the groundwater levels, reaches the water table.

There is downwards vertical gradient from the overburden to the micritic limestone below in the northwest of the Project area, while nearer the River Cacheu, the overburden receives upward flow from the underlying limestone. The vertical flow changes seasonally in the area of monitoring boreholes MW02, MW03 and MW04 from downwards in the wet season to upwards in the dry season.

Monitoring borehole MW02B has a higher EC than the other monitoring boreholes, and with its close proximity to both the River Cacheu and the Rio de Bunja suggests there may be some recharge from the rivers in this area. This is also indicated by the higher concentrations of chloride and sodium reported in the sample taken from borehole MW02B during the wet season. The concentrations recorded in the surface water samples taken from the rivers, and discussed in Section 7 (Surface Water), are an order of magnitude higher than those reported in the groundwater. There are two layers of sand encountered within the overburden at the MW02 location (-8.58 m asl to -18.58 m asl and -23.58 m asl to -26.58 m asl), these appear to tie in with two layers observed in the geotechnical boreholes BH16 and BH8 that were drilled in the same vicinity (Golder, 2012b). It is possible that these sand layers are promoting connectivity with the river.

5.4.5.2 Intermediate Aquitards

The FPB has been identified as an intermediate aquitard, between the upper and lower aquifers (BRGM, 1986). Previous studies have indicated that where the FPB unit is of significant thickness (to the west of the Rio de Bunja) it is possible that it is acting as an aquitard. However, in the proposed Project area data obtained by Golder indicates that, where present, this is less than 4 m thick. Five of the monitoring

boreholes drilled in 2008 and 2009 (F1, F2, P1, P3, and P4) in the southern part of the Project area show the presence of the unit.

The grey blue clay at the base of the overburden was encountered in both pumping well boreholes (PW1 and PW2) drilled in the 2011 to 2012 investigations, at both locations the clay is in the order of 10 m thickness. The pumping test data recorded for both wells showed a rapid increase in drawdown (reduction in groundwater level) at elevations consistent with encountering the clay. The grey blue clay in the proposed Project area is therefore interpreted to be acting as an aquitard in addition to the FPB.

5.4.5.3 Lower Aquifer

The lower aquifer in the proposed Project area consists of the limestone and the FPA; where the FPB is present, the FPA and the limestone may form two separate deep aquifers.

The analysis of the pumping test data indicates that the limestone and phosphate aquifer transmissivity ranges between 4.0 x 10^{-4} m^2/s and 3.3 x 10^{-3} m^2/s).

The groundwater elevations recorded by Golder within the lower aquifer between 2011 and 2013 indicate that the groundwater flows from the higher ground in the northwest towards the River Cacheu. The groundwater elevations ranged between -1.27 m asl and 4.75 m asl during the monitoring period. The groundwater elevations are higher during the wet season, following recharge from percolating rainfall.

Monitoring borehole MW02A has higher concentrations of chloride and sodium reported in the sample taken from the borehole during the wet season. It also has a higher electrical conductivity reported in the dry season than the other deep monitoring boreholes. This along with its close proximity to both the River Cacheu and the Rio de Bunja it may indicate there is an element of recharge from the river in this area.

Based on the findings of the hydrocensus, it is evident that groundwater in the overburden is an important source of potable and domestic supply for local inhabitants in the Project area. All the villages within the study area have at least one hand-dug well, excavated into the shallow aquifer within this unit. These wells can range in depth from 7 m to 27 m below ground level. They will respond to seasonal rainfall patterns and as the dry season prevails, water levels will fall. This is illustrated by the hydrographs presented in Section 5.4.1.3 - Groundwater Elevations.

These shallow groundwater supplies are likely to be most vulnerable to the effects of the mine operation, particularly in terms of derogation from de-watering or pollution from accidental spillages and releases in close proximity to them.

There are no known local abstractions from the lower aquifer unit in the Project area. Based on the pumping test data, this aquifer unit may have the potential to yield water and may have the potential to support drilled community wells. Such a scenario would be subject to further investigation; however, the aquifer's resource value should be protected or conserved. Although it is afforded some protection from anthropological activities by the middle aquitard unit, the effects of long term de-watering at the proposed mine should be considered.

Whilst the results of the aquifer testing demonstrated there was limited impact on the shallow wells installed in the zone of influence of the pumping boreholes, the duration of these tests was limited. Therefore, a preliminary groundwater model will be produced in order to consider the potential effects of dewatering the open pit during mining operations. The model will consider a long term, steady state pumping regime within the overburden and the limestone aquifers.

The water quality in the Project area is reflective of the undeveloped and natural environment present as a baseline. With the exception of samples taken from boreholes MW02B (shallow borehole) and MW05B (deep borehole) in September 2013, none of the available health guideline values for chemical parameters were exceeded. Where results did exceed guideline values it was generally in respect of metals e.g. arsenic, copper, which may be present as a consequence of localised ground conditions.

The chloride and sodium concentrations reported for all the hydrogeological units are generally low, indicating a freshwater source or water that has had low residence time in the underlying strata. The water

quality reported in 2013 (wet season) from the MW02 borehole pair, located close to the River Cacheu and Rio de Bunja, is the exception to this where concentrations increased compared to those in the dry season. This indicates the groundwater in the area of this borehole may have an element of recharge from the river water during the wet season.

5.5 Abbreviations and Acronyms

EC	Electrical Conductivity
ESIA	Environmental and Social Impact Assessment
m asl	metres above mean sea level
PAH	Polyaromatic Hydrocarbons
TDS	Total Dissolved Solids
WHO	World Health Organisation

5.6 References

- Bureau de Recherches Geologiques et Minieres, 1986. Troisième phase du projet phosphate Farim (campagne de terrain d'avril à août 1985) simulation prèliminaire de l'exhaure de la future exploitation à ciel ouvert. 86 GNB 049 EAU. Report provided in French;
- Champion Industrial Minerals Inc, 2000. Farim Phosphate Project Resource Audit;
- GBM, 2011. Technical report on the preliminary economic assessment of the Farim Phosphate Project, Guinea-Bissau. An NI 43-101 Report;
- GEEEM, 2008. Field of Phosphate, Farim, Validity of Operation. Google English translation of report provided by GBM;
- GEEEM, 2009. Farim Phosphate Deposit, Pumping Test. Information in French.
- Golder Associates (UK) Ltd, 2011a. Technical Memorandum: Site Report for visit to Farim Phosphate Mine Site July 2011 dated 12 August 2011. 11514950043.509/B.0;
- Golder Associates (UK) Ltd, 2011b. Farim Phosphate Mine, Hydrology and Hydrogeology Desk and Field Study dated 2 September 2011. 11514950043.510/B.0;
- Golder Associates (UK) Ltd, 2012a. Farim Phosphate Mine, Guinea-Bissau, Groundwater and Dewatering Report, dated May 2012. 11514950096.525/B.0;
- Golder Associates (UK) Ltd, 2012b. Farim Phosphate Mine, Guinea Bissau, 2012 Ground Characterisation – Factual Report. 12514950591.504/B.1;
- Health Canada, 2012. Guidelines for Canadian Drinking Water Quality Summary Table.
- Healy, R.W, 2010. Estimating Groundwater Recharge, Cambridge University Press;
- Prian, J. P, 1989. The Farim-Saliquinhe Eocene Phosphate deposit Guinea-Bissau, West Africa. Chapter 43 of Phosphate Deposits of the World: Volume 2, Phosphate Rock Resources, Ed. A. J. G. Notholt, R. P. Sheldon, D. F. Davidson, Cambridge University Press;
- Prian, J. P, Gama, C, Bourdillon de Grissac, J, and Roger J, 1987. The Eocene Farim-Saliquinhe phosphate deposit (Republic of Guinea-Bissau) chron. Rech.min Number 486 p25-54. Paper provided in French; and
- World Health Organisation, 2011. Guidelines for Drinking Water Quality 4th Edition.

6.0 SURFACE WATER

6.1 Introduction

The surface water baseline study describes the existing hydrology and water quality of the River Cacheu and tributaries within and adjacent to the proposed mine site (Drawing 550-6.1).

6.2 Baseline Study Areas

From a surface water perspective, the proposed mine site and areas potentially influenced by the proposed mine development are contained entirely within a sub-catchment of the River Cacheu drainage basin. Regional and Local Study Areas have been defined as shown on Drawing 550-6.1. Approximate catchment sizes for these areas are available in Table 6.1. Catchments extents have been estimated based on publicly available 30m resolution ASTER tile data[1].

Table 6.1: Study Area Catchment Geometry

Description	Total Catchment Area (km^2)	Maximum Reach Length (km)
Local Study Area (LSA)	310	25
Regional Study Area (RSA)	2450	100

6.2.1.1 RSA

The RSA catchment encompasses the upstream River Cacheu, tributaries and wetlands, extending to Binta (downstream) and upstream to the catchment boundary of the River Cacheu (Drawing 550-6.1). The downstream boundary is at the lowest point in the catchment in receipt of inflows (watercourses or overland) from areas that could, potentially, be directly impacted by the proposed mine. This point reflects the lowest point on the River Cacheu which may be subject to measurable influences from proposed mining activities.

RSA surface water baseline data collection points on the River Cacheu have been selected to gain an understanding of this regionally significant watercourse (Drawing 550-6.2).

6.2.1.2 LSA

The LSA comprises the area drained by local watercourses and ephemeral tributaries of the River Cacheu (that are subject to tidal ponding in their lower extents) immediately adjacent to the proposed mine site; these drain directly to the River Cacheu, with topographic elevations varying between 5 and 40 m above mean sea level.

6.3 Previous Work and Existing Data

Only climate data is available (Section 6.4) predating Golder's activitites at the site. No locally or regionally relevant information or data on the surface water environment has been made available to Golder and none has been found through extensive research.

6.4 Method

6.4.1 Climate, Hydrology and Setting

6.4.1.1 River Cacheu

At a length of approximately 260 km, the River Cacheu is one of the larger rivers in Guinea-Bissau and is locally known as the "Rio de Farim" upstream of Farim village. The River Cacheu extends 150 km inland from the estuary, is subject to tidal flow and subsequently the water is brackish. A number of smaller watercourses flow in a southerly direction through the proposed mining area and into the River Cacheu which then flows in a westerly direction. The upper reaches of these watercourses are generally ephemeral,

[1] Based on watersheds defined using Aster mapping data for the region; ASTER GDEM is a product of METI and NASA

flowing only during periods of wet weather (i.e. they are freshwater). The lower reaches, typically within 1 to 2 km of the main river channel, are often permanent water bodies, featuring ponded conditions due to tidal inflow of brackish water from the River Cacheu.

6.4.1.2 Regional Climate

Guinea-Bissau receives approximately 1,500 to 2,000 mm of rainfall per annum. The weather pattern is highly seasonal and there is a seven month dry period from November to May inclusive. This is most severe in the north of the country where weather stations may record no rain at all for periods of between 30 and 60 days. In the dry season, the total rainfall may be less than 30 mm. The wet season occurs from June to October and rainfall is most intense from July to September. Table 6.2 presents historic average monthly rainfall totals from 1990 to 2009 for Guinea-Bissau.

Table 6.2: Average Monthly Total Rainfall (1990 to 2009)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	0	0	0	0	31.6	177.6	371.0	435.2	336.5	168.0	23.5	0	**1543.4**

Source: Climate Research Unit of University of East Anglia

The climate is tropical with the mean temperature of the coldest month (December/January) being 25°C and that of the warmest months (April/May) being 28°C.

Section 2, Air Quality and Meteorology, describes the methods used for regional climate data collection in more detail and provides further information on available climate data.

6.4.1.3 Local Climate

Farim Weather Station

Local climate data has been been collected on-site since December 2011 by Golder (Golder 2013a). In 2012, an ARG100 tipping bucket Rain Gauge was installed on site by Golder; rainfall data was collected from December 2011 until October 2013 (Table 6.3).

Table 6.3: Recorded Monthly Total Rainfall (2012, Golder Met. Station at Farim)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	0	0	0	0	11.6	213.6	400.6	572.4	455.4	105.4	11.2	3.2	1773.4

Abulzinho Climate Data

In the absence of a long-term daily rainfall record at Farim, monthly rainfall data has been sourced from a number of regional rainfall stations. As part of Air Quality and Meteorology studies (Section 2), a quality assurance review was carried out on the Bissau Port dataset and no usable long-term rainfall data was found to be available. The 2011 rainfall data for Bissau Port has been obtained and is presented in the Meterology baseline (Section 2)

A rainfall record was sourced for the Abulzinho rain gauge, approximately 65 km to the west of the site for use as hydrology studies input independent of the meterology baseline. The long term average monthly rainfall and days of rain are summarised in Table 7.4.

Table 6.4: Long Term Rainfall Statistical Distribution at Abulzinho

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Rainfall (mm)	0	0	0	0	2	78	291	331	294	110	3	3
No. Rain Days in Month	2	0	0	0	1	8	19	24	21	11	1	1

This rainfall data was collected at a location within the same climatological zone and which is adequately close to the proposed mine site to be used as a reasonable proxy.

In the absence of local long-term evaporation data, monthly averages used in this study have been sourced (Reddy et al, 1980) for Kolda, Senegal, approximately 50 km north of Farim (Table 6.5). The monthly evaporation averages are based on a long-term record of indeterminate duration.

Table 6.5: Long Term Average Monthly Evaporation – Kolda

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Evaporation (mm)	129	134	171	175	184	15	125	115	121	135	119	117

Climate Data Assessment

No concurrent regional rainfall data was available for the period of site rainfall data collected (January-December 2012). A comparison of the 2012 weather station record with rainfall data collected at Bissau Port in 2011 shows similar monthly patterns of rainfall in these two non-concurrrent years of rainfall data (Section 2, Air Quality and Meterology).

In the absence of site specific, long-term, continuous climate data, it is intended that this synthesised daily climate dataset (Abulzinho and Kolda) will be used in impact assessment and water balance studies.

The main channel of the river is around 150 to 200 m wide in the vicinity of the proposed mine. The overbank areas to the north and south of the river are flat, and susceptible to frequent inundation during periods of high rainfall and/or high tides. These floodplains extend 1,500 m to the north and south of the river; vegetation is dense and marshy conditions persist.

The LSA shares the same downstream boundary at Binta as the RSA and extends upstream to a point approximately 1.5 km downstream of the Farim River Crossing. This location represents the uppermost point in the catchment in receipt of inflows (watercourses or overland) from areas that have the potential to be impacted by the proposed mine.

6.4.2 Water Quality

6.4.2.1 Legislation and Standards

This baseline has been prepared in support of a planned ESIA and is being conducted towards international standards guidelines, with particular reference to the IFC Performance Standards (PS). IFC PSs contain guidance on the approach to be taken with respect to identification of guideline baseline water quality. The IFC advises that reference be paid to appropriate local and international water quality standards. As Guinea-Bissua does not have a defined set of surface water standards or guidelines, a range of international standards and guidelines were reviewed to determine the appropriate screening levels for baseline water quality.

Baseline water quality guidelines which are considered include:

- South African Water Quality Guidelines, Volume 7 Aquatic Ecosystem, Department of Water Affairs and Forestry, 2nd edition, 1996;

- Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines 1999; and
- United States Environmental Protection Agency (USEPA), National Recommended Water Quality Criteria, 2012.

Given the brackish water quality in the River Cacheu, estuarine ambient water quality guidelines from Australian (ANZECC 2000) and Trinidadian authorities were also examined. These were found to be geographically specific and in general less stringent than the thresholds for freshwater.

The freshwater water standards which were reviewed have comparable guideline levels for common determinands and are internationally accepted. The CCME water quality guidelines have been selected from the examined options as being most conservative for many determinands and also as having an equivalent set of sediment guidelines. The available standards with relevant notes are presented in Appendix D1.

Further discussion of local and international standards is presented in Section 1.1.3.

6.4.2.2 Water Quality Field Programme and Methods

The following fieldwork has been undertaken:

- Initial site familiarisation visit and visual assessment (dry season) of local rivers and watercourses potentially affected by the proposed mine development (December 2011) including:
  - Site assessment of surface water health (field observations);
  - A survey of local surface water users and associated land uses; and
  - In-situ water quality measurements were undertaken using a Hanna Multimeter (HI928). Sample parameters included temperature, pH, conductivity, dissolved oxygen (% and mg/L), ORP, total dissolved solids and salinity;
- Surface water quality sampling for laboratory testing (dry season, February 2012) during combined groundwater investigation programme;
  - In-situ water quality measurements were undertaken using a Hanna pH/EC/T parameter probe (HI-98129);
- Sample collection for laboratory testing including surface water samples and sediment samples (wet season, September 2012) collected by aquatic ecology and river morphology teams;
  - *In-situ* water quality measurements were collected using the river morphology team's YSI multiparameter probe;
- Sample collection for laboratory testing including surface water samples and sediment samples (dry season, May 2013) carried out by river morphology and ground investigation teams;
- Surface water quality sampling for laboratory testing (wet season, September 2013), installation of water level monitoring stations on the River Cacheu and on an ephemeral channel; and
  - *In-situ* water quality measurements were undertaken using a Hanna pH/EC/T parameter probe (HI-98129).

Table 6.6 presents field sampling carried out at three locations on the lower reaches of the tributaries of the River Cacheu (LSA) and at 21 locations along the River Cacheu (RSA) at locations indicated on Drawing 550-6.2.

Table 6.6: Preliminary baseline In-situ sampling locations

Study Area	Site Number	UTM Coordinate (Zone 28N)		Alternate ID
		Easting	Northing	
RSA	45	479371	1378833	Northing
	44	480060	1379007	-
	43	479630	1379675	-
	42	479399	1379368	-
	41	477904	1379851	-
	40	477140	1379448	SW6
	39	476312	1379329	-
	38	479371	1379328	-
	10	475809	1379315	-
	12	475877	1379428	SW5
	13	475878	1379581	-
	14	475468	1379380	-
	15	474720	1379722	-
	16	474708	1379727	-
	17	473921	1379173	-
	18	474404	1377824	-
	19	472405	1377158	SW7
	21	468806	1375566	-
	22	468678	1375566	-
	23	465874	1373083	-
	24	465869	1372900	-
LSA	7	473926	1380567	SW3
	9	473884	1380541	SW4
	28	473241	1377817	SW2

Coordinates and elevatons recorded using Garmin handheld GPS unit

Water samples for laboratory analysis were collected from a total of four locations on the River Cacheu (RSA) and four locations within the LSA. Table 7.7 presents the sample locations and provides some commentary on their selection.

Table 6.7: Surface Water Baseline Laboratory Sample Locations

Study Area	ID	Location and Description UTM Coordinate (Zone 28N)	Comments
RSA	SW06	River Cacheu, U/S of Farim 477884.8E 1379437.6N	2 km upstream of Farim and proposed mine site. Tidally influenced.
	SW05	River Cacheu at River Crossing 475953.3E 1379376.7N	Located at the Farim ferry crossing, upstream of proposed mine site; primary access route to Farim from Bissau and the South. Tidally influenced.
	SW07	River Cacheu, mouth of Rio de CM 472071.6E 1377144.4N	Located on River Cacheu main channel near mouth of ephemeral Rio de Cavaras Marinhos. Tidally influenced.
	SW01	River Cacheu, D/S of Mine Site 466198.7E 1374148.5N	River Cacheu downstream of the proposed mine site, 1.2 km upstream of Binta pier. Tidally influenced.
LSA	SW02	Rio de Caur (permanent, tidal) 467757.1E 1377787.8N	Permanent watercourse to the west of the proposed mine site. Sample location at a concrete bridge crossing on the route between Cansenhe and Salinquinhe, 4 km west of Salinquinhe. Tidally influenced.
	SW03	Rio de Banim (permanent, tidal) 473920.0E 1380564.7N	Permanent watercourse/inlet from Cacheu main channel, tidally influenced. Sample taken at eastern timber bridge crossing on Farim - Salinquinhe road, 1.8 km west of Farim.
	SW04	Rio de Bunja (permanent, tidal) 473229.4E 1380544.8N	Permanent watercourse/inlet from Cacheu main channel, tidally influenced. Sample taken at western timber bridge crossing on Farim - Salinquinhe road, 1.8 km east of Salinquinhe.
	SW08	Rio de Caveras Marinhos 470986.8E 1379441.8N	Sample collected where ephemeral stream flows across the road between Cansenhe and Salinquinhe (0.5 km west of Salinquinhe). This watercourse is ephemeral and flows through the proposed mine site.

Coordinates and elevatons recorded using Garmin handheld GPS unit

Table 6.8 provides the dates on which each location was sampled during the baseline period.

Table 6.8: Surface Water Baseline Laboratory Sample Collection Schedule

Sample ID	Description	February 2012	September 2012	May 2013	September 2013
		(Dry Season)	*(Wet Season)*	*(Dry Season)*	*(Wet Season)*
SW06	River Cacheu	✓	✓	✓	✓
SW05		✓	✓	✓	✓
SW07			✓	✓	✓
SW01		✓	✓	✓	✓
SW02	Rio de Caur	✓	✓	✓	✓
SW03	Rio de Banim	✓		✓	✓
SW04	Rio de Bunja	✓		✓	✓
SW08	Rio de Caverhas Marinhos		✓		

6.4.3 Hydrology Field Studies

Aside from the site orientation field visit during December 2011, hydrology fieldwork was carried out during the September 2013 field trip. This trip fell during the wet season, limiting access to some locations. The following describes the location, installation and data obtained from these studies.

6.4.3.1 Gauging Station Locations

As part of the Septermber 2013 field studies, three water level monitoring stations were installed on the River Cacheu and on a smaller stream in the vicinity of the mine site. The locations of these stations are indicated on Drawing 550-6.3 with UTM coordinates and approximate elevations indicated in Table 6.9. Figures 7.1 and 7.2 show the installed stations.

Table 6.9: Surface Water Level Monitoring Stations

Site ID	Description	UTM Coordinate (Zone 28N)		Elevation (masl)
		Easting	Northing	
SWL 1	River Cacheu (upstream of Canico Porto)	472471.18	1377261.18	1
SWL 2	River Cacheu (opposite bank, downstream of Farim)	475231.50	1379200.98	11
SWL 3	Rio Banim adjacent to Sara loba	474468.38	1382950.68	10

Coordinates and elevations recorded on handheld GPS unit

These stations are intended to provide a continuous (15 minute frequency) record of water level. The stations include:

- A non-vented pressure transducer (Solinst Levelogger) installed at each location along with a water level gauge board constructed from local materials (for calibration measurements);
- The transducers have been installed with a data-download cable attached, allowing the record to be periodically downloaded without requiring the removal of the pressure transducer;
- An existing barometric pressure record installed inside groundwater monitoring well MW04 west of Salinquinhe provides a corresponding record of atmospheric pressure which can be used to correct the non-vented pressure transducer readings; and
- The corrected pressure dataset can then be converted into an equivalent water level record using the calibration water level readings from the gauge board.

6.4.3.2 River Cacheu (RSA) Stations

RSA monitoring locations were chosen to be as close to the proposed mine site as was practicable, adjacent to deep water (to avoid drying out at low tide) and where less active siltation was evident. The gauge boards and transducers were secured to wooden poles which in turn were tied back to the mangrove knees; this provides a relatively stable and secure platform for measurement of water level. No clear areas of bank are present on this reach of the river which might permit a land based installation with the River Cacheu being lined on both sides by mangroves.

Figure 6.1: SWL1 Station assembly (left) and installed upstream of Canico Porto (right)

Figure 6.2: SWL2 Station installed downstream of Farim on southern bank of River Cacheu

Two stations were installed on the main channel of the River Cacheu. These stations were installed with the following goals:

- To measure the tidal variation in water level at locations immediately adjacent to the proposed mine site. Previously data had been collected at Binta, approximately 20 km downstream of Farim and for a shorter period near Farim;
- To measure long term variation in water level (if any) between the wet season and dry season; and
- To allow a better understanding of the interaction of groundwater and surface water in the vicinity of the proposed mine site (integrated ground and surface water studies).

6.4.3.3 LSA Station

Following an inspecting of the potential options of installing a gauging station on the ephemeral stream which flows through the proposed mine area, it was evident, as illustrated in Figure 6.3, that the ephemeral channel

was not defined clearly and was not constrained at any point to the extent that would permit a reliable measurement of water level.

Figure 6.3: Example of RdCM unconstrained ephemeral channel at point where it crosses main road west of Saliquinhe (SW8 sample site)

An alternative measurement point was chosen on the Rio Banim, draining a hydrologically similar adjacent catchment subject to comparable land uses and topography.

The location is at a 600 mm diameter concrete double culvert which conveys the upper Rio Banim across the main road north from Farim towards Canico Tumané, immediately south of the small village of Sara Ioba. Figure 6.4 illustrates the extent of the upstream catchment at the chosen crossing and provides and indication of the local vegetation cover and topography. The total catchment area to this point has been estimated using GIS software as being 25.2 km²

This water level monitoring station (Figure 6.4) was installed with a number of key goals:

- Measure the response of the catchment to a given rainfall event through comparison with observed concurrent rainfall record at Farim; and
- Estimate flow based on observed water level and compare with the incident rainfall volume.

Figure 6.4: SWL3 Station on Rio Banim south of Sara foba village

6.4.3.4 Hydrology – Data capture

Water level data was downloaded by the local GB Minerals team from the 3 water level monitoring stations and the barometric pressure transducer on 19 October 2013 following procedures outlined in Golder memo 13514950200.507. No additional spot measurements of water level were provided and so the initial (installation) water level measurments have been used to correct the transducer record. Following data retrieval, water level monitoring at these stations will continue indefinitely, facilitating future data gathering anad analysis

Concurrent rainfall and water level data is limited to the period extending from installation of the water level stations (4 and 11 September, 2013) until the end of the available rainfall dataset, 27 September, 2013 at the time of data processing. A total of 23 days of concurrent data is available for the RSA stations (SWL1 and SWL2) and 16 days of concurrent data for the LSA station.

6.5 Results and Discussion

6.5.1 Water Quality - In-situ sampling data

Data for the field investigation in-situ sampling during December 2011 for the Regional Study Area are provided in Table 6.10.

Table 6.10: RSA – In-situ sampling data (December 2011, Dry Season)

Site Number	Sample Depth (m)	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Conductivity (µS/cm)
45	0.4	6.99	24.73	1.22	14.7	2586
	1.8	6.97	24.72	1.16	14.0	2588
44	0.4	7.02	24.79	1.46	17.6	2578
	1.8	6.99	24.79	1.40	17.0	2580
43	0.4	7.01	24.79	1.39	16.8	2574
	1.8	6.99	24.78	1.37	16.6	2577
42	0.4	7.23	24.82	1.74	21.1	2571
	1.8	7.09	24.79	1.64	19.8	2579

Site Number	Sample Depth (m)	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Conductivity (µS/cm)
41	0.4	7.01	24.82	1.6	19.40	2571
	1.8	6.98	24.78	1.4	17.40	2573
40	0.4	7.07	24.84	1.80	21.8	2570
	1.8	7.01	24.89	1.60	19.5	2575
39	0.4	7.10	24.92	1.99	24.4	2575
	1.8	6.98	24.92	1.76	21.5	2579
38	0.4	7.20	25.02	2.30	27.0	2584
	1.8	7.04	25.02	1.86	22.9	2584
10	NR	7.25	25.16	2.16	26.7	2577
	NR	7.43	25.39	8.51	103.2	2651
12	NR	7.26	24.96	2.11	25.4	2590
	NR	7.26	25.28	8.04	98.1	2660
13	NR	6.95	25.09	2.4	28.0	2623
	NR	7.28	25.68	7.34	90.4	2668
14	0.4	7.24	25.36	7.7	94.0	2681
	1.5	7.18	25.32	7.44	90.8	2689
15	0.4	7.31	25.97	7.14	87.2	2713
	1.5	7.23	25.34	7.05	86.1	2713
16	0.4	7.13	25.51	6.94	84.9	2735
	1.5	7.12	25.51	6.72	82.1	2757
17	0.4	7.20	25.5	7.27	88.6	2785
	1.5	7.14	25.45	6.82	83.1	2800
18	0.4	7.22	25.46	7.5	93.3	2837
	1.5	7.12	25.47	6.72	82.8	2853
19	0.4	7.48	25.46	6.81	83.7	3095
	1.5	7.20	25.44	6.75	83.0	3114
21	0.4	7.05	25.52	6.6	81.4	3509
	1.5	7.03	25.52	6.52	80.7	3512
22	0.4	7.08	25.82	6.67	82.0	3504
	1.5	7.03	25.51	6.55	80.7	3505
23	0.4	7.00	25.49	6.33	78.2	3939
	1.5	6.98	25.49	6.15	76.1	3956
24	0.4	7.07	25.48	6.31	77.9	3929
	1.5	7.01	25.49	6.06	74.0	3957

NR = Data not recovered

Table 6.11 provides the in-situ parameters recorded within the LSA during December 2011.

Table 6.11: LSA – In-situ sampling data (December 2011, Dry Season)

Site Number	Sample Depth (m)	pH	Temp (°C)	DO (mg/L)	DO (%)	Cond (µS/cm)
7	0.3	7.02	23.12	8.2	96.5	2750
9	0.3	7.04	22.34	9.01	111.1	2970
28	0.3	6.78	23.87	2.61	30.4	3132

In-situ water quality parameter measurements were taken during water sampling on subsequent field trips during 2012 and 2013; Table 6.12 to Table 6.16 detail the recorded parameters. Subsequent measurements

were taken with a calibrated basic Hanna probe excepting the September 2012 trip when the river morphology team's YSI multiparameter probe was used.

Table 6.12: RSA – In-situ sampling data (February 2012, Dry Season)

Site Number	Date	pH	Conductivity (µS/cm)	Temperature (°C)
SW01	01/02/2012	7.36	>3999	23.4
SW05	04/02/2012	7.45	3725	25.6
SW06	04/02/2012	7.46	3615	25.2

>3999 indicates that the conductivity is outside the range of measurement of the Hanna parameter probe

Table 6.13: LSA – In-situ sampling data (February 2012, Dry Season)

Site Number	Date	pH	Conductivity (µS/cm)	Temperature (°C)
SW02	03/02/2012	7.34	>3999	23.8
SW03	03/02/2012	7.4	3769	24.5
SW04	04/02/2012	7	>3999	21.0

>3999 indicates that the conductivity is outside the range of measurement of the Hanna parameter probe

Table 6.14: LSA – In-situ sampling data (September 2012, Wet Season)

Site Number	Date	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (ppm)
SW02	19/09/2013	6.54	1075	28.2	2.46	537
SW08	19/09/2013	6.51	57	30.3	4.65	29

Table 6.15: RSA – In-situ sampling data (September 2013, Wet Season)

Site Number	Date	pH	Conductivity (µS/cm)	Temperature (°C)
SW06	04/09/2013	7.02	>3999	27.7

>3999 indicates that the conductivity is outside the range of measurement of the Hanna parameter probe

Table 6.16: LSA – In-situ sampling data (September 2013, Wet Season)

Site Number	Date	pH	Conductivity (µS/cm)	Temperature (°C)
SW04	07/09/2013	6.45	>3999	28.2
SW03	07/09/2013	7.04	>3999	28.3
SW02	10/09/2013	4.69*	1798	29.0

>3999 indicates that the conductivity is outside the range of measurement of the Hanna parameter probe

** Anomalous reading - to be disregarded*

Overall, the character of the waters at the monitoring locations on the River Cacheu is consistent between wet and dry seasons for conductivity and pH. As expected, conductivity increases from upstream to downstream where the water becomes more saline and tidally influenced. Similarly, SW08 on the ephemeral Rio de Cavarhas Marinhos (RdCM) has a very low conductivity being predominantly generated by freshwater runoff. Appendix D2 contains the compiled set of all recorded surface water in-situ sampling data.

6.5.2 Water Quality – Laboratory analysis

One of main aims of the water quality field programme was to capture the wet and dry seasons. Surface water samples for laboratory analysis were captured at six locations during February 2012 and September 2012; and seven locations in May 2013 and September 2013. The full water quality results are presented in Appendix D3 and summarised results including only those parameters for which significant (above detection limit) results were recorded are presented here. The initial round of water sample analysis in February of 2012 was carried out by the Institut Pasteur at their Dakar and Paris laboratory facilities. Due to logistical difficulties with this arrangement, the UK based Jones Environmental laboratory performed for subsequent rounds of water quality analysis.

6.5.2.1 Dry Season Data

Dry season samples were collected from locations in the LSA in February and May of 2012. The summary results are presented in Table 6.17 and Table 6.18.

Table 6.17: Surface Water Quality Laboratory Data (February 2012)

Parameter	Units	RSA			LSA		
		SW01	SW05	SW06	SW02	SW03	SW04
Alkalinity	mmole/L	6.4	6	6.8	7.2	6.6	8.6
Calcium	mg/L	48	36	40	16	16	48
Chloride	mg/L	1,817.5	1,331.2	1,276	1,455.5	1,242.5	1,562
Conductivity	µS/cm	5,700	3,450	4,010	3,970	3,330	4,570
Dissolved Oxygen	mg/L	5.8	6.6	5.7	6.5	6.1	5.8
Dissolved Iron	µg/L	40	50	20	30	10	30
Total Iron	µg/L	120	110	26	40	60	60
Magnesium	mg/L	48	26.4	43.2	48	38.4	48
Dissolved Manganese	µg/L	130	30	5	130	50	200
pH	pH units	7.28	7.55	7.47	7.33	7.39	7.23
Sodium	mg/L	1,050	705	687	841	688	788
Sulphate	mg/L	130	81	84	102	77	93
Temperature	°C	24.9	24	23.7	24	24	23.7
Total Dissolved Solids	ppm	3,200	1,850	2,160	2,140	1,790	2,460
Dissolved Zinc	mg/L	0.047	0.0025	0.0024	0.0032	0.0098	0.0027
Total Zinc	mg/L	0.061	*0.0025*	*0.0025*	*0.0025*	0.011	*0.0025*
Ammoniacal Nitrogen	mg/L	*0.25*	*0.25*	0.5	*0.25*	0.5	*0.25*
Phosphates	mg/L	*0.25*	*0.025*	*0.25*	*0.25*	*0.25*	*0.25*
Copper - Dissolved	mg/L	*0.025*	*0.0005*	*0.025*	*0.0005*	0.0013	*0.025*
Copper - Total	mg/L	*0.025*	*0.0025*	*0.025*	*0.0025*	*0.0025*	*0.025*
Potassium	mg/L	*0.25*	27.2	26.2	33.4	26.3	29.3
Arsenic - Dissolved	ug/L	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*
Arsenic - Total	ug/L	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*
Cadmium - Dissolved	ug/L	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*
Cadmium - Total	ug/L	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
Chromium -	ug/L	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*

Parameter	Units	RSA			LSA		
		SW01	SW05	SW06	SW02	SW03	SW04
Dissolved							
Chromium - Total	ug/L	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*
Mercury - Dissolved	ug/L	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*
Mercury - Total	ug/L	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*
Nickel - Dissolved	ug/L	0.7	0.7	0.7	0.6	0.7	0.9
Nickel - Total	ug/L	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*
Lead - Dissolved	ug/L	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Lead - Total	ug/L	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*
TPH	ug/L	*50*	*50*	*50*	*50*	*50*	*50*

Note: Values in italics signify results below the laboratory detection limit which instead is substituted.

Table 6.18: Surface Water Quality Laboratory Data (May 2012)

Parameter	Units	RSA				LSA		
		SW6	SW5	SW7	SW1	SW02	SW04	SW03
Dissolved Arsenic	ug/L	5.2	*<0.9*	*<0.9*	*<0.9*	*<0.9*	*<0.9*	*<0.9*
Dissolved Cadmium	ug/L	0.07	*<0.03*	0.3	*<0.03*	*<0.03*	0.05	0.1
Dissolved Calcium	mg/L	53.9	79	53.9	75	63.9	55.5	56.2
Total Dissolved Chromium	ug/L	1.9	2.6	7.6	1.9	4.3	13.2	1.1
Dissolved Copper	ug/L	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*
Total Dissolved Iron	ug/L	8	194.3	45.1	6.8	107	73.4	7
Dissolved Lead	ug/L	*<0.4*	*<0.4*	*<0.4*	*<0.4*	*<0.4*	*<0.4*	*<0.4*
Dissolved Magnesium	mg/L	95.6	122.9	134.1	219.5	167.8	118.3	119.3
Dissolved Manganese	ug/L	25.1	12.5	11.1	3.9	21.9	19	21.1
Dissolved Nickel	ug/L	1.8	2	3.3	0.9	1.8	6.9	0.6
Dissolved Potassium	mg/L	33.3	35.7	37.3	61.6	49	35.3	36.1
Dissolved Sodium	mg/L	914.5	997.8	1138	1765	1426	944.6	973.9
Dissolved Zinc	ug/L	5.1	*<1.5*	*<1.5*	*<1.5*	*<1.5*	*<1.5*	*<1.5*
Total Iron	ug/L	948.9	196.2	105.1	287.1	115.4	146.3	298
Total Zinc	ug/L	6.5	1.7	*<1.5*	*<1.5*	*<1.5*	5.5	*<1.5*
Dissolved Mercury	ug/L	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Total Mercury	ug/L	0.01	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Sulphate	mg/L	154	133.77	219.05	370.24	267.51	167.07	172.77
Chloride	mg/L	1574.4	1624.4	1951.5	3145.2	2315.1	1658	1729.7
Ortho Phosphate as PO4	mg/L	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*
Ammoniacal Nitrogen as N	mg/L	0.14	0.11	0.28	0.19	0.16	0.16	0.12
Total Alkalinity as CaCO3	mg/L	62	62	62	68	68	64	62
Dissolved Oxygen	mg/L	9	10	10	10	9	9	9
Electrical Conductivity @25C	uS/cm	5368	4511	6308	9734	7617	5686	5646
pH	pH units	7.03	7.46	7.39	7.36	7.32	7.18	7.18
Total Dissolved Solids	mg/L	3439	2878	4622	6487	5073	3689	3692
Total Suspended Solids	mg/L	102	35	24	45	16	31	34

Note: Values in italics signify results below the laboratory detection limit which instead is substituted.

6.5.2.2 Wet Season Data

Wet season samples were collected from locations in the LSA in September 2012 and September 2013. The summary results are presented in Table 6.19.

Table 6.19: Surface Water Quality Laboratory Data (September 2012)

Parameter	Units	RSA				LSA	
		SW01	SW06	SW05	SW07	SW08	SW02
Dissolved Arsenic	ug/L	*0.45*	1	*0.45*	*0.45*	1	*0.45*
Dissolved Cadmium	ug/L	0.05	0.06	0.08	0.08	0.04	0.12
Dissolved Calcium	mg/L	21.3	19.5	18.9	19.6	4.8	25
Total Dissolved Chromium	ug/L	0.7	1.5	1.1	0.9	0.8	1.3
Dissolved Copper	ug/L	*1.5*	*1.5*	*1.5*	*1.5*	*1.5*	*1.5*
Total Dissolved Iron	ug/L	473.1	732.6	726.2	584.9	577.7	923.5
Dissolved Lead	ug/L	0.9	1.7	0.8	1	1.1	1.4
Dissolved Magnesium	mg/L	16.4	10.5	10.7	12.5	1.6	25.7
Dissolved Manganese	ug/L	32.5	153.1	116.4	39.5	40.3	150.8
Dissolved Nickel	ug/L	1.8	2	1.8	1.8	0.3	4.3
Dissolved Potassium	mg/L	5.3	2.9	2.9	3.4	0.6	5.8
Dissolved Sodium	mg/L	133.3	84	88.3	100.9	3	202.5
Dissolved Zinc	ug/L	8.1	7.6	8	7.9	6.3	17.2
Total Iron	ug/L	521.9	746.8	796.2	801.8	1055	940.5
Total Zinc	ug/L	8.2	9.6	9	8.1	10	18.6
Sulphate	mg/L	19.27	10.13	10.46	13.13	3.54	30.04
Chloride	mg/L	249.1	161.8	163.8	190.8	3.9	378
Ortho Phosphate as PO4	mg/L	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*
Ammoniacal Nitrogen as N	mg/L	0.12	0.17	0.12	0.14	0.12	0.13
Total Alkalinity as CaCO3	mg/L	28	36	28	32	26	34
Dissolved Oxygen	mg/L	9	9	9	5	9	9
Electrical Conductivity @25C	uS/cm	935	647	656	746	91	1401
pH	pH units	6.66	7.6	6.67	6.68	6.75	7.46
Total Dissolved Solids	mg/L	536	402	372	448	118	828
Total Suspended Solids	mg/L	24	*5*	27	*5*	12	23

Note: Values in italics signify results below the laboratory detection limit which instead is substituted.

Table 6.20: Surface Water Quality Laboratory Data (September 2013)

Parameter	Units	RSA				LSA		
		SW06	SW05	SW07	SW01	SW03	SW04	SW02
Dissolved Arsenic	ug/L	1.5	*<0.9*	1.1	2.3	*<0.9*	*<0.9*	1
Dissolved Cadmium	ug/L	0.24	0.12	0.03	0.26	*<0.03*	0.14	0.12
Dissolved Calcium	mg/L	43.2	42.1	51.4	65	47.5	46.1	15.2
Dissolved Chromium	ug/L	*<0.2*	*<0.2*	2.2	*<0.2*	5.1	*<0.2*	0.2
Dissolved Copper	ug/L	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*
Total Dissolved Iron	ug/L	10.9	10.9	325.1	10.1	37.2	*<4.7*	56.2
Dissolved Lead	ug/L	*<0.4*	*<0.4*	0.9	*<0.4*	*<0.4*	*<0.4*	0.9
Dissolved Magnesium	mg/L	75.2	73.8	141	206.2	94.3	88.9	28.8
Dissolved Manganese	ug/L	5.8	4.3	72.6	4.4	12.8	13.2	50.4
Dissolved Nickel	ug/L	0.9	0.9	1.6	0.3	2.4	0.7	0.3
Dissolved Potassium	mg/L	24.6	24.2	36	50.8	30.7	29.6	10.3
Dissolved Sodium	mg/L	821.3	861.3	1085	1588	934.7	868.2	302.9
Dissolved Zinc	ug/L	11.8	15.2	11.9	3.3	2.9	2.8	3.1
Total Iron	ug/L	398.4	635.9	325.1	766.1	256.1	575	339.2
Total Zinc	ug/L	11.8	15.2	11.9	3.3	2.9	2.8	8.5
Sulphate	mg/L	0.56	106.43	179.81	44.27	142.09	125.89	302.02

Parameter	Units	RSA				LSA		
		SW06	SW05	SW07	SW01	SW03	SW04	SW02
Chloride	mg/L	1.7	1315.9	1970.3	471.5	1737.8	1558.9	2939.4
Ortho Phosphate as PO4	mg/L	1.7	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*
Ammoniacal Nitrogen as N	mg/L	0.95	0.68	0.28	0.32	0.33	0.16	0.22
Total Alkalinity as CaCO3	mg/L	82	82	76	46	70	76	68
Dissolved Oxygen	mg/L	10	10	11	10	10	11	10
Electrical Conductivity @ 25C	uS/cm	4710	53	6554	5116	5401	5128	187
pH	pH units	6.79	6.84	6.83	6.56	6.68	6.74	6.71
Total Dissolved Solids	mg/L	2693	2698	3674	874	234	2941	5412
Total Suspended Solids	mg/L	60	91	62	33	58	60	82

Note: Values in italics signify results below the laboratory detection limit which instead is substituted.

6.5.3 Water Quality Data – Interpretation and Analysis

Appendix D3 identifies those results above the CCME freshwater quality guideline values. Exceedances are noted for chloride, cadmium, iron, lead, zinc and dissolved oxygen as described below. It should be noted that though most of the sampled locations are estuarine in nature, some of the freshwater guidelines against which the analytes have been screened (e.g. Chloride, Cadmium) are higher than their marine environment equiavlents. Nevertheless the CCME freshwater aquatic life guidelines are the more conservative and complete set and have been used for initial screening.

6.5.3.1 Salinity Results

The surface water quality results reflect the brackish estuarine environment with some seasonal variation evident. Figure 6.5 shows results for salinity related analytes.

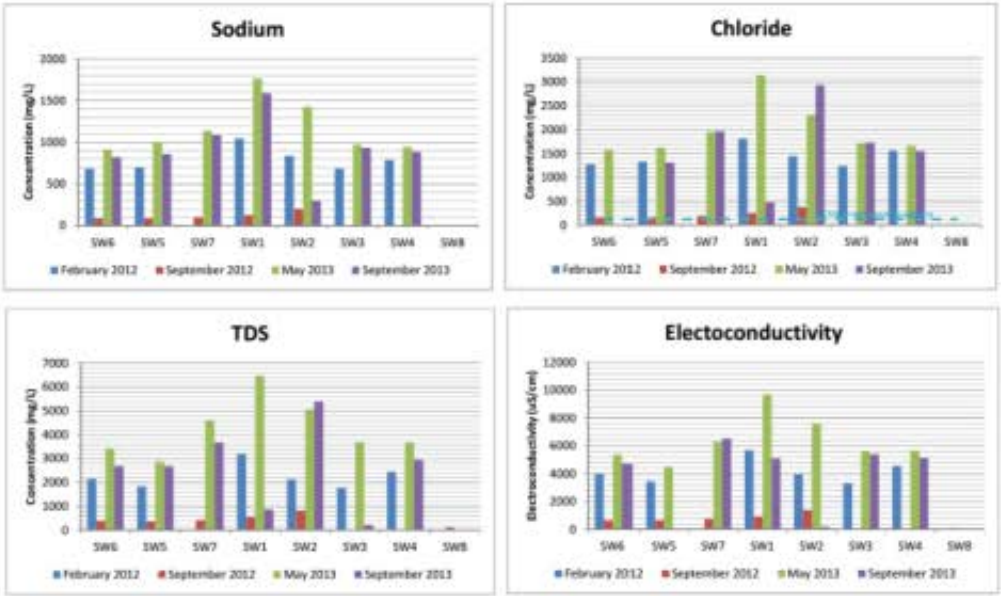


Figure 6.5: Salinity related results at selectred RSA and LSA locations

Figure 6.5 illustrates that there is considerable variation within the wet and dry season water quality data. Results are generally higher for the dry season (February 2012 and May 2013) although September 2013 wet season results are also notably high. This could reflect the timing of sampling relative to the tidal cycle.

6.5.3.2 Metals Results

Figure 6.6 shows the results for selected metals which are noted to exceed CCME guidelines in some samples or to have a wide variation in concentration (Manganese).

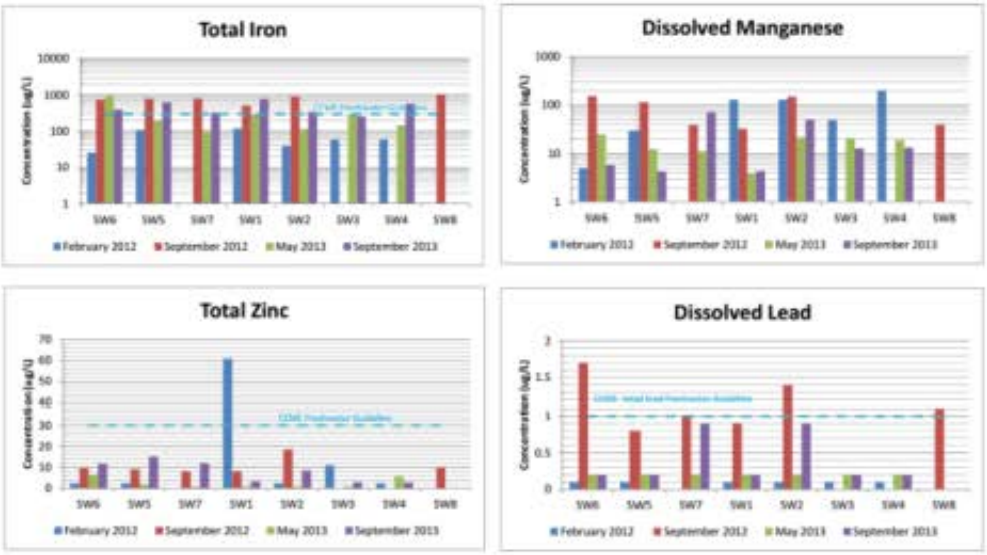


Figure 6.6: Selected metals results at RSA and LSA sampling locations

Higher concentrations of metals, (iron and manganese in particular) are observed in the LSA samples taken at SW2 on the Rio Caur and at SW8 on the RdCM. Both of these rivers drain the same opposite sides of the same hill northwest of the mine site.

Metals concentrations are generally observed to increase from upstream (SW6) to downstream (SW1) on the River Cacheu RSA samples.

Almost all samples were in exceedance of the CCME freshwater iron guideline of 300 ug/L. This likely reflects the natural mineralisation of the local water environment as similarly high concentrations were found in some groundwater samples collected from monitoring wells in the vicinity of the mine site.

6.5.3.3 Total Suspended Solids (TSS)

Figure 6.7 shows TSS levels at all sampled locations for the 3 field trips for which this analysis was conducted.

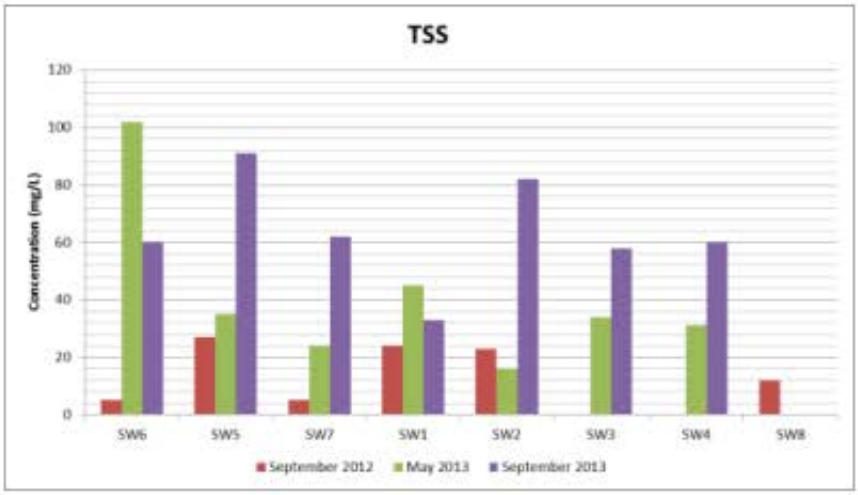


Figure 6.7: TSS laboratory analysis reuslts

TSS were found to vary significantly between relatively low levels observed during the 2012 wet season to relatively high levels at all locations during the 2013 wet season.

Particle size distribution analysis was carried out on sediment samples collected during the September 2012 and May 2013 river morphology trips (Golder 2013b). This analysis indicates that sediment samples collected within the surface water RSA were characterised as being primarily silty/clayey in nature, particularly in the wet season.

6.5.3.4 pH Results

Figure 6.8 indicates that the RSA pH levels vary from slightly acidic, approaching the CCME freshwater aquatic life guideline value during the wet season with a more alkaline character during the dry season. This suggests a relatively acidic runoff entering the upstream catchment of the River Cacheu. Levels recorded in the LSA were slightly less acidic during the wet season than those in the RSA. Anomalous alkaline pH values were observed at SW6 (the upstream-most River Cacheu location) and at SW2 on the Rio Caur.

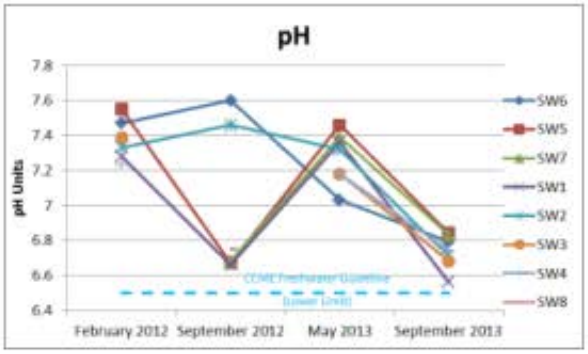


Figure 6.8: pH measurements from laboratory analysis

6.5.3.5 Additonal Laboratory Analysis Results

Surface water samples collected during the February 2012 dry season and September 2013 wet season field trips were analysed for PAH with all results below detection levels. Similarly samples collected from September 2013 onward were analysed for Extractable Petroleum Hydrocarbons and again all results were below detection levels.

Dissolved oxygen (DO) results were low in the range of 5-10 mg/L with one observed wet season result below the CCME freshwater guideline near the outflow from Rio Caur.

6.5.4 Laboratory Analysis Quality Assurance

Duplicate samples were collected from surface water locations during the May 2013 and September 2013 field trips (dry season and wet season respectively). Concurrent samples were collected at site SW1 in May 2013; and at sites SW2 and SW4 in September 2013. Some variation was observed in the reported results for both trip but is considered to be within acceptable limits.

Results where a greater than 20% deviation was observed and where both samples had values of more than 5 times the limit of detection were identified as notable. For the May 2013 trip, 7% of the reported analytes showed notable deviations; and for the September 2013 trip 12% (SW4) and 14% (SW2) of the reported analytes showed notable deviations. This results in high to moderate classification for the analytical precision and field sampling. Full details are contained in Appendix D4 to this report.

Due to the logistical challenges which the relative locations of the laboratory and site presented, some of the samples were not completed within the time window required for accreditation. Nevertheless, best efforts were made to meet these time windows as much as was practicable.

6.5.5 Hydrology

6.5.5.1 RSA Hydrology Data

Figure 6.9 and Figure 6.10: SWL2 (Farim) Instantaneous Water level versus Daily RainfallFigure 6.10 illustrates the water level fluctuation on the tidal River Cacheu plotted with the daily rainfall totals from the meterological station.

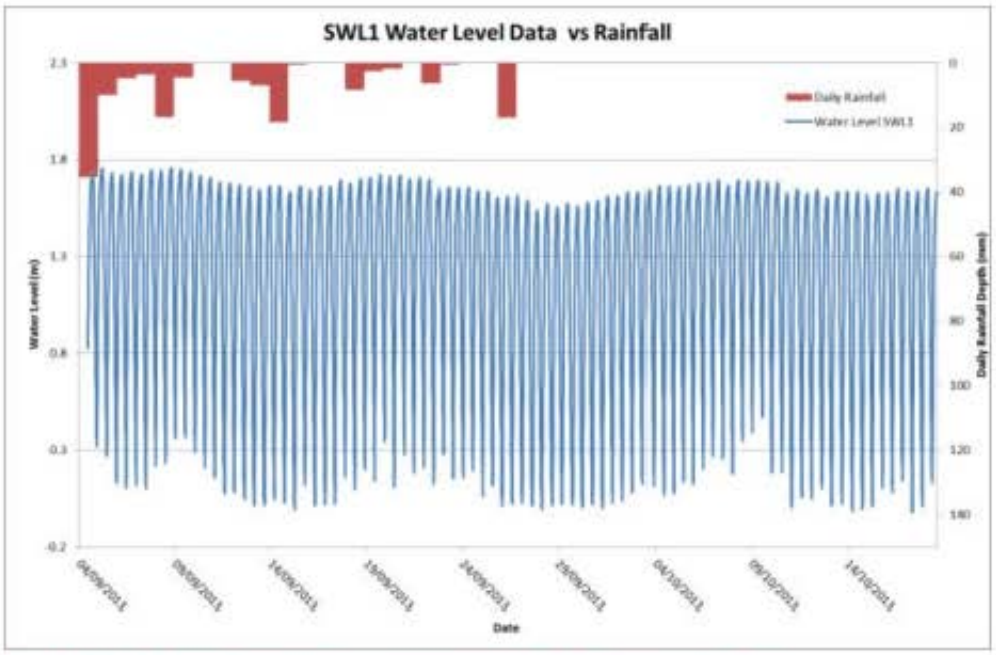


Figure 6.9: SWL1 (Canico, River Cacheu) Instantaneous Water level versus Daily Rainfall

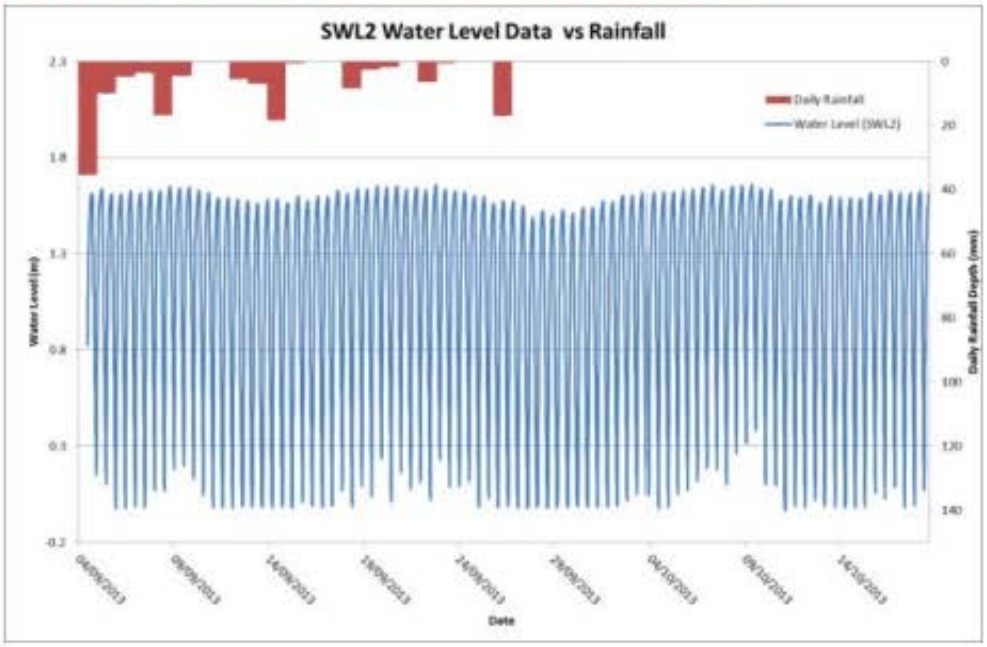


Figure 6.10: SWL2 (Farim) Instantaneous Water level versus Daily Rainfall

This RSA dataset (at reporting date) informs the following observations:

- A tidal range of about 1.7 m was observed at both locations;
- No concurrent groundwater and surface water data was available for the period of monitoring; and
- Some increase in low tide level is observed over the period of monitoring which might be related to observed rainfall and consequent runoff events; a longer term dataset would be needed to support this conclusion.

As the stations were installed with direct read cables, additional water level data can be added to this baseline prior to completion of the impact assessment allowing further analysis to be carried out. Further analysis of the River Cacheu flow regime is detailed in the river morphology assessment.

Additonal hydrology studies were conducted in the surface water RSA by the river morphology team during the May 2013 (dry season) site visit including water level measurements and discharge measurements using an ADCP (Acoustic Doppler Current Profiler).

- A low tide flow of 304 m^3/s was estimated for SW7 near Canico Porto; and
- A falling tide flow of 782 m^3/s was estimated for SW1 (Golder 2013b).

No flow data are available for the River Cacheu at Farim so rainfall runoff estimation (catchment/areal runoff model) will need to be employed to understand the potential impact on the flood regime.

6.5.5.2 LSA Hydrology Data

In order to interpret the LSA water level data, an appreciation of the local antecedent condtions in the study catchment is required. Figure 6.11 shows the cumulative weekly rainfall during the period leading up to the available water level monitoring data.

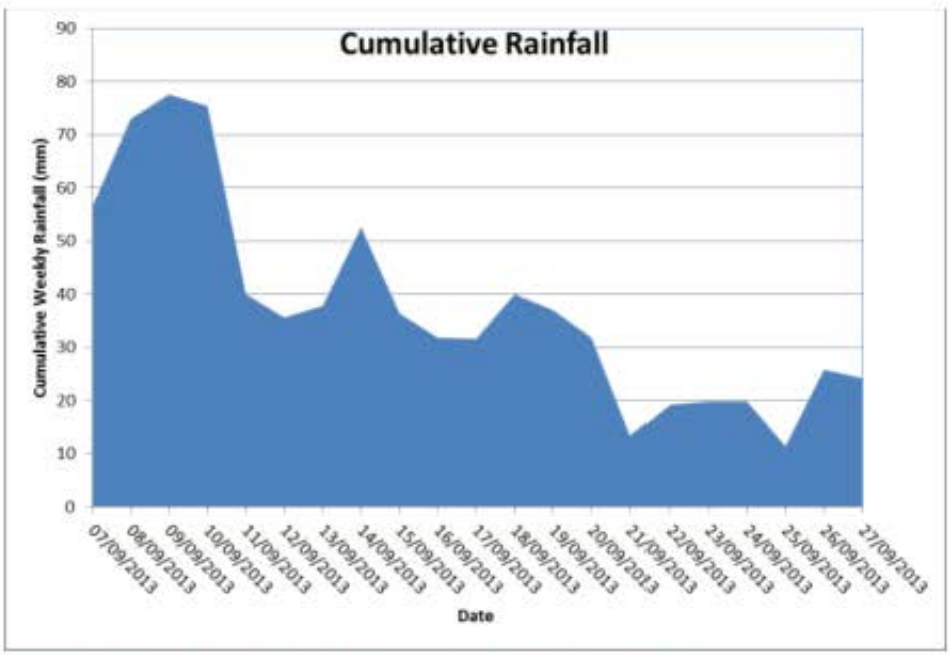


Figure 6.11: Cumulative weekly rainfall, at Farim Weather Station September 2013.

Figure 6.12 illustrates the water level fluctuation at the LSA monitoring station (SWL3) plotted with the 10 minute rainfall data from the meterological station at Farim. Figure 6.13 shows the water level at SWL3 plotted against daily total rainfall.

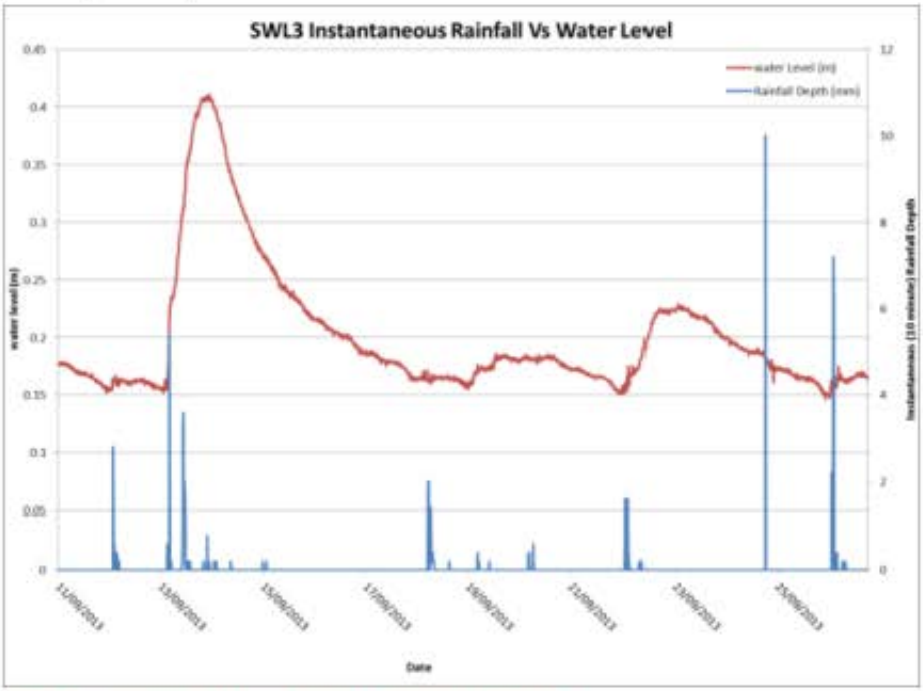


Figure 6.12: Instantaneous Water level vs 10-minute Rainfall data

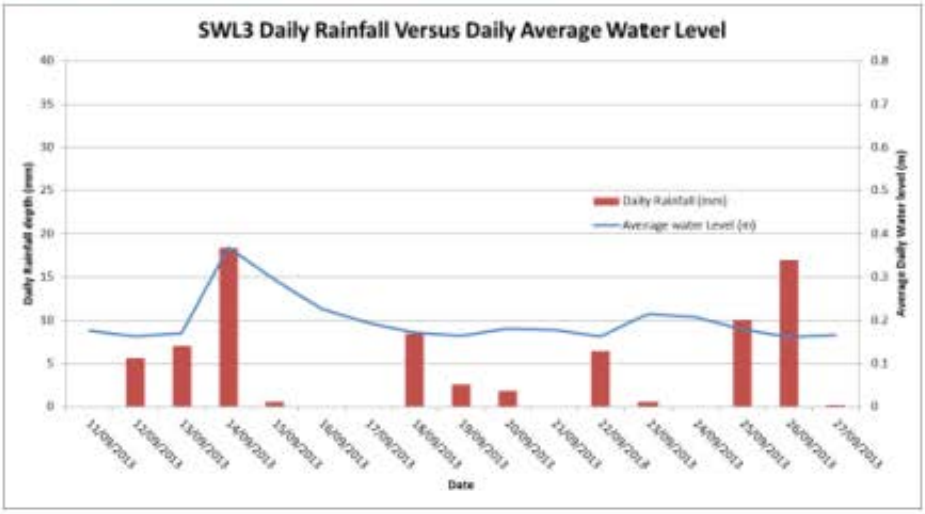


Figure 6.13: Average daily Water level vs 10-minute Rainfall data

Analysing the water level response to rainfall, Figure 6.12 indicates the catchment responds very rapidly to an intense rainfall event (>5 mm/10 minute period) captured on the 13 September, 2013, rising to over 0.4 m depth which approaches the soffit of the 600 mm culvert. Over the course of the relatively dry week that follows, the water level/flood slowly recedes back to pre-event levels. Rainfall events of an even greater intensity on the 25 and 26 September 2013 (>10 mm/10 minute and >7 mm/10minute) do not result in an increase in a significant water level at the monitoring site.

Examining the weekly cumulative rainfall plot for the period (Figure 6.11) leading up to these latter rainfall events, notably lower levels of antecedent rainfall was available to "pre-wet" the catchment. This coupled with the slowly receding flood curve suggests a catchment with a large storage capacity which if exceeded can still result in a flashy flood event in response to an intense individual storm.

It should be noted that:

- Backwater conditions were observed at the culvert prior to installation along with a large amount of floating debris which might result in water level readings which are non-representative of the upstream catchment; and
- A large rice paddy is located immediately upstream of the monitoring location. It is possible that the local farmers (here and throughout the region) control water levels artificially in the catchment and divert flows in other parts of the catchment. This might provide an alternative explanation for the unusual flood water level recession profile detailed above.

6.5.5.3 Estimated LSA Flow and Runoff Coefficients

Discharge at the LSA station has been estimated for the concurrent rainfall and water level monitoring period. This exercise will allow validation of the assumed runoff coefficients to be used during impact assessments and inform engineering design and provide a baseline snapshot of the flow regime during the monitoring period.

In the absence of long term stage-flow records, standard values for Manning's roughness have been used and the presence of a relatively static backwater has been ignored. Table 6.21 specifies the input parameters used for the runoff estimate.

Table 6.21: Runoff Calculation Inputs

Parameter	Value	Unit
Catchment Area	25.20	km²
Culvert Slope	0.005	m/m
Culvert Diameter	0.6	m (double bore)
Manning's Roughness	0.011	-
Rainfall (11 September - 27 September 2013, Farim Station)	0.069	m

Based on the parameters in Table 6.21, the water level time series has been converted to an instantaneous flow time series using a Manning's calculation. This results in an average discharge of 0.272 m³/s for the period of measurement. For each 10 minute interval in the continuous water level record, the cumulative flow through the pipe has been computed at that instantaneous rate. Over the entire period of measurement, this provides an estimate of the total volume which has flowed past the station.

Using the catchment area and the concurrent rainfall record for the period of monitoring, the volume of rainfall-runoff available has also been estimated. For the purposes of this exercise, no preliminary losses (e.g evaporation) have been assumed (i.e. the runoff coefficient is inclusive of all hydrologic losses). The results of these calculations are shown in Table 6.22.

Table 6.22: Estimated LSA Flow and Runoff Coefficients

Parameter	Value	Unit
Runoff Volume (Areal Rainfall based)	1,728,720	m^3
Runoff Volume (Manning's Flow Estimates)	238,769	m^3
Estimated Runoff Coefficient	14	%

The estimated runoff coefficient value of 14% is considerably lower than the assumed 35% value (annual) used in previous feasibility studies. The lower number should be regarded as representative of modified local surface water conditions and not the natural surface water environment. However, diversion of water has been observed throughout the LSA as part of agricultural activities and this dataset supports this observation.

The following points are noted:

- There is evidence of both downstream backwater restrictions and artificial blockages at the location. If the culvert was blocked during the monitoring period, the flow estimation methodology employed here will not be valid;
- The extent of open water (i.e. rice paddies) within the catchment will have a strong influence on losses. Relatively high levels of rice cultivation are observed in the study catchment and the RdCM catchment;
- Observed flow rates during station installation were below the threshold of measurement for standard flow measurement devices. Logistics preclude collection of measurements during or immediately after a rainfall event to record flows at higher stage levels, perhaps being possible over a longer monitoring period;
- The 14% runoff coefficient estimate is representative of conditions during the data collection period and not of year round conditions throughout the LSA. As a conservative measure, calculations of runoff and flow will continue to be based on a runoff coefficient of 0.35 (35%); and
- The runoff data collected has provided evidence of thea highly modified surface water environment throughout the LSA.

6.5.6 Summary of Conclusions

6.5.6.1 General

- The River Cacheu is perennial and tidal, with low energy flow in tributaries in the proposed mining area;
- The streams and rivers within the vicinity of the proposed mine are used by local communities for washing, transportation (by canoe and ferry), fishing, irrigation, cropping, domestic livestock and salt production. Groundwater wells are evident in each of the local villages, and these (not surface water) are belived to be the primary source of drinking water; and
- Mangroves grow along the River Cacheu; on the landward side of the mangroves are silty and muddy soils that have been transformed into rice paddies.

6.5.6.2 Water Quality

- No obvious (visible) surface water quality contamination was evident at any of the monitoring locations;
- Elevated conductivity was recorded at all locations (in-situ sampling measurements and laboratory sampling), consistent with the brackish nature of the natural river regime;
- Water quality along the River Cacheu is turbid, neutral pH and high dissolved oxygen level;

- Physical parameters including TDS, TSS and pH are found to vary significantly from wet to dry season. Dissolved oxygen is generally low with one observed exceedance;
- High levels of iron and manganese were observed in the epehemeral stream flowing through the proposed mine site location and in the Rio Caur to the west of the mine site; and
- Concentrations of some metals increase from upstream of Farim to the lowest RSA sample location. This could be related to the influence of inflows from tribuataries draining the mine site and other areas along this reach.

6.5.6.3 Hydrology conclusions

- The River Cacheu is tidal. Water level monitoring at Binta and the recent installed stations near Farim indicates a tidal range of up to 1.7 m. Additional analysis of this aspect of the river hydrology is summarised in the River Morphology baseline (Section 4);
- Based on field observations, the smaller watercourses within the LSA are strongly ephemeral mirroring the dry/wet seasonal rainfall pattern. Multiple modifications to the natural flow paths of these smaller streams have been made to facilitate agricultural activities, most significantly the construction of rice paddies;
- River Cacheu point flow estimates were used by the River Morphology team to develop a tidal flow-stage relationship which can be used in refining flood impacts; and
- The monitored LSA stream exhibites a quick response to rainfall events given sufficient antecedant rainfall. A slower response is observed where a drier period precedes the storm event, with a significant amount of recharge of upstream areas required.

6.5.7 Study Limitations and Recommendations

Ongoing monitoring and data recovery will produce more data which should be added to the baseline dataset at a later date.

- Site rainfall and evaporation data should be continuously collated and validated to compare the on-site and adopted proxy climate data set compiled from a number of regional sources. To date, only one complete year (2012) of site meterological data was available for comparison (Section 2, Air Quality and Meteorology);
- Water monitoring stations at the ephemeral watercourse and on the River Cacheu; only a short period of data was available for September 2013; this can be added to when more data has been downloaded; and
- A programme of ongoing water level monitoring and flow estimation recommended to improve the current baseline dataset This will enable quantification of changes (due to the proposed mine site) within these water courses as part of the ESIA process;

6.6 References

- Canadian Council of Ministers of the Environment (CCME), 2012. Canadian Environmental Quality Guidelines.
- World Bank Group, Climate Change Portal- data from Climate Research Unit (CRU) of University of East Anglia (UEA). Link accessed October 2013 http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Africa&ThisCCode=GNB.
- Golder 2013b: Golder Associates, September 2013; River Morphology and Physical Oceanography Baseline Study – 13514950200.503/B 0.

- International Finance Corporation (IFC) World Bank Group 2007b. Environmental, Health and Safety Guidelines for Mining. December 2007.
- REDDY, S.J and VIRMANI, S.M., (1980). Potential evapotranspiration estimates in the semi-arid West African region.
- International Crops Research Institute for Semi-Arid Tropics (ICRISAT).
- South African Water Quality Guidelines, Volume 7 Aquatic Ecosystem, Department of Water Affairs and Forestry, 2nd edition, 1996.
- United States Environmental Protection Agency (USEPA), 2012. National Recommended Water Quality Criteria.
- World Health Organis ation (WHO). 2011. Guidelines for drinking-water quality, 4th edition.

7.0 SOILS

7.1 Introduction

A baseline assessment of soil, land use, land capability, and wetlands was carried out by Viljoen & Associates under contract to Golder.

7.2 Study Area

The study area was approximately 1,958 hectares within the area anticipated to be disturbed by the proposed mining activities shown on Figure 7.1.

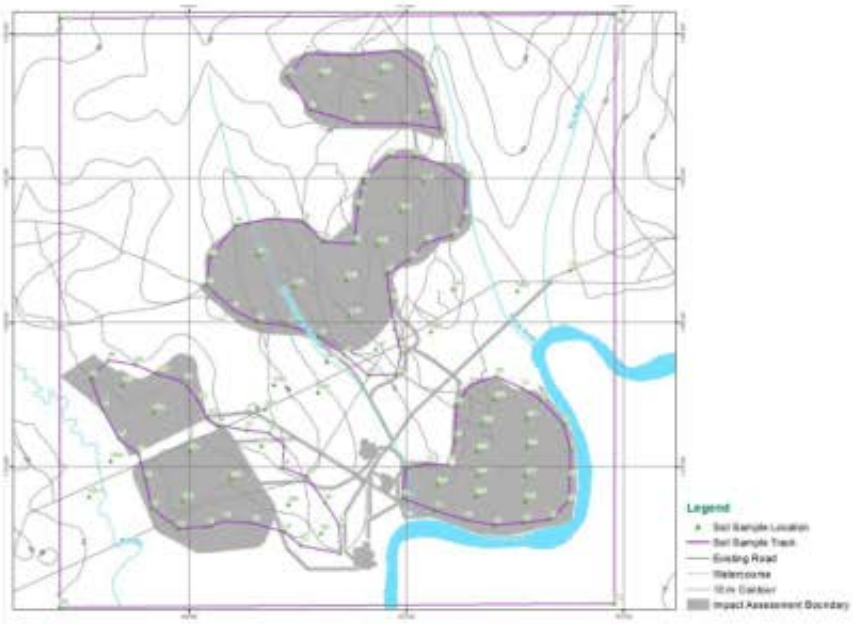


Figure 7.1: Soils and land capability study area (1,958 ha)

7.3 Previous Work

No previous work has been carried out on the soil type and quality within the study area.

7.4 Methods

The following scope of work was conducted:

- A soil survey according to standard soil survey techniques comprising of auger holes on a flexible grid system GPS referenced (Datum 1984, degrees, minutes, seconds) to produce an electronic soil map to be available in AutoCAD, Micro Station, tif, pdf and/or jpeg;
- Soil profile studies according to the latest version of the Taxonomical Soil Classification System of South Africa;
- Representative sampling of different soil types;
- Inorganic analysis of the samples according to standard methods and techniques (Table 7.1); and
- Interpretation of analytical data and field observations.

7.4.1 Sampling Procedures

A total of 102 soil samples were taken during the investigation (Figure 7.2) according to the following procedures:

- Auger holes were drilled with a 75 mm diameter 1.8 m mechanical steel auger;
- The ground surface at the position of the auger hole was cleared of loose material. If present, surface vegetation was carefully removed and the soil clinging to any roots left behind collected with the surface soil sample;
- The sampling interval in the auger holes was 150 mm and consolidated to one sample per auger hole;
- The auger was advanced to the required depth and then carefully removed from the hole. The hole was covered to prevent foreign material from entering;
- Approximately 1.5 kg soil sample was taken from the hole raisings and soil material removed from the auger. The samples were quartered to produce a representative sample of suitable weight, *i.e.* 500 g;
- Prior to the taking of each sample, both the steel auger and stainless steel trowel used to collect the soil samples were wiped clean of soil, washed with tap water, rinsed in a phosphate-free detergent, and finally sprayed with de-ionised water to prevent cross contamination between sampling depths;
- The soil samples were placed directly in zip-lock freezer bags, clearly labelled in indelible ink with the name of the site, auger hole number and sampling date;
- The soil samples were stored in the shade prior to being transported to an air-conditioned environment awaiting transport to the analytical laboratory;
- Chain of custody forms accompanied the soil samples to the laboratory and the samples were verified and signed for by the laboratory chemist; and
- All auger hole logs were geo-referenced (GPS: datum WGS1984, decimal degrees).

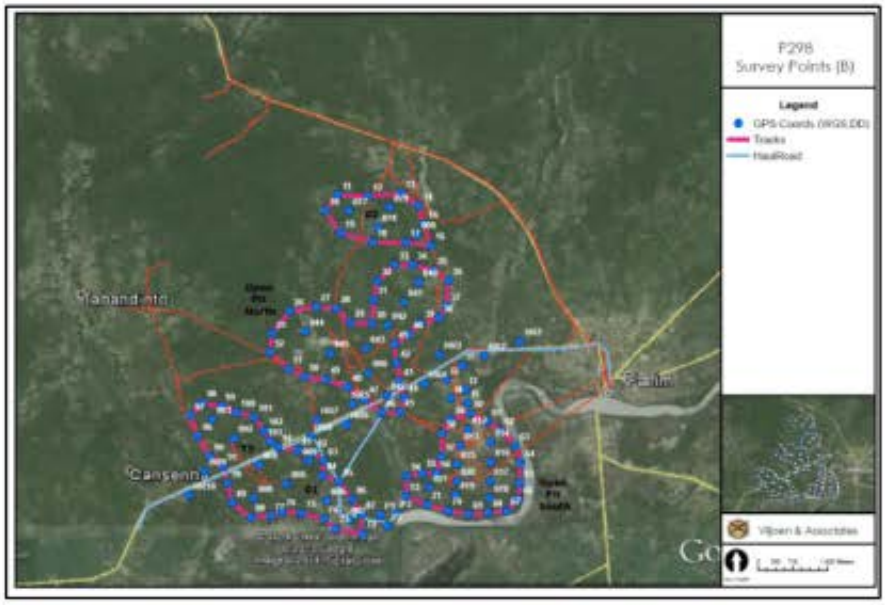


Figure 7.2: Soil Sampling Positions (WGS84 Decimal Degrees)

7.4.2 Inorganic Analyses

Table 7.1 shows the analytical soil parameters for analyses.

Table 7.1: Soil Analytical Parameters

Element	Method
Chemical	
Sample Preparation	Standard
pH (H_2O)	Standard
CEC+K+Na	NH_4Ac-extraction
EC+NO_3	Saturated distilled water extract
P	Bray 1-extract
Lime Requirement	Double Buffer Titration
Mineralogy	
Clay fraction (<0.002mm) identification	XRD-scan (6 treatments)
Physical	
Particle size distribution (3 fractions-sand+silt+clay)	Hydrometer

7.4.3 Quality Assurance and Quality Control

The quality assurance/quality control procedure for the investigation entailed a combination of the following:

- Duplicate analyses on 5% of the samples submitted;
- Additional checks using standard reference materials;
- Multi linear regression techniques to ensure analytical equipment are properly calibrated; and

- Double check calibrated equipment with spiked standards above highest standard and confirm with 10x dilution.

7.4.4 Soil Classification and Effective Soil Depth

The South African Taxonomical Soil Classification System has been used which describes 53 different soil types. Each soil type is characterised by a sequence of diagnostic horizons (Figure 7.3).

Soils can be formed *in situ* from underlying geology through natural weathering and/or could be transported and deposited through wet and dry geological periods. The soils will be a function of the mineralogy from which it was derived, which will determine the prevailing chemical, physical and mechanical properties.

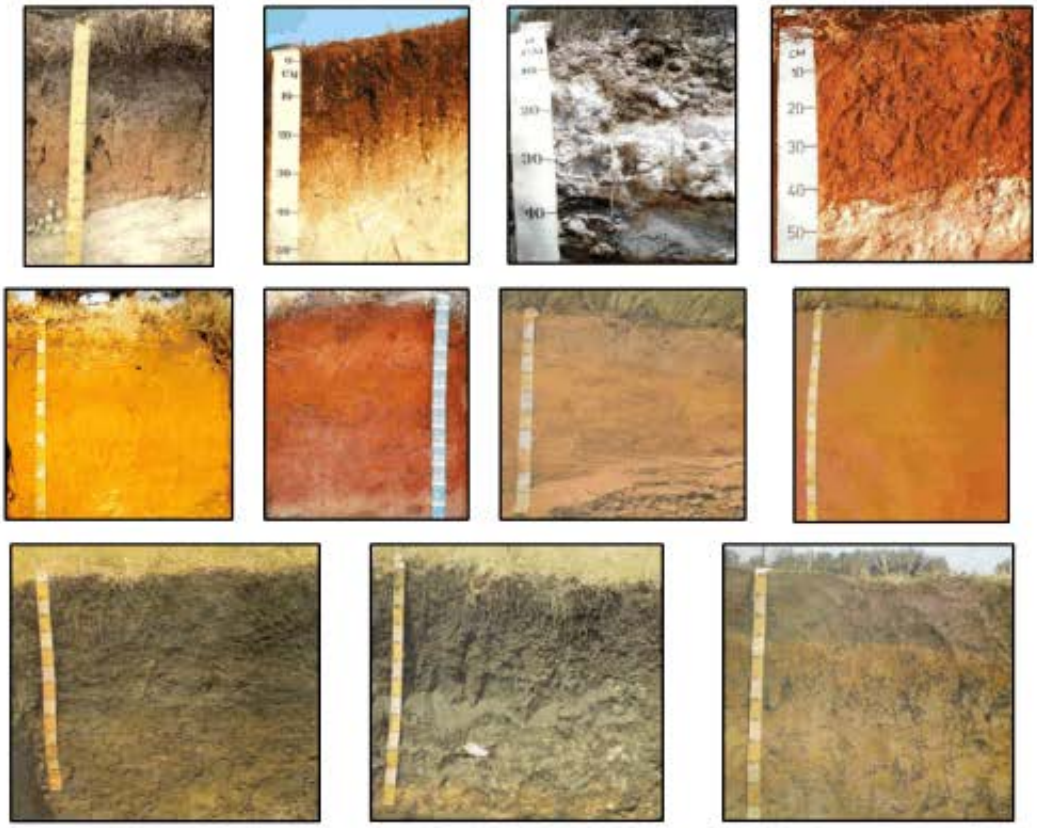


Figure 7.3: Soil types (examples from South African Taxonomical Soil Classification System)

7.4.5 Agricultural Potential

The agricultural potential of the five soil types was assessed using the following formula:

$$YIELD\ (kg/ha) = R/B \times ED/A \times C \times X$$

Where:

R – Rainfall (mm)

B - Species growth characteristics factor.

ED - Effective depth of the soil.

A - Soil wetness factor for textural classes of soil above effective depth.

C - Correction factor for aeration of soil.

X - Fixed coefficient for species.

7.5 Results and Discussion

A total of 102 soil samples were taken during the investigation (Table 7.2) and analysed for chemical and physical properties (Table 7.1) according to Standard Methods and Techniques (Sparks, *et. al.*, 1996). The Test Results are summarised in Appendix G.

Table 7.2: Soil Sample Location and Depth

Openpit South			TSO1			Openpit North			D2		
Sample Nr	GPS Nr	Depth (mm)	Sample Nr	GPS Nr	Depth (mm)	Sample Nr	GPS Nr	Depth (mm)	Sample Nr	GPS Nr	Depth (mm)
1	012	300	21	002	300	37	040	300	53	077	300
2	012	600	22	002	600	38	040	600	54	077	600
3	013	300	23	003	300	39	041	300	55	078	300
4	013	600	24	003	600	40	041	600	56	078	600
5	014	300	25	004	300	41	042	300	57	079	300
6	014	600	26	004	600	42	042	600	58	079	600
7	015	300	27	005	300	43	043	300	59	080	300
8	015	600	28	005	600	44	043	600	60	080	600
9	016	300	29	006	300	45	044	300			
10	016	600	30	006	600	46	044	600			
11	017	300	31	007	300	47	045	300			
12	017	600	32	007	600	48	045	600			
13	018	300	33	008	300	49	046	300			
14	018	600	34	008	600	50	046	600			
15	019	300	35	009	300	51	047	300			
16	019	600	36	009	600	52	047	600			
17	020	300									
18	020	600									
19	021	300									
20	021	600									
20			16			16			8		
20			36			52			60		

Haul Road			Plant			Infill			Harbour		
Sample Nr	GPS Nr	Depth (mm)	Sample Nr	GPS Nr	Depth (mm)	Sample Nr	GPS Nr	Depth (mm)	Sample Nr	GPS Nr	Depth (mm)
61	HR1	300	81	P1	300	87	I1	300	97	197	300
62	HR1	600	82	P1	600	88	I1	600	98	197	600
63	HR2	300	83	P2	300	89	I2	300	99	198	300
64	HR2	600	84	P2	600	90	I2	600	100	198	600
65	HR3	300	85	P3	300	91	I3	300	101	204	300
66	HR3	600	86	P3	600	92	I3	600	102	204	600
67	HR4	300				93	I4	300			
68	HR4	600				94	I4	600			
69	HR5	300				95	I5	300			
70	HR5	600				96	I5	600			
71	HR6	300									
72	HR6	600									
73	HR7	300									
74	HR7	600									
75	HR8	300									
76	HR8	600									
77	HR9	300									
78	HR9	600									
79	HR10	300									
80	HR10	600									
20			6			10			6		
80			86			96			102		

Figure 7.4: Soil Sampling

7.5.1 Soil Classification and Effective Soil Depth

Figure 7.5 shows the distribution of soil types in the study area according to the latest version of the South African Taxonomical Soil Classification System.

Figure 7.5: Soil type distribution

The diagnostic horizons of the Avalon, Clovelly, Hutton, Katspruit and Westleigh soils classified according to the South African Taxonomical Soil Classification System are summarised in **Table 7.3**

Table 7.3: Soil Types

Soil type	Diagnostic horizons	Effective depth (mm)
Avalon	Orthic A – Horizon/Yellow Brown Apedalic B – Horizon/Soft Plinthic B - Horizon	>300
Clovelly	Orthic A – Horizon/Yellow Brown Apedalic B – Horizon/Unspecified	>300
Hutton	Orthic A – Horizon/Red Apedalic B – Horizon/Unspecified	>300
Katspruit	Orthic A – Horizon/G – Horizon	<300
Westleigh	Orthic A – Horizon/Soft Plinthic B – Horizon	<300

7.5.2 Agricultural Potential

The main variables determining the agricultural potential of the soils (**Table 7.4**) include the effective depth (>300 mm), clay content (15%) and rainfall (650mm).

Table 7.4: Agricultural Potential of Soils

Soil Type	Agricultural Potential	
	Dry Land	Irrigation
Avalon	Medium	High
Clovelly	High	High
Hutton	High	High
Katspruit	Low	Medium
Westleigh	Low	Medium

7.5.3 Assessment of Erodibility of Soils and Evidence of Misuse

The exchangeable sodium percentage of the soil samples (except for samples 9, 12, 13, 14, 15, 16, 17, 63, 64 and 65) is below 15% of the cation exchange capacity, rendering the soils free of dispersion anomalies caused by the hydration of sodium and consequent soil erosion.

No evidence of soil contamination or misuse (Figure 7.6) was observed during the investigation.

Sample Number	Na (cmol(+)/kg)	CEC (cmol(+)/kg)	ESP (%)
1	0.120	7.882	1.52%
2	0.111	15.175	0.73%
3	0.121	9.853	1.23%
4	0.085	13.258	0.64%
5	0.608	20.168	3.01%
6	0.572	16.777	3.41%
7	0.064	7.577	0.84%
8	0.090	11.021	0.82%
9	3.499	21.591	[illegible]
10	2.843	21.679	13.11%
11	2.799	20.924	13.38%
12	3.489	19.880	[illegible]
13	10.879	23.434	[illegible]
14	17.845	21.938	[illegible]
15	9.992	35.460	[illegible]
16	5.232	30.082	[illegible]
17	2.688	17.491	[illegible]

Sample Number	Na (cmol(+)/kg)	CEC (cmol(+)/kg)	ESP (%)
51	0.076	8.515	0.89%
52	0.071	4.349	1.63%
53	0.043	3.246	1.32%
54	0.070	2.717	2.58%
55	0.048	7.336	0.65%
56	0.048	7.865	0.61%
57	0.053	6.608	0.80%
58	0.046	8.317	0.55%
59	0.066	8.772	0.75%
60	0.071	6.793	1.05%
61	0.087	4.892	1.78%
62	0.096	5.092	1.89%
63	8.084	16.207	[illegible]
64	11.123	23.049	[illegible]
65	0.322	1.252	[illegible]

Figure 7.6: Soil sample contamination and misuse estimation

7.5.4 Land Use and Land Capability

Table 7.5 summarises the land use of the area investigated (Figure 7.7).

Table 7.5: Land Use

Area	Land Use	Surface Area (ha)	% of Total
Farim	Natural veld	2,023	83
	Wetlands	233	8
	Ploughed land	201	9
	Total	**2,457**	**100**

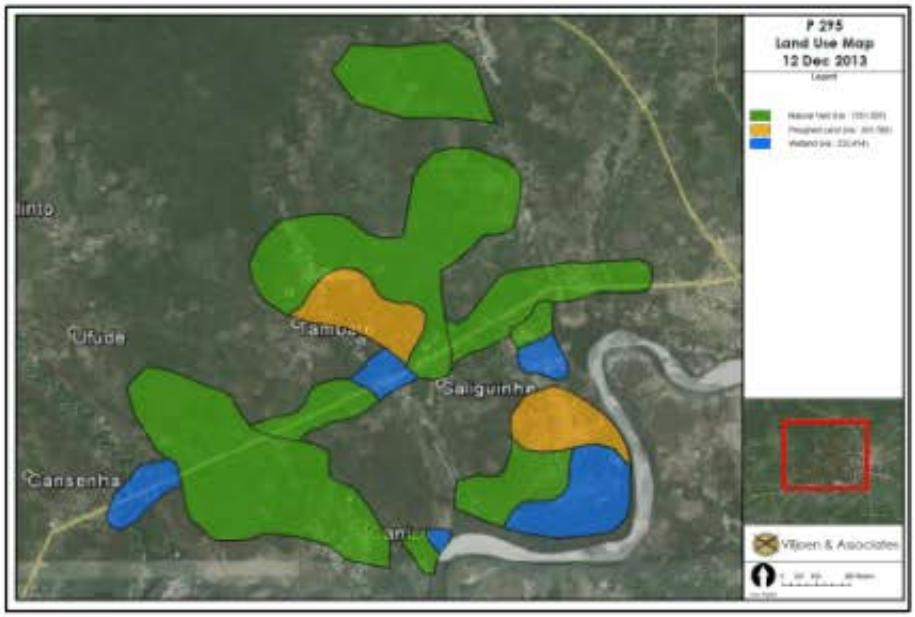


Figure 7.7: Land use

Table 7.6 summarises the *land capability* of the area investigated (Figure 7.8).

Table 7.6: Land Capability

Area	Land Capability	Surface Area (ha)	% of Total
Farim	Arable	1,597	65
	Wilderness	83	3
	Grazing	417	17
	Wetlands	362	15
	Total	**2,457**	**100**

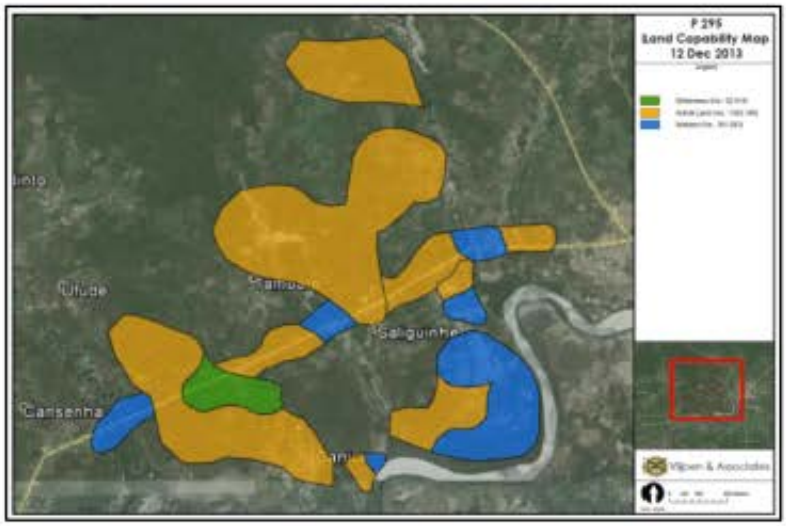


Figure 7.8: Land capability

7.5.5 Overview of Basic Soil Chemical, Physical and Mineralogical Properties of Soils

A total of 102 soil samples were taken during the investigation (Table 7.2) and analysed for chemical and physical properties (Table 7.1) according to Standard Methods and Techniques (Sparks, *et. al.*, 1996). The results of the laboratory testing are provided in Appendix G.

pH

Standard: pH(H_2O) between 5.3 and 7.2

This parameter has a direct influence on the properties of the soil. The negative logarithm of the hydrogen ion concentration indicates the intensity of the acid or alkaline conditions of the soil solution. The pH-scale varies from very acid (pH=1) to very alkaline (pH=14). A pH of 7 is neutral. The pH of the soil serves as an indicator of the conditions that favour the mobility of elements, possible toxicity problems, and dispersion due to sodium.

Salinity

Standard: Electrical Conductivity (EC)<450mS/m (Saturated water extract).

The salt quality of the soil is expressed in terms of the electrical conductivity of a saturated extract (EC), which represents the electrical conductivity of the soil solution in the field. The SI-unit for electrical conductivity is siemens (S). The most important negative effect of a high salt content in the soil solution is the reduction of water available to the plants. The plant must apply more energy to absorb water due to the higher osmotic water potential.

Sodium

Standard: Exchangeable Sodium Percentage <15 (1NH_4Ac-extract).

The exchangeable sodium percentage (ESP) gives an indication of the potential danger concerning excess amounts of sodium in the soil solution that will induce dispersive anomalies in soils. Table 7.7 outlines the potential Na-dispersive capability in relation to the pH of the soil solution.

Table 7.7: Na-dispersive capabilities in relation to pH

pH Value	Exchangeable Sodium (%)	Dispersive Capabilities
8.0-8.2	<15	None
8.2-8.4	15-30	Low
8.4-8.6	30-50	Medium
8.6-8.8	50-70	High
>8.8	>70	Very high

Sodium can be replaced through the application of calcium salts ($CaSO_4.2H_2O$) or acid generating chemicals (*i.e.* sulphuric acid (H_2SO_4), iron sulphate ($FeSO_4.7H_2O$) or aluminium sulphate ($Al_2(SO_4)_3.18H_2O$) when free calcium carbonate ($CaCO_3$) is present).

Metals

Standard: <1 mg/kg (saturated water extract ICP-Scan).

Below pH 5.3 and above pH 7.2, the solubility and mobility of heavy metals tend to increase and pose a significant contamination risk towards the surrounding environment.

Nitrogen, Phosphorus and Potassium

Standard: NO_3: 10 to 20 mg/kg (saturated water extract)

P: 5 to 15 mg/kg (Bray 1 extract)

K: 75 to 250 mg/kg (1N NH_4Ac-extract)

Inorganic nitrogen in the soil occurs mainly as NO_3. Where nitrification readily occurs, most of the mineral nitrogen occurs as nitrate with concentrations of up to 150 mg/kg NO_3 in the soil solution. The solubility of phosphorus is lowered where pH is less than 6. In the case of acidic circumstances, phosphorus is precipitated as Iron and Aluminium phosphates. High phosphorus concentrations (Bray 1 extract) contribute to eutrophication of surrounding environment. Solubility of potassium is lowered where pH<5.3.

Calcium, Magnesium and Potassium

Standard: Ca:Mg (1.5 to 4.5) 1N NH_4Ac-extract cmol+/kg

Mg:K (3 to 4) 1N NH_4Ac-extract cmol+/kg

Ca+Mg/K (10 to 20) 1N NH_4Ac-extract cmol+/kg

Imbalances of Calcium, Magnesium and Potassium will induce antagonistic anomalies in the soil solution, (*i.e.* there could be enough plant available concentration, however cations cannot be absorbed by plants).

Sulphur

Standard: <800 mg/kg (saturated water extract)

Plants are comparatively insensitive to high SO_4 concentrations in the nutrient medium. Only in cases where SO_4 concentrations are in the order of 50 mM (4,800 mg/kg), as for example in some saline soils, is plant growth adversely affected.

Chloride

Standard: <1 mg/kg (saturated water extract)

In nature, Chloride is widely distributed and subject to rapid cycling. Chloride in the soil is not adsorbed by minerals and is one of the most mobile ions, being easily lost by leaching under freely drained conditions.

Boron

Standard: <1 mg/kg (saturated water extract)

The total Boron content of soils is in the range of 20 to 200 mg/kg. Most soil Boron is unavailable to plants, the available (hot water soluble) Boron fraction ranging from 0.4 to 5 mg/kg. Soluble Boron in the soil consists mainly of boric acid $B(OH)_3$. Under soil pH conditions, this acid is not deprotonated (dissociated) and thus in contrast to all other essential plant nutrients Boron is mainly present in an ionised form in the soil solution. This is the main reason why Boron can be leached so easily from the soil.

Particle Size Distribution

The clay percentage (hydrometer method) ranges from 10 to 56%. The dominant clay fractions (0.002mm) are 1:1 layer silicates (kaolinite) and oxides of Iron and Manganese in the light textured soils (Avalon, Clovelly, Hutton and Westleigh).

The Katspruit soil associated with gley mottling conditions in wetland areas contain predominantly 2:1 layer silicates (vermiculite and/or smectite).

7.5.6 Conclusions

The dominant soils according to the Taxonomical Soil Classification System of South Africa are Avalon, Clovelly, Hutton, Katspruit and Westleigh soils.

The effective depth of the soils is >300 mm for Avalon, Clovelly, and Hutton soils and <300 mm for the Katspruit restricted to the Orthic A – Horizon.

The agricultural potential under dry land and irrigation conditions is available in Table 7.4. The agricultural potential of the Clovelly and Hutton soils is high under dryland (650 mm/y rainfall) and irrigation conditions (>10 to 15 mm/week, 33 to 1,500 kPa plant available water). For the Avalon soil, the agricultural potential is medium to high. For the Katspruit and Westleigh soils, it is low to medium.

No evidence of soil erosion was observed on any of the soils during the investigation. However, there are areas where the exchangeable sodium percentage exceeds 15% of the cation exchange capacity, which render the soils susceptible to dispersion and erosion.

The current land use on the 2,457 ha investigation area includes veld (83%), ploughed land (8%) and wetlands (9%). Land capability includes wilderness (3%), arable (65%), grazing (17%) and wetlands (15%).

The Avalon, Clovelly, Hutton, Katspruit and Westleigh soils are characterised by neutral pH values (between 5.3 and 7.2), however some samples have pH levels below 5.3 which can be attributed to the high rainfall and leaching and dilution conditions. The low electrical conductivity values (<250 mS/m) is indicative of the absence of free salts in the soil solution. Under these conditions, plant-available nitrogen (15-20 mg/kg), phosphorus (10-15 mg/kg), and potassium (>50 mg/kg) are readily available for plant uptake and sustainable plant growth. Inorganic fertilisation should be considered to optimise nutrient requirements for commercial agricultural purposes. The Orthic A, Red and Yellow Apedalic B - -Horizons are typically characterised by a low dense structure and texture distribution of approximately 65% sand, 20% silt and 15% clay with drainage properties in order of 10 mm/h. The dominant clay mineral is kaolinite (1:1 layer silicate), with a low buffer capacity due to the low cation exchange capacity (<10 cmol+/kg).

7.6 References

Sparks, D.L, et. al. 1996. Methods of Soil Analyses. Soil Science Society Of America, Inc. American Society Of Agronomy, Inc. Madison, Wisconsin,USA.

Van Der Watt, H. and Van Rooyen, T.H. 1990. A Glossary for Soil Science. V&R Printing Works (Pty) Ltd.

Soil Classification Working Group (1991) Soil Classification: a Taxonomic System for South Africa.Memoirs on the Agricultural Natural Resources of South Africa No. 15. Department of Agricultural Development, Pretoria.

BIOLOGICAL ELEMENTS

8.0 TERRESTRIAL ECOLOGY

8.1 Introduction

Golder was commissioned to conduct an ecological assessment of ecosystems associated with the Farim Phosphate Project.

The key aims and objectives of this study included:

- Describe the ecological setting of the Project;
- Identify species likely to be impacted by the project with special reference to species on the IUCN Red List of Threatened Species;
- Identify sensitive habitats likely to be impacted by the project; and
- Describe the terrestrial baseline information to be used in the ESIA.

8.2 Study Area

The LSA was defined by the possible local area of influence of the mine: bounded by the Cacheu River in the south, the tributaries of the Cacheu River to the east of Cansenha and to the west of Farim, and to the north by an east-west line along the beginning of the natural forest (Drawing 550-8.1).

The RSA was determined by conducting a power analysis. The power analysis was used in order to determine the number of sites that would need to be investigated in the area in order to obtain a good understanding of the ecological systems within the region by using fauna and flora requirements as the base standards.

8.3 Previous Work

No site specific surveys were available relating mining in the Farim area. The following documents were reviewed to obtain data on the terrestrial ecology environment and to gain an understanding of the scope and context of the proposed project:

- Barbosa, C., Broderick, A., & Catry, P. (1998). Marine Turtles in the Orango National Park (Bijagós Archipelago, Guinea-Bissau). (81), 6-7.
- Catarino, L., Martins, E., Pinto Basto, M., & Diniz, M. (2008). An annotated checklist of the vascular flora of Guinea Bissau. Blumea, 53: 1– 222.
- Catry, P., Barbosa, C., Indjai, B., Almeida, A., Godley, B., & Vié, J. C. (2002). First census and conservation of the green turtle at Poilão, Bijagós Archipelago (Guinea-Bissau); the most important nesting colony on the Atlantic coast of Africa. Oryx (36), 400-403.
- Dodman, T., Barlow, C., Sá, J., & Robertson, P. (2004). Zonas Importantes para as Aves na Guiné-Bissau / Important Bird Areas in Guinea-Bissau. . Dakar: Wetlands International.
- Pritchard, P. (1976). Post nesting movements of marine turtles (Cheloniidae and Dermochelyidae) tagged in the Guianas. Copeia , 4(1976), 749-754.
- Ribeiro, O. (1950). Missão de geografia à Guiné em 1947. Junta Missões Geográficas e Invest, 5: 5–25.
- White, F. (1983). The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa3 plates, Northwestern Africa, Northeastern Africa, and Southern Africa, 1:5,000,000. Paris: UNESCO.

8.4 Methods

8.4.1 Legislative Standards and Guidelines

8.4.1.1 International

- International Finance Corporation Performance Standards on Environmental and Social Sustainability, Performance Standard 6 (2012)

Treaties and Conventions

The Republic of Guinea-Bissau is a signatory of the following relevant international treaties and conventions:

- Convention of Biological Diversity;
- International Tropical Timber Agreement;
- United Nations Framework Convention on Climate Change;
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES);
- The Ramsar Convention (The Convention on Wetlands of International Importance);
- The Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals);
- United Nations Convention to Combat Desertification;
- The Kyoto Protocol;
- International Plant Protection Convention;
- World Heritage Convention (Convention Concerning the Protection of World Cultural and Natural Heritage);
- Stockholm Convention on Persistent Organic Pollutants; and
- West African Aquatic Mammals Memorandum of Understanding.

8.4.1.2 Guinea Bissau Legislation and Standards

- Republic of Guinea-Bissau Decree-Law No. 2/2004 Establishing the Basic Norms for Protection, Promotion and Exploitation of Wildlife;
- Republic of Guinea-Bissau Decree No. 5/2001 Forestry Act;
- Republic of Guinea-Bissau Law No. 1/2000 Mining Act;
- Republic of Guinea-Bissau Decree-Law No. 6/2006 amending Law No. 1/2000 approving the Mining Act;
- Republic of Guinea-Bissau Decree-Law No.7/2000 Pesticides;
- Republic of Guinea-Bissau Law No.10/2010 Environmental Impact Assessment Regulation;and
- Republic of Guinea-Bissau Decree-Law No. 5-A/2011 establishing the legal framework of protected areas.

8.4.2 Methodology

8.4.2.1 Methods for Investigation of Existing Terrestrial Ecology

Desktop study

A significant number of published information was reviewed as detailed in Section 8.3.

Field surveys

Three field surveys were conducted for the purposes of this study:

- 8 to 18 November 2011;
- 15 to 21 September 2012; and
- 29 August 2013 to 12 September 2013.

Baseline surveys included visiting sites associated with the Project, an assessment of identified vegetation communities, and targeted surveys to collect baseline data. Drawing 550-8.1 shows the sites visited and sampled.

The terrestrial ecology baseline study focussed on the following flora and fauna groups:

- Vegetation;
- Arthropoda;
- Avifauna;
- Mammals;
- Herpetofauna (Reptiles); and
- Amphibia.

Survey methods were based on accepted scientific investigative techniques and principles, and were performed to accepted standards and norms, whilst taking the limitations of this investigation into consideration. The Precautionary Principle was applied throughout the assessment.

It is important to note that the absence of a species or Red List species during a survey does not support the assumption that the species does not occur in the area; it can only indicate a decreased probability of the species occurring in the area. This is particularly pertinent if the species has been recently or historically recorded in the area.

8.4.2.2 Limitations of Baseline Studies

The baseline studies for terrestrial have included wet season and dry season field surveys and represent a snapshot in time over the fieldwork period. A species of concern survey has also been undertaken such that the surveys exceed the minimum requirement for international standards. Longer term studies improve the understanding of dynamics of communities (e.g., endemic, rare or threatened species). The minimum requirements for the study have been met but the following should be noted:

- Temporal changes in biodiversity can only be identified through longer term data collection and monitoring;
- Animal movements such as migrations can only be identified and monitored through long term studies;
- Events such as unusually high or unusually low rainfall may cause unusual states of biodiversity during a period of study;
- Imagery used as the basis for field studies and mapping was 2.5m per pixel and was adequate for the studies ; and
- Portions of the study area are densely vegetated and it is possible that some species remain undiscovered.

The plan of study considered the bulleted items and, in Golder's opinion, the data collected is adequate for the impact assessment and meets international standards.

8.4.2.3 Methods for Assessment of Existing Terrestrial Ecology

General Floristic Attributes

The vegetation assessment was based on a variation of the Braun-Blanquet method whereby vegetation is stratified, by means of aerial or satellite imagery with physiognomic characteristics as a first approximation, overlaid with the current Project footprint.

Representative areas within these stratifications are then surveyed by means of line-point transects for grasses, sedges and forbs, and belt transects for shrubs and trees. Data obtained from these surveys were analysed to establish differences or similarities between observed units.

Additional data collected while undertaking baseline surveys included:

- Biophysical environment (e.g., geology, topography, aspect, slope);
- Regional vegetation;
- Current status of habitats;
- Red List habitat suitability;
- Digital photographs; and
- GPS reference points.

Phytosociological data were also gathered, including:

- Plant species and growth forms;
- Dominant plant species;
- Cover abundance values; and
- Samples or digital images of unidentified plant species.

These data were analysed to establish descriptions of the vegetation communities in the area of the Project, which were then described in terms of floristic species composition and driving environmental parameters.

Red List Floral Assessment

Due to the nature of the survey, it was not possible to compile an exhaustive list of Red List species observed in the area. Emphasis was therefore placed on identifying habitat suitable for sustaining these species, by comparing the available habitat to the known habitat requirements of Red List plant species. Data collected during the baseline surveys were analysed to compile a list of Red List plant species that may occur within the study area.

Floristic Sensitivity Analysis

Floristic sensitivity was quantified by assessing the ecological integrity and conservation importance of the vegetation.

Ecological Integrity

- High ecological integrity: Sensitive ecosystems with either low inherent resistance or resilience towards disturbance factors or highly dynamic systems considered to be stable and important for the maintenance of ecosystems integrity (e.g. pristine grasslands, pristine wetlands and pristine ridges);
- Medium ecological integrity: Relatively important ecosystems at gradients of intermediate disturbances. An area may be considered of medium ecological integrity if it is directly adjacent to sensitive / pristine ecosystem; and
- Low ecological integrity: Degraded and highly disturbed systems with little or no ecological integrity.

Conservation Importance

- High conservation importance: Ecosystems with high species richness and usually provide suitable habitat for a number of threatened species. Usually termed 'no-go' areas and unsuitable for development, and should be protected;
- Medium conservation importance: Ecosystems with intermediate levels of species diversity without any threatened species. Low-density development may be allowed, provided the current species diversity is conserved; and
- Low conservation importance: Areas with little or no conservation potential and usually species poor (most species are usually exotic).

General Faunal Attributes

Arthropoda

Arthropods were surveyed using visual identification (transect surveys) and physical collection (pitfall traps, sweep netting) in selected areas within the vegetation communities. Identification of species was done to the lowest possible taxonomic level using *inter alia* Picker et al (2002).

Habitat analysis was undertaken to identify sampling locations for scorpions, spiders and butterflies, as well as assessing the potential for Red List or protected species of these taxa.

Reptilia

Suitable areas were identified and sampled using active search and capture methods. Searches were concentrated in rocky areas and disused ant hills were investigated for the presence of snakes. Snakes and other reptiles are identified visually and only captured if visual identification was hampered by swift-moving snakes or where the snake was obscured from view. Branch (1996) and Broadley (1971) were used as identification guides, where necessary.

Amphibia

Suitable areas for frogs were sampled using active search and capture methods and acoustic identification, especially at night when amphibian activity is highest. Areas were also netted for tadpoles. The guide by Du Preez and Carruthers (2009) was used to confirm identification where necessary.

Avifauna

Avifauna were surveyed by means of transects and point counts (Bibby, Burgess, & Hill, 1993). Bird call recognition was used to identify species, supplemented wherever possible by visual identification to confirm the call identifications. Bird ranges were confirmed using Harrison *et al* (1997). Other guides were also utilised (Hockey, Dean, & Ryan, 2005) (International, 2000) (Sinclair & Ryan, 2003).

Mammalia

Visual sightings and ecological indicators were used to identify the small mammals present in the study area. Scats were also collected and used for identification of nocturnal small mammals. A number of reference sources *inter alia* Stuart and Stuart (2007) and Smithers (1983) were used for identification purposes.

Red List Faunal Assessment

The following parameters were used to assess the probability of occurrence of each Red List species:

- Habitat requirements (HR) – Most Red List animals have very specific habitat requirements, so the presence or absence of these habitat characteristics in the study area was evaluated;
- Habitat status (HS) – The status or ecological condition of available habitat was assessed, as a high level of habitat degradation can decrease the likelihood of Red List species being present (this is especially evident in wetland habitats); and

- Habitat linkage (HL) – Movement between areas for breeding and feeding forms an essential part of the existence of many species. Connectivity of the study area to surrounding habitat and the adequacy of these linkages were evaluated for the ecological functioning of Red List species within the study area.

Probability of occurrence is presented in four categories, namely:

- Low;
- Medium;
- High; and
- Recorded.

In order to assess the status of Red List fauna species in the study area, the following sources were used:

- IUCN Red List Categories and Criteria (IUCN, 2001); and
- IUCN Red List of Threatened Species (IUCN, 2011).

8.5 Results and Discussion

This section provides a detailed discussion of the terrestrial ecology baseline environment and context in which the proposed project will take place.

8.5.1 Regional Overview of the Vegetation

The coastal lowlands are covered by dense forests, mostly swamp forests, while the interior is savanna with gallery forests along streams. The low coasts and estuarine shores are cloaked by mangroves.

Upstream of the mangroves, and behind them, are swamps dominated either by palms and pandans or by freshwater swamp forest trees. Inland, the country is characterised by low hills, 30 to 100 m asl. There is little flat land and no important wetlands according to the Ramsar listings. However, almost all the narrow gallery forests are subject to periods of inundation during the rainy season (Catarino, Martins, Pinto Basto, & Diniz, 2008).

Tidal forests (mangroves) cloak much of the coast and extend far up many streams. They reach 100 km up the Cacheu River, whereafter they grade into palm swamps and freshwater swamp forest. This latter vegetation once extended for another 42 km upstream to the town of Farim (12°29'N/15°13'W), but much of it has been replaced by rice fields. Towards the rivermouth, the mangroves reach a maximum width of 15 km on the north bank. While there was once more than 110,000 ha of mangrove forest and 13,000 ha of freshwater swamp forest on this single river system, 10 to 15% has been cleared in recent years. Tidal forests backed by freshwater swamp forests used to extend for 110 km up the Mansoa River, but here too most of the upper 65 km of brackish and freshwater forests have been cleared. Mangrove forests still reach 35 km up the Tombali River, but up the Cumbija River the upper 55 km have again been cleared. On this river, mangroves now occupy only the lower 15 km. By contrast, the Geba Estuary, the largest inlet in Guinea-Bissau, never had extensive mangroves as it is characterised by banks of high relief. Nevertheless, 9,000 ha of mangroves which used to extend along the south bank upstream from the rivermouth for nearly 50 km, reaching widths of 3 km, has now been reduced to scattered stands. Above this, for many kilometres upstream, mangroves have always been scarce although small stands do occur in suitable sites. The estuaries of the Grande de Buba and Cacine Rivers are also lacking in extensive mangrove forests, except near the rivermouths. The offshore islands are partly fringed by mangroves, but this is a coast of submergence and the high islands of the Bijagos Archipelago, which represent old hilltops, rise quite steeply from the sea in places. However, all along the coast, numerous recent offshore mudbanks are largely, or even completely, covered by mangroves. There were approximately 250,000 ha of tidal forest in Guinea Bissau in 1975, but this had been reduced by 15 to 20% by 1986 (Catarino, Martins, Pinto Basto, & Diniz, 2008). Floodplains occur on almost all rivers in Guinea Bissau above the limits of tidal influence. They extend, in semi-continuous fashion, up the Corubal for 230 km to the border with Guinea, and far up the Geba River. In general they are forested, but narrow, about 0.5 to 2 km wide. Many hectares of riverine floodplain have been cleared for rice paddy (Catarino, Martins, Pinto Basto, & Diniz, 2008).

The mangrove and Guinean / Soudanian freshwater swamp forest flora is as described in the regional introduction. The fauna is typical of tropical West African coastal swamps, again as detailed in the regional introduction. The coastal mudflats are important as a wintering ground for palearctic waders, and the Bijagos Islands support many sea birds (Catarino, Martins, Pinto Basto, & Diniz, 2008).

Mangrove timber has long been cut for fuel, and mangrove poles are used for building. There are many villages in the mangroves, and fish, crabs and prawns from the mangroves have traditionally been an important source of protein for the people. Many thousands of hectares of swamp forest have been cleared for rice cultivation, particularly on the upstream ends of estuarine swamp forests. Annual production now exceeds 45 000 tonnes, and this is to be increased. Fishing is the second most important export industry in Guinea Bissau, most of the fish being trawled offshore and exported to the USSR. These fish and prawns however, spend their juvenile stages in the mangroves, and the vast annual catches, exceeding 100 000 tonnes of fish and 2000 tonnes of prawns, will inevitably alter the balance of the estuarine food chains. (Catarino, Martins, Pinto Basto, & Diniz, 2008).

8.5.2 Local Study Area Floral Assessment

The flora assessment was conducted in the wet and dry seasons of November 2011 and March 2012 respectively. A total of 341 plant species were recorded during the surveys. Floral species diversity in the area is moderate to high, but not as high as many regions of West Africa, such as the Upper Guinea Forest. A large proportion of the species recorded are indigenous with few exotic species occurring in the area, although in areas of higher anthropogenic disturbances some exotic species are more prevalent.

Based on physiognomy, moisture regime, rockiness, slope and soil properties, five main communities were recognised, namely:

- *Rhizophora – Avicennia* Mangrove community;
- Natural Forest vegetation community;
- Secondary Forest community;
- *Elias – Cyperus* Floodplain community; and
- *Oryza* Paddy vegetation community.

These vegetation communities are shown in Drawing 550-8.2. A further vegetation community referred to as 'townships vegetation community' was identified within the villages and towns in the area, but due to the transformed nature of these areas, these communities were not extensively surveyed and are indicated in Drawing 550-8.2 in black.

The study area was calculated to be 15,255 hectares (ha). Table 8.1 gives the areas of each of the vegetation communities in relation to the total study area.

Table 8.1: Areas of vegetation communities

Vegetation Community	Area (hectares)	% of total study area
Rhizophora – Avicennia Mangrove community	854.4	5.6%
Natural Forest vegetation community	5,048.1	33.1%
Secondary Forest community	6,949.8	45.6%
Elias – Cyperus Floodplain community	907.4	5.9%
Oryza Paddy vegetation community	789.1	5.2%
Townships	706.3	4.6%

8.5.2.1 Floral Species Composition

In the currently accepted phytogeographic framework of Africa (White, 1983), Guinea-Bissau is included in the Guinea-Congolia / Sudania regional transition zone, or zone XI. The phytogeographic zone XI can be

characterised by the occurrence of transition woodland types, which are an ecotone between the Guineo-Congolian forest to the south and the woodland and savannah woodland to the north and north-east of the zone. As a consequence of human intervention, mainly fire and shifting agriculture, the more common vegetation types in this zone are secondary formations, such as woodland and savannah woodland. On the other hand, some residual patches of closed forest types may have significant commonalities to the peripheral and driest types of Guinean forest. Nevertheless, according to White (1983), even before the increase of human activity, the open formations could have been already dominant, especially where the soils are shallow.

8.5.2.2 Vegetation Communities

Oryza paddy Community

A total of 103 flora species were recorded in this vegetation community (listed in Appendix E1). This vegetation community occurs in areas of freshwater wetlands which are not affected by tidal ebbs and flows throughout the country. These freshwater wetlands have been modified to facilitate the planting of rice, through alteration to the flow of freshwater to create large inundated areas.

Although tree species are sparse within these areas, a few species are often associated with these areas, especially *Anthostema senegalense*, *Elaeis guineensis*, *Pterocarpus santalinoides* and *Sarcocephalus latifolius*. Close to the permanently inundated areas there are communities in which some common species are *Eichhornia natans*, *Nymphoides indica*, *Ottelia ulvifolia*, *Rotala tenella*, *Sphenoclea zeylanica* and *Utricularia gibba*. The herbaceous layer in this vegetation community is dominated by *Oryza glaberrima*, *Oryza longistaminata* and *Oryza sativa*, which have been planted for food.

The only species recorded during baseline surveys known to be on the Red List is *Raphia palma-pinus*, which is found along rivers and is listed by the IUCN as Data Deficient.

Sensitivity aspects

- This vegetation community has been moderately disturbed;
- As little vegetation clearing takes place for this agriculture, this vegetation community could be relatively easily rehabilitated to a natural state;
- Moderate species diversity;
- Floristic status of this variation is low to moderate;
- Suitability of the habitat for Red List flora and fauna species is moderate;
- One floral Red List species, *Raphia palma-pinus*, was found in this vegetation community;
- Ecological integrity of this community is moderate; and
- The conservation importance of this community is moderate.

Secondary Forest Community

Large sections of natural forests have been cleared in order to grow cashew nuts (*Anacardium occidentale*) and other crops. The cashew plantations vary from areas which are dominated by cashew trees, but some local trees still occur within the plantations (such as *Albizia zygia*, *Detarium senegalense*, *Dialium guineense* and *Malacantha alnifolia)*. Other areas are devoid of natural vegetation and are completely dominated by *Anacardium occidentale*. Many of the areas that have been recently cleared are devoid of larger trees, but still contain many of the species associated with natural forests. These areas may be easily rehabilitated, but, areas where a greater deal of disturbance has taken place would be far more difficult to rehabilitate.

A total of 145 flora species were recorded in this vegetation community (listed in Appendix E1).

Sensitivity aspects

- This vegetation community has been moderately to severely disturbed;

- Depending on the severity of the vegetation clearing , which has taken place, rehabilitation of this vegetation community could be relatively easily conducted, but in more severely degraded areas rehabilitation will be more difficult;
- Low to moderate species diversity;
- Floristic status of this variation is low to moderate;
- Suitability of the habitat for Red List flora and fauna species is moderate;
- No floral Red List species were recorded in this vegetation community;
- Ecological integrity of this community is moderate; and
- The conservation importance of this community is moderate.

Elias – Cyperus Floodplain Community

A halophytic community recorded in the study area is the so-called salt water *lala*, a grassland savannah. This vegetation community is found on Fluvisols in the floodplain areas adjacent to the larger rivers which are under tidal influence. The salinity of the water which floods these areas has resulted in the dominance of salt-tolerant species, such as *Paspalum vaginatum, Blutaparum vermiculare, Cyperus amabilis, Cyperus crassipes, Cyperus cyperoides, Cyperus difformis, Cyperus dilatatus* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. The woody layer of these areas is poorly defined but *Hyphaene thebaica, Phoenix reclinata* and *Elias guineensis* occur in this vegetation community with occasional *Adansonia digitata* also scattered within this vegetation community. The treeless areas of this vegetation community are widely utilised by local communities for the gathering of salt during the dry season and the savannah appears to be an important dry season grazing area. A total of 76 floral species were recorded in this vegetation community (listed in Appendix E1).

Sensitivity aspects

- This vegetation community has been very slightly disturbed in some areas, mainly due to trampling by cattle;
- Where degraded, rehabilitation of this vegetation community will occur naturally;
- There is low species diversity due to the effects of the saline water on this vegetation community, but many specialised species occur;
- Floristic status of this variation is low - moderate;
- Suitability of the habitat for Red List flora and fauna species is moderate to high;
- No floral Red List species were recorded in this vegetation community;
- Ecological integrity of this community is high; and
- The conservation importance of this community is high.

Natural Forest Community

The natural forest vegetation community occupies large areas of the northern part of the study area, with some variation in structure and composition. Common tree species include *Albizia zygia, Detarium senegalense, Dialium guineense, Malacantha alnifolia, Anisophyllea laurina, Dialium guineense, Hunteria umbellata, Malacantha alnifolia, Parinari excelsa* and *Strombosia pustulata*. Lianas such as *Agelaea pentagyna, Calycobolus heudelotii* and *Landolphia dulcis* are also common. The shrub layer is usually poor in these areas, but some common shrub species include *Clerodendrum sinuatum, Combretum micranthum* and *Psychotria peduncularis* and among the most frequent climbers are *Mezoneuron benthamianum, Saba senegalensis* and *Tetracera potatoria*. This vegetation community is currently under threat due mainly to slash and burn agricultural practises for the cultivation of food crops or cashew nuts.

Although only one Red List species was recorded in this vegetation community, the likelihood of occurrence of Red List species in this community is high. A total of 209 flora species were recorded in this vegetation community (listed in Appendix E1).

Sensitivity aspects

- This vegetation community has been very slightly disturbed in some areas;
- Where degraded, rehabilitation of this vegetation community will occur naturally, if not further impacted;
- Moderate to high species diversity;
- Floristic status of this variation is moderate - high;
- Suitability of the habitat for Red List flora and fauna species is high, with one Red List species recorded;
- Ecological integrity of this community is high; and
- The conservation importance of this community is high.

Rhizophora – Avicennia Mangrove Community

Mangrove forests line all the larger rivers in the region. These areas are dominated by *Rhizophora* spp. (mainly *R. mangle*, but also *R. racemosa* and to a lesser extent *R. harrisonii*). In the zones less frequently flooded by salt water, *Avicennia germinans* is the prominent species.

No Red List species were recorded in this vegetation community and it is unlikely that any of the Red List species known to occur in the area would occur in this vegetation community due to the specialisation required for plants to survive in the saline conditions. Species diversity is low in this vegetation community, but species occurring in the area are highly specialised and this vegetation community can be characterised as a unique vegetation community. This vegetation community is integral to the functioning of the estuarine nature of the larger rivers in the area. A total of 29 highly speciallised flora species were recorded in this vegetation community (listed in Appendix E1).

Sensitivity aspects

- This vegetation community has been very slightly disturbed in some areas;
- Where degraded, rehabilitation of this vegetation community will occur naturally, if not further impacted;
- Moderate to high species diversity;
- Floristic status of this variation is moderate - high;
- Suitability of the habitat for Red List flora and fauna species is high, with one Red List species recorded;
- Ecological integrity of this community is high; and
- The conservation importance of this community is high.

8.5.2.3 Species of Importance

During the surveys, two Red List floral species were recorded (Table 8.2). One species was found within the natural forest vegetation communtiy and the other was recorded in both the *Elias – Cyperus* floodplain and the *Oryza* paddy communities. Table 8.2 shows the Red List floral species that may occur in the area, according to the IUCN database for the area (IUCN, 2013), as well as available habitat, with the recorded species indicated.

Table 8.2: Red List floral species for Guinea-Bissau

Family	Scientific Name	Red List status	Probability of Occurrence
LEGUMINOSAE	*Afzelia africana*	VU	High

Family	Scientific Name	Red List status	Probability of Occurrence
LEGUMINOSAE	*Albizia ferruginea*	VU	Recorded
GRAMINEAE	*Digitaria patagiata*	DD	Low
COMMELINACEAE	*Floscopa axillaris*	DD	Low
MELIACEAE	*Khaya senegalensis*	VU	Moderate
PODOSTEMACEAE	*Ledermanniella adamesii*	DD	Moderate
MORACEAE	*Milicia regia*	VU	Low
PALMAE	*Raphia palma-pinus*	DD	Recorded

No Red List species were recorded within the Project footprint during the studies conducted.

8.5.3 Faunal Assessment

The faunal assessment was conducted in the wet and dry seasons of November 2011 and March 2012.

8.5.3.1 Recorded Faunal Species

Non-chordates

Non-chordate diversity within the study area was relatively high with a total of 124 arthropod species being recorded during the study. Most species recorded were common species with some specialised species being recorded in the mangrove communities. Although the mangrove species are highly specialised for this habitat type, they are locally common and not of conservation importance. Most of the species recorded are not restricted in terms of range and habitat preferences. Common species included Red Winged Dropwing (*Trithemis kirbyi*) and locust (*Locusta* sp.) Figure 8.1. The complete list of species recorded is given in Appendix E2.

Trithemis kirbyi

Locusta sp.

Figure 8.1: Non-Chordate Examples

Herpetofauna

The herpetofauna of the region can be classified as having moderate diversity. Of the 69 reptile species known to occur in Guinea-Bissau (Appendix E3), only 11 species were recorded during baseline studies. This may be due to the proximity of the project area to the town of Farim and other settlements in the area. Common species occurring in the area include Monitor (*Varanus ornatus*) and Tree Agama (*Agama agama*) Figure 8.2. The complete list of recorded species is given in Table 8.3.

Agama agama

Varanus ornatus

Figure 8.2: Herpetofauna Examples

Table 8.3: Reptile species recorded in the study area.

Family	Scientific Name	IUCN Status
AGAMIDAE	*Agama agama*	Not Listed
ELAPIDAE	*Bitis arietans*	Not Listed
ELAPIDAE	*Causus rhombeatus*	Not Listed
CROCODYLIDAE	*Crocodylus niloticus*	Not Listed
COLUBRIDAE	*Dasypeltis fasciata*	Not Listed
ELAPIDAE	*Naja melanoleuca*	Not Listed
ELAPIDAE	*Naja nigricollis*	Not Listed
COLUBRIDAE	*Philothamnus irregularis*	Not Listed
COLUBRIDAE	*Psammophis lineatus*	Not Listed
VARANUS	*Varanus exanthematicus*	Not Listed
VARANUS	*Varanus ornatus*	Not Listed

Amphibia

The region can be classified as having low amphibian diversity. Of the 34 amphibian species recorded in Guinea-Bissau (Appendix E4), 5 species were recorded during the baseline surveys (Table 8.4). Amphibian species do not appear to be utilised by the local community for food, although some species are said to have cultural importance or medicinal uses.

Five amphibian species recorded during the surveys, which included only common species such as *Ametia angolensis* and *Ametiophrynus regularis* (Figure 8.3). None of the recorded species are listed as Red List species or restricted in terms of range or habitat. It must be noted that the rivers in the area are tidal and have a very high salinity, to which amphibians are very sensitive. Due to the permeability of amphibian skin, saline water causes loss of fluids and dehydration in frog species. For this reason most of the rivers in the study area are uninhabitable for amphibian species.

Ametia angolensis

Ametiophrynus regularis

Figure 8.3: Amphibia Examples

Table 8.4: Amphibian species recorded in the study area

Family	Genus & Species	IUCN Status
BUFONIDAE	*Amietophrynus regularis*	Not Listed
HYPEROLIIDAE	*Hyperolius occidentalis*	Not Listed
HYPEROLIIDAE	*Kassina senegalensis*	Not Listed
PHRYNOBATRACHIDAE	*Phrynobatrachus natalensis*	Not Listed
RANIDAE	*Ametia angolensis*	Not Listed

8.5.3.1.1 Avifauna

Avifaunal diversity in the study area was high. Seventy five species were recorded (listed in Appendix E5), including a number of upper trophic level species. The species recorded include Palmnut Vulture (*Gypohierax angolensis)*, Long-crested eagle (*Lophaetus occipitalis:* Figure 8.4), Hooded vulture *(Necrosyrtes monachus:* Figure 8.4*)*, currently listed as Endangered by the IUCN (2013), and Gymnogene (*Polyboroides typus)*. Species diversity was moderate to high throughout the study area with the natural forests showing the highest levels of species diversity.

Long-crested Eagle

Hooded Vulture

Figure 8.4: Avifauna Examples

8.5.3.1.2 Mammalia

Mammal species diversity was very low in the study area, probably due to severe subsistence hunting. Hunters were regularly seen or heard during the surveys often with animals ranging from snakes to monkeys. This not only reduces the number of animals and species in the area, but also causes the remaining animals to be very shy of humans, which in turn makes accurate survey of species very difficult.

Of the 192 mammal species known to occur in the study area (Appendix E6), 15 species were recorded during the baseline surveys (Table 8.5). The species recorded in the study area include Striped Ground Squirrel (*Xerus erythropus)*, Musk shrew *(Crocidura* sp), Lesser Spot-nosed Guenon (*Cercopithecus petaurista)*, and Red colobus *(Procolobus badius)*. Species trapped during the surveys included *Mastomys natalensis* and *Crocidura* sp (Mastomys natalensis Crocidura poensis

Figure 8.5). All species recorded are common species, with the exception of *Procolobus badius,* which is listed as Endangered (IUCN, 2010).

Mastomys natalensis

Crocidura poensis

Figure 8.5: Mammalia Examples

Table 8.5: Mammal species recorded in the study area

Family	Scientific Name	IUCN Status
BOVIDAE	*Cephalophus monticola*	
CERCOPITHECIDAE	*Cercopithecus aethiops*	
CERCOPITHECIDAE	*Cercopithecus petaurista*	
CERCOPITHECOIDEA	*Procolubus badius*	EN
GALAGIDAE	*Galago senegalensis*	
HYSTRICIDAE	*Atherurus africanus*	
MURIDAE	*Lemniscomys striatus*	
MURIDAE	*Mastomys erythroleucus*	
MURIDAE	*Mastomys natalensis*	
MURIDAE	*Praomys rostratus*	
NESOMVIDAE	*Cricetomys gambianus*	
NESOMVIDAE	*Dendromus melanotis*	
NYCTERIDAE	*Nycteris gambiensis*	
SCIURIDAE	*Xerus erythropus*	
SORICIDAE	*Crocidura poensis*	
VESPERTILIONIDAE	*Pipistrellus nanulus*	

8.5.3.2 Red List Faunal Species

Based on the latest IUCN red data list (IUCN, 2013), of species recorded in Guinea-Bissau, a total of 28 Red List fauna species may occur in the area (Table 8.6), made up of 2 reptile species, 15 avian species and 11 mammal species. Some of the animals listed are believed to be locally extinct and for others no suitable habitat is available. The probability of occurrence in the study area was determined for each of the 28 Red List species (Table 8.6). The habitat suitability for the 28 Red List species ranges from low to high, with 4 species for which the habitat suitability can be classified as high. Only two of the Red List species were recorded during the baseline surveys (Table 8.6).

Table 8.6: Red List fauna species which may occur in the study area

FAMILY	Scientific Name	Common Name	IUCN Status	Probability of Occurence
GRUIDAE	*Balearica pavonina*	Black Crowned-Crane	VU	High
BUCEROTIDAE	*Ceratogymna elata*	Yellow-casqued Hornbill	NT	High
ACCIPITRIDAE	*Circaetus beaudouini*	Beaudouin's Snake-Eagle	VU	High
ACCIPITRIDAE	*Circus macrourus*	Pallid Harrier	NT	Moderate
SCOLOPACIDAE	*Gallinago media*	Great Snipe	NT	Low
ACCIPITRIDAE	*Gyps africanus*	White-backed Vulture	NT	Low
ACCIPITRIDAE	*Gyps rueppellii*	Rueppell's Griffon	NT	Low
SCOLOPACIDAE	*Limosa limosa*	Black-tailed Godwit	NT	Moderate
ACCIPITRIDAE	*Necrosyrtes monachus*	Hooded Vulture	EN	Recorded
ACCIPITRIDAE	*Neophron percnopterus*	Egyptian Vulture	EN	Low
OTIDIDAE	*Neotis denhami*	Stanley Bustard	NT	Low
SCOLOPACIDAE	*Numenius arquata*	Eurasian Curlew	NT	Moderate
PHOENICOPTERIDAE	*Phoenicopterus minor*	Lesser Flamingo	NT	Moderate
PSITTACIDAE	*Psittacus erithacus*	Gray Parrot	NT	Moderate
ACCIPITRIDAE	*Trigonoceps occipitalis*	White-headed Vulture	VU	Low
CANIDAE	*Lycaon pictus*	African Wild Dog	EN	Locally Extinct
CERCOPITHECIDAE	*Cercocebus atys*	Sooty Mangabey	VU	Low
CERCOPITHECIDAE	*Colobus polykomos*	King Colobus	VU	Low
CERCOPITHECOIDEA	*Papio papio*	Guinea Baboon	NT	Low
CERCOPITHECOIDEA	*Procolubus badius*	Red Colobus	EN	Recorded
ELEPHANTIDAE	*Loxodonta africana*	African Bush Elephant	VU	Locally Extinct
FELIDAE	*Panthera leo*	Lion	VU	Locally Extinct
FELIDAE	*Panthera pardus*	Leopard	NT	Locally Extinct
HIPPOPOTAMIDAE	*Hippopotamus amphibius*	Common Hippopotamus	VU	Locally Extinct
HOMINIDAE	*Pan troglodytes*	Common Chimpanzee	EN	Locally Extinct
PTEROPODIDAE	*Eidolon helvum*	Straw-coloured Fruit Bat	NT	High
CROCODYLIDAE	*Crocodylus cataphractus*	Slender-snouted Crocodile	DD	Low
CROCODYLIDAE	*Osteolaemus tetraspis*	African Dwarf Crocodile	VU	Low

8.5.4 Ecological Integrity

The ecological integrity of the area can generally be described as moderate for the majority of the study area, although this does vary from low (in the highly transformed areas due to slash and burn cropping techniques) to high in the more inaccessible areas (Drawing 550-8.3). Ecological integrity is reduced in areas of prospecting, and slash and burn farming, as well as areas in which settlements have been established.

8.5.5 Conservation Importance

The study area falls within the dry tropical forest biome of the Guinean Forest zone and due to the high species diversity, it is classified as having high conservation importance. In order to show the area of highest conservation importance due to the presence of Red List species or other factors, the area has been divided into areas of low, moderate and high ecological integrity (Drawing 550-8.4).

Areas that have been significantly disturbed such as settlements are considered of low conservation importance. These areas are only a proportion the overall study area (>30% of the study area). Areas that have been disturbed by farming are considered of moderate conservation importance due to the fact that rehabilitation of these areas is possible. The natural forest, floodplain and mangrove areas are considered of very high conservation importance due to the presence of Red List species in these areas and the intrinsic importance of these areas.

8.5.6 Discussion

The vegetation within the study area can be classified into five vegetation communities, namely:

- *Rhizophora – Avicennia* Mangrove community;
- Natural Forest vegetation community;
- Secondary Forest community;
- *Elias – Cyperus* Floodplain community; and
- *Oryza* Paddy vegetation community.

Relationships between fauna and flora do exist within these systems, but are tentative at best. The reasons for the lack of distict relationships are most likely:

- Degradation of natural habitat;
- Little variation in structural diversity between different vegetation communities;
- Lack of natural habitat remaining in the area; and
- Reduction (and in some cases local extinction) of local fauna species;

That been said, there are certain species that show a distinct affinity to specific vegetation communities, namely:

- Crocodiles (*Crocodylus niloticus*) are found exclusively in the *Rhizophora – Avicennia* Mangrove community.
- Palmnut vultures (*Gypohierax angolensis*) show a definite affinity for the *Elias – Cyperus* Floodplain community; and
- The hooded vulture (*Necrosyrtes monachus*) shows an affinity for the degraded areas in and around townships.

Other than these specific affinities for specific habitat types, there is little definite evidence of fauna species being limited to certain habitats. Village weavers (*Ploceus cucullatus*) do often nest in villages, but are found in a number of other vegetation communities. The main observation that can be noticed from this study is

that there is a significant reduction in species diversity of the fauna species diversity, with an increase in vegetation community level of degradation.

Three Red List species will potentially be impacted upon by any development in this area. Two of the species recorded during the baseline surveys are listed as Endangered and therefore warrant an extended study under IFC Performance Standard 6, which was undertaken in the Species of Concern Assessment.

Although the baseline assessment results provide a good representation of the species richness of the area, these surveys are merely "snapshots". Some species of importance, such as *Hygrophila species* and *Floscopa axillaris*, were not recorded during baseline surveys. They are species which can only be confidently identified while in flower and this was not possible due to the timing of the baseline surveys.

The natural freshwater wetlands in the study area have almost all been converted to rice paddies. The creation of a monoculture in these areas has greatly reduced the species diversity in these areas from what would usually be expected in tropical wetlands.

Mangrove forests, although unique systems, do not show high levels of terrestrial species diversity as the plants and animals occurring in these habitats are very specifically adapted for the prevailing conditions.

8.6 Species of Concern Assessment

8.6.1 Background

During the baseline study, the question of potential impacts on species of concern was raised. Species of concern are commonly defined as "*species that are declining or appear to be in need of concentrated conservation actions*". A number of organisations have their own definitions and lists for these species; for example, according to the IFC these would include endangered (EN) or critically endangered species (CR). For the purpose of this study, the common definition was extended to include keystone species (e.g., crocodiles) and charismatic species.

In order to assess the potential impacts of the Project on species of concern, a desktop study was conducted using information from the baseline biodiversity assessment and further literature reviews. A number of species of concern (SoC) were identified according to the extended definition for the purposes of this study:

- Five species of sea turtles:
  - Green turtle (*Chelonia mydas*);
  - Hawksbill turtle (*Eretmochelys imbricata*);
  - Olive Ridley turtle (*Lepidochelys olivacea*);
  - Leatherback turtle (*Dermochelys coriacea*); and
  - Loggerhead turtle (*Caretta caretta*);
- Three species of crocodile:
  - Nile crocodile (*Crocodylus niloticus*);
  - West African dwarf crocodile (*Osteolaemus tetraspis*); and
  - Slender-snouted crocodile (*Crocodylus cataphractus*);
- Two species of vultures:
  - Palm-nut vulture (*Gypohierax angolensis*); and
  - Hooded vulture (*Necrosyrtes monachus*).

Golder was commissioned to further investigate these species and field surveys were conducted during the wet season of 2013, from 29 August to 13 September 2013.

8.6.2 Aim of the Study

The aim of the SoC study was two-fold. Firstly, the study area was investigated to determine the occurrence, or probability of occurrence, of each of the SoC identified during the literature review. Secondly, to determine potential adverse effects on the SoC.

The initial study area is shown on Drawing 550-8.5. This study area was increased in order to sufficiently study all of the SoC; these extensions are described in the relevant sections below.

8.6.3 Sea Turtles

Sea turtles occur in large numbers off the coast of Guinea-Bissau and are known to enter estuarine areas. All sea turtle species are included on the Red List (IUCN, 2011), with a number of species listed as endangered or critically endangered.

The presence or absence of sea turtles in the estuary area of the River Cacheu, and potential impacts on this taxon, were investigated for a number of reasons:

- Current status of the turtle species known to occur in the area, according to the IUCN;
- Potential impacts on endangered and critically endangered species need to be investigated in order to comply with IFC performance standard 6; and
- Turtles are seen as sacred to a number of groups of the local population in Guinea-Bissau and negative impacts on these species will affect the way the Project is perceived by the local population.

Four species of sea turtle are known to nest in the Bijagós Archipelago of Guinea-Bissau:

- Green turtle (*Chelonia mydas*);
- Hawksbill turtle (*Eretmochelys imbricata*);
- Olive Ridley turtle (*Lepidochelys olivacea*); and
- Leatherback turtle (*Dermochelys coriacea*).

Although the Loggerhead turtle (*Caretta caretta*) is also known to occur in the area, no breeding has been recorded for this species. Information regarding the breeding of most species in the area is scant, as little research has been conducted. Further information on all species of concern is provided in Appendix E7.

The conservation status of all sea turtles in the area ranges between vulnerable (VU) and critically endangered (CR) (IUCN, 2011). The current and breeding status of each species is given in Table 8.7.

Table 8.7: Sea turtle species known to occur in the study area

Common Name	Scientific Name	IUCN Status	Regional Breeding Status
Green turtle	*Chelonia mydas*	Endangered (EN)	Breeding
Hawksbill turtle	*Eretmochelys imbricata*	Critically Endangered (CR)	Breeding
Olive Ridley turtle	*Lepidochelys olivacea*	Vulnerable (VU)	Breeding
Leatherback turtle	*Dermochelys coriacea*	Critically Endangered (CR)	Breeding
Loggerhead turtle	*Caretta caretta*	Endangered (EN)	Non-breeding

Overall the Bijagós Archipelago of Guinea-Bissau is considered as the 7th most important turtle area globally (Fortes, Pires, & Bellini, Green Turtle, Chelonia mydas in the Island of Poilão, Bolama-Bijagós Archipelago, Guinea-Bissau, West Africa., 1998) and the most important Green turtle nesting site in the Atlantic Ocean. In order to conserve this important marine habitat, the Joao Vieira - Poilao Marine National Park, the Orango National Park, and the Boloma-Bijagos Marine Biosphere were proclaimed (Fortes, Pires, & Bellini, Green Turtle, Chelonia mydas in the Island of Poilão, Bolama-Bijagós Archipelago, Guinea-Bissau, West Africa., 1998). These areas are shown in Drawing 550-8.6.

8.6.3.1 Objectives

The objectives of this study were to investigate the mouth of the River Cacheu and associated beaches to determine whether any sea turtles utilise this area, including gathering of local knowledge about sea turtles. If sea turtles were found to use the area, an assessment would be conducted to identify any potential impacts associated with the Project.

8.6.3.2 Methodology

The field surveys took place from 30 to 31 August 2013. Day 1 consisted of boat-based surveys for signs of sea turtles between Cacheu and Bolor (Drawing 550-8.7) and a land-based survey of the beach area from Bolor to the west for signs of turtle nesting and an assessment of habitat suitability for turtle nesting. Indicators of sea turtle presence would include turtle tracks and abandoned or hatched nests. On Day 2, local fishermen and residents of Cacheu were surveyed regarding the presence or absence of sea turtles. Photographs of the turtle species were used to identify which species may have been observed by residents.

8.6.3.3 Results

During a previous survey of the river, a single sea turtle was observed in the estuary near Cacheu. During this survey, however, no turtles were observed. The survey of the beach area from Bolor towards the Atlantic Ocean did not identify any nests or sign of current nesting, even though the survey took place during the known nesting period of many of the sea turtle species (June to October).

During discussions with fishermen and residents in Cacheu, it was advised that although turtles do occasionally enter the Cacheu estuary and even make landfall at times, these are isolated incidents and can probably be attributed to vagrants. Fishermen and residents also confirmed that turtle breeding is mostly restricted to the islands of the Bijagós Archipelago, according to their knowledge.

8.6.3.4 Discussion

The results of the survey were initially unexpected, given the knowledge that the coast of Guinea-Bissau is considered an important area for the nesting and breeding of sea turtles (Fortes, Pires, & Bellini, Green turtle Chelonia mydas in the island of Poilão, Bolama-Bijagós Archipelago, Guinea-Bissau, West Africa , 1998). However, the fine silt-like substrate on the banks of the estuary is not conducive to turtle nesting as turtles prefer a sandy substrate (Carr, 1986; Cornelius, Alvarado-Ulloa, Castro, Mata del Valle, & Robinson, 1991; Fontanes, 2003; Eckert, 1999). On inspection of the beaches from Bolor towards the Atlantic Ocean, it was found that these beaches are equally unsuitable for turtle nesting as the beaches are quite narrow with shallow sand before reaching the silt layer. Furthermore, the sand on these beaches is interspersed with large numbers of mangrove pneumatophores, which would make it very difficult for turtles to dig adequate holes for nesting purposes.

Another contributing factor may be the turbidity of the water. Herbivorous species may not find adequate food sources due to the reduction of seagrass and other aquatic plant life in the light-poor water (Larkum, et al., 2006). Carnivorous species may avoid turbid water as it reduces the chance of success during hunting (Grosse, et al., 2010).

These factors account for the absence of sea turtles, other than the odd vagrant moving up into the estuary. Based on these findings, it may be safe to assume that this area, and similar habitats along the Guinea-Bissau coastline, represent poor habitat for sea turtles and are not likely to be utilised for feeding or breeding.

8.6.4 Crocodiles

Three species of crocodiles are known to occur in Guinea-Bissau (IUCN, 2011):

- The Nile crocodile (*Crocodylus niloticus*);
- The West African dwarf crocodile (*Osteolaemus tetraspis*); and
- The African slender-snouted crocodile (*Mecistops cataphractus*).

According to the latest IUCN assessments, *Mecistops cataphractus* is thought to be extinct in Senegal, the Gambia, and Guinea-Bissau. Furthermore, although reported to occur in Guinea-Bissau by the IUCN, there is conflicting information with regards to the range of *Osteolaemus tetraspis*, with many literature sources only indicating its range as far west as Guinea.

Osteolaemus tetraspis and *Mecistops cataphractus* are also known to be strictly freshwater species and therefore do not occur in estuaries and other saline or brackish-water systems. Because the water in the River Cacheu has very high salinity, it is highly unlikely that either of these species would occur within the study area.

8.6.4.1 Objectives

The objectives of the crocodilian study were to determine the abundance and diversity of crocodiles within the River Cacheu.

8.6.4.2 Methodology

Due to their aquatic and cryptic nature and the wide range of habitats used, total population counts are rarely, if ever, achieved in the wild (Games, Zohlo, & Chande, 1992; Nichols, 1992) and comprehensive surveys are often prohibitively expensive (Bayliss, Webb, Whitehead, Dempsy, & Smith, 1986). In addition, abundance surveys are unrealistic in large areas such as the Okavango Delta where much of the habitat is inaccessible (Hutton & Woolhouse, 1989). However, this method has successfully been used in small rivers and lakes (Hutton, Report of the Coordinator of the CITES Nile Crocodile Project to the CITES Secretariat as Presented to the Parties at the Seventh Meeting of the Conferenceof the Parties, 1992).

Sample counts involve dividing the total sample area up into more manageable subdivisions, surveying the subdivisions, and then extrapolating for the whole region (Games, Zohlo, & Chande, 1992). Individuals in crocodilian populations are almost never randomly spaced (Combrink, 2004). Rather, they concentrate in favourable habitats or areas where resources are abundant. Reasons for this may include seemingly insignificant factors such as avoidance of prevailing winds and subsequent wave action (Combrink, 2004). For this reason, stratified sampling (defined as sampling over a range of habitats within which the population density is fairly uniform (Caughley, 1977)) is commonly used when surveying crocodilian populations (Combrink, 2004).

The River Cacheu was surveyed from the river mouth to the 180 km inland point (Drawing 550-8.8). Based on the findings noted above, the River Cacheu was divided into 20 km sections which were surveyed by boat with a crew of 4 actively searching for crocodiles in the river or on the banks. Equal survey effort was applied in all areas of the river. Approximate size, species, and age group were recorded for each of the crocodiles spotted.

The survey was conducted from 1 to 4 September 2013.

8.6.4.3 Results

Only the Nile crocodile (*C. niloticus*) was recorded during the study. This was as expected as *Mecistops cataphractus* is expected to be extinct in Guinea-Bissau and *Osteolaemus tetraspis* is unlikely to occur in the habitat available and has not been recorded in Guinea-Bissau.

A total of 25 crocodiles were recorded along the 180 km stretch of the River Cacheu (Table 8.8, Drawing 550-8.9). These results demonstrate a low total number of crocodiles compared to that expected to be present in healthy populations, although there is a good distribution of crocodiles over the size classes (Combrink, 2004).

Table 8.8: Crocodile survey data

Distance from river mouth	Number recorded	Density (crocodiles per km)	Crocodile size class			
			3-4 m	2-3 m	1-2 m	<1 m
0-20 km	0	0	0	0	0	0
20-40 km	0	0	0	0	0	0
40-60 km	0	0	0	0	0	0

Distance from river mouth	Number recorded	Density (crocodiles per km)	Crocodile size class			
			3-4 m	2-3 m	1-2 m	<1 m
60-80 km	0	0	0	0	0	0
80-100 km	1	0.05	0	1	0	0
100-120 km	0	0	0	0	0	0
120-140 km	1	0.05	0	0	0	0
140-160 km	4	0.2	0	2	1	1
160-180 km	19	0.95	4	6	6	3

Although these results amount to an average of only 0.14 crocodiles per km, this is a slightly skewed due to the stretch of river where no crocodiles were recorded. The results indicate that the density of crocodiles increases exponentially with increasing distance from the river mouth (Figure 8.6). The surveys found that 76% of crocodiles recorded were found in the 20 km reach furthest from the river mouth, with no crocodiles recorded in the first 80 km of the River Cacheu.

It must be noted that these surveys cannot be assumed to be a total count of crocodiles within the River Cacheu and is more of an indication of the distribution of crocodiles throughout the river.

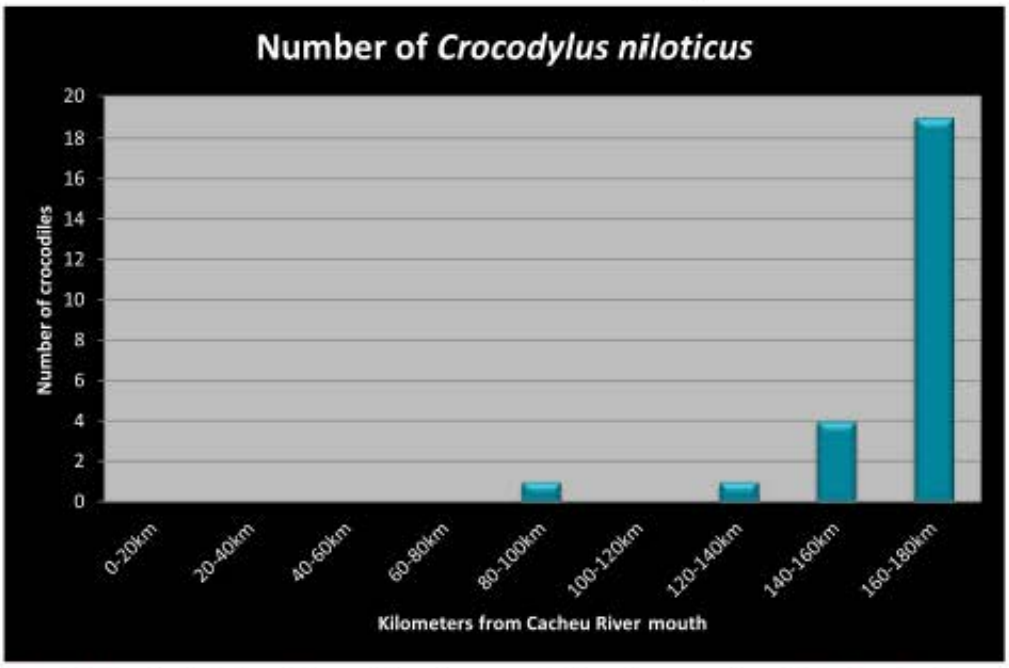


Figure 8.6: Graphical depiction of the crocodile numbers recorded along the surveyed reach of the River Cacheu

8.6.4.4 Discussion

Crocodilian populations have been studied worldwide, as most wild populations are under serious threat due to habitat loss, degradation, and pollution (Pooley, 1969; Ross, 1998). Although these large predators are perceived by many as non-essential members of healthy aquatic ecosystems, they are actually keystone and sentinel species that can provide information on the long-term health of an ecosystem. The data reported indicates that the Nile crocodile population in the River Cacheu is healthy and probably still fulfils an integral role in the system.

The results showed that the crocodile population increases exponentially with an increase in distance from the Cacheu river mouth. Nile crocodiles are a freshwater species and although they possess a salt gland, they are not able to excrete salt as efficiently as their saltwater counterparts (Guggisberg, 1972). The more saline the water, the less suitable the habitat is for the Nile crocodile. As shown by the study by Combrink (2004), crocodile density is not randomly distributed, but dependant on habitat suitability. This study therefore concurs with the findings of Combrink (2004), showing that the crocodiles in the River Cacheu are dependent on habitat suitability and increase in density with an increase in habitat suitability.

The mean population density of the current crocodile population in the River Cacheu equates to 0.14 crocodiles per km of river. However, the entire shoreline is not good habitat for basking, nesting and other behaviours.

An area of the river around Farim was being utilised as a nursery area, with young crocodiles using the exposed mangrove mud flats to hunt for mudskippers and fiddler crabs. This has not been studied extensively in the past and could warrant further study, as this area may be an important area for the propagation of the species in the River Cacheu.

8.6.5 Vultures

Two vulture species of concern were investigated as species of concern: the Palm-nut Vulture (*Gypohierax angolensis*) and the Hooded Vulture (*Necrosyrtes monachus*). The Palm-nut Vulture was studied as it is considered by the WWF as one of the vulturine charismatic mega fauna. The Hooded Vulture was studied due to its classification as a Critically Endangered species (IUCN, 2011).

8.6.5.1 Objectives

The objectives of the vulture study were to determine the abundance and diversity of *Necrosyrtes monachus* and *Gypohierax angolensis* within the Project area.

8.6.5.2 Methodology

Field methodology

For the purposes of the vulture study, 40 sites were randomly selected in the area of influence (AoI) and adjacent areas (Drawing 550-8.10). At each site, the presence or absence of vultures was investigated by means of a 10 minute point count and three 300 m transects, as described in Bibby et al. (1993). The following environmental factors were also recorded at each site and given a rating between 0 and 5:

- The level of urbanisation at the site (0 being very low and 5 being very high);
- The number of palm trees occurring on site and proximity to large numbers of palm trees (0 being very low and 5 being very high);
- The amount of natural vegetation on site and proximity to natural vegetation (0 being very low and 5 being very high);
- The amount of livestock in the vicinity of the site or proximity to areas with large numbers of livestock (0 being very low and 5 being very high); and
- The level of agricultural activity in the areas and proximity to areas of agricultural activity (0 being very low and 5 being very high).

The vulture study took place between 5 and 10 September 2013. A single sampling event was held at each site with a number of sites surveyed each day (Table 8.9).

Table 8.9: Vulture Sampling Sites and Dates They Were Sampled

Locations	Completion Date
VS 1 - VS16	5 September 2013
VS 17 - VS20	6 September 2013
VS 21 - VS24	7 September 2013

Locations	Completion Date
VS 25 – VS30	8 September 2013
VS 31 – VS35	9 September 2013
VS 36 - VS40	10 September 2013

Surveys were conducted throughout the day and not only in the early mornings when bird activity is at its most (Bibby, Burgess, & Hill, 1993). As vultures are active throughout the day and are a visually conspicuous taxon, this did not affect the counts. Transects were carried out on foot at a steady walking pace of around 3 km per hour. Observations of the target species and the number of individuals observed were recorded with a Trimble Juno GPS enabled PDA.

Correlations and non-metric multidimensional scaling (PC-Ord) (McCune & Grace, 2002) were used to determine whether there was a correlation between the vulture data and any of the environmental factors.

8.6.5.3 Results

Palm-nut Vulture (Gypohierax angolensis)

A total of 51 Palm-nut Vultures were recorded during the survey. The vast majority of *Gypohierax angolensis* recorded (47 individuals) occurred at study sites with a palm-tree index of 3 or higher, of which 24 occurred at study sites with a palm-tree index of 5.

When represented graphically, the data show that *G. angolensis* populations (average number of individuals per site) within the study area show a linear correlation (P=0.035) (Figure 8.7) when compared to the palm tree index of the various sites. The other indices showed no correlation to the number of *G. angolensis* observed (P>>0.05). *G. angolensis* were also found to be numerous along rivers and noted to be catching fish in these areas. These areas had not been included in the study area, but this observation was recorded and rivers were noted as an area of high *G. angolensis* activity.

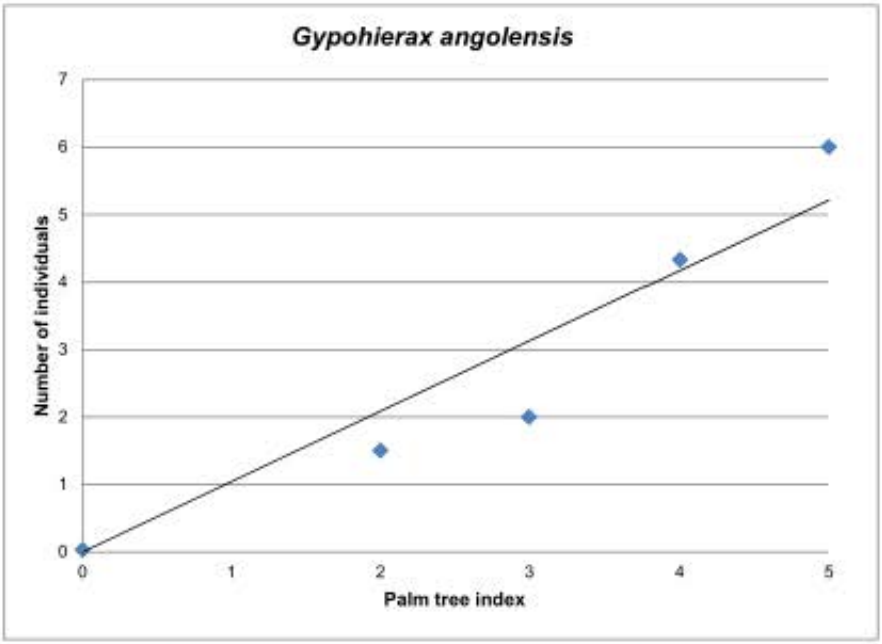


Figure 8.7: Correlation between average number of individuals and palm tree index

Hooded Vulture (Necrosyrtes monachus)

A total of 659 Hooded Vultures were recorded during the surveys.

The vast majority of *Necrosyrtes monachus* recorded (616 individuals) occurred at study sites with a urbanisation index of 3 or higher, of which 396 occurred at study sites with a urbanisation index of 5. When represented graphically, the data show that *N. monachus* populations (average number of individuals per site) within the study area show a linear correlation (P=0.02) (Figure 8.8) when compared to the urbanisation index of the various sites.

The vast majority of *N. monachus* recorded (648 individuals) occurred at study sites with a livestock index of 3 or higher, of which 463 occurred at study sites with an livestock index of 5. When compared with the livestock index, *N. monachus* populations within the study area showed an exponential correlation (Figure 8.9).

N. monachus populations showed no correlation when plotted against the palm tree index or agricultural indices. Contrary to initial expectations, *N. monachus* populations showed a weak negative linear correlation to the natural vegetation index.

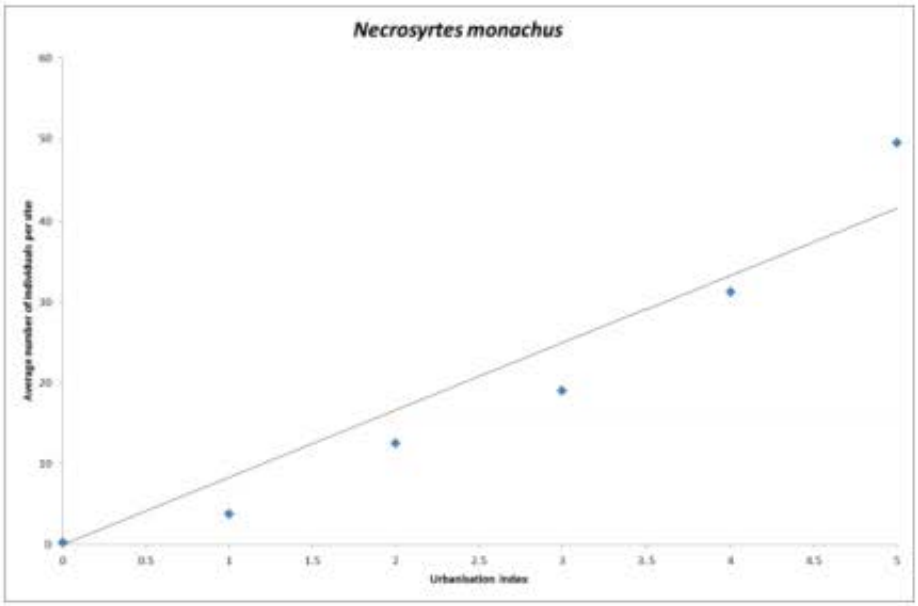


Figure 8.8: Correlation between average number of Necroyrtes monachus individuals per site and the urbanisation index of the sites

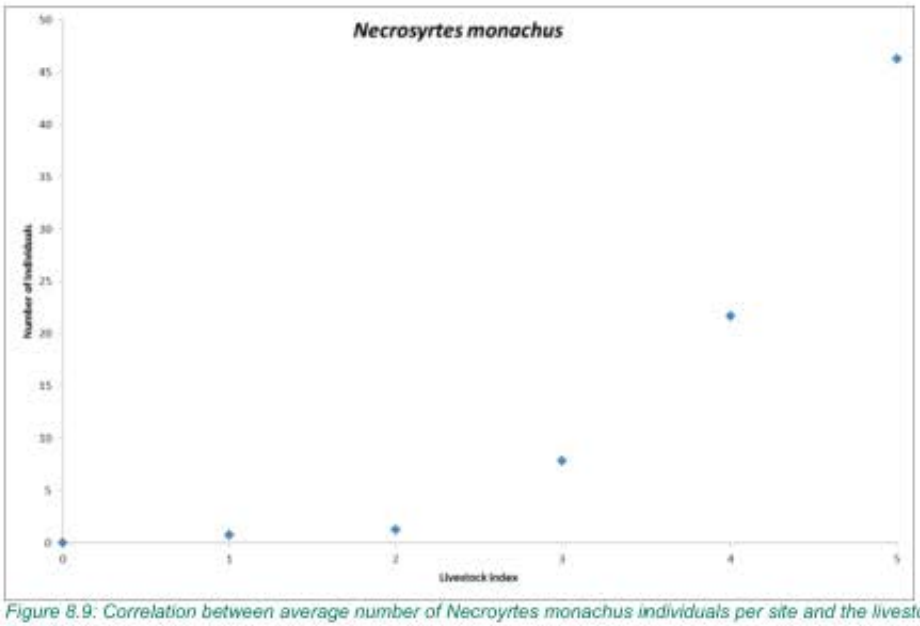


Figure 8.9: Correlation between average number of Necroyrtes monachus individuals per site and the livestock index of the sites

8.6.5.4 Discussion

The geographic distribution of birds is usually restricted (to varying degrees) by food, water, nesting sites, competition, predation, and vegetation structure (Hudson & Bouwman, 2007). Human activities can affect these factors which in some cases can result in the absence of a species from an area or conversely can cause an influx of certain species to previously unsuitable areas.

Palm-nut Vulture (Gypohierax angolensis)

The Palm-nut Vulture (*Gypohierax angolensis*) is not considered endangered or critically endangered by the IUCN, but was included in this study due to its classification as "charismatic megafauna" by the WWF.

This study indicates that *G. angolensis* is restricted in its range mainly by food sources. Its distribution is associated with the presence of palm-trees (the producers of palm nuts, the main diet of *Gypohierax angolensis*) or fish which are a secondary diet of this species (hence its alternative common name, the vulturine fish eagle).

Water availability is not a limiting factor to any species (including *G. angolensis*) in this region due to the high rainfall during the wet season and perennial water bodies scattered throughout the study area. Suitable vegetation for nesting sites for *G. angolensis* occur throughout the study area and this was not seen as a limiting factor in the distribution of this species.

Because of the specialised nature of *G. angolensis*, there is no real competition for food sources, with the possible exception of human populations in the area. These species will often pre-empt the harvesting of palm nuts by humans and therefore reduce the effect of this competition. Few species prey on vultures of any kind and no known predators of *G. angolensis* occur in the study area. There may be isolated incidents of old or sick individuals being attacked and killed by domestic or feral dogs, but such incidences are very unlikely.

Vegetation structure is thought unlikely to play a role in the distribution of this species as vegetation throughout the study area is highly impacted by anthropogenic disturbances. Furthermore, the areas in which this species was found are already impacted by to agriculture (e.g., rice paddies). The vegetation

structure of the rice paddies is very different to that of the mature mangroves lining the river, which is the other vegetation community in which this species was recorded.

This species is absent in areas of urbanisation, although they do occur in rice paddies and near small villages where palm trees are present, indicating some sensitivity to urbanisation.

Hooded Vulture (Necrosyrtes monachus)

Based on the findings of the study, it would appear that the hooded vulture has adopted an alternative hunting strategy in order to adapt to the absence of its usual food sources. The preferable food source for hooded vultures would be medium to large mammal species; however these have become almost extinct due to over-utilisation by the human population. To avoid extinction, the vulture populations have left the natural areas and moved to areas of human habitation to utilise the food resources available there (livestock, dogs, animals dying of disease or other causes).

It would appear that this species has adapted to a symbiotic relationship with humans and become a human commensal species. In order to survive, this species has adapted to factors which would have previously been a deterrent, such as anthropogenic noise. There is a strong correlation between *N. monachus* and urbanisation, while there is no correlation between *N. monachus* and factors such as natural vegetation.

Water availability is not a limiting factor due to the high rainfall during the wet season and perennial water bodies. Suitable vegetation for nesting sites for *N. monachus* occurs throughout the study area and was not seen as a limiting factor in the distribution of this species within the study area.

Because of the specialised nature of *N. monachus*, there are no real competitors with regards to food sources, with the possible exception of human populations in the area. That being said, these species will often pre-empt the harvesting of palm nuts by humans and therefore reduce the effect of this competition. Few species prey on vultures of any kind and no known predators of *Necrosyrtes monachus* occur in the study area. There may be the isolated incidence of old or sick members of this species being attacked and killed by domestic or feral dogs, but such incidences are very unlikely.

Vegetation structure is thought unlikely to play a role in the distribution of this species as vegetation throughout the study area is highly impacted by anthropogenic disturbances. Furthermore, the areas in which this species was found, were already impacted due to agriculture by means of rice paddies. Vegetation structure of the rice paddies is also very different to that of the mature mangroves lining the river, which is the other vegetation community in which this species was recorded.

8.6.6 Conclusions and Recommendations

Marine turtles

No marine turtles appear to utilise the beaches south of Bolor, which are likely to be impacted by the DSO. There are reports of the odd vagrant using the estuary, but these are unlikely to be the norm as the substrate on the banks of the estuary are not conducive to turtle nesting, the beaches are quite narrow with shallow beach sand and the sand on these beaches is interspersed with large numbers of mangrove pneumatophores.

Furthermore, another contributing factor to the lack of sea turtles inhabiting the estuarine area may be the turbidity of the water. These factors account for the fact that it does not appear that sea turtles are using the estuarine area for breeding or even feeding, other than the odd vagrant moving up into the estuary. Furthermore, it may be safe to assume that this part, and similar habitats along the Guinea-Bissau coastline are unideal habitats for sea turtles and, therefore, not likely to be frequented by this taxon.

Crocodiles

All indications of this study appear to show that the African slender –snouted crocodile and the West African dwarf crocodile do not occur in this area. Features of the demographics of the crocodile population in the Cacheu river system showed that the crocodile population increases exponentially with an increase in distance from the Cacheu River Mouth. Only two individuals were recorded in the Cacheu River downstream from Farim indicating the majority of individuals of this taxon occur upstream of the mining area.

Young crocodiles use the area close to the mine site along the river as a nursery area.

Vultures

Although *Necrosyrtes monachus* is currently listed on the Red List as critically endangered (CR), it is a locally common species in the area with a total of more than 600 individuals being recorded during the surveys. This species has become highly human commensal throughout West Africa and is well adapted to anthropogenic disturbance. *Necrosyrtes monachus* appears to be unaffected by the current anthropogenic activities in the area.

Due to the specialised nature of *Gypohierax angolensis*, their range is very restricted in the study area that can be related to the density of palm trees.

8.7 Abbreviations and Acronyms

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CR	critically endangered
DD	data deficient
ESIA	environmental and social impact assessment
HL	habitat linkage
HR	habitat requirements
HS	habitat status
IFC	International Finance Corporation
IUCN	The International Union for Conservation of Nature
LSA	local study area
NEMP	National Environmental Management Plan
RSA	regional study area
SoC	species of concern
VU	vulnerable
WWF	World Wildlife Fund

8.8 Glossary

Chordates	Animals with an internal skeletal structure
Ecotone	A region of transition between two biological communities.
Power analysis	The analysis of the ability to find a statistically significant difference when the null hypothesis is in fact false. In other words power is your ability to find a difference when a real difference exists. The power of a study is determined by three factors: the sample size, the alpha level, and the effect size.
Ramsar	The Ramsar Convention is an international treaty for the conservation and sustainable utilization of wetlands
Study area	Refers to the entire area of study.
Study site	Are individual data collection points within the study area.
Ecological integrity	The abundance and diversity of organisms at all levels, and the ecological patterns, processes, and structural attributes responsible for that biological

	diversity and for ecosystem resilience.
Conservation importance	The importance of an area for conservation, based on the probability of occurrence or presence or absence of species of concern, intrinsic conservation value of the habitat and ecological services provided.
Mangroves	Mangroves are various types of trees up to medium height and shrubs that grow in saline coastal sediment habitats in the tropics and subtropics – mainly between latitudes 25° N and 25° S
Field surveys	Surveys conducted in the field in order to collect real data for purposes of the study
The Precautionary Principle	The precautionary principle or precautionary approach states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking an action.
Spatial changes	Changes over a space or geographic area
Temporal changes	Changes over a chronological period
Migration	Movement of an individual organism or a number of organisms from one locality to another
Habitat	A habitat is an environment that is occupied by a particular species of plant, animal or any other kind of organism.
Phytosociological	The compositional and developmental charcteristics of plant communities, as well as the relationships between the species within them.
Species diversity	Species diversity is the effective number of different species that are represented in a collection of individuals (a dataset). The effective number of species refers to the number of equally-abundant species needed to obtain the same mean proportional species abundance as that observed in the dataset of interest (where all species may not be equally abundant). Species diversity consists of two components, species richness and species evenness. Species richness is a simple count of species, whereas species evenness quantifies how equal the abundances of the species are.
Species richness	The number of species occurring in a defined area.
Species abundance	The number of individuals of a species occurring in a defined area.

8.9 References

Bayliss, P., Webb, G., Whitehead, P., Dempsy, K., & Smith, A. (1986). Estimating the Abundance of Saltwater Crocodiles, Crocodylus porosus Schneider, in Tidal Wetlands of the Northern Territory. *Australian*(13), 309-320.

Bibby, C., Burgess, N., & Hill, D. (1993). *Bird Census Techniques.* London: Harcourt Brace & Company.

Branch, W. (1996). *Snakes and other reptiles of Southern Africa* (2nd Edition ed.). Cape Town: Struik.

Broadley, D. (1971). *The reptiles and amphibians of Zambia.* Puku.

Carr, A. (1986). *New perspectives on the pelagic stage of sea turtle development. NOAA Tech. Memo. NMFSSEFC-190.* U.S. Dept. Commerce. 36 pp.

Catarino, L., Martins, E., Pinto Basto, M., & Diniz, M. (2008). An annotated checklist of the vascular flora of Guinea Bissau. *Blumea*, 53: 1– 222.

Caughley, G. (1977). Analysis of Vertebrate Populations. London: John Wiley & Sons, Wiley Interscience.

Combrink, A. (2004). Population Status of Crocodylus niloticus (Nile crocodile) at Lake Sibaya, Republic of South Africa. MSc Thesis. University of KwaZulu Natal.

Cornelius, S., Alvarado-Ulloa, M., Castro, J., Mata del Valle, M., & Robinson, D. (1991). Management of Olive Ridley Sea Turtles (Lepidochelys olivacea) nesting at Playas Nancite and Ostional, Costa Rica. In J. Robinson, & K. Redford (Eds.), *Neotropical Wildlife Use and Conservation* (pp. 111-135). Chicago, IL.: The University of Chicago Press.

Du Preez, L., & Carruthers, V. (2009). *A Complete Guide to the Frogs of Southern Africa.* Cape Town: Struik.

Eckert, S. (1999). *Global distribution of juvenile leatherback sea turtles.* Hubbs Sea World Research Institute Technical Report.

Fontanes, F. (2003). ADW: Dermochelys coriacea: Information. Michigan: Animal Diversity Web. University of Michigan Museum of Zoology.

Fortes, O., Pires, A. J., & Bellini, C. (1998). Green turtle Chelonia mydas in the island of Poilão, Bolama-Bijagós Archipelago, Guinea-Bissau, West Africa . *Marine Turtle Newsletter*(80), 8–10.

Fortes, O., Pires, A., & Bellini, C. (1998). *Green Turtle, Chelonia mydas in the Island of Poilão, Bolama-Bijagós Archipelago, Guinea-Bissau, West Africa.* Marine Turtle Newsletter .

Games, I., Zohlo, R., & Chande, B. (1992). Utilization of the Crocodile Resource of Lake Cahora Bassa, Mozambique, 1987 and 1988. In *The CITES Nile Crocodile Project* (p. 133). Lausanne-Switzerland: Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Guggisberg, C. (1972). *Crocodiles: Their Natural History, Folklore, and Conservation.* ISBN 0-7153-5272-5.

Harrison, J., Allan, D., UnderhillL, L., Herremans, M., Tree, A., Parker, V., et al. (1997). *The Atlas of Southern African Birds* (Vol. I). Johannesburg: BirdLife South Africa.

Hockey, P., Dean, W., & Ryan, P. (2005). *Roberts Birds of Southern Africa* (7th Edition ed.). Cape Town: The Trustees of the John Voelker Bird Book Fund.

Hudson, A., & Bouwman, H. (2007). Different land-use types affect bird communities in the Kalahari, South Africa. *African Journal of Ecology*(45), 423–430.

Hutton, J. (1992). Report of the Coordinator of the CITES Nile Crocodile Project to the CITES Secretariat as Presented to the Parties at the Seventh Meeting of the Conferenceof the Parties. Lausanne-Switzerland: Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Hutton, J., & Woolhouse, M. (1989). Mark-Recapture to Assess Factors Affecting the Proportion of a Nile Crocodile Population Seen During Spotlight Counts at Ngezi, Zimbabwe, and the Use of Spotlight Counts to Monitor Crocodile Abundance. *Journal of Applied Ecology*(26), 381-395.

International, B. (2000). *Threatened birds of the world.* Barcelona and Cambridge: Lynx Edicions and BirdLife International.

IUCN. (2001). IUCN Red List Categories and Criteria. In IUCN, *Red Data Book of the Mammals of South Africa: A Conservation Assessment.*

IUCN. (2010). *IUCN Red List of Threatened Species.* Retrieved November 2010, from www.iucnredlist.org: http://www.iucnredlist.org

IUCN. (2011). Retrieved July 08, 2011, from IUCN Red List of Treatened Species. Version 2011.2: http://www.iucnredlist.org

IUCN. (2013). Retrieved July 08, 2013, from IUCN Red List of Treatened Species. Version 2011.2: http://www.iucnredlist.org

McCune, B., & Grace, J. B. (2002). *Analysis of Ecological Communities*. Gleneden Beach, Oregon, USA (www.pcord.com) With a contribution by Dean L. Urban: MjM Software.

Nichols, J. (1992). Capture-Recapture Models: Using Marked Animals to Study Population Dynamics. *BioScience*(42), 94-102.

Picker, M., Griffiths, C., & Weaving, A. (2002). *Field Guide to Insects of South Africa*. Cape Town: Struik.

Pooley, A. (1969). Preliminary Studies on the Breeding of the Nile Crocodile Crocodylus niloticus, in Zululand. *The Lammergeyer*(10), 22-44.

Ross, J. (1998). *Crocodiles: Status Survey and Conservation Action Plan*. Gland, Switzerland: IUCN.

Sinclair, I., & Ryan, P. (2003). *A comprhensive illustrated field guides to Birds of Africa south of the Sahara*. Cape Town : Struik.

Smithers, R. (1983). *The mammals of the Southern African subregion*. Pretoria: University of Pretoria.

Stuart, C., & Stuart, M. (2007). *Field Guide to the Mammals of Southern Africa* (4th Edition ed.). Cape Town: Struik Publishers.

White, F. (1983). *The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa3 plates, Northwestern Africa, Northeastern Africa, and Southern Africa, 1:5,000,000*. Paris: UNESCO.

9.0 AQUATIC ECOLOGY

9.1 Introduction

The aquatic ecology baseline study was developed in consideration of potential ecological impacts arising from the Farim Phosphate Project and the phosphate product barge transport option (Project) using the River Cacheu (e.g., surface water discharges from the mine site, construction of facilities for loading of barges near the mine site, potential spills while loading barges, river barge traffic, potential spills of phosphate product and fuels along the river/estuary, storage of barges near Bolor, and the transfer of phosphate product from barges to bulk solids carriers in the vicinity of the estuary) (Drawing 550-9.1).

This aquatic ecology section characterises the baseline conditions of the River Cacheu in the vicinity of Farim, in Guinea-Bissau, during the 2013 dry and wet seasons. The River Cacheu Aquatic Ecology Baseline Study (Golder 13514950200.508/B.0 dated January 2014) details the full baseline study.

Based on salinity measurements taken during the river morphology and physical oceanography baseline study, the River Cacheu is a relatively fresh water system during the wet season, but becomes more saline during the dry season. As the salinity of the river / estuary increases, there is a shift from fresh water flora and fauna to more estuarine and marine species. This aquatic ecology baseline study includes the fresh water, estuarine, and coastal aquatic ecosystems.

9.1.1 Objectives

The objectives of this baseline study are to provide aquatic biological information for the phosphate product barge transport option. This baseline study:

- Characterises the river aquatic ecology potentially affected by the Project, including fisheries, benthic communities, planktonic organisms, and chlorophyll-a. The terrestrial ecology baseline report (Section 8.0) includes wildlife species such as coastal birds, crocodiles, sea turtles, and marine mammals;
- Determines the current ecological status of the aquatic environment; and
- Identifies specific important ecological indicators and attributes.

The aquatic ecology baseline described in this report is based on:

- A literature review of available public data; and
- A summary of quantitative data collected during the 2013 dry and wet season surveys.

9.2 Baseline Study Area

The local study area (LSA) includes the River Cacheu – 180 kilometres (km) of the river from approximately 3 km upstream of the town of Farim to the estuary at the river mouth.

9.3 Previous Work

9.3.1 Baseline Aquatic Assessment for the Proposed Farim Phosphate Project – Mine Site

A baseline aquatic ecological survey was conducted for the mine footprint and a proposed product pipeline in November 2011 (wet season) and March 2012 (dry season) (Golder, 2012). During these baseline studies, the smaller streams in the region were evaluated.

The aquatic survey of smaller streams included:

- Analysis of benthic macroinvertebrates;
- Metal analysis of aquatic sediments;
- Metal analysis of gastropods;

- Zooplankton taxonomy; and
- Quantitative analysis of benthic organisms (snails counted on a 1 metre (m) grid square).

This initial aquatic baseline study found that many of the stream sites evaluated during the wet season were dry during the dry season; only sites with tidal influence were found to contain water. Some water quality data were collected on the River Cacheu in the vicinity of Farim during the mine site baseline, but no biological data were collected on the river or estuary.

9.3.2 Literature Review of Aquatic Ecology Resources

Once the barge transport option was proposed, a literature review was conducted to identify ecological data gaps to aid the planning of baseline field data collection programmes (for the potential impact of shipment of phosphate product via barges in the River Cacheu and storage of barges in the estuary). This initial literature review found that there is little publicly available biological information on the River Cacheu and estuary. No site-specific quantitative information was found at that time for Guinea-Bissau on fisheries (fish and shellfish), macroinvertebrates, plankton, or sea grasses. The literature review was used to understand the aquatic ecology of the area based on information from estuaries and rivers in West Africa. Limited biological information was available for the estuaries and coastal zones. Information regarding regional sensitive receptors was obtained from international sources.

9.3.3 Aquatic Ecology Scoping Site Visit

An aquatic ecology scoping site visit was conducted by Golder during September 2012, during the wet season. The visit consisted of a reconnaissance of the River Cacheu, from approximately 3 km upstream of Farim to the estuary (in the vicinity of Bolor). Approximately 180 km of river was traversed and photographed, benthic sediments were collected, and a visual assessment of the riparian and coastal environments was carried out. The survey methods used are detailed in Section 9.4.3. Qualitative observations were made of sediment types, aquatic benthic organisms found, aquatic reptiles, and marine mammals. Sediment samples collected were analysed for particle size distribution (PSD) measurements and chemical composition; these data are discussed in the River Morphology and Physical Oceanography Baseline study (Golder Associates Ltd, 13514950200.505/B.0, 2013).

Based on a review of results from the aquatic baseline assessment conducted for the scoping site visit, it was concluded that the River Cacheu and estuary appeared to be largely in a natural state with few modifications or existing impacts. This information was used to develop the plan of study for the river and estuary baseline.

The preliminary conclusions from the scoping visit were that the extreme tidal influence within the River Cacheu (Figures 9.2 and 9.3) and the substantial changes in river flow between the wet and dry seasons were important to the biology of the system, affecting the types of aquatic species present. Therefore dry and wet season baseline surveys were recommended to characterise the LSA. It was also concluded that the regional study area (RSA) would be described from existing scientific sources.

Figure 9.1: River Cacheu at Farim -- low tide during the wet season

Figure 9.2: River Cacheu at Farim -- high tide during the wet season

Mangroves (*Rhizophora* spp. and *Avicennia germinans*) line the River Cacheu along its length (Figure 9.3). Their root area is submerged during high tide and can provide important aquatic habitat. The mangroves in the region are considered of very high conservation importance as they represent important habitat for many aquatic species and they typically provide shelter for fish and invertebrates. In the estuary, the mangrove forests reach a maximum width of 15 km on the north bank. In contrast, the coastal estuary near Bolor has narrow white sandy beaches that appear to be in pristine condition (Figure 9.4).

Figure 9.3: River Cacheu lined with mangroves (high tide)

Figure 9.4: Narrow white sandy beaches in the northern estuary near Bolor

9.4 Methods

Standard scientific methods were used for the design of the field studies, data collection and taxonomic identifications. Fish and invertebrates were taxonomically identified by senior Golder fisheries staff as well as taxonomic experts from Water and Air Research, BSA Environmental and Coastal Solutions LLC. Chemical analysis of fish tissues were conducted by Jones Environmental Laboratory (UK).

9.4.1 Standards and Legislation

9.4.1.1 Guinea-Bissau Legislation and Standards

Guinea-Bissau legislation relevant to the proposed project includes the following:

- Environmental and Social Policy: The National Environmental Management Plan (NFSP), 2004, outlines the national policy on environmental conservation and sustainable development based on principles of equality and equity, environment and development, precaution, preservation, protection, and valuation of natural and built heritage;
- The National Strategy and Action Plan for Biodiversity (2004) sets out the national guidance and areas for conservation and sustainable use of biological diversity. Other policy documents include:
  - National Forest Management Plan;
  - The Agricultural Development Policy Letter;
  - Environmental Strategy for the management of the coastal zone;
  - The Master Plan for water and sanitation; and
  - The Master Plan of artisanal fisheries.
- The creation of the Unit for Environmental Impact Assessments (*Cellule d'Evaluation des Impacts Environnementaux* - CAIA) in the document entitled Project Management of Biodiversity and Coastal Zone of Guinea-Bissau (*le projet gestion de la biodiversité et des zones côtières en Guinée-Bissau* - PGBZC-GB) reflects a desire to promote greater inclusion of environmental considerations into development activities. Founded in 2005, the CAIA is under the authority of the Prime Minister. Its aim is to ensure the effective consideration of environmental issues into development activities in general, and the activities of PGBZC in particular. The activities selected to accomplish this mission through Component 3 of the PGBZC are:
  - Create a legal framework for environmental impact assessments in Guinea-Bissau;

- Ensure that all development projects initiated in the country are analysed for their potential environmental and social impacts before the existence of a national law for the sector; and
- Ensure that proposals and mitigation measures to reduce impacts of development projects are implemented.

Guinea-Bissau has recently developed a framework law on the environment that lays the foundation for environmental policy and environmental assessments. These two laws are pending validation by the Cabinet and the National Assembly. In addition, there is a reference guide on conducting environmental assessments in the mining sector. The following decrees and laws regulate the management and use of natural resources:

- Law No. 1 / 2000 of 24 July – Mines and Minerals Act;
- Decree-Law No. 4-A/91 29 October approved the Forestry Law;
- Decree-Law No. 7 / 2000 created the National Commission on Pesticides, which is part of the Sahelian Pesticides Committee;
- Decree No. 11 / 2000 which created the National Park Group of Islands Orango;
- Decree No. 12 / 2000 which created the Natural Park of Mangroves in Cacheu;
- Decree No. 13 / 2000 which created the National Park Lagoon (Marais) in Cufada; and
- The fisheries legislation has undergone in 1986 a Decree Law (Decree-Law No. 2 / 86 of March 29) and an Order under Decree No. 10 / 86 of 26 April.

9.4.1.2 International Standards and Guidelines

This work conforms to international standards: the Performance Standards (PS) of the International Finance Corporation (IFC) and Equator Principles (EPs).

A summary of the key international regulations and guidelines is provided in Table 9.1. Planning of the baseline data collection programme for the aquatic ecology component considered these standards.

Table 9.1: Key International Regulations and Guidelines

Regulations and Guidelines	Date	Summary
IFC Performance Standards on Environmental and Social Sustainability, 1 to 8	January 2012	Applies to the management of social and environmental risks and impacts and enhancement of development opportunities in the private sector.
World Bank Group (IFC) Environmental Health and Safety Guidelines	April 2007	The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry specific examples of Good International Industry Practice (GIIP).
Equator Principles	June 2013	Adopted by Equator Principles Financing Institutions in order to ensure that the projects they finance are developed in a manner that is socially responsible and reflect sound environmental management practices.
International Council on Mining and Metals - Sustainable Development Principles	May 2003	10 principles relating to the sustainable development framework.

9.4.2 Study Limitations

The extent of the baseline study area and the scope of the field studies were established based on the following:

- It was assumed that barge loading and movement would occur from the mine site near Farim to the vicinity of Bolor (and return);
- No dredging will be required to provide navigation access to the mine site or to the trans-shipment area offshore of Guinea-Bissau; and
- This baseline section is based upon data that were collected during the 2013 dry and wet seasons.

Major aquatic trophic levels were sampled using a variety of methods to characterise the aquatic environment. The chemicals for tissue concentration measurements were selected to focus on metals that are similar to the key geochemical features of the ore as well as polyaromatic hydrocarbons (PAH) typical of fuels.

9.4.3 River and Estuary Reconnaissance

The aquatic ecology scoping site visit was conducted in September 2012 during the wet season and consisted of a biological and logistical reconnaissance of the river by boat (Figure 9.5) between Farim and Bolor.

Figure 9.5: Rosa B at Sao Vicente Bridge – Vessel used for scoping site visit and baseline surveys of the River Cacheu and estuary

During the reconnaissance survey, salinity and temperature were measured at multiple locations along the river and estuary. Superficial river and estuary sediment samples were collected using an Ekman sampler (Figure 9.6) for PSD analysis and qualitative biological evaluation of benthic organisms (Figure 9.7). The qualitative biological survey was used to select the type of field equipment to use for benthic community evaluation during the dry and wet season baseline study.

Sediment samples collected from the river and estuary were placed in plastic bags for shipment to the laboratory. Sediments were also photographed prior to sieving at some locations to document their consistency. The sediment physical and chemical data are included in the river morphology and physical oceanography baseline report (Golder 13514950200.503/B.0 2013).

Figure 9.6: Collection of sediment samples using an Ekman sediment sampler

Figure 9.7: Sediments were sieved to qualitatively assess benthic organisms present and substrate types

Photographs were taken to document the shoreline habitats along the River Cacheu, primarily mangrove forests. The tidal stages were very visible along the river banks (Figures 9.9 and 9.10).

Figure 9.8: Mangrove forest on river banks at high tide

Figure 9.9: Mangroves on river banks at low tide during the dry season

9.4.4 Aquatic Ecology Baseline Field Study (2013)

The aquatic ecology field programme developed quantitative and qualitative data for aquatic biological resources of the River Cacheu from the vicinity of the planned mine near Farim to the coastal environment (estuary). Project activities have the potential to affect aquatic biological resources near Farim, along the River Cacheu, in the vicinity of the proposed barge marshalling area near Bolor, and nearshore in the estuary and coastal areas.

The baseline study evaluated aquatic trophic levels to characterise the aquatic baseline for this river and estuary system. The aquatic trophic levels evaluated included:

- Benthic invertebrates (bottom dwelling organisms);
- Phytoplankton;

- Zooplankton (including ichthyoplankton);
- Fish;
- Shellfish;
- Macroinvertebrates;
- Seagrasses (presence/absence);
- Isolated corals (presence/absence); and
- Chlorophyll-a measurements.

Benthic invertebrates, phytoplankton, zooplankton, fish, shellfish, and macroinvertebrates were sampled quantitatively. Seagrasses and isolated coral presence/absence were qualitatively evaluated using a limited number of video transects (if visibility allowed) and visual observations of benthic grab samples and trawls. Water quality measurements were also taken at each station (Figure 9.10).

Figure 9.10: Water quality measurements being taken in the River Cacheu

Field surveys were conducted at 17 stations from the vicinity of Farim to the estuary (Drawing 550-9.1):

- Vicinity of Farim:
  - Two (2) stations upstream of Farim;
  - Two (2) stations near Farim and the proposed barge loading area; and
  - Two (2) stations downstream of the proposed barge loading area.
- River Cacheu (from Farim to Cacheu area):
  - Four (4) stations.
- Vicinity of the proposed barge marshalling area in the estuary:
  - Four (4) stations.
- Nearshore coastal area (in vicinity of the original phosphate material transfer area):

- Three (3) stations.

The following discussion summarises the aquatic ecology baseline field program by resource component. All field sampling was carried out from the boat (the Rosa B).

Benthic Invertebrates

Benthic sampling was carried out by collecting three replicate sediment grab samples at each station. Benthic invertebrate samples were collected using a petite ponar grab sampler (Figures 9.12 and 9.13). This weighted sampler was lowered to the bottom of the water column using a hand line. Once on the bottom, tension was removed from the arms of the sampler, allowing the spring-loaded holding pin to release and the jaws of the grab to close, effectively scooping up the sediment as it was retrieved. Each sample was sieved through 500 micron (µm) mesh in the field and preserved in a 10 percent buffered formalin solution. Benthic organisms were shipped to a taxonomic laboratory (Water and Air Research) for taxonomic identification to the lowest practical level. An additional un-sieved sediment sample was collected from each station, iced and shipped for PSD and chemical characterisation by Jones Environmental Laboratories.

Figure 9.11: Benthic sampler (petite ponar) used for sediment collection

Figure 9.12: Sediments sieved through a 500 µm mesh size to collect the benthic organisms

Phytoplankton

Samples for phytoplankton taxonomic analysis were collected in triplicate at each station (Figure 9.13). Surface grab samples (500 millilitres [mL]) were collected and preserved in the field using Lugol's solution. The samples were shipped to BSA Environmental for taxonomic identification to the lowest practical level.

Figure 9.13: Collection of water sample for phytoplankton taxonomic analysis

Zooplankton

Water samples for zooplankton taxonomic analyses were collected using 0.3 metre (m) diameter plankton net with 40 µm mesh (Figure 9.14). This fine mesh also captures invertebrate larval stages and ichthyoplankton (fish larvae and eggs). Zooplankton samples were collected in triplicate using a vertical plankton net tow (bottom to surface) at each station. Each sample was preserved in a buffered formalin solution for taxonomic identification, with attention to ichthyoplankton (fish eggs and larvae) and commercial invertebrate species (such as shrimp and crab early life stages). The main objective of the zooplankton assessment was to develop a list of species present and provide approximate density estimates. These data will also be used to evaluate the species that are using the river and estuary as nurseries. The preserved samples were shipped to BSA Environmental.

Figure 9.14: Deployment of plankton net for the collection of zooplankton

Fish and Macroinvertebrates

Several types of equipment were used to collect fish and macroinvertebrates from the water column and bottom of the river / estuary:

Minnow and Fish Traps

Small-bodied and juvenile fish and invertebrates often inhabit the riparian and intertidal zone where shoreline structures, such as mangroves, can provide shelter from predators. These same structures can make sampling difficult by obstructing nets or other sampling gear. To target these habitats, two different sized traps were used: 0.23m by 0.45m minnow traps, with 3.2mm mesh made from galvanised steel wire and containing two 0.025m diameter entrance openings; and larger 0.66m by 0.48m by 0.23m semi-oval fish traps with 9.5mm nylon mesh and a single 0.15m door opening.

Three minnow traps and three fish traps were deployed at each river station (Stations 1 to 10, Figures 9.16 and 9.17). The traps were placed against the mangroves at a depth that would ensure they remained submerged for the duration of the deployment (approximately 1 to 3 m). The traps were spaced approximately 50 to 100 m apart along the shoreline at each station and allowed to soak for a minimum of 2 hours before being retrieved and the contents examined.

Fish and invertebrates collected were preserved for taxonomic identification. The fish and minnow traps were not deployed in the estuary stations (Stations 11 to 17) because high tidal currents in open water areas associated with the estuarine sites, and lack of adequate vegetation or structure to secure the traps, made this gear ineffective in this region of the estuary.

Figure 9.15: Fish and minnow traps

Figure 9.16: Fish and shrimp caught in traps

Gill Net

To sample the transitional area between the intertidal mangrove-dominated shoreline and the main body of the river, a gill net was used at stations within the river (Stations 1 to 10). Gill nets are a type of entanglement net that captures fish (and other organisms) by entangling them in the mesh of the net (Figures 9.18 to 9.21). The effectiveness of this type of equipment depends on the mesh size of the net and the size of fish being targeted.

To maximise the range of sizes targeted for this study, the gill net used was a multi-panel net with each panel containing a different size of mesh The net was made up of six panels with mesh sizes of 13mm-square(sq.)/25mm-stretch(str), 25mm-sq./51mm-str., 38mm-sq./76mm-str, 51mm-sq./102mm-str., and 76mm-sq./152mm-str., respectively. All panels were 1.8m deep and 7.6m long, making for a total net size of 1.8m by 38.1m.

Figure 9.17: Gill net being deployed

Figure 9.18: Gill net being retrieved with fish

Figure 9.19: Catch

Figure 9.20: Catch

Figures 9.18 to 9.21 show the gill net being deployed, retrieved and the catch at two stations. The net was deployed with the smallest mesh adjacent to the mangrove shoreline and extended its length (38m) offshore into the river, perpendicular to the river flow. The bottom of the net is held along the river bottom with a lead-core bottom line and the net is held vertically in the water column through the use of a foam-core float line. The gill net was deployed at each river station and allowed to soak for a minimum of 2 hours before being retrieved. Once retrieved, all fish and macroinvertebrates collected were identified on-site or preserved for later taxonomic identification. Similar to the fish and minnow traps, the gill net was not applicable in the estuary stations (Stations 11 to 17) due to the high currents in the open water areas.

Otter Trawl

To sample the epibenthic (bottom-dwelling or near bottom) fish and macroinvertebrates within the main body of the river and estuary, an otter trawl was used at all stations in the study area. This net is conical in shape with a wide elliptical mouth opening which tapers gradually backwards towards a narrow bag (codend), which is tied off at the end to prevent escape of organisms. Each side of the mouth of the trawl has lines attached to weighted doors. A tow line is tethered to each of these doors and is used to pull the net through the water. When fishing the net, the mouth of the net is held open, through the use of 0.3m x 0.6m doors as well as floats on the head rope. The foot rope on the bottom of the net was paired with a galvanised steel chain to ensure it maintained contact with the bottom. The trawl used in this study was 3.0m x 0.6m with the body of the net made with 38mm stretch mesh, and it had 13mm stretch mesh in the codend with a 6mm Delta Mesh (non-stretch) inner liner.

For this study the otter trawl was fished in a variety of depths, ranging from 3.5 to 13.0 m, depending on the depth at the stations. For stations located in the river (Stations 1 to 10), one trawl tow was conducted at each station over a distance of approximately 100 to 200 m, depending on a variety of factors, including current, availability of straight-line distance at the station, and presence of local fishing nets or other

obstructions. For stations located in the estuary (Stations 11 to 17), three trawl tows were conducted at each station over a distance of approximately 200 to 300 m.

Figures 9.22 to 9.25 show the deployment, fishing, and the type of species collected by the trawl net. Fish and macroinvertebrates collected were identified to the lowest practical taxonomic level in the field and photo-documented by Golder fisheries staff (Figure 9.26). Macroinvertebrate taxonomic identifications were verified by Coastal Solutions LLC. Other macroinvertebrates such as fiddler crabs were collected opportunistically along the shoreline during low tide (Figure 9.27). Fiddler crabs burrow in sediments in the intertidal zone of the river and estuary.

Figure 9.21: Gill net deployment instruction

Figure 9.22: Field deployment

Figure 9.23: Fishing

Figure 9.24: Species collected by the trawl net

Figure 9.25: Fish taxonomist identifying fish caught during the dry season sampling

Figure 9.26: Fiddler crab collected along the shorelines during low tide

Fish tissues

Fish tissue samples were collected at all stations where sufficient fish were available for chemical analysis. In order to conduct this type of chemical analysis, fish tissue samples were iced in the field, frozen for preservation, and shipped to Jones Environmental Laboratories for chemical analysis (metals and PAH). Fish representing several trophic levels were sent for chemical analysis in order to potentially evaluate bioaccumulation potential and baseline levels of chemicals in fish tissues.

The fish tissues were analysed for selected PAHs and the following metals:

- Arsenic;
- Cadmium;
- Chromium;
- Calcium;
- Copper;
- Iron;
- Lead;
- Magnesium;
- Manganese;
- Nickel;
- Phosphorus;
- Potassium;
- Sodium;
- Zinc;
- Mercury; and
- Methyl mercury.

Seagrasses and Isolated Corals

Multiple methods were employed to survey the benthic (bottom) environment in regard to suitability to support the growth of seagrasses or isolated corals. These methods included underwater video transect surveys, directed grab samples using a petite ponar grab, and examination of bottom trawl catches for evidence of seagrasses or corals.

These efforts were concentrated in sampling stations located in the estuary (Station 11 to 17) as these sites presented the highest potential for suitable substrate and water quality conditions. Figure 9.27 shows the deployment of the underwater video camera (arrow).

Figure 9.27: Deployment of underwater video camera to conduct visual transects of benthic substrate for presence of seagrasses

Chlorophyll-a

Samples for chlorophyll-a concentration were collected in triplicate at each sampling station. Either 250 mL or 125 mL of surface water were collected and vacuum filtered through a 1.2 µm pore glass microfiber filter; with the smaller aliquot being used at sites where suspended solids and other materials clogged the filter. Sample filters were then placed inside folded foil sheets (to prevent light penetration) and placed on ice to preserve the samples. Once back at the field lab (in Farim or Bissau), sample filters were frozen until processing.

To process the samples, chlorophyll-a was extracted from the sample filters by digesting in 90 percent acetone. Florescence of extracted chlorophyll-a solutions were read using a Turner Designs Aquafluor field fluorometer. This fluorometer is designed to read extracted chlorophyll-a before and after acidification with 10 percent hydrochloric acid (HCl) following the Holm-Hanson method for chlorophyll-a extraction as outlined in EPA Method 445.0 (EPA 1997).

From the fluorometer readings, chlorophyll-a concentrations were calculated using the "corrected" chlorophyll method presented by Turner Designs for use with the Aquafluor instrument. The acidification method calculations were as follows:

Acidification Method

Variables stored during calibration phase of fluorometer

$C_{stand[1]}$ = Concentration of standard 1

F_{blank} = Fluorescence of blank value

$F_{stand[1],B}$ = Fluorescence of standard 1 before acidification

$F_{stand[1],A}$ = Fluorescence of standard 1 after acidification

F_m = Acidification Ratio = $(F_{stand[1],B} - F_{blank}) / (F_{stand[1],A} - F_{blank})$

Variables required from the sample analysis phase

$F_{samp,B}$ = Fluorescence of sample before acidification

$F_{samp,A}$ = Fluorescence of sample after acidification

$V_{solvent}$ = Volume of solvent used to extract sample

V_{water} = Volume of water filtered

Interpolation equation used in end calculation of chlorophyll *a* and pheophytin concentrations

$$Interp_{,B} = C_{stand[1]} * (F_{samp,B} - F_{blank}) / (F_{stand[1],B} - F_{blank})$$

$$Interp_{,A} = C_{stand[1]} * (F_{samp,A} - F_{blank}) / (F_{stand[1],B} - F_{blank})$$

End calculation for corrected chlorophyll and pheophytin *a*

$$\text{Chlorophyll-a concentration} = [F_m/(F_m-1)] * (Interp_{,B} - Interp_{,A}) * (V_{solvent} / V_{water})$$

$$\text{Pheophytin-a concentration} = [F_m/(F_m-1)] * [(F_m * Interp_{,A}) - Interp_{,B}] * (V_{solvent} / V_{water})$$

Prior to the start of the field surveys, the Turner Designs Aquafluor field fluorometer was calibrated following manufacturer's instructions and using known primary standards from Turner Designs. Continued calibration verification was conducted using a solid secondary standard prior to reading extracted chlorophyll-a samples.

Water Quality Measurements

A YSI 600QS multimeter was used to take in situ water quality readings at each sampling station to characterise the physical environment at the time of sampling. Water temperature, dissolved oxygen, specific conductivity, salinity, and pH measurements were taken at one metre increments from the surface (0.2 m from the water surface) to the bottom of the water column.

Prior to the start of the surveys, the YSI 600QS multi-meter was cleaned and calibrated by an YSI-authorised service centre. Continued calibration verification was conducted approximately every two to three days in the field and recalibration was performed once per week or if any parameter was found to be outside of the acceptable range during verification.

Additionally, a secchi disk was used to estimate water clarity. This small contrasting disk is lowered into the water and the depth at which it is no longer visible provides a consistent estimate of the clarity of the water.

9.5 Results and Discussion

Detailed descriptions of the morphology and physical properties of the study area are presented in the River Morphology and Physical Oceanography baseline report (Golder, 13514950200.503/B.0, 2013). In the context of the aquatic ecological characterisation within the study area LSA, two general habitat types characterised the sampling stations: habitats representative of the River Cacheu (Stations 1 to 10), and habitats representative of the coastal estuary (Stations 11 to 17). These are detailed in the River Cacheu Aquatic Ecology Baseline Study (Golder 13514950200.508/B.0, 2014). This section summarises the River Cacheu element of the study.

9.5.1 River Cacheu Stations

Golder surveyed approximately 160 km of river, and for much of its length from Farim to Cacheu (approximately 140 km), the River Cacheu has a mangrove-dominated shoreline. With a tidal range of approximately 1.5 to 2.0 m (Golder 13514950200.503/B.0, 2013), the sediments at the roots of the mangroves are regularly exposed during low tides. Many small crabs and other macroinvertebrates inhabit these intermittently exposed mudflat habitats.

Within the river itself, exploratory sediment grab samples collected using the petite ponar grab sampler were used to characterise the river and estuarine sediments and to identify sediments (habitats) suitable for supporting benthic communities. These grab samples showed that once away from the nearshore riparian area, sediments quickly became coarse and unsuitable for benthic grab sampling. As such, the silt deposits near the mangrove shorelines were selected for sampling. This area of softer, muddy substrate varied slightly in width among river stations, but generally was restricted to 5 to 10 m adjacent to the edge of the mangrove roots.

The trawl net deployed within the main body of the river provided information regarding the characteristics of the deeper river substrates. When the trawl net was retrieved, it typically was relatively clean (i.e., not muddy) and had very little debris (such as leaves or sticks). This suggested that the river bottom at the depths where the trawl net was deployed was firm with little depositional sediments or organic material. Considering the strong currents during both the rising and falling tides, these observations are consistent with the morphological characteristics described in the river morphology report (Golder, 13514950200.503/B.0, 2013). Furthermore, the field team did not experience any snags with the trawl net, indicating a lack of bottom structures in the main body of the river.

This relatively consistent river morphology facilitated the deployment of all gear types at all stations in the River Cacheu (Stations 1 to 10; Drawing 550-9.1).

9.5.2 Water Quality

The water quality measurements collected during the dry and wet season aquatic ecology baseline study are summarised in Appendix F1.

Water temperatures were relatively consistent throughout the study area, ranging from 27.6 to 30.6°C during the dry season and 27.6 to 29.6°C during the wet season for the length of the river and estuary. Based on the data collected, the river and estuary do not appear to be thermally stratified. The stations sampled ranged in depth from approximately 4.4 to 13.6 m in the river; the coastal estuary stations ranged in depth from 3.9 to 14.1 m (measured at the time of sampling).

During the dry season, salinity ranged from 2.4 parts per thousand (ppt) at Station 1 (upstream of Farim) to 4.9 ppt at Station 6 in the vicinity of the mine (Figure 4). The salinity gradually increased, ranging from 12.6 to 18.0 ppt at Stations 7 and 8, respectively (near Canja). Downstream of the Sao Vicente Bridge (Stations 9 to 17) the salinity ranged from 31.4 to 36.6 ppt (full strength seawater).

During the wet season, salinity ranged from 3.6 ppt at Station 1 to 7.2 ppt at Station 6, from 12.5 to 16.8 ppt at Stations 7 and 8 respectively, and from 21.5 to 30.6 ppt at Stations 9 to 17.

Dissolved oxygen (DO) was >4.5 milligrams per litre (mg/L) at all stations during the dry season, except at Stations 7 and 8, where lower DO levels were recorded (2.8 to 3.85 mg/L). The DO during the wet season was >4.3 mg/L at all stations, except at Stations 7 and 8, where lower DO levels were again recorded (2.7 to 3.0 mg/L). Stations 9 and 10 slowly increased in DO (3.6 to 4.1mg/L). The upstream and the estuarine stations had the highest DO levels (4.9 to 5.2 mg/L). Most animals and plants can grow and reproduce unimpaired when the DO levels exceed 5 mg/L. When levels drop to between 3 and 5 mg/L, some organisms often become stressed. If levels fall below 3 mg/L, a condition known as hypoxia, mobile species will move elsewhere and those that are unable to move can die.

The water was highly turbid with a water visibility of 1.1 m or less at all stations; during the wet season the lowest water visibilities were recorded (down to 0.2 m). Tidal currents were relatively high throughout the study area (Golder Associates Ltd, 2013), in particular in the estuary.

9.5.3 Summary of Finding

The River Cacheu and estuary are in a relative pristine state. The majority of the mangrove and beach shorelines are undisturbed and the fish tissue analysis shows that the system is not contaminated from anthropogenic sources. PAHs were not detected in any of the tissue samples, indicating the lack of fossil fuel use in the area. Methyl mercury was not detected in any of the fish tissues, indicating that mercury methylation is not likely to occur in this aquatic system.

The aquatic biology ecosystem is driven primarily by the natural wet and dry season fluctuations resulting in nutrient and sediment transport to the coastal areas. The aquatic system is deep and affected by tides throughout its length. The river and estuary are highly turbid with strong currents. Shellfish and other invertebrates reproduce throughout the length of the river and estuary as shown by the zooplankton data. There was a lack of fish eggs and larvae in the main body of the river and estuary, and this was observed during both the dry and wet seasons. The fine mesh used for the zooplankton tows was fine enough to collect very small species (such as rotifers) and therefore clearly documents that the main body of the River Cacheu is not the primary habitat for fish reproduction. It is likely that the mangrove ecosystems along the tributaries or permanently inundated mangrove zones serve as nursery areas for fish.

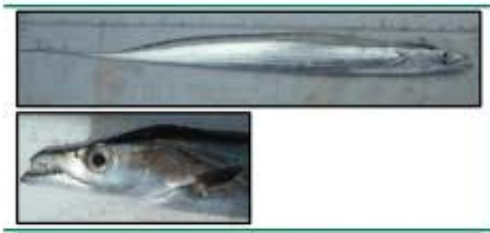
The highest diversity of fish and invertebrates (infaunal and water column) was observed in the more saline stations. Signs of seagrasses were not observed at or in the vicinity of the stations sampled throughout the length of the river and estuary studied. The naturally high turbidity and fluctuating salinity are most likely the cause for the lack of seagrasses in the estuarine stations sampled.

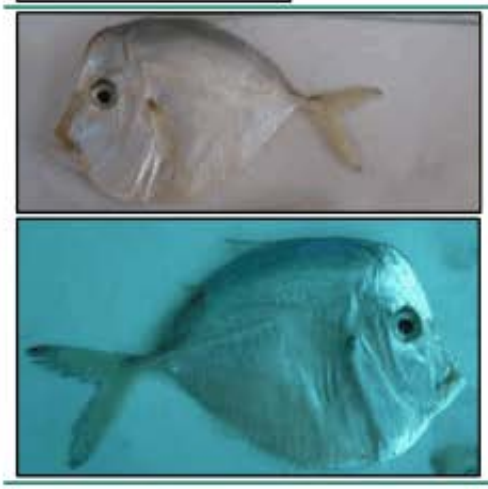
9.5.4 General Biota

The following series of photographs illustrates the types of fish and invertebrates collected during the baseline surveys. Quantitative data are presented in Sections 9.5.8 and 9.5.9.

Table 9.2: Fish and Invertebrates Collected

Examples of Fish Species Sampled	
	Family: Dasyatidae **Species:** *Dasyatis margaritella* **Trophic Level:** Mid-level omnivore

Examples of Fish Species Sampled	
	**Family:** Trichiuridae **Species:** *Trichiurus lepturus* **Trophic Level:** Mid-level omnivore
	Family: Polynemidae **Species:** *Galeoides decadactylus* **Trophic Level:** Mid-level omnivore
	Family: Polynemidae **Species:** *Pentanemus quinquarius* **Trophic Level:** Mid-level omnivore
	Family: Polynemidae **Species:** *Polydactylus quadrifilis* **Trophic Level:** Mid-level omnivore

Examples of Fish Species Sampled	
	Family: Carangidae **Trophic Level**: Mid-level omnivore
	**Family:** Carangidae **Species:** *Selene dorsalis* **Trophic Level:** Mid-level omnivore
	Family: Sciaenidae **Species:** *Pseudotolithus brachygnathus* **Trophic Level:** Mid-level omnivore

Examples of Fish Species Sampled	
	Family: Sciaenidae **Species:** *Pseudotolithus elongatus* **Trophic Level:** Mid-level omnivore
	Family: Sciaenidae **Species:** *Pseudotolithus senegalensis* **Trophic Level:** Mid-level omnivore
	Family: Sciaenidae **Species:** *Pseudotolithus typus* **Trophic Level:** Mid-level omnivore
	Family: Haemulidae **Species:** *Plectorhinchus macrolepis* **Trophic Level:** Mid-level omnivore

Examples of Fish Species Sampled	
	Family: Haemulidae **Species:** *Brachydeuterus auritus* **Trophic Level:** Mid-level omnivore
 	Family: Haemulidae **Species:** *Pomadasys peroteti* **Trophic Level:** Low-level omnivore
	Family: Gerreidae **Species:** *Eucinostomus melanopterus* **Trophic Level:** Low-level omnivore
	Family: Ariidae **Species:** *Arius gigas* **Trophic Level:** Mid-level omnivore
	Family: Paralichthyidae **Species:** *Citharichthys stampflii* **Trophic Level:** Mid-level omnivore

Examples of Fish Species Sampled	
	Family: Soleidae **Species:** *Synaptura lusitanica* **Trophic Level:** Low-level omnivore
	Family: Cynoglossidae **Species:** *Cynoglossus senegalensis* **Trophic Level:** Low-level omnivore
	Family: Drepaneidae **Species:** *Drepane africana* **Trophic Level:** Low-level omnivore
	Family: Monodactylidae **Species:** *Monodactylus sebae* **Trophic Level**: Low-level omnivore

Examples of Fish Species Sampled	
	Family: Tetraodontidae **Species:** *Ephippion guttifer* **Trophic Level:** Low-level omnivore
	Family: Tetraodontidae **Species:** *Lagocephalus laevigatus* **Trophic Level:** Low-level omnivore
	Family: Mugilidae **Species:** *Liza grandisquamis* **Trophic Level:** Low-level omnivore
	Family: Clupeidae **Species:** *Ethmalosa fimbriata* **Trophic Level:** Planktivore

Examples of Fish Species Sampled	
	Family: Pristigasteridae **Species:** *Ilisha Africana* **Trophic Level**: Planktivore
	Family: Clupeidae **Species:** *Pellonula leonensis* **Trophic Level:** Low-level omnivore
	Family: Clupeidae (larvae)
	Family: Poeciliidae **Species:** *Aplocheilichthys spilauchen* **Trophic Level:** Low-level omnivore
	Family: Gobiidae **Species:** *Gobionellus occidentalis* **Trophic Level:** Low-level omnivore

Examples of Fish Species Sampled	
	Family: Gobiidae **Species:** *Porogobius schlegelii* **Trophic Level:** Low-level omnivore
	Family: Eleotridae **Species:** *Butis koilomatodon* **Trophic Level:** Low-level omnivore
	Family: Batrachoididae **Species:** *Batrachoides liberiensis* **Trophic Level:** Mid-level omnivore
	Superorder: Elopomorpha (leptocephalus)

Examples of Invertebrate Species Sampled	
	Family: Portunidae **Species:** *Callinectes pallidus*
	Family: Pisidae **Species:** *Herbstia sp.*
	Family: Paguridae

Examples of Invertebrate Species Sampled	
	Family: Xanthidae
	Family: Penaeidae **Species:** *Farfantepenaeus notialis*
	Family: Penaeidae **Genus:** *Parapenaeopsis* sp.
	Infraorder: Caridea **Genus:** *Alpheus* spp.

Examples of Invertebrate Species Sampled	
	Infraorder: Caridea **Genus:** *Macrobrachium* spp.
	Infraorder: Caridea **Genus:** *Plesionika* spp.
	Family: Squillidae **Genus:** *Squilla* sp.
	Super-Order: Decabrachia **Order:** Sepiida **Family:** Sepiidae
	Super-Order: Decabrachia **Order** Teuthida **Family:** Loliginidae

Examples of Invertebrate Species Sampled	
	Order: Echinoida
	Family: Melongenidae **Species:** *Pugilina morio*

Additional Species Observed but not Sampled	
	Family: Ocypodidae **Common Name:** Fiddler Crab
	Family: Physaliidae **Species:** *Physalia physalis* **Common Name:** Portuguese Man-of-War Jellyfish

Additional Species Observed but not Sampled	
	Class: Scyphozoa **Common Name:** Unknown Jellyfish

9.5.5 Phytoplankton and Zooplankton

Phytoplankton samples were collected near the water surface and Appendix F2 presents these data by phylogenetic division, genus and species, as well as densities (number of plankton cells per millilitre), and biovolume (micrometre^3 per litre).

The relative contributions of the biovolume of freshwater/brackish and marine phytoplankton taxa as a function of location (station) and season are presented in Figure 9.28 and Figure 9.29.

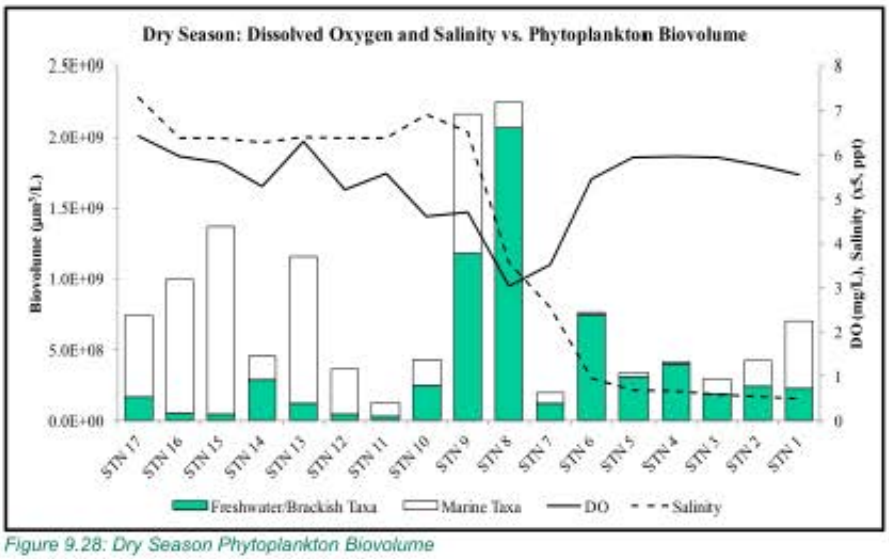


Figure 9.28: Dry Season Phytoplankton Biovolume

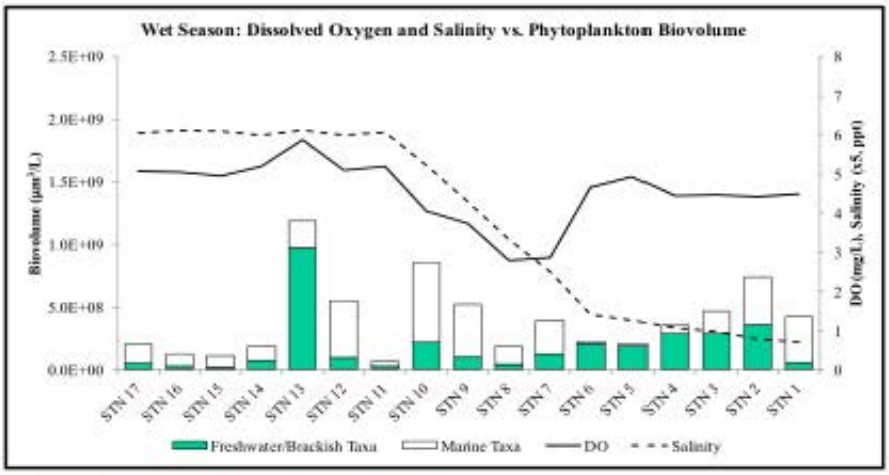


Figure 9.29: Wet Season Phytoplankton Biovolume

Salinity and DO concentrations are superimposed over the phytoplankton biovolume in Figures 9.28 and 9.29. Regardless of season, diatoms were the overwhelming dominant algal division observed in all the stations. During the dry season, phytoplankton composition at Stations 1 through 8 was dominated by freshwater/brackish species which became progressively less dominant downstream in Stations 9 through 17. A large peak in phytoplankton biovolume was noted in Stations 8 (mostly freshwater/brackish taxa) and 9 (approximately equal portions of freshwater/brackish and marine taxa) during the dry season and coincided with a transitional zone of decreasing salinity and low DO.

During the wet season, the distribution of freshwater/brackish and marine phytoplankton taxa differed from the pattern described for the dry season. Freshwater/brackish phytoplankton biovolume dominated at most stations and the large peak noted in the dry season was not observed during the wet season. The zone of transition for salinity (noted in the dry season near Station 9) was pushed further downstream to Station 11 during the wet season.

It is important to note that marine species are found up to Station 1 during both seasons. The phytoplankton biovolume was significantly higher during the dry season in the estuary as compared to the wet season.

9.5.6 Chlorophyll-a

Understanding phytoplankton population and distribution enables researchers to draw conclusions about the health of a waterbody. A waterbody's 'carrying capacity' or its ability to support productive and diverse populations of flora and fauna, including highly valued species, depends largely on how well phytoplankton meet the nutritional needs both in quantity and quality of the various consumers (fish and invertebrates). Often, phytoplankton forms the base of a system's food web, linking nutrients and sunlight energy with forage fish and bottom-dwelling invertebrates. Chlorophyll is bound within the living cells of algae and other phytoplankton found in surface water and is a key biochemical component for photosynthesis.

Chlorophyll is used as an indicator of the measurement and distribution of microscopic living plant matter. Chlorophyll-a is the most abundant form of chlorophyll and is used in oxygenic photosynthesis. For the most part, chlorophyll-a gives plants their green colour and it is the primary photosynthetic pigment in algae and cyanobacteria (blue-green algae). From a water quality perspective, chlorophyll-a is considered one of the best available and most direct measures of the amount and quality of phytoplankton in aquatic systems. It can also be used to predict the potential for phytoplankton blooms which can lead to reduced water clarity and low DO.

Surface waters with high chlorophyll levels are typically nutrient rich with nitrogen and phosphorus. Chlorophyll levels can be tracked in surface water and, with time, can be used to characterise waterbodies. Characterisations can be used for the indirect monitoring of indicator pollutants including phosphorus and

nitrogen. Nutrient-rich waters can lead to algal growth or blooms. When algal blooms crash and die in response to changing environmental conditions they deplete DO levels. Algal blooms are a primary cause of fish kills and can create conditions that are toxic to fish, wildlife, livestock, and humans. It is possible that the high levels of phytoplankton at Stations 9 and 10 (and low DO levels in that section of the river) during the dry season could be representative of an algal bloom in that region of the river around the time of sample collection. These naturally occurring conditions are important to document during a baseline study. It is important during a baseline study to document that these conditions can occur naturally as they may be incorrectly perceived to occur as the result of the project.

Studying chlorophyll levels in marine systems can also help to track and predict algal blooms. Nutrient enrichment of waterbodies can lead to increased production of organic matter resulting in low levels of DO that can eventually kill marine life. Rivers and streams can be monitored for excessive growth of phytoplankton due to high concentrations of plant nutrients.

Figure 9.30 presents the chlorophyll-a measured from water samples during the dry and wet seasons. These data provide baseline measurements for the River Cacheu and estuary.

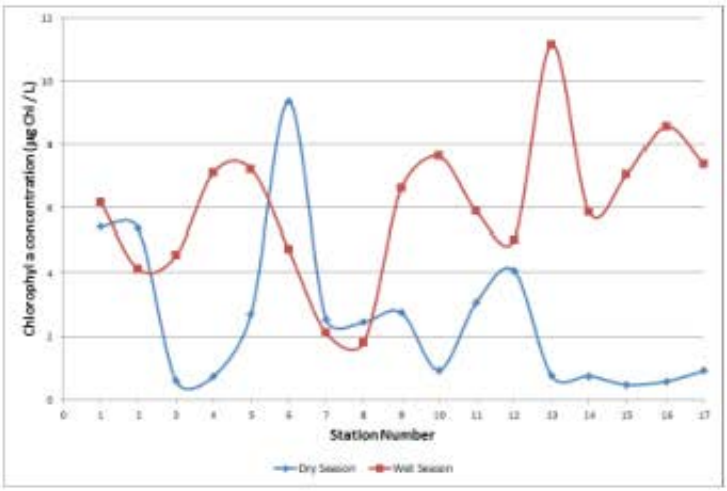


Figure 9.30: Average chlorophyll a concetrations during the wet and dry seasons

9.5.7 Zooplankton

Zooplankton were collected from the whole water column (from near the bottom to the water surface) because zooplankton can migrate within the water column at different times of the day. Appendix F3 presents the zooplankton species collected by division and down to the lowest practical phylogenetic level and/or life stage. Densities (number of individuals per litre) and species biomass (µg dry weight per litre) were also estimated for each species and life stage collected. These data are important to document baseline conditions during the wet and dry seasons for the river and estuary area prior to the development of the mine. Figures 9.31 and 9.32 summarise the zooplankton biomass for the dry and wet season and their relationship to salinity and DO.

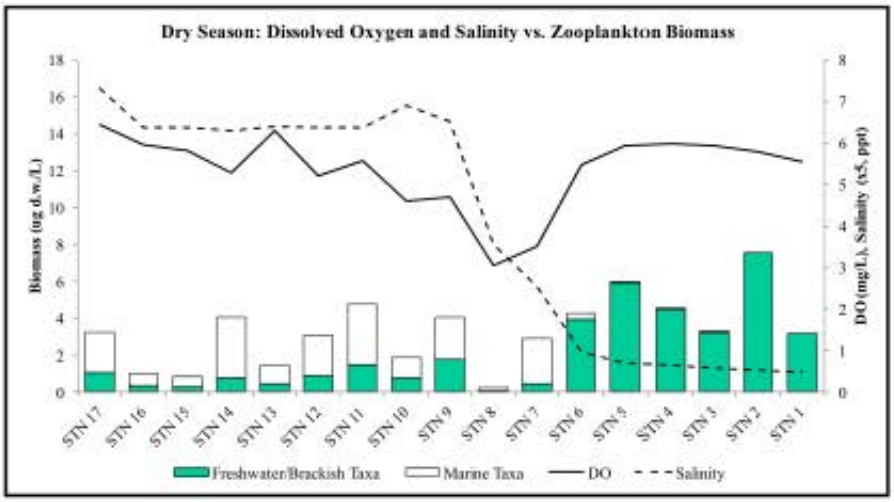


Figure 9.31: Dry Season Zooplankton Biomass

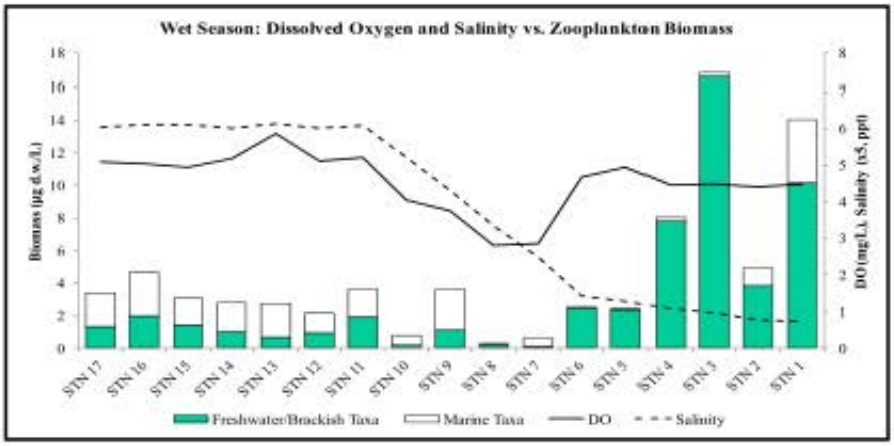


Figure 9.32: Wet Season Zooplankton Biomass

The majority of the biomass of the zooplankton community was composed of calanoid copepods for both seasons. During both the dry season and wet season, zooplankton biomass at the upstream portions of the river (Stations 1 to 6) was by dominated by freshwater / brackish taxa while marine forms were more dominant at downstream locations (Stations 7 to 17). Higher zooplankton biomass was noted at the upstream stations during both the dry season (mean of 4.16 µg dry weight/L) and wet season (mean of 5.32 µg dry weight/L) when compared to the downstream stations (means of 1.39 and 1.49 µg dry weight/L, respectively, for the dry and wet seasons).

Similar to the patterns described for phytoplankton, the freshwater/brackish and marine zooplankton community demonstrated a clear upstream / downstream taxonomic separation in the transition zone in the vicinity of Stations 7 and 8 where the salinity started to increase. Marine zooplankton species dominate seaward from Station 7 for both seasons. The zooplankton data appear to show a sharp decline in zooplankton density in areas of the river where the DO drops significantly, such as Station 8 during the dry season (DO 2.8 to 3.1 mg/L) and at Stations 7 and 8 during the wet season (DO 2.7 to 3.0 mg/L). Aquatic species are very sensitive to DO levels in water.

An assessment of zooplankton grazing pressure on the phytoplankton community was also performed by comparing the ratios of zooplankton biomass (expressed as estimate of carbon content) to phytoplankton biovolume (expressed as estimate of carbon content) for each station. These estimates are provided in Table 9.3. Higher ratios of zooplankton to phytoplankton were usually observed during the wet season as compared to the dry season, suggesting that zooplankton grazing pressure on phytoplankton is more intense during the wet season. The high ratios observed at Station 11 are the result of the low phytoplankton population at that location.

Table 9.3: Mean Ratio of Zooplankton Carbon Content to Phytoplankton Carbon Content/10^6 for the Dry and Wet Seasons

Ratio C-zoop to C-phyto/10^6		
	Dry Season	Wet Season
STN 17	0.005	0.014
STN 16	0.001	0.061
STN 15	0.001	0.044
STN 14	0.011	0.019
STN 13	0.001	0.003
STN 12	0.008	0.004
STN 11	0.037	0.087
STN 10	0.003	0.001
STN 9	0.001	0.006
STN 8	0.000	0.002
STN 7	0.007	0.001
STN 6	0.002	0.008
STN 5	0.008	0.007
STN 4	0.005	0.009
STN 3	0.009	0.016
STN 2	0.016	0.005
STN 1	0.009	0.053

One of the most critical observations made using the dry season data was that the zooplankton samples were virtually devoid of fish eggs and larvae for the length of the river and estuary. Invertebrate developmental stages (e.g., veliger, trocophore larvae, zoea) were found throughout the length of the river and estuary. The zooplankton was dominated by copepods, but a large number of bivalves, polychaetes, decapods, hydrozoan, gastropods, tunicates, and rotifers were also identified making up the bulk of the zooplankton. It appears that invertebrates actively reproduce throughout the length of the river and estuary, while fish reproduction was not evident from the sampling efforts using very fine mesh plankton tows. This was observed in the main body of the river and the estuary.

Based on the dry season observations, the taxonomic laboratory conducted full sample scans for ichthyoplankton (fish eggs and larvae, with no sub-sampling) during the wet season. These data are included in Appendix F3 and support the findings of the dry season. Almost no fish eggs or larvae were found in the river and estuarine samples. Densities at the upstream stations (Stations 1 to 7) ranged from 0 to 0.067 organisms per litre of water. Stations 8 to 11 had no ichthyoplankton specimens. Stations 12 to 16 had from 0.005 to 0.035 organisms per litre of water in the estuary, while Station 17 had 0 organisms per litre. This is noteworthy in that the results suggest that the main body of the river and estuary during the periods of sampling are not significant nursery areas for fish eggs and larvae. It is likely that the broad mangrove forests and tributaries to the River Cacheu serve as the primary nursery areas.

9.5.8 Benthic Invertebrates

The benthic macroinvertebrate data are included in Appendix F4, and the community indices are summarised in Tables 9.4 and 9.5. The dry season data show that the number of benthic taxa and diversity increases as the system becomes more saline, and stations 12 to 17 appear to typically have a higher number of taxa and higher diversity. The total number of organisms per square meter is generally low throughout the system, and this was observed for both seasons.

Table 9.4: Dry Season Benthic Assessment Results (pooled)

Station	STN 1BG	STN 2BG	STN 3BG	STN 4BG	STN 5BG	STN 6BG	STN 7BG	STN 8BG	STN 9BG	STN 10BG	STN 11BG	STN 12BG	STN 13BG	STN 14BG	STN 15BG	STN 16BG	STN 17BG
Replicates Pooled	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Shannon Diversity Index (H')	1.279	1.972	0	2.069	1.741	1.671	1.04	1.732	1.212	1.584	1.677	3.3	2.444	3.554	2.862	2.74	3.284
Base e: H' = [Σ (ni / n) * ln(ni / n)]																	
Pielou's Evenness (J')	0.615	0.948	0	0.942	0.792	0.672	0.946	0.89	0.552	0.721	0.936	0.779	0.882	0.858	0.842	0.9	0.91
J' = H' / H'max																	
McIntosh's Dominance (M)	0.41	0.864	0	0.849	0.615	0.535	0.775	0.732	0.365	0.513	0.813	0.762	0.799	0.837	0.791	0.838	0.864
M = (n - √[Σ n 2]) / (n - √n)																	
Margalef's Richness Index (D	2.148	2.919	0	3.031	2.114	2.525	1.443	2.216	2.035	2.184	2.276	11.249	4.328	10.675	6.231	5.625	7.961
D = (S - 1) / ln(N)																	
Number of Taxa	8	8	1	9	9	12	3	7	9	9	6	69	16	63	30	21	37
Number of Genera	8	8	1	9	9	12	3	7	9	9	6	68	16	61	27	20	36

Table 9.5: Wet Season Benthic Assessment Results (pooled)

Station	STN 1BG	STN 2BG	STN 3BG	STN 4BG	STN 5BG	STN 6BG	STN 7BG	STN 8BG	STN 9BG	STN 10BG	STN 11BG	STN 12BG	STN 13BG	STN 14BG	STN 15BG	STN 16BG	STN 17BG
Replicates Pooled	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Shannon Diversity Index (H')	1.609	1.51	2.05	1.401	2.632	1.379	0.271	0.868	1.013	2.253	1.229	3.183	1.792	2.458	3.438	3.391	3.101
Base e: H' = [Σ (ni / n) * ln(ni / n)]																	
Pielou's Evenness (J')	0.827	0.776	0.89	0.72	0.818	0.769	0.246	0.79	0.63	0.795	0.632	0.781	1	0.596	0.85	0.854	0.865
J' = H' / H'max																	
McIntosh's Dominance (M)	0.644	0.532	0.738	0.495	0.757	0.537	0.072	0.495	0.417	0.667	0.46	0.722	1	0.512	0.831	0.826	0.821
M = (n - √[Σ n 2]) / (n - √n)																	
Margalef's Richness Index (D	2.003	1.576	2.531	1.662	5.04	1.265	0.572	1.116	1.125	4.111	1.558	10.46	2.791	9.921	9.907	9.805	7.418
D = (S - 1) / ln(N)																	
Number of Taxa	7	7	10	7	25	6	3	3	5	17	7	59	6	62	57	53	36
Number of Genera	7	7	10	7	24	6	3	3	5	17	7	57	6	60	55	52	31

For the wet season, Stations 12 to 17 (with the exception of Station 13) had higher number of taxa and higher diversity than the more upstream stations. Of the remaining upstream stations, Stations 5 and 10 had the highest number of taxa and diversity (Table 9.5). The wet season data show a higher number of taxa than the dry season in the more saline stations.

For both seasons, benthic macroinvertebrate diversity tends to be highest in the more saline regions of the estuary (Stations 12 to 17), and lower in the mid- to upper-reaches of the sampled portions of the river. The observed pattern in invertebrate diversity may be attributed to several primary interacting factors: flow, sediment stability (a function of particle size distribution), food availability, and salinity.

The difference in freshwater inflow between the dry and wet season affects the benthic community structure, alters the availability of sediment types, and changes water chemistry (e.g., salinity, nutrients). The dynamic shifts that occur between freshwater and estuarine benthic species in a tidal river are driven by the osmotic tolerances of the individual species. In general, estuarine species are better adapted to these changes in salinity than are freshwater species and are more tolerant of these salinity shifts.

Sediment type significantly affects the type of benthic community present. Water quality parameters, such as nutrients and metals, can become more concentrated in sediment pore water with lower flows. Sediment loading increases during periods of higher flow and can bury and suffocate benthic communities. Sediments dominated by clays and silts tend to be less stable. In general, increased substrate stability and presence of organic detritus as a food resource lead to an increase in invertebrate abundance and diversity. Reduced sediment stability in the upper reaches of the river, where silts and clays are prevalent, may explain at least in part the lower diversity in those areas (Stations 1 to 9).

The influence of salinity on macroinvertebrate community composition can be seen in its correlation with number of taxa observed. There is a well-known relationship between estuarine salinity and numbers of taxa. Taxa richness is highest in full strength seawater. Marine species decline in richness as salinity decreases and this shift is accompanied by the appearance of some opportunistic estuarine species that tolerate a wide range of salinities. Often between salinities of 5 and 10 ppt, macroinvertebrate taxa richness reaches a nadir, with most species captured being estuarine specialists with some freshwater taxa also present. As salinity approaches 0 ppt, taxa richness again increases as freshwater taxa begin to dominate.

9.5.9 Fish and Macroinvertebrates

Fish and macroinvertebrates were sampled using a wide variety of methods in order to characterise the communities in the River Cacheu and estuary. The number of organisms collected per station varied, but there appeared to be an overall trend of higher numbers near the estuary. Several species were found throughout the aquatic system and they included shrimp species, blue crabs and *Ilisha africana* (small planktivorous fish). Some estuarine species such as sea urchins were found only in the more saline areas of the estuary. A moderate number of fish species were captured throughout the river although there was an absence of significant fish eggs and larvae (as previously noted).

Table 9.6 summarises the species list for the dry season and the numbers collected using all gear types and Table 9.7 summarises lengths and weights. Tables 9.8 and 9.9 show similar data for the wet season.

Table 9.6: Fish and Macroinvertebrate (Water Column) Species Richness – Dry Season Monitoring
(Count of Species by Station)

Lowest Taxonomic ID	STN 1	STN 2	STN 3	STN 4	STN 5	STN 6	STN 7	STN 8	STN 9	STN 10	STN 11	STN 12	STN 13	STN 14	STN 15	STN 16	STN 17	Total
Alpheidae										1								1
Aplocheilichthys spilauchen								2										2
Arius gigas			1						3						3	1	14	22
Batrachoididae										1								1
Brachydeuterus auritus								1			2		1		7		1	12
Callinectes sp.	5	2	1	6	1	1	2	1	4	5		1		2	1	4		36
Carangidae															1			1
Caridea		1	3	10	8	1		45		3	16			13	3	19		122
Citharichthys stampfli														2		2		4
Clupeidae					1						1	4	2		1	2		11
Cynoglossus senegalensis				1					15	1					3	4	4	28
Drepane africana															1			1
Echinoida														2	2	1		5
Ephippion guttifer																1	3	4
Ethmalosa fimbriata	1																	1
Ethmalosa sp.	1																	1
Eucinostomus melanopterus											1							1
Galeiodes decadactylus																8		8
Gobiidae			1															1
Ilisha africana							9	1			22	15		18	9		22	96
Lagocephalus laevigatus														1			1	2
Leptocephalus											1			1				2
Liza falcipinnis	1																	1
Liza grandisquamis	1			2	1	1		5	1									11
Loliginidae														1	4		1	6
Monodactylus sebae			5			1	1											7
Pellonula sp.					4													4
Penaeidae	33		2	1		1	4	1	2	1				11	11		1	68
Penaeoidea																9	17	26
Pentanemus quinquarius																	1	1
Plectorhinchus macrolepis							1											1
Polydactylus quadrifilis	1	14							1	1								17
Pomadasys peroteti																	2	2
Pseudotolithus brachygnathus															1	5	4	10
Pseudotolithus elongatus		3	4		13			9	2									31
Pseudotolithus senegalensis								1	9	11				11	4		7	43
Pseudotolithus sp.	2						12											14
Selene dorsalis											1							1
Stomatopoda														2	1	1	1	5
Trichiurus lepturus											1			1		2		4
Total	**45**	**20**	**17**	**20**	**28**	**5**	**29**	**66**	**37**	**24**	**45**	**20**	**4**	**65**	**52**	**59**	**79**	**615**

Table 9.7: Dry Season Fish and Macroinverterbrate Average Lengths and Weights

Lowest Taxonomic ID	N [a]	Average length (mm)	Average weight (g)
Alpheidae	1	16	0.5
Arius sp.	22	122	52.8
Batrachoididae	1	40	0.8
Brachydeuterus auritus	12	118	24.5
Callinectes sp.	36	72	51.7
Carangidae	1	11	0.1
Caridea	107 (97)	7	0.5
Citharichthys stampflii	4	105	12.1
Clupeidae	6	48	5.6
Cynoglossus senegalensis	28	234	99.2
Echinoida	4	24	6.2
Ephippidae	1	15	0.2
Ephippion guttifer	4	169	62.1
Ethmalosa fimbriata	1	244	107.0
Ethmalosa sp.	1	91	5.5
Eucinostomus melanopterus	1	143	36.5
Galeiodes decadactylus	8	35	0.8
Gobiidae	1	22	0.1
Ilisha Africana	91 (90)	114	14.8
Lagocephalus laevigatus	2	149	56.4
Leptocephalus	2	44	0.1
Liza falcipinnis	1	321	359.0
Liza grandisquamis	10	157	63.0
Loliginidae	6	24	3.4
Monodactylus sebae	7	117	37.0
Penaeidae	65	18	2.9
Penaeidea	1	43	35.6
Penaeoidea	26	13	1.3
Pentanemus quinquarius	1	196	58.5
Plectorhinchus macrolepis	1	293	270.0
Poeciliidae	2	45	0.8
Polydactylus quadrifilis	17	303	222.0
Pomadasys peroteti	2	150	52.1
Pseudotolithus brachygnathus	10	97	23.1
Pseudotolithus elongatus	30	76	15.9
Pseudotolithus senegalensis	42 (41)	70	16.3
Pseudotolithus sp.	14	75	2.2
Selene dorsalis	1	76	4.8
Sicyonia sp.	7	2	0.03
Stomatopoda	5	75	19.7
Trichiurus lepturus	4	366	58.5

[a] N for weight provided in parentheses if different from N for lengths

Table 9.8: Native Species Expected in Guinea-Bissau and IUCN Red List Status

Order	Family	Species	Occurrence	FishBase name	Name	IUCN Status
Characiformes	Alestidae	*Alestes baremoze*	native	Silversides		
Siluriformes	Amphiliidae	*Amphilius platychir*	native	Mountain barbel		
Siluriformes	Amphiliidae	*Amphilius rheophilus*	native			
Cyprinodontiformes	Poeciliidae	*Aplocheilichthys spilauchen*	native	Banded lampeye		
Siluriformes	Ariidae	*Arius parkii*	native	Guinean sea catfish	Bagre	
Siluriformes	Claroteidae	*Auchenoglanis occidentalis*	native	Bubu		
Cypriniformes	Cyprinidae	*Barbus ablabes*	native			
Cypriniformes	Cyprinidae	*Barbus annae*	native			Vulnerable
Cypriniformes	Cyprinidae	*Barbus macrops*	native	Blackstripe barb		
Cypriniformes	Cyprinidae	*Barbus niokoloensis*	native			Vulnerable, but not listed for GB
Cypriniformes	Cyprinidae	*Barbus pobeguini*	native			
Cypriniformes	Cyprinidae	*Barbus salessei*	native			Vulnerable, but not listed for GB
Cypriniformes	Cyprinidae	*Barbus stigmatopygus*	native			
Osteoglossiformes	Mormyridae	*Brienomyrus brachyistius*	native			
Characiformes	Alestidae	*Brycinus leuciscus*	native			
Characiformes	Alestidae	*Brycinus longipinnis*	native	Longfin tetra		
Characiformes	Alestidae	*Brycinus macrolepidotus*	native	True big-scale tetra		
Characiformes	Alestidae	*Brycinus nurse*	native	Nurse tetra		
Siluriformes	Claroteidae	*Chrysichthys johnelsi*	native			
Siluriformes	Claroteidae	*Chrysichthys maurus*	native			
Pleuronectiformes	Paralichthyidae	*Citharichthys stampfili*	native	Smooth flounder		
Characiformes	Citharinidae	*Citharinus citharus*	native	Moon fish		
Characiformes	Citharinidae	*Citharinus latus*	native			

Order	Family	Species	Occurrence	FishBase name	Name	IUCN Status
Siluriformes	Clariidae	*Clarias anguillaris*	native	Mudfish		
Siluriformes	Clariidae	*Clarias buettikoferi*	native			
Siluriformes	Clariidae	*Clarias salae*	native			
Perciformes	Anabantidae	*Ctenopoma kingsleyae*	native	Tailspot ctenopoma		
Anguilliformes	Ophichthidae	*Dalophis boulengeri*	native			
Myliobatiformes	Dasyatidae	*Dasyatis ukpam*	native	Thorny freshwater stingray		Endangered, but not listed for GB
Characiformes	Distichodontidae	*Distichodus rostratus*	native	Grass-eater		
Siluriformes	Amphiliidae	*Doumea chappuisi*	native			Vulnerable
Perciformes	Eleotridae	*Eleotris vittata*	native			
Elopiformes	Elopidae	*Elops senegalensis*	native	Senegalese ladyfish		
Cyprinodontiformes	Nothobranchiidae	*Epiplatys bifasciatus*	native			
Cyprinodontiformes	Nothobranchiidae	*Epiplatys fasciolatus*	native			
Cyprinodontiformes	Nothobranchiidae	*Epiplatys spilargyreius*	native			
Clupeiformes	Clupeidae	*Ethmalosa fimbriata*	native	Bonga shad	Bonga	
Perciformes	Gerreidae	*Eucinostomus melanopterus*	native	Flagfin mojarra	Peixe-prata	
Perciformes	Gobiidae	*Gobioides sagitta*	native			
Perciformes	Gobiidae	*Gobionellus oceanicus*	native	Highfin goby		
Perciformes	Cichlidae	*Hemichromis bimaculatus*	native	Jewelfish		
Perciformes	Cichlidae	*Hemichromis fasciatus*	native	Banded jewelfish		
Characiformes	Hepsetidae	*Hepsetus odoe*	native	Kafue pike		
Osteoglossiformes	Arapaimidae	*Heterotis niloticus*	native	African bonytongue		
Osteoglossiformes	Mormyridae	*Hippopotamyrus pictus*	native			
Characiformes	Alestidae	*Hydrocynus forskahlii*	native	Elongate tigerfish		

Order	Family	Species	Occurrence	FishBase name	Name	IUCN Status
Osteoglossiformes	Mormyridae	*Hyperopisus bebe*	native			
Characiformes	Distichodontidae	*Ichthyborus quadrilineatus*	native			Near threatened
Perciformes	Eleotridae	*Kribia kribensis*	native			
Perciformes	Eleotridae	*Kribia nana*	native			
Cypriniformes	Cyprinidae	*Labeo coubie*	questionable	African carp		
Cypriniformes	Cyprinidae	*Labeo parvus*	native			
Cypriniformes	Cyprinidae	*Labeo senegalensis*	native			
Clupeiformes	Clupeidae	*Laeviscutella dekimpei*	native	Roundbelly pellonuline		
Perciformes	Latidae	*Lates niloticus*	native	Nile perch		
Mugiliformes	Mugilidae	*Liza falcipinnis*	native	Sicklefin mullet		
Mugiliformes	Mugilidae	*Liza ramada*	questionable	Thinlip grey mullet	Tainha	
Siluriformes	Malapteruridae	*Malapterurus occidentalis*	native			Near threatened
Osteoglossiformes	Mormyridae	*Marcusenius mento*	native			
Osteoglossiformes	Mormyridae	*Marcusenius senegalensis*	native			
Osteoglossiformes	Mormyridae	*Marcusenius thomasi*	native			
Elopiformes	Megalopidae	*Megalops atlanticus*	native	Tarpon		Vulnerable, but not listed for GB
Characiformes	Alestidae	*Micralestes elongatus*	native	Elongated Turkana robber		
Characiformes	Alestidae	*Micralestes occidentalis*	native			
Syngnathiformes	Syngnathidae	*Microphis aculeatus*	native			
Osteoglossiformes	Mormyridae	*Mormyrops anguilloides*	native	Cornish jack		
Osteoglossiformes	Mormyridae	*Mormyrops breviceps*	native			
Osteoglossiformes	Mormyridae	*Mormyrus hasselquistii*	native	Elephant snout		
Osteoglossiformes	Mormyridae	*Mormyrus rume rume*	native	Mormyrids		

Order	Family	Species	Occurrence	FishBase name	Name	IUCN Status
Mugiliformes	Mugilidae	*Mugil cephalus*	native	Flathead grey mullet		
Characiformes	Distichodontidae	*Nannocharax ansorgii*	native			
Perciformes	Gobiidae	*Nematogobius maindroni*	native			
Characiformes	Distichodontidae	*Neolebias unifasciatus*	native			
Clupeiformes	Clupeidae	*Odaxothrissa ansorgii*	native	Ansorge fangtooth pellonuline		
Synbranchiformes	Synbranchidae	*Ophisternon afrum*	native	Guinea swamp eel		
Osteoglossiformes	Notopteridae	*Papyrocranus afer*	native	Reticulate knifefish		
Perciformes	Channidae	*Parachanna obscura*	native			
Characiformes	Distichodontidae	*Paradistichodus dimidiatus*	native			
Siluriformes	Schilbeidae	*Parailia spiniserrata*	native			
Siluriformes	Amphiliidae	*Paramphilius trichomycteroides*	native			
Clupeiformes	Clupeidae	*Pellonula leonensis*	native	Smalltoothed pellonula		
Clupeiformes	Clupeidae	*Pellonula vorax*	native	Bigtoothed pellonula		
Perciformes	Cichlidae	*Pelmatochromis buettikoferi*	native			
Perciformes	Gobiidae	*Periophthalmus barbarus*	native	Atlantic mudskipper		
Osteoglossiformes	Mormyridae	*Petrocephalus bovei bovei*	native			
Osteoglossiformes	Mormyridae	*Petrocephalus levequei*	native			Near threatened
Polypteriformes	Polypteridae	*Polypterus ansorgii*	native	Guinean bichir		
Polypteriformes	Polypteridae	*Polypterus bichir*	native	Nile bichir		
Polypteriformes	Polypteridae	*Polypterus endlicheri*	native	Saddled bichir	Saié	
Polypteriformes	Polypteridae	*Polypterus palmas*	native	Shortfin bichir		
Polypteriformes	Polypteridae	*Polypterus senegalus*	native	Gray bichir		
Perciformes	Haemulidae	*Pomadasys jubelini*	native	Sompat grunt	Cor-cor	

Order	Family	Species	Occurrence	FishBase name	Name	IUCN Status
Perciformes	Gobiidae	*Porogobius schlegelii*	native			
Cyprinodontiformes	Poeciliidae	*Poropanchax normani*	native	Norman's lampeye		
Pristiformes	Pristidae	*Pristis microdon*	native	Largetooth sawfish		Critically Endangered (CR)
Cypriniformes	Cyprinidae	*Raiamas steindachneri*	native			
Characiformes	Alestidae	*Rhabdalestes septentrionalis*	native			
Perciformes	Cichlidae	*Sarotherodon caudomarginatus*	native			
Perciformes	Cichlidae	*Sarotherodon galilaeus*	native	Mango tilapia		
Perciformes	Cichlidae	*Sarotherodon melanotheron*	native	Blackchin tilapia		
Perciformes	Cichlidae	*Sarotherodon occidentalis*	native			
Siluriformes	Schilbeidae	*Schilbe intermedius*	native	Silver catfish		
Siluriformes	Schilbeidae	*Schilbe micropogon*	native			
Siluriformes	Schilbeidae	*Schilbe mystus*	native	African butter catfish		
Cyprinodontiformes	Nothobranchiidae	*Scriptaphyosemion geryi*	native	GÃ©rys killi		
Cyprinodontiformes	Nothobranchiidae	*Scriptaphyosemion guignardi*	native			
Clupeiformes	Clupeidae	*Sierrathrissa leonensis*	native	West African pygmy herring		
Siluriformes	Mochokidae	*Synodontis annectens*	native			
Siluriformes	Mochokidae	*Synodontis ansorgii*	native			
Siluriformes	Mochokidae	*Synodontis nigrita*	native			
Siluriformes	Mochokidae	*Synodontis schall*	native	Wahrindi		
Siluriformes	Mochokidae	*Synodontis waterloti*	native			
Tetraodontiformes	Tetraodontidae	*Tetraodon lineatus*	native	Globe fish		
Perciformes	Cichlidae	*Tilapia brevimanus*	native			

Order	Family	Species	Occurrence	FishBase name	Name	IUCN Status
Perciformes	Cichlidae	*Tilapia buttikoferi*	native			
Perciformes	Cichlidae	*Tilapia guineensis*	native	Guinean tilapia		
Perciformes	Cichlidae	*Tilapia louka*	native			
Perciformes	Cichlidae	*Tilapia zillii*	native	Redbelly tilapia		
Perciformes	Cichlidae	*Tylochromis jentinki*	native			
Perciformes	Cichlidae	*Tylochromis sudanensis*	questionable			
Perciformes	Gobiidae	*Yongeichthys thomasi*	native			

Table 9.9: Fish and Macroinvertebrate (Water Column) Species Richness – Wet Season Monitoring (Count of Species by Station)

Lowest Taxonomic ID	STN 1	STN 2	STN 3	STN 4	STN 5	STN 6	STN 7	STN 8	STN 9	STN 10	STN 11	STN 12	STN 13	STN 14	STN 15	STN 16	STN 17	Species Total
Arius gigas	3								4	2	4	20	1	19	14		18	85
Batrachoides liberiensis										1	1				1			3
Brachydeuterus auritus											1				1		3	5
Butis koilomatodon							1	12		1				2		1		17
Callinectes pallidus	10	13	7	10	9	12	16	15	30	10	4	5	4	14	8	1	4	172
Caridea-*Alpheus* spp.			2	1			2			1								6
Caridea-*Eualus* sp.										1								1
Caridea-*Latreutes* spp.		11	11	11			11	11										55
Caridea-*Macrobrachium* spp.			2															2
Caridea-*Plesionika* spp.		14				1			3	2	23	33	11	27			7	121
Chrysichthys sp.										1								1
Clupeidae											1							1
Cynoglossus senegalensis		4	3						4		1	11	3	1	3	2	2	34
Dasyatis margaritella											2	2		1	4		5	14
Decabrachia-Loliginidae															1			1
Decabrachia-Sepiidae											1	1	1		1	5	1	10

Lowest Taxonomic ID	STN 1	STN 2	STN 3	STN 4	STN 5	STN 6	STN 7	STN 8	STN 9	STN 10	STN 11	STN 12	STN 13	STN 14	STN 15	STN 16	STN 17	Species Total
Drepane Africana											2	2	7	2			1	14
Echinoida												1			2			3
Elopomorpha-*Leptocephalus*								1			1	2		1			1	6
Ephippion guttifer													1	1			3	5
Ethmalosa fimbriata	1																	1
Galeiodes decadactylus							1		1		9	16	20	7	18	1	13	86
Gobionellus occidentalis														2				2
Ilisha Africana											2			2	12	9	7	32
Isopoda-Asellidae								5			5							10
Larvae-Clupeidae												3		5		17		25
Larvae-Scianidae											5		10					15
Majoidea-*Eurynome* spp.											2							2
Majoidea-*Herbstia* spp.																	1	1
Melongenidae												1			2			3
Melongenidae-*Pugilina morio*										1								1
Monodactylus sebae						1												1
Paguridae															2		1	3
Pellonula leonensis				2		1	2	6		1								12
Penaeidae-*Farfantepenaeus notialis*	9	2	1	1	4	7	1			2	29	15	27	26	32	17	9	182
Penaeidae-*Parapenaeopsis* sp.						2												2
Pentanemus quinquarius									1	1	1			2			1	6
Polydactylus quadrifilis	2				1	1		2										6
Pomadasys peroteti																	1	1
Porogobius schlegelii					1	1		4				1						7
Pseudotolithus brachygnathus										1	3	7		5	1		1	18
Pseudotolithus elongates	8		3	2	2	5	10	4	11	11	19	29	21	19	12		22	178
Pseudotolithus senegalensis											7		12	15	9	1	6	50

Lowest Taxonomic ID	STN 1	STN 2	STN 3	STN 4	STN 5	STN 6	STN 7	STN 8	STN 9	STN 10	STN 11	STN 12	STN 13	STN 14	STN 15	STN 16	STN 17	Species Total
Pseudotolithus typus													1					1
Squilla sp.														3	1	1		5
Synaptura lusitanica									2									2
Trichiurus lepturus												1						1
Xanthidae							1	1		1								3
Station Total	**33**	**44**	**29**	**27**	**17**	**31**	**45**	**61**	**56**	**37**	**123**	**150**	**119**	**154**	**124**	**55**	**107**	**1,212**

Table 9.10: Wet Season Fish and Macroinverterbrate Average Lengths and Weights

Lowest Taxonomic ID	N [a]	Average length (mm)	Average weight (g)
Arius gigas	83	119	20.5
Batrachoides liberiensis	3	61	4.5
Brachydeuterus aurifus	5	98	13.8
Butis koilomatodon	17	37	2.7
Callinectes pallidus	172	89	77.9
Caridea-*Alpheus* spp.	6	5	0.5
Caridea-*Eualus* sp.	1	9	0.8
Caridea-*Latreutes* spp.	50	2	0.0
Caridea-*Macrobrachium* spp.	2	20	4.6
Caridea-*Plesionika* spp.	113	8	0.7
Chrysichthys sp.	1	263	163.8
Clupeidae	1	30	0.2
Cynoglossus senegalensis	34	133	29.9
Dasyatis margaritella	13 (7)	200	596.4
Decabrachia-Loliginidae	1	18	1.7
Decabrachia-Sepiidae	10	24	4.3
Drepane africana	14	36	2.2
Elopomorpha-Leptocephalus	6	38	0.1
Ephippion guttifer	5 (4)	182	67.2
Ethmalosa fimbriata	1	98	7.8
Galeiodes decadactylus	84	58	5.6
Gobionellus occidentalis	2	84	2.1
Ilisha africana	31	140	24.1
Isopoda-Asellidae	10	10	0.1
Larvae-Clupeidae	23	23	0.1
Larvae-Scianidae	14	21	0.1
Majoidea-*Eurynome* spp.	2	5	0.1
Majoidea-*Herbstia* spp.	1	10	0.4
Melongenidae	3		1.7
Melongenidae-Pugilina morio	1		80.3
Monodactylus sebae	1	62	5.7
Paguridae	2		11.5
Pellonula leonensis	12	105	9.8
Penaeidae-Farfantepenaeus notialis	168	13	2.1
Penaeidae-*Parapenaeopsis* sp.	2	29	10.9
Pentanemus quinquarius	6	181	39.5
Polydactylus quadrifilis	6	303	278.0
Pomadasys peroteti	1	121	23.9
Porogobius schlegelii	7	50	1.1
Pseudotolithus brachygnathus	18	133	35.8
Pseudotolithus elongatus	169	73	11.2
Pseudotolithus senegalensis	49	100	23.6
Pseudotolithus typus	1	156	29.6
Squilla sp.	5	17	8.0
Synaptura lusitanica	2	115	11.2
Trichiurus lepturus	1	399	30.9
Xanthidae	3	10	0.7

[a] N for weight provided in parentheses if different from N for lengths

Figures 9.33 and 9.34 summarise the presence or absence for the dominant shellfish and fish species in the River Cacheu and estuary.

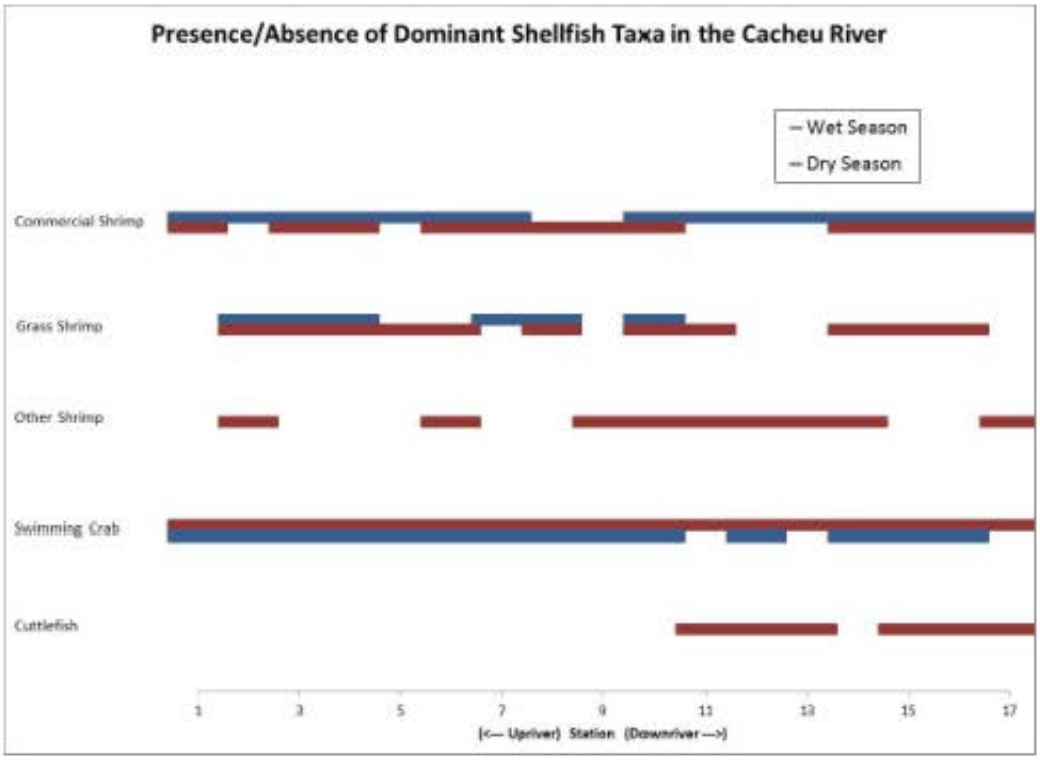


Figure 9.33: Shellfish Presence / Absence

The dominant shellfish are shown in Figure 9.33 and these species are found throughout the river and estuary. The following is a description of these species.

Commercial Shrimp

Primarily in the Family Penaeidae, these shrimp reach a size sufficient for harvest and consumption. Life-cycles vary but frequently include annual migrations between freshwater and marine environments for spawning and foraging. Seagrass beds, mangrove forests and other estuarine habitats such as mud flats, oyster beds, and emergent vegetation all provide valuable nursery areas for these shrimp. These shrimp typically form a substantial portion of the diet of in-shore mid-level omnivores and are therefore an important trophic link between primary production and higher trophic levels. They are an important commercial species in the region.

Grass Shrimp

Primarily in the family Caridea, grass shrimp are small-bodied shrimp, typically not exceeding 3 to 4 cm total length and can be very abundant in productive estuarine waters. Similar to commercial shrimp, they are heavily preyed upon by higher trophic levels.

Swimming Crabs

Blue crabs and other crabs from the family Portunidae are known as 'swimming crabs'. The last walking leg on each side is modified into a paddle-like swimmeret and these species swim can through the water column

as opposed to only crawling. They have distinct strong spines on either end of the carapace. Swimming crabs are harvested by a variety of methods including dip nets and traps and are typically harvested throughout their range.

Cuttlefish

Cuttlefish are cephalopods similar to squid and octopi. They have "broad sac-like bodies with lateral fins" (FAO 1981) and are considered to be among the most intelligent invertebrate with a large brain relative to their body size. They prey on a wide variety of fish and invertebrates, including other cuttlefish. They typically live in high salinity or fully marine environments.

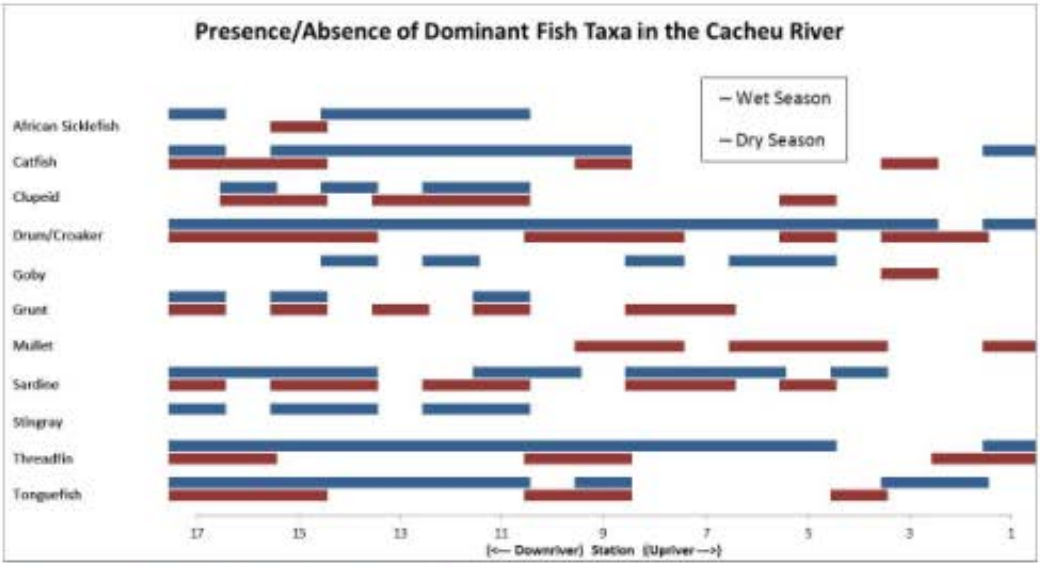


Figure 9.34: Presence / Absence of Dominant Fish Taxa

Figure 9.34 summarises the distribution by season of the dominant fish species. As shown, most species are found in the estuary during both seasons. The following is a description of the most common species.

African Sicklefish (Drepane africana)

The African Sicklefish is a coastal species native to central western Africa, ranging from the Canary Islands and Mauritania to Angola (Desoutter, 1990). Its diet consists primarily of invertebrates (FAO 1981). Though not directly targeted, it is harvested in trawls and purse seines and marketed either fresh or salted (FAO 1981).

Catfish

Catfish of the families Ariidae (primarily marine catfish) and Claroteidae (freshwater) were sampled from the Cacheu river and estuary system. Catfish are generally demersal, swimming and feeding near the bottom of lakes, rivers, estuaries and coastal environments and are locally abundant, particularly in large estuaries (FAO 1981). Catfish are omnivorous, feeding on fish and invertebrates. Species of Ariidae in the region may reach 1.2 m in length (FAO 1981) and are targeted with a wide array of fishing gears. They are of high economic value (FAO 1981).

Clupeids

Clupeids are composed of menhaden, herrings, sardines, and shad. They are planktivorous schooling fish, typically silver in color, that form important links between primary production and higher trophic levels in aquatic environments.

Drum/Croaker

Drum and croaker are in the Sciaenidae family that also includes sea trout. They are higher mid-level omnivores in coastal and estuarine environments, feeding on fish and invertebrates. Many species within the family have inferior (downward-facing) mouths specialized for feeding on benthic invertebrates.

Gobies

Gobies are small-bodied benthic fish that inhabit coastal and estuarine habitats. They are low-level omnivores that primarily feed on benthic invertebrates. They are of little to no commercial value and are likely only consumed if harvested as by-catch of other targeted fisheries

Grunts

Grunts are medium-sized fish in the family Haemulidae. They are mid-level omnivores in estuarine and coastal habitats. They are structure-oriented fish that can be found on reefs, rocky substrates, and mangroves. Grunts frequently form schools around structure but can also be found individually.

Mullet

Mullet are a common coastal and estuarine fish that also ranges into freshwater. They have a high tolerance for large variability in salinities. Mullet are a medium–sized fish (growing to ~50 cm) have generally blunt heads with small terminal mouths. Their diet consists of zooplankton, benthic organisms, and detritus. Mullet frequently form schools in shallow coastal areas and are commonly harvested with seines and cast-nets (FAO, 1981).

Sardine

Sardines are in the family Clupeidae previously discussed.

Stingray

Stingrays are cartilaginous fish similar to sharks. They have compressed bodies and lie virtually flat on sand and mud bottoms, preying on benthic fish and invertebrates. Stingrays are named for the venomous barb on their tails which is used for defense.

Threadfin

Threadfin is a moderately elongate, shallow-water fish that is typically found in turbid water over sand and mud bottoms. They have inferior mouths and feed primarily on benthic invertebrates. Threadfin draw their name from their detached pectoral fin rays which may serve both tactile and sensory functions. They are important commercial fish in Western Africa (FAO 1981).

Tonguefish

Tonguefish are small-bodied flatfish similar in appearance to flounders, however with more elongated bodies. The largest species in the area can reach up to 60 cm in length, though other species are considerably smaller than this. The dorsal and anal fins are confluent with the caudal fin, effectively creating a single fin around the entire body, with the exception of the head area. Tongue fish have very small mouths relative to their body size and feed on small benthic invertebrates.

Appendix F5 includes fish and invertebrate data, and tissue metal concentration charts for representative fish species collected during the dry and wet seasons.

9.5.10 Fish Tissue Analysis

The levels of metals in the tissues analysed are generally low, and methyl mercury was not detected in any of the fish tested (< 5ug/kg; Appendix F6 includes all the fish tissue chemical data). None of the PAHs analysed were detected in any of the fish tissues chemically characterised, and all hydrocarbons were below detection limits. This indicates that the aquatic system is in a relatively pristine condition and is not contaminated with hydrocarbons or heavy metals.

The following charts summarise the combined wet and dry season tissue data for each metal. Appendix F5 also includes individual metal charts per season.

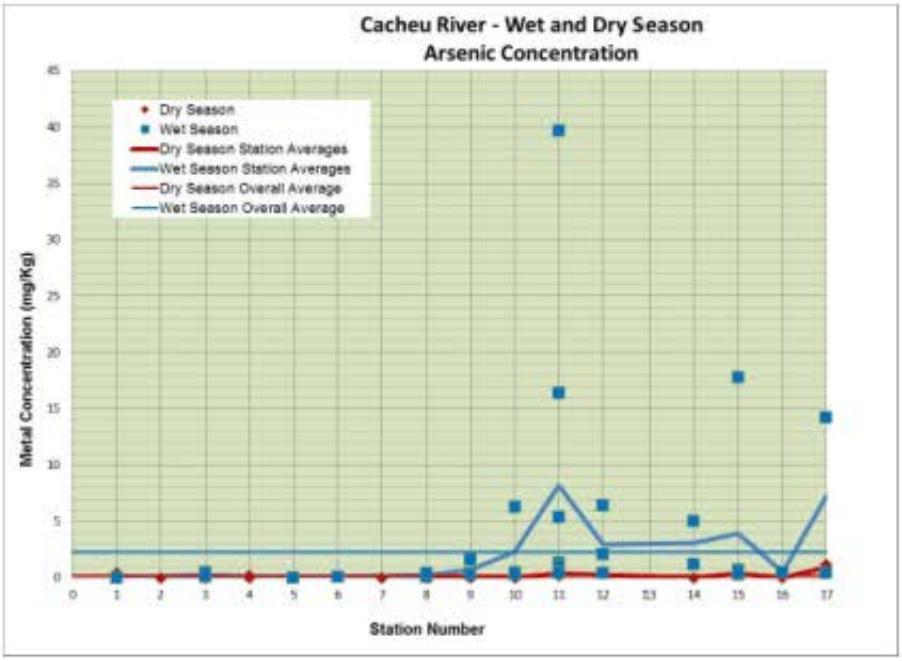


Figure 9.35: Arsenic Concentration (Wet and Dry Seasons)

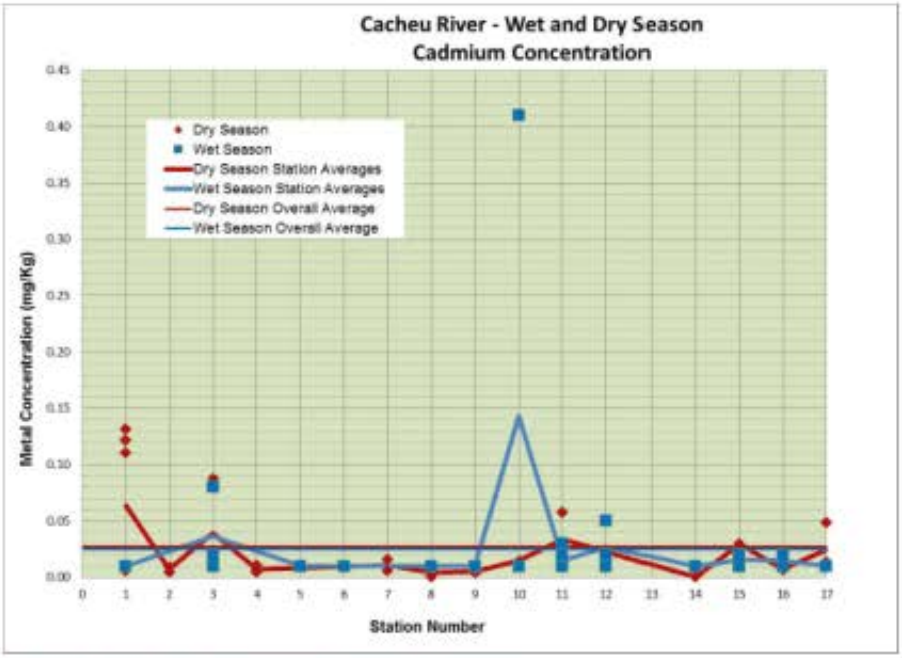


Figure 9.36: Cadmium Concentration (Wet and Dry Seasons)

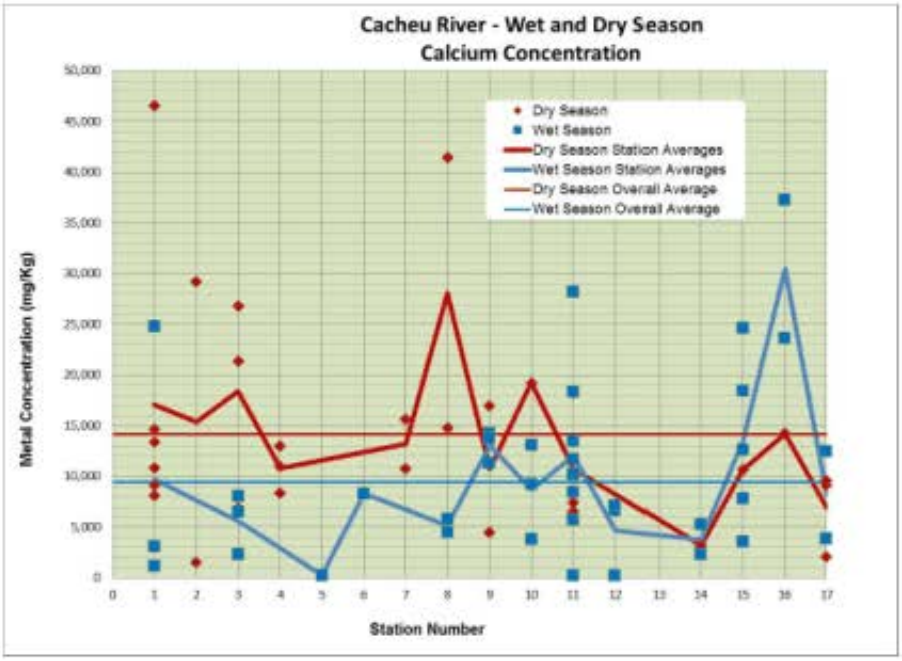


Figure 9.37: Calcium Concentration (Wet and Dry Seasons)

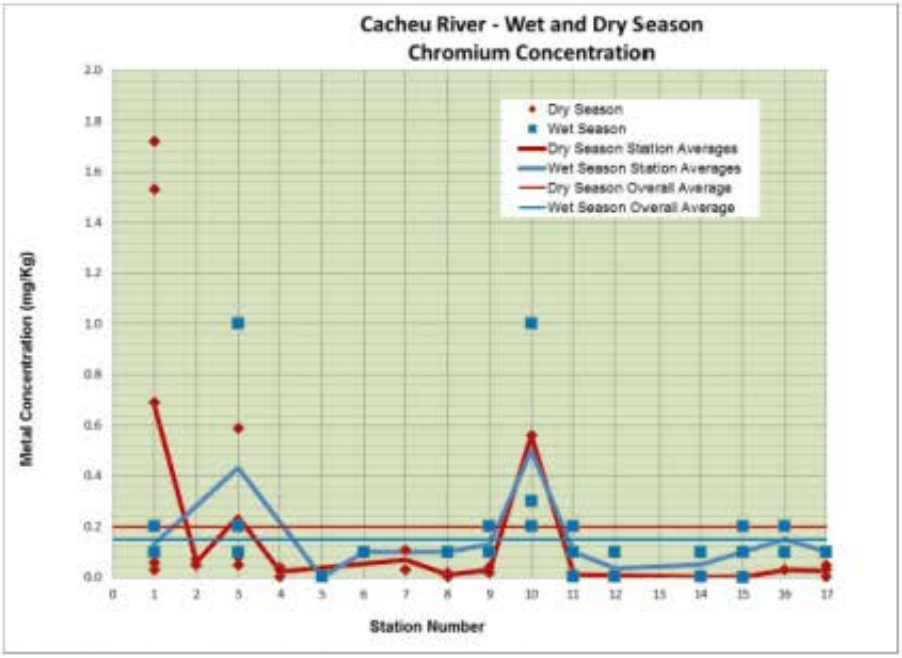


Figure 9.38: Chromium Concentration (Wet and Dry Seasons)

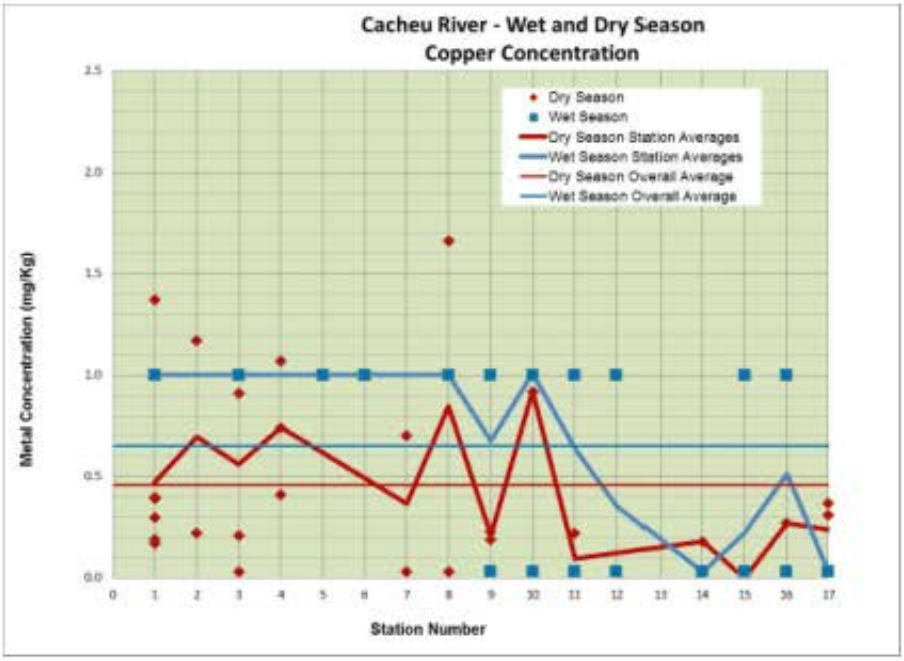


Figure 9.39: Copper Concentration (Wet and Dry Seasons)

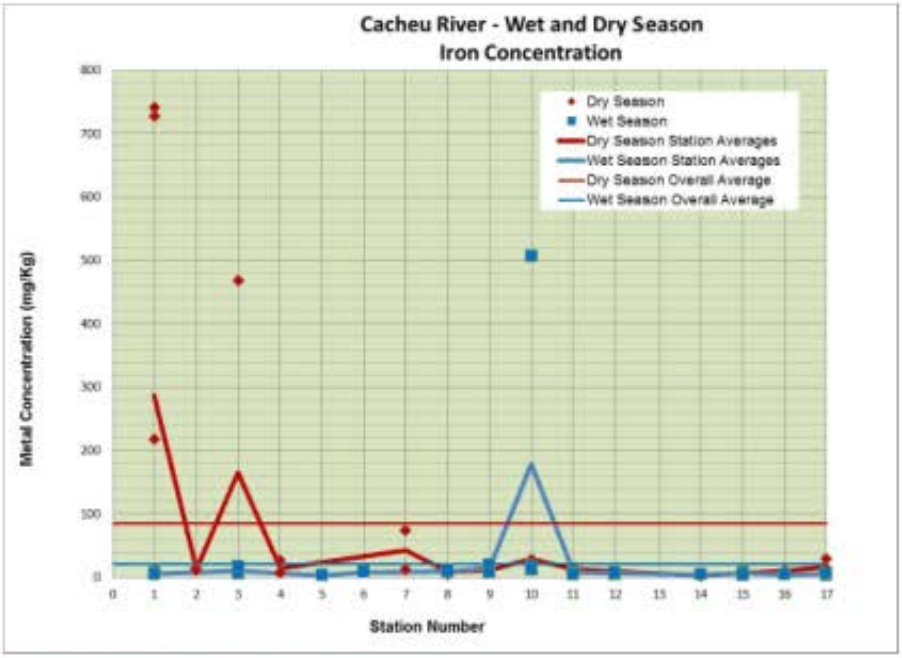


Figure 9.40: Iron Concentration (Wet and Dry Seasons)

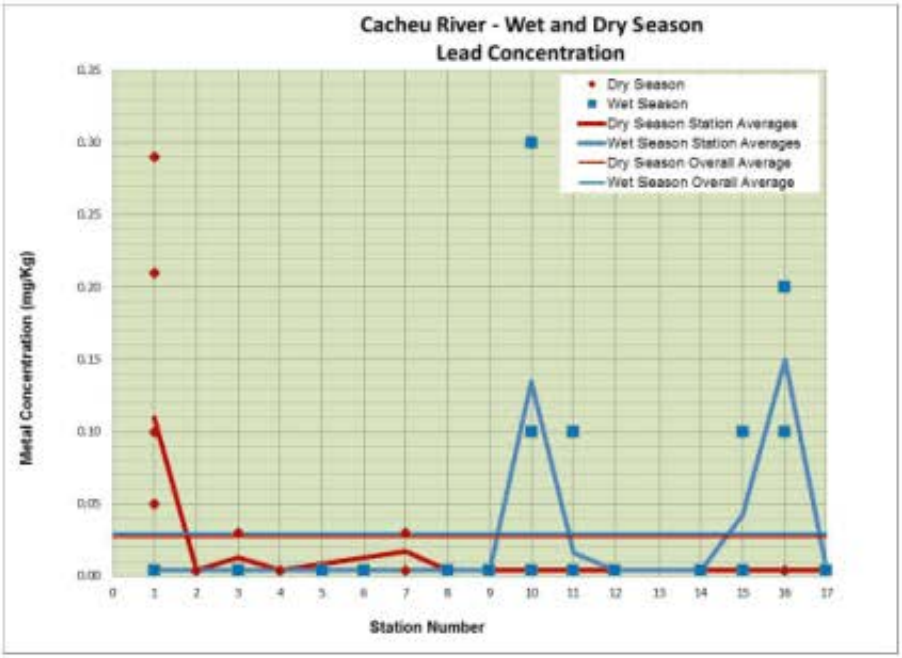


Figure 9.41: Lead Concentration (Wet and Dry Seasons)

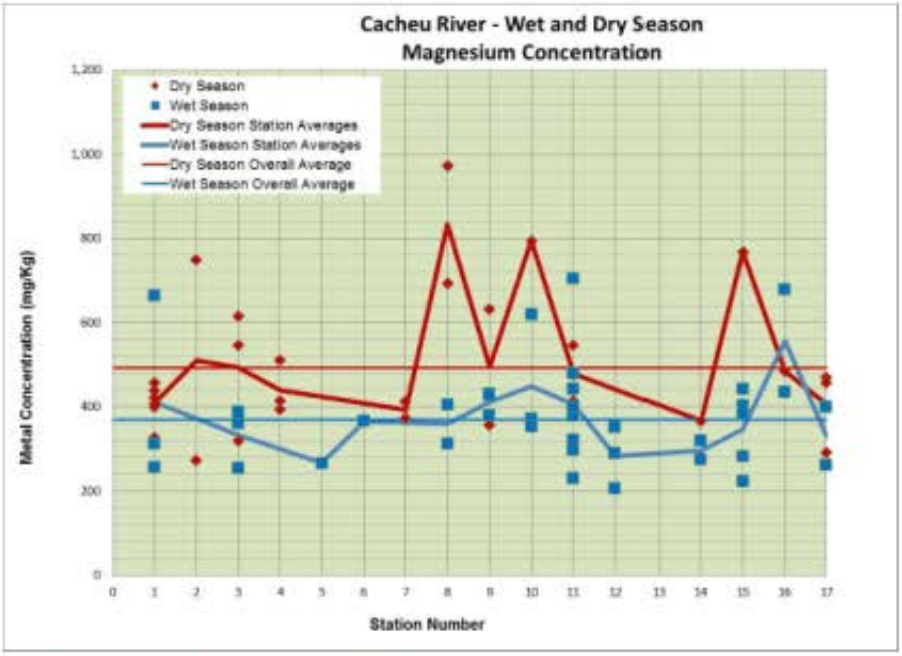


Figure 9.42: Magnesium Concentration (Wet and Dry Seasons)

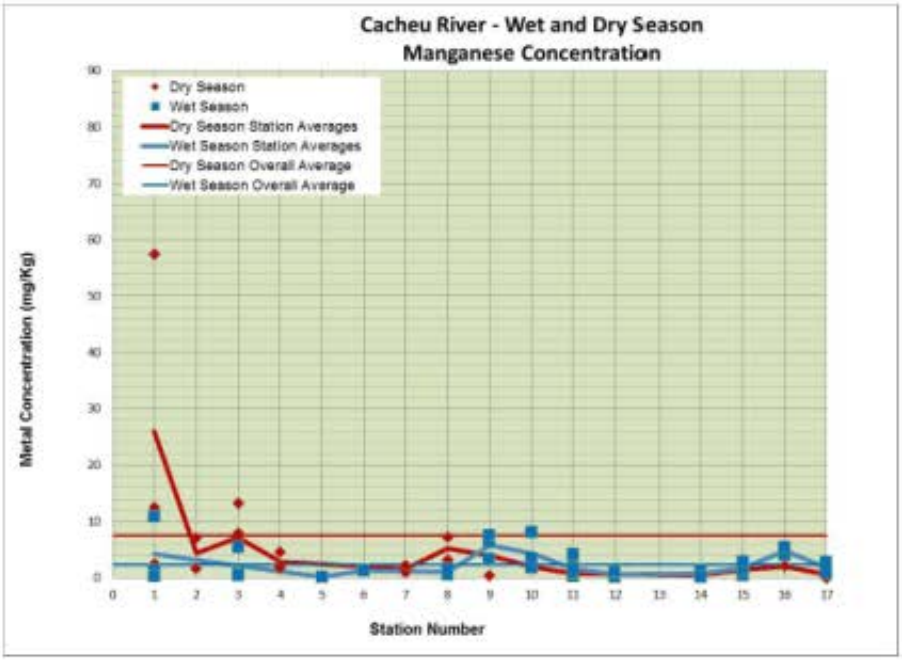


Figure 9.43: Manganese Concentration (Wet and Dry Seasons)

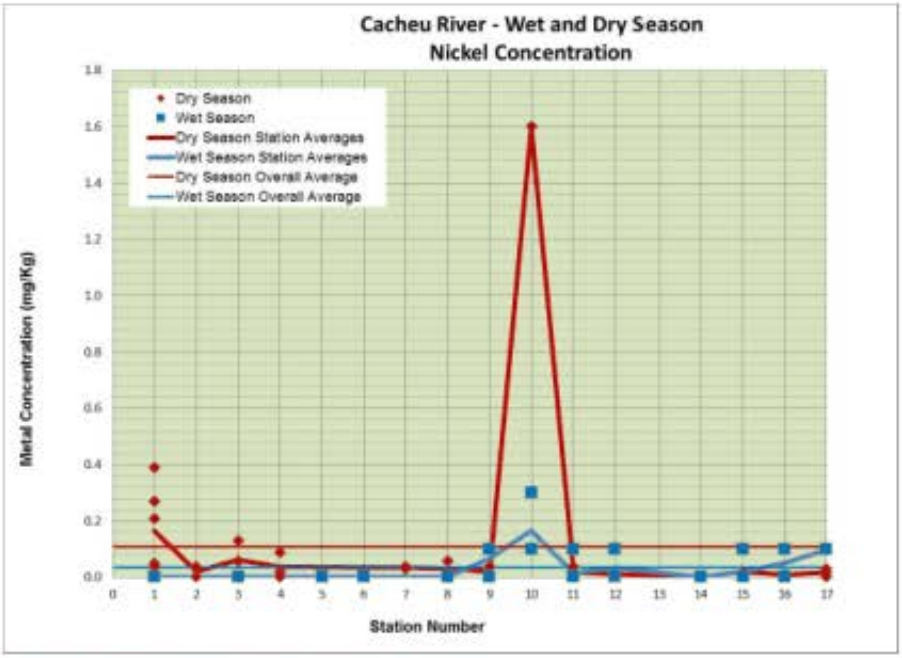


Figure 9.44: Nickel Concentration (Wet and Dry Seasons)

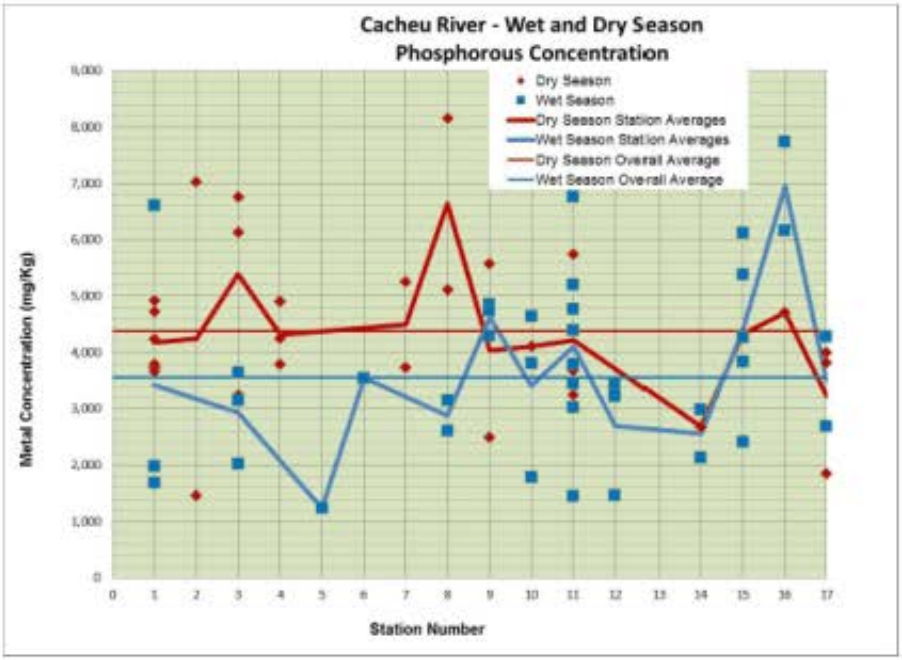


Figure 9.45: Phosphorous Concentration (Wet and Dry Seasons)

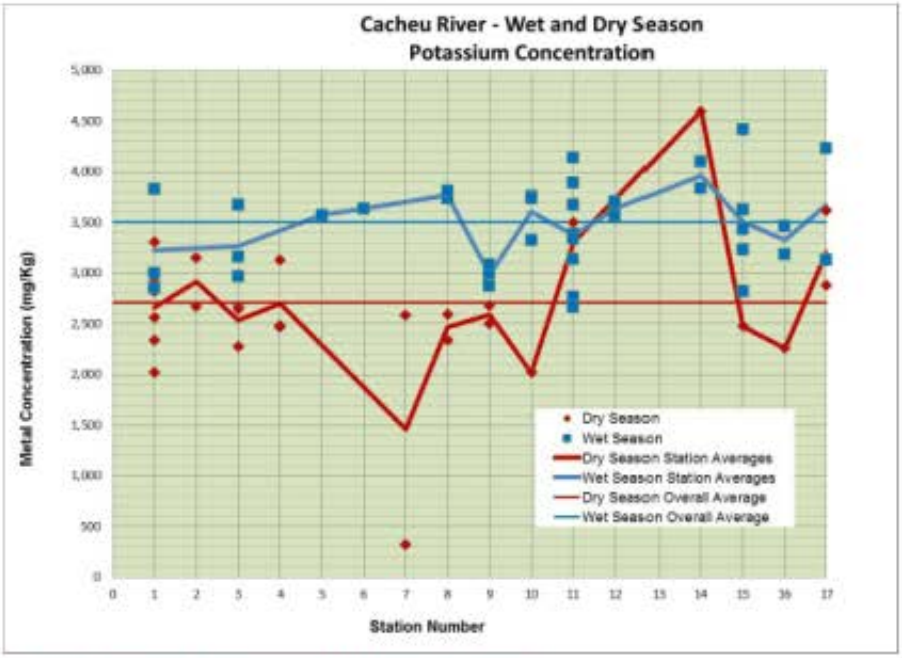


Figure 9.46: Potassium Concentration (Wet and Dry Seasons)

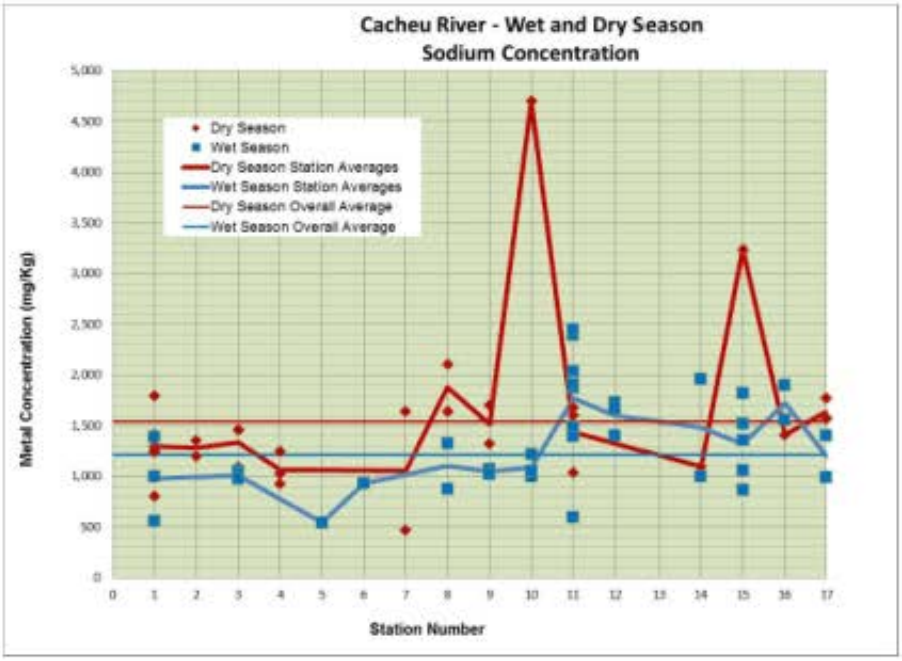


Figure 9.47: Sodium Concentration (Wet and Dry Seasons)

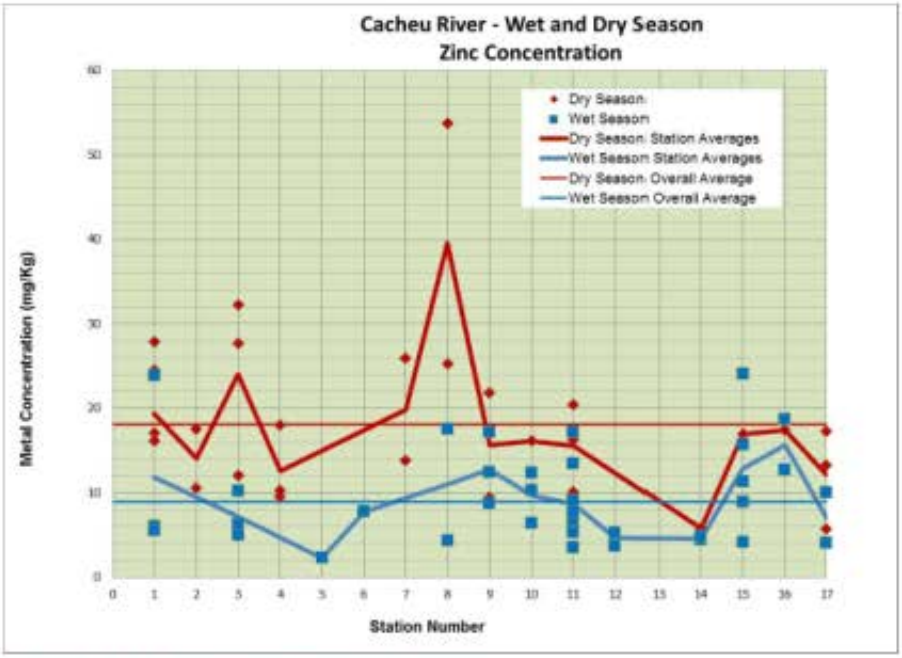


Figure 9.48: Zinc Concentration (Wet and Dry Seasons)

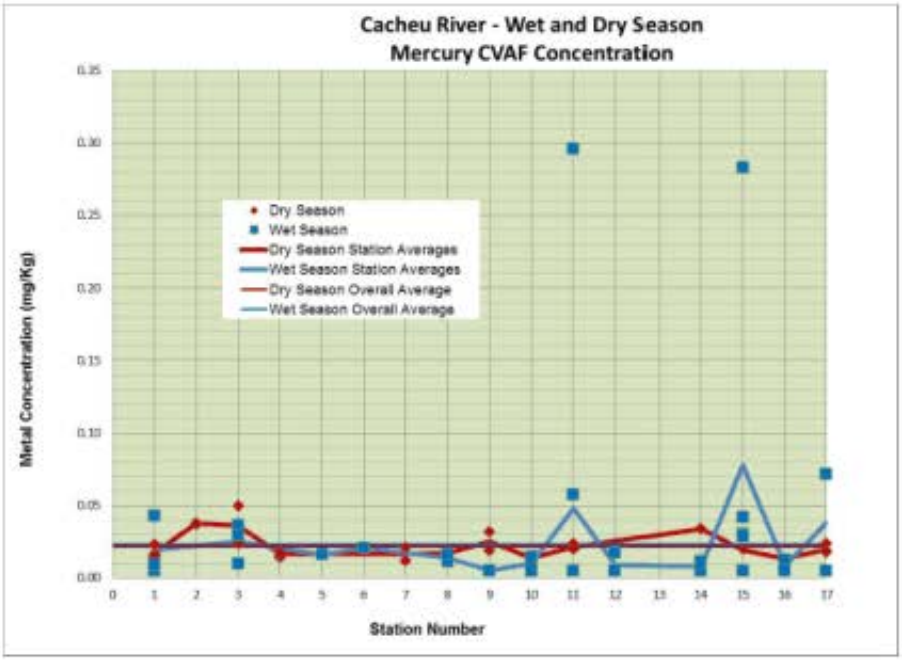


Figure 9.49: Mercury Concentration (Wet and Dry Seasons)

9.5.11 Summary of Findings

The River Cacheu and estuary are in a relative pristine state. The majority of the mangrove and beach shorelines are undisturbed and the fish tissue analysis shows that the system is not contaminated from anthropogenic sources. PAHs were not detected in any of the tissue samples, indicating the lack of fossil fuel use in the area. Methyl mercury was not detected in any of the fish tissues, indicating that mercury methylation is not likely to occur in this aquatic system.

The aquatic biology ecosystem is driven primarily by the natural wet and dry season fluctuations resulting in nutrient and sediment transport to the coastal areas. The aquatic system is deep and affected by tides throughout its length. The river and estuary are highly turbid with strong currents. Shellfish and other invertebrates reproduce throughout the length of the river and estuary as shown by the zooplankton data. There was a lack of fish eggs and larvae in the main body of the river and estuary, and this was observed during both the dry and wet seasons. The fine mesh used for the zooplankton tows was fine enough to collect very small species (such as rotifers) and therefore clearly documents that the main body of the River Cacheu is not the primary habitat for fish reproduction. It is likely that the mangrove ecosystems along the tributaries or permanently inundated mangrove zones serve as nursery areas for fish.

The highest diversity of fish and invertebrates (infaunal and water column) was observed in the more saline stations. Signs of seagrasses were not observed at or in the vicinity of the stations sampled throughout the length of the river and estuary studied. The naturally high turbidity and fluctuating salinity are most likely the cause for the lack of seagrasses in the estuarine stations sampled.

9.6 Abbreviations and Acronyms

BMA	barge marshalling area
cm	centimeter
C-phyto	carbon content of phytoplankton

$C_{stand[1]}$	concentration of standard 1
C-zoop	carbon content of zooplankton
D	Margalef's Richness Index
DO	dissolved oxygen
EHS	Environmental Health and Safety
EP	Equator Principles
EPA	Environmental Protection Agency
et al.	et alia, "a number of people"
FAO	UN Food and Agriculture Organization
F_{blank}	fluorescence of blank value
F_m	acidification ratio = $(F_{stand[1],B} - F_{blank}) / (F_{stand[1],A} - F_{blank})$
$F_{samp,A}$	fluorescence of sample after acidification
$F_{samp,B}$	fluorescence of sample before acidification
$F_{stand[1],A}$	fluorescence of standard 1 after acidification
$F_{stand[1],B}$	fluorescence of standard 1 before acidification
G	gram
GIIP	Good International Industry Practice
H'	Shannon Diversity Index
HCl	hydrochloric acid
i.e.	id est, "that is"
IBAP	Institute of Biodiversity and Protected areas
IFC	International Finance Corporation
J'	Pielou's Evenness Index
Km	kilometre
LSA	local study area
m	metre
M	McIntosh' Dominance Index
m^2	square metre
Mg/kg	milligram per kilogram
mg/L	milligram per litre
ml	millilitre
mm	millimeter
N	number of individuals
^oC	degrees celsius
PAH	polycyclic aromatic hydrocarbon
ppt	parts per thousand
PSD	particle size distribution

RSA	regional study area
S	number of species
sp.	used to indicate an unknown species within a genus
spp.	used to indicate suspected multiple unknown species within a genus
sq	square
STN	station
str	stretch
TSA	trans-shipment area
UK	United Kingdom
$V_{solvent}$	volume of solvent used to extract sample
V_{water}	volume of water filtered
Yr	year
µg Chl/L	micrograms of chlorophyll per litre
µg d.w./L	microgram dry weight per litre
µm	micron
$\mu m^3/L$	cubic micrometre per litre (biovolume)

9.7 Glossary

Alluvial	Describes a river in which the bed and banks are composed of mobile sediments and substrates that are continually deposited and eroded
Aquatic reptiles	Refers to crocodilians, marine and freshwater turtles, and snakes that spend a significant part of their life cycle in water
Benthic	The bottom of a river, lake, or other water body consisting of the sediment surface and some subsurface layers
Bioaccumulation	The buildup of ingested substances in an organism above the concentration to which it is exposed. Typically results in higher concentrations at higher trophic levels as substances are concentrated, then consumed moving up the food chain
Biome	A large geographical area with distinctive flora and fauna adapted to the conditions within that area
Bivalve	A mollusk characterized by having a hinged shell composed of two similar sides ("valves") such as a clam, oyster, or scallop
Brackish	Water that has more salinity than fresh water but is not full
Chlorophyll a	Photosynthetic pigment that absorbs light energy and converts it to chemical energy
Continental shelf	The relatively shallow and flat near
Copepod	Crustaceans of the subclass Copepoda, typically small (1
Decapod	Crustaceans of the order Decapoda, characterized by having 10 legs such as shrimp, lobster, and crabs
Detritus	Non-living, particulate organic material typically composed of decomposing or decomposed remnants or excretions of organisms
Epibenthic	On or near, but not within, the bottom of a body of water
Estuary	A semi-enclosed, generally highly biologically productive, area where freshwater

	inputs from rivers and streams mix with marine waters
Fauna	Refers to the assemblage of animals within a given area or region
Fish kill	Substantial fish mortality resulting from a rapid spread of disease or propagation of conditions that do not support life such as rapid changes in temperature or depletion of dissolved oxygen
Flora	Refers to the assemblage of plants within a given area or region
Gastropod	Animal in the class Gastropoda including slugs and snails
Hydrozoan	Solitary or colonial animals in the class Hydrozoa including the Portuguese Man o' War and siphonophores
Hypoxia	Low-oxygen condition (<2-3 mg/L) that is detrimental to living aquatic organisms
Ichthyoplankton	Component of the plankton community made up of fish eggs and larvae
Intertidal zone	Section of the coast between the high tide line and low tide line. This area is submerged during high tide, and exposed to the air during low tide
Margalef's Richness Index	An index of the number of taxa within a sampled community
McIntosh's Dominance Index	An index of biological community diversity in which a higher value corresponds to higher diversity
Mudflat habitat	Typically intertidal or sub
Omnivore	An animal with a diet consisting of a variety of items potentially including animals, plants, and fungi
Phytoplankton	Autotrophic component of the plankton community
Pielou's Evenness Index	Measure of how similar in abundance the components of a community are
Planktivore	Organism whose diet consists of plankton. Also referred to as filter
Polychaete	Polyphyletic class of Annelid worms characterized by chitinous bristles extending from each body segment
Primary production	Production of chemical energy in organic compounds from carbon dioxide by living organisms. Energy may be derived from light as in photosynthesis or inroganic sources of chemical energy as in chemosynthesis
Riparian	Refers to the terrestrial habitat immediately adjacent to rivers and streams
Rotifer	Animals in the phylum Rotifera that are common in freshwater worldwide and have a few marine species.
Secondary production	Generation of biomass by heterotrophs (higher trophic levels) through assimilation of lower trophic level organisms
Shannon Diversity Index	Index derived from the probability that an individual selected from a sampled population will be from a particular species
Shell hash	Substrate consisting of broken and remnant shell fragments
Trophic level	Position within a food chain. Primary producers are at a low trophic level and apex predators are at a high trophic level.
Trophic Link	Connections between trophic levels based on the flow of energy
Tunicate	Marine invertebrate of the subphylum Tunicata which has a dorsal nerve cord and notochord. Also referred to as Sea Squirts or Sea Tulips
Zooplankton	Heterotrophic component of the plankton community

9.8 References

Binet, D., L.L. Reste, and P.S. Diouf. The Influence of Runoff and Fluvial Outflow on the Ecosystems and Living Resources of West African Coastal Waters. In: Effects of Riverine Inputs on Coastal Ecosystems and Fisheries Resources. Food and Agriculture Organisation of the United Nations Rome. 1995.

Desoutter, M. 1990. Ephippidae. p. 834-836. In J.C. Quero, J.C. Hureau, C. Karrer, A. Post and L. Saldanha (eds.) Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris. Vol. 2. (Ref. 7350)

Food and Agriculture Organization of the United Nations. 1981. FAO Species Identification Sheets for Fishery Purposes – Eastern Central Atlantic. Ed. Fisher, W., Bianichi, G., and W.B. Scott.

Golder Associates (UK) Ltd. 2012. Farim Phosphate Project, Guinea-Bissau. Baseline Aquatic Assessment for the Proposed Farim Phosphate Project.

Golder Associates Ltd. 2013. Farim Phosphate Project, Guinea-Bissau. River Morphology and Physical Oceanography Baseline Study, 13514950200.503/B.0.

Government of Guinea-Bissau, United Nations Development Programme. 2010. Support to the Consolidation of a Protected Area System in Guinea-Bissau's Forest Belt. UNDP GEF PIMS #3650.

HUMAN AND SOCIAL ELEMENTS

10.0 NOISE AND VIBRATION

10.1 Introduction

This section presents the noise baseline environment for the the Project. The Project will give rise to noise from mine facilities, including open pit mining, phosphate processing and transportation. Noise effects can lead to disturbance of people, therefore it is important to characterise the baseline environment.

This section presents the findings of the baseline noise survey, and an interpretation of these survey findings. The section also considers measured baseline noise and vibration levels in the context of international standards to develop evaluation criteria which would be applied as part of the environmental and social impact assessment (ESIA).

10.2 Baseline Study Area

Noise effects are typically experienced at close proximity to the emitting source. Noise from activities associated with the Project is unlikely to be audible beyond 2 to 3 km from the source of noise.

As noise effects are localised there is no regional effect, thus it is unnecessary to consider a regional study area (RSA). The report considers a local study area (LSA) only, based on a buffer of approximately 3 km from operations (Drawing 550-10.1).

The LSA comprises the mine pits, materials stockpiles, processing facilities transport routes. The area is divided between forest and 'bush' comprising dense vegetation and cultivated land of maize and rice fields and cashew tree plantations. Human inhabitation is primarily confined to villages which are typically more densely populated in the centre; however, the outlying properties may be some distance from the centre. Crops and livestock are commonly present interspersed with dwellings as well as in the surrounding area.

Sensitive receptors include communities / villages, locations of cultural value (including places of worship and burial sites).

The nearest settlements to the proposed locations of each component of the Project are also shown on Drawing 550-10.1.

10.3 Previous work and Existing Data

No previous noise information or existing data was available.

10.4 Methods

To characterise the baseline noise environment, 12 monitoring locations were selected to represent different environments within the LSA and to include areas where mine components will be located.

The noise environment across the LSA was dominated by natural noises with anthropogenic noise predominantly limited to the conversation and activities of villagers. Natural noise includes weather-induced noise (e.g., rustling of vegetation in wind), running water (rivers and waterfalls), and human and animal activity. There is no electricity in any of the villages in the study area, so little mechanical noise is generated.

A description of the specific noise environment at each monitoring location is detailed in Table 10.1. All monitoring equipment was left unattended; however, local noise sources were observed and noted during equipment commissioning / decommissioning.

Table 10.1: Baseline Noise Monitoring Locations

	Monitoring Location	Source of Noise	Distance from Mine / Mine Facility
MP1 Farim, GB Minerals Office Compound	Monitoring undertaken in a secure courtyard at the rear of GB Minerals' office in the centre of Farim. Monitoring location: 475993, 1380092	Natural sources. Villager activities and interactions. Infrequent road traffic.	Approximately 3 km from proposed open pit area. Adjacent to road which may experience increased traffic due to mine.
MP2 Farim,	Monitoring undertaken adjacent to meteorological mast close to GB Minerals office close to the centre of Farim. The location is on the bank of a small pond and adjacent to flooded rice fields. Monitoring location: 476005, 1380153	Natural sources. Villager activities and interactions. Infrequent road traffic.	Approximately 3 km from proposed open pit area. Adjacent to road which may experience increased traffic due to mine.
MP3 Binta	Monitoring undertaken adjacent to existing concrete jetty on periphery of village. Monitoring location: 465777, 1372979	Natural sources. Villager activities and interactions.	Site of potential barge loading facility.
MP4 Canico	Monitoring undertaken in cleared area in centre of village, close to main route through village. Monitoring location: 470656, 1377078	Natural sources. Villager activities and interactions. Noise from livestock.	1 km from southern extent of proposed mine pit
MP5 Cansenhe	Monitoring undertaken at edge of cleared area in centre of close to a residence. Monitoring location: 466829, 1377444	Natural sources. Villager activities and interactions. Noise from livestock.	Approximately 2 km west of Tailings Facility (T5).
MP6 Sanjalo	Monitoring undertaken within cleared area in centre of village. Monitoring location: 466906, 1381331	Natural sources Villager activities and interactions Noise from livestock.	3 km west of proposed mine pit.

	Monitoring Location	Source of Noise	Distance from Mine / Mine Facility
MP7 Ufude	Monitoring undertaken within cleared area in centre of village. Monitoring location: 467344, 1379975	Natural sources. Villager activities and interactions. Noise from livestock.	3 km west of proposed mine pit.
MP8 Saliquenhe	Monitoring undertaken within cleared area in centre of village close to main route through village. Monitoring location: 471850, 1379684	Natural sources. Villager activities and interactions. Noise from livestock.	Within footprint of proposed mine pit.
MP9 Sancalanco	Monitoring undertaken on concrete plinth of a disused water pump in a cleared area within the village. Monitoring location: 478751, 1384096	Natural sources. Villager activities and interactions. Radio. Noise from livestock.	Outside study area
MP10 Sarajobe	Monitoring undertaken at the edge of a cleared area near the centre of the village. Monitoring location: 474156, 1383458	Natural sources. Villager activities and interactions. Radio. Noise from livestock.	Approximately 2 km east of proposed overburden storage dump O2.
MP11 Canico Tumane	Monitoring undertaken at the edge of a cleared area near the centre of the village. Monitoring location: 471955, 1384718	Natural sources. Villager activities and interactions. Noise from livestock.	Approximately 1 km from proposed overburden storage dumps O2.
MP12 Saliquenhedim	Monitoring undertaken in a cleared area near the centre of the village close to the main route to river crossing to Farim. Monitoring location: 476022, 1376868	Natural sources. Villager activities and interactions. Intermittent road traffic; motorbikes, minibuses and small trucks. Noise from livestock.	Approximately 2 km from southern open pit.

Coordinates are UTM, zone 28N, datum WGS 84.

10.4.1 International Standards

In assessing the impact of noise from the development, the appropriate evaluation criteria have been considered with reference to IFC Environmental, Health and Safety (EHS) Guidelines (International Finance Corporation, 2007); World Health Organisation (WHO) are the proposed guideline values (Guidelines for Community Noise, WHO 1999) as outlined in Table 10.2.

Table 10.2: IFC Environmental, Health and Safety Guideline Values for Noise, dB L_{Aeq}

Receptor	Period	
	Daytime (07:00 – 22:00)	Night-time (22:00 – 07:00)
Residential, institutional and educational	55[a]	45[a]
Industrial and commercial	70[a]	70[a]

[a] Or a 3 dB increase in background noise levels, if higher.

Source: IFC Environmental, Health and Safety Guidelines

The guideline values are, therefore specified as either a fixed noise limit or an increase of 3 dB in background noise levels (where the resultant level is greater than the fixed limit).

In the context of the IFC EHS Guidelines, 'background levels' are taken as the conventionally accepted definition of 'background' noise in terms of L_{A90}. For the purposes of the baseline assessment 'background' noise levels are based on measured L_{A90} noise levels, and the resulting limits expressed in dB L_{Aeq}. Definitions of noise terms, L_{Aeq} and L_{A90}, are provided in Section 10.7, Glossary.

10.4.2 Guinea-Bissau Legislation and Standards

The NFSP does not specifically reference noise, nor propose national noise standards. The baseline therefore considers existing noise levels in the context of international standards.

10.4.3 Assessment Methodology

10.4.3.1 Methods for Assessment of Existing Noise

Monitoring was undertaken in accordance with ISO 1996 Parts 1 and 2 (ISO, 2003). This sets out the equipment to be used to undertake measurements, conditions under which noise measurements should be undertaken, measurement parameters and appropriate siting of monitoring equipment.

Instrumentation

ISO 1996 provides a specification of the capability of a sound level meter to measure particular noise indices. The accuracy of a noise meter is defined by IEC 61672 (IEC, 2002), with the Type or Class of a sound level meter describing its accuracy. Class 1 sound level meters, with a tolerance of ± 0.7 dB were used to undertake baseline surveys.

The monitoring equipment used during the baseline monitoring survey is detailed in Table 10.3.

Table 10.3: Baseline Noise Monitoring Equipment

Equipment	Type	Serial Number	Calibration Due Date
Sound level meter	Norsonic NOR-140	140.1402742	April 2013
Environmental microphone	Gras 41AL	44958	August 2013
Sound level meter	Norsonic NOR-140	140.1402790	April 2013
Environmental microphone	Gras 41AL	63151	June 2014
Sound level meter	Norsonic NOR-140	140.1403330	July 2013
Environmental microphone	Gras 41AL	42111	August 2014
Sound level meter	Norsonic NOR-140	140.1402871	May 2013
Environmental microphone	Gras 41AL	63150	June 2014

Note: the microphone listed beneath each sound level meter was used exclusively with that meter at all monitoring locations during the survey.

All instrumentation was certified by a UKAS accredited facility, and was within calibration date. Field calibration of sound level meters was undertaken prior to and following measurement. No significant deviations in calibrations were noted.

The sound level meters were housed in an environmental case which provided weather protection and contained an external 12 volt battery. The microphones were mounted in GRAS protection assemblies, and protected by enhanced wind shields to minimise wind flow disturbance of the microphone. The sound level meters were connected to the microphone via an external cable. The sound level meter assembly is shown below.

Figure 10.1: Noise monitoring equipment assembly

Measurement Location

ISO 1996 specifies that monitoring equipment should be located at least 3.5 m away from any vertical reflective surface, at a height of between 1.2 to 1.5 m above ground level.

All baseline noise survey measurements were undertaken in external, free-field locations, therefore negating interference of vertical reflective surfaces, consistent with ISO 1996.

Measurement duration

Monitoring was undertaken during both daytime (07:00 to 22:00) and night-time (22:00 to 07:00) hours, as defined by IFC EHS Guidelines. The duration enabled each location to be characterised in terms of typical daytime and night-time conditions; the diurnal variation could also be determined.

The durations of measured noise and the indices recorded are consistent with the requirements of ISO 9613.

Meteorological Observations

Meteorological data was obtained from the permanent met station by the GB Minerals office in Farim. Details of the instrumentation can be found in the air quality chapter.

10.4.3.2 Methods for Assessing the Sensitivity of Receptors

IFC EHS Guidelines define a noise receptor as:

A point of reception or receptor may be defined as any point on the premises occupied by persons where extraneous noise and / or vibration are received. Examples of receptor locations may include: permanent or seasonal residences; hotels / motels; schools and daycares; hospitals and nursing homes; places of worship; and parks and campgrounds.

In relation to the LSA, residential properties, schools and places of worship were identified as noise sensitive receptors.

No scale of sensitivity is applied to receptors when assessing noise, rather only those locations which meet the above definition are considered as receptors.

10.5 Results and Discussion

10.5.1 Meteorological Observations

The wind speed and rainfall occurring during the baseline noise survey were recorded at the Farim met station (Figure 10.2).

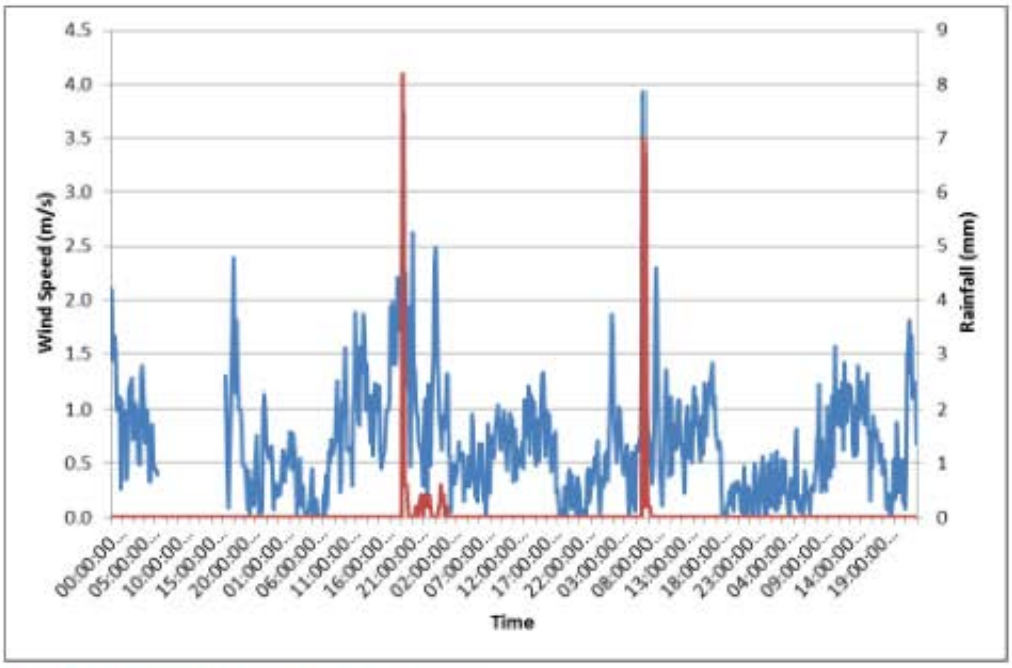


Figure 10.2: Measured wind speed and rainfall - Farim

Measured wind speeds during the baseline noise monitoring period ranged from 0.0 m/s to 3.9 m/s, with an average of 0.7 m/s. Such a range of wind speeds is representative of conditions experienced throughout the year; in 2012 the wind speed rarel exceeded 5 m/s and was most commonly between 1 m/s and 3 m/s. During the baseline noise survey the 10 minute averaged wind speed was below 1 m/s for 80 percent of the time, by comparison wind speeds lower than 1 m/s occurred for 53% of the year during 2012. The adopted baseline noise levels are therefore considered to be conservative, since wind-induced noise during the survey will therefore have been lower than the yearly average.

Typical rainfall levels in Farim varied greatly throughout the year, with most rainfall occurring between June and October. During the baseline noise survey, two rainfall events were recorded; one on 11 September which lasted from 19:30 to 02:00, and one on 13 September which lasted from 07:00 to 08:20. During the heavier of the two rainfall events, on the 11 September, 16.4 mm was recorded in a 50 minute period. During these periods of heavy rain it is likely that measured noise levels would have been affected.

Meteorological data was only recorded in Farim and not in all of the receptors at which noise levels were measured, it has therefore not been possible to directly correlate increased noise levels and recorded rainfall, due to the localised nature of the storms and the size of the study area. Given that the lowest measured background noise level has been adopted as the baseline noise level for these receptors,, however, will eliminate the effect of such short-duration events.

10.5.2 Measured Noise Levels

Measured baseline noise levels and an interpretation of those levels are presented in the following sections.

At each location, lowest measured noise levels during daytime and night time periods are presented as noise limits as applied to the development will be determined based on these values.

10.5.2.1 Farim – GB Minerals Office

Monitoring of baseline noise levels at Farim was undertaken between 10 and 11 September 2012 (Figure 10.3).

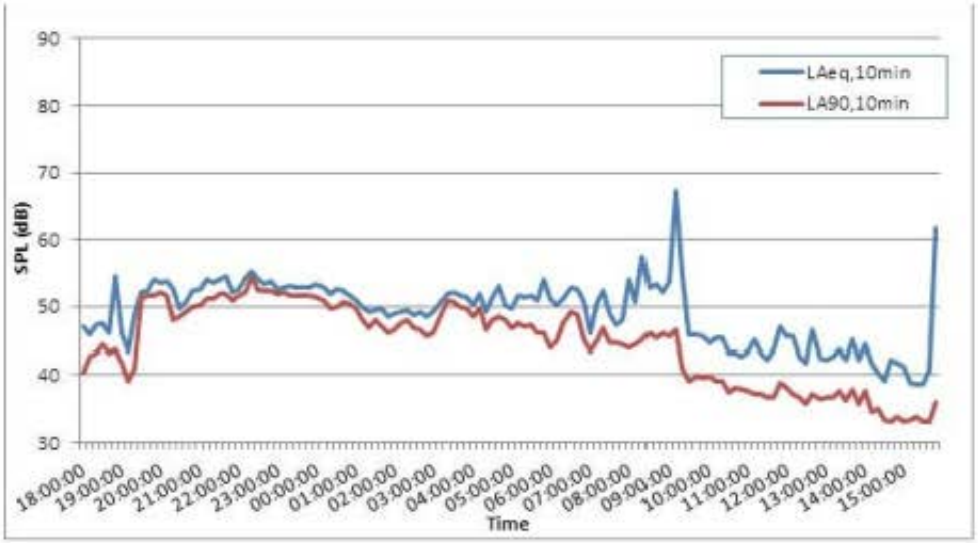


Figure 10.3: Measured Noise Levels – GB Minerals Office, Farim

The graph indicates a close correlation between measured L_{Aeq} and L_{A90} noise levels. During the evening and night-time, the difference between measured L_{Aeq} and L_{A90} noise levels is typically less than 5 dB, indicating a consistent noise environment with few noisier events affecting the measured L_{Aeq} level.

The graph shows an increase in L_{Aeq} and L_{A90} values at 20:00 to approximately 50 dB. The L_{Aeq} and L_{A90} levels remain at this level until around 04:00, at which point the L_{A90} exhibits a gradual decrease from approximately 04:00 until 15:00, dropping below 40 dB at approximately 10:00. The L_{eq} follows a similar trend, although the difference between the L_{Aeq} and L_{A90} increases over this period.

The gradual decrease in noise level throughout the day may reflect the increasing heat and humidity and associated decrease in human and animal activity. A spike in occurs in both L_{Aeq} and L_{A90} levels around 09:00, likely to be a result of maintenance works being carried out in nearby buildings.

The lowest measured noise levels are presented in Table 10.4.

Table 10.4: Lowest Average Hourly Measured Noise Levels - Farim

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	05:00	06:00	51.8	46.9
Day	15:00	16:00	54.1	33.9

10.5.2.2 Farim – Met Station

Monitoring of baseline noise levels at Farim was undertaken between 10 and 11 September 2012 (Figure 10.4).

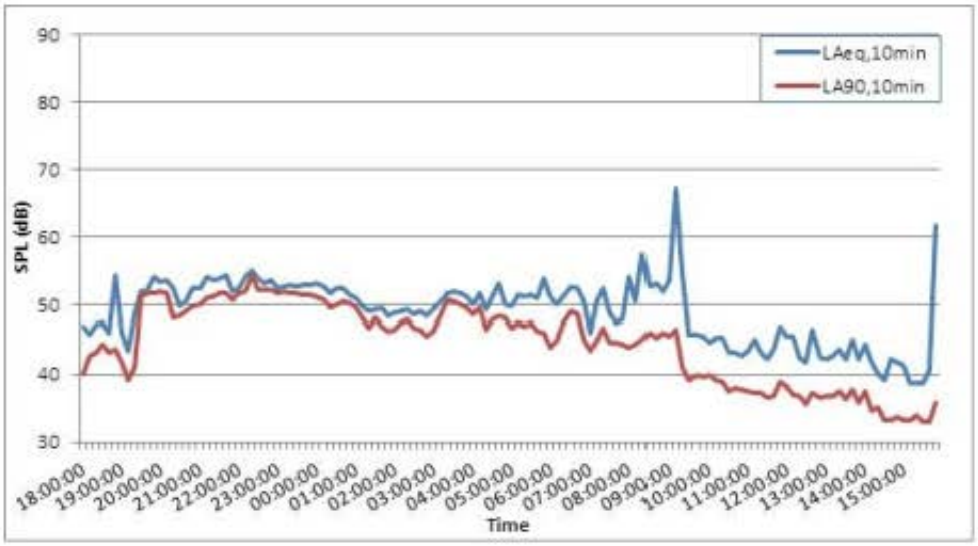


Figure 10.4: Measured Noise Levels – Met Station, Farim

The graph shows a close correlation between the measured L_{A90} and L_{Aeq} values, particularly throughout the night time period. A sharp increase in the L_{A90} values occurs between 19:10 and 19:30, roughly corresponding to sundown, after which the level remains steady at approximately 50 dB until around 04:00. The L_{A90} then exhibits a decreasing trend from 04:00 until 15:00.

The meter was stopped at 15:50 due to a generator being started up nearby.

The noise levels recorded at the met station location show a similar profile to those measured at the office compound. A similar spike in both L_{A90} and L_{Aeq} at around 09:00 may also arise from the nearby works at the office compound.

The lowest measured noise levels are presented in Table 10.5.

Table 10.5: Lowest Average Measured Noise Levels - Met Station, Farim

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	05:00	06:00	54.4	50.7
Day	16:00	17:00	52.2	48.4

10.5.2.3 Binta

Monitoring of baseline noise levels at Binta was undertaken between 11 and 12 September 2012 (Figure 10.5).

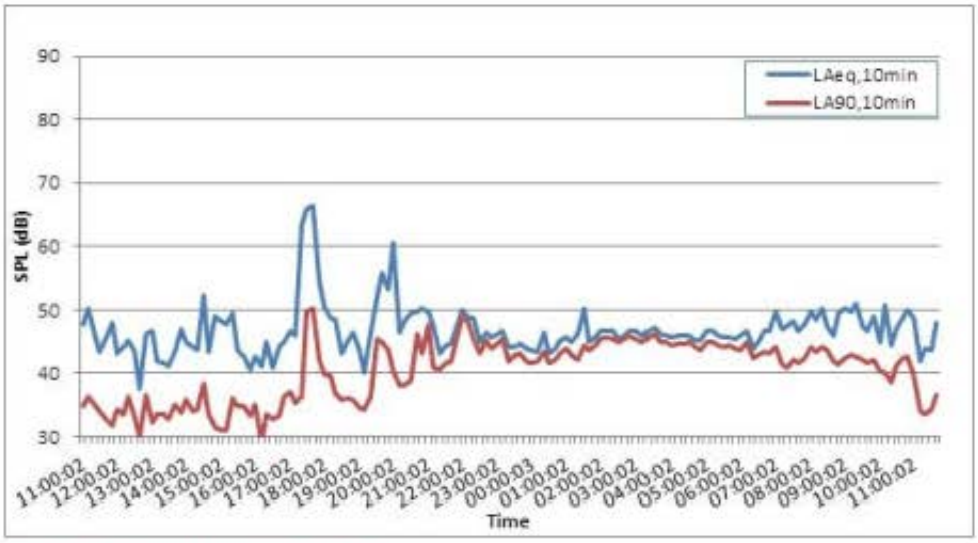


Figure 10.5: Measured Noise Levels – Binta

The graph indicates a close correlation between measured L_{Aeq} and L_{A90} noise levels; however the difference between measured L_{Aeq} and L_{A90} noise levels ranges from less than 5 dB during the night to 15 dB during the daytime period.

During the night-time the noise level is relatively constant; both L_{A90} and L_{Aeq} remain steady at approximately 45 dB between 23:00 and 07:00. It is considered likely that this is a result of constant level of animal noise. During the daytime the L_{A90} is typically lower than during the night-time and the difference between L_{Aeq} and L_{A90} noise levels is typically greater. The increase in the difference between indices is likely to reflect the influence of human activities on ambient noise levels during the daylight hours and a reduction in animal noise. A spike in both L_{Aeq} and L_{A90} levels between 17:30 and 17:40 is thought to coincide with a rain shower.

The lowest measured noise levels are presented in Table 10.6.

Table 10.6: Lowest Average Hourly Measured Noise Levels - Binta

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	00:00	01:00	44.5	42.3
Day	13:00	14:00	44.3	33.6

10.5.2.4 Canico

Monitoring of baseline noise levels at Canico was undertaken between 11 and 12 September 2012 (Figure 10.6).

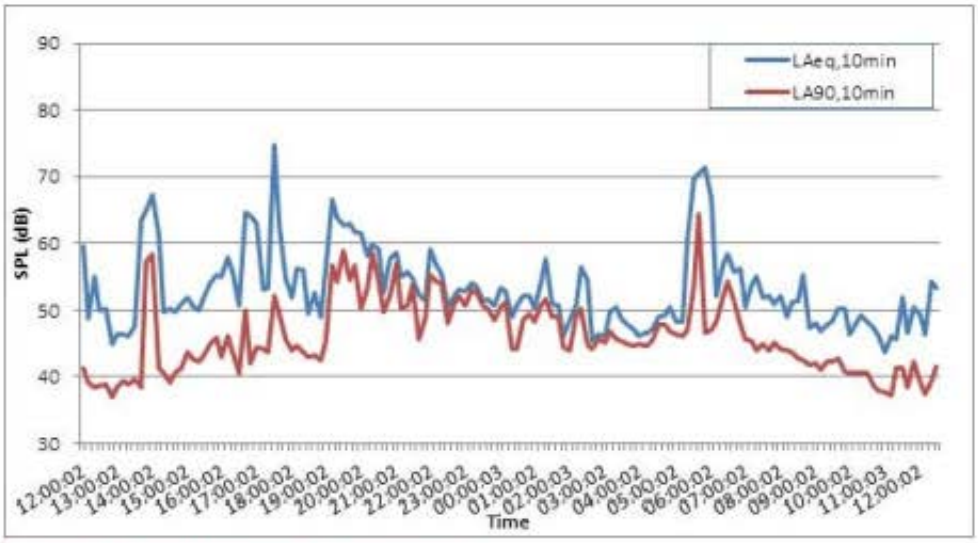


Figure 10.6: Measured Noise Levels – Canico (south)

The graph indicates a close correlation between measured L_{Aeq} and L_{A90} noise levels. The difference between L_{Aeq} and L_{A90} noise levels ranges from less than 5 dB during the night, up to approximately 20 dB during the daytime period.

During the night-time both L_{A90} and L_{Aeq} levels exhibit a general decrease from approximately 60 dB at 20:00 to 45 dB at 04:00. It is considered that night-time noise levels are likely to be dominated by animal noise.

During the daytime the L_{A90} is typically lower than during the night-time and the difference between L_{Aeq} and L_{A90} noise levels is typically much greater. The increase in the difference between these indices occurs between approximately 07:00 and 22:00 and is likely to reflect the influence of human activities on ambient noise levels during the daylight hours. A spike in noise levels is observed at 05:30, this is thought to represent a rainfall event of short duration. A similar spike occurs from 13:50 to 14:00.

The lowest measured noise levels are presented in Table 10.7.

Table 10.7: Lowest Average Hourly Measured Noise Levels - Canico

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	03:00	04:00	48.6	45.5
Day	12:00	13:00	54.1	39.1

10.5.2.5 Cansenhe

- Monitoring of baseline noise levels at Cansenhe was undertaken between September 12 and 13, 2012 (Figure 10.7).

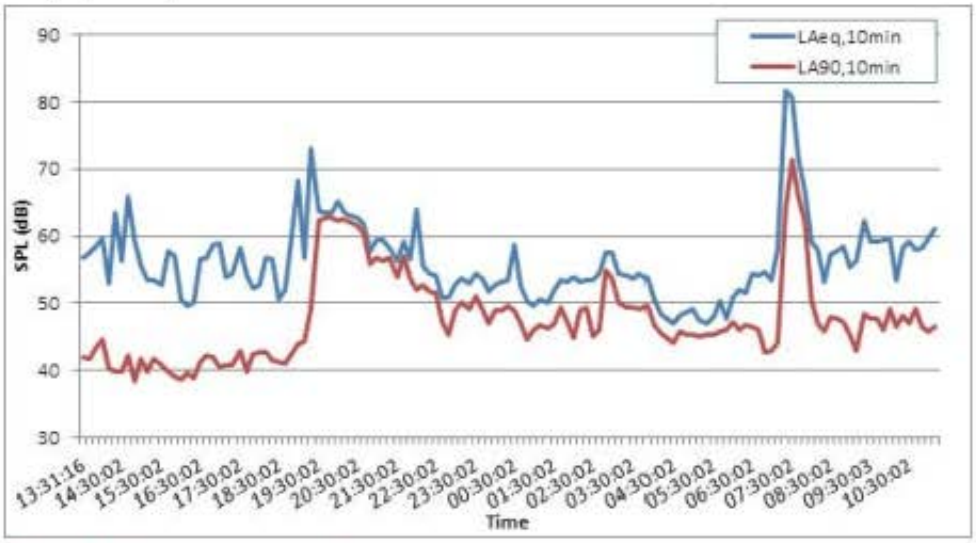


Figure 10.7: Measured Noise Levels – Cansenhe

The graph indicates a reasonable correlation between measured L_{Aeq} and L_{A90} levels during the evening and night-time, with a difference of approximately 5 dB between the two indices. During the daytime the difference between L_{Aeq} and L_{A90} levels increased to approximately 20 dB.

As with other locations it is likely that noise from wildlife such as crickets is the dominant and constant noise source during the night-time. During the daytime the L_{Aeq} varied between 50 and 60 dB, however the L_{A90} decreased to approximately 40 dB.

An increase of approximately 20 dB occurs in the LA90 level between 19:10 and 19:30, possibly corresponding with an increase in human activity in the village during the evening. Noise levels exhibit a spike between 07:10 and 08:20 which broadly corresponds with sunrise (06:52).

The lowest measured noise levels are presented in Table 10.8.

Table 10.8: Lowest Average Hourly Measured Noise Levels – Cansenhe

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	04:00	05:00	48.6	45.4
Day	15:00	16:00	55.4	40.6

10.5.2.6 Sanjalo

Monitoring of baseline noise levels at Sanjalo was undertaken between 12 and 13 September 2012 (Figure 10.8).

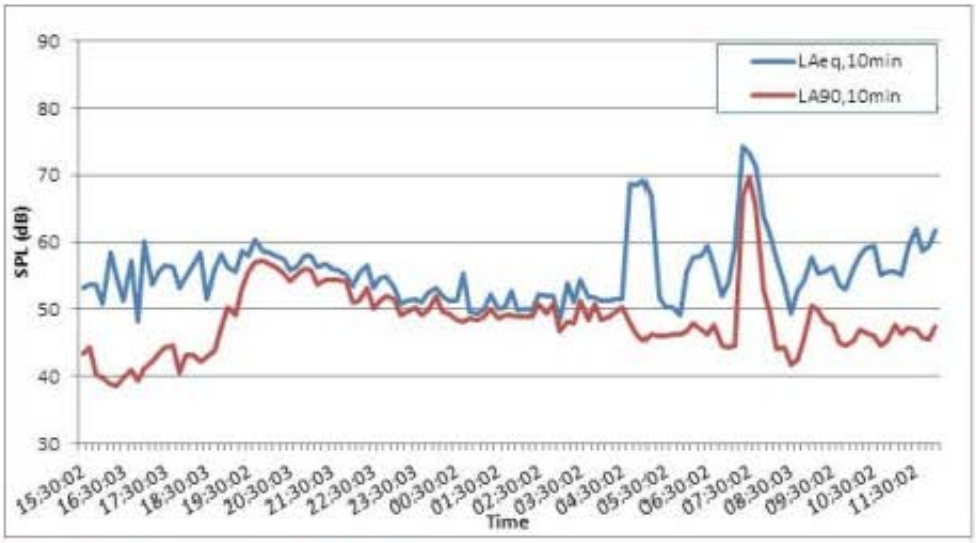


Figure 10.8: Measured Noise Levels – Sanjalo

The graph indicates a reasonable correlation between measured L_{Aeq} and L_{A90} noise levels. Noise levels follow a broadly similar pattern to Cansenhe, with a 20 dB increase in the LA90 level between 18:30 and 19:30, after which both L_{Aeq} and L_{A90} exhibit a gradual decrease to approximately 50 dB.

The L_{Aeq} and L_{A90} levels remain within 5 dB of each other throughout the majority of the night-time period, indicating a fairly constant noise source. During the daytime the difference between the L_{Aeq} and L_{A90} increases to approximately 15 dB, when human activities are likely to be the dominant contributor. A spike in noise levels occurs between 07:00 and 08:00, which is considered to represent an increase in both human and animal noise following the sunrise.

The lowest measured noise levels are presented in Table 10.9.

Table 10.9: Lowest Average Hourly Measured Noise Levels – Sanjalo

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Day	16:00	17:00	54.8	39.7
Night	05:00	06:00	63.6	46.0

10.5.2.7 Ufude

Monitoring of baseline noise levels at Ufude was undertaken between 12 and 13 September 2012 (Figure 10.9).

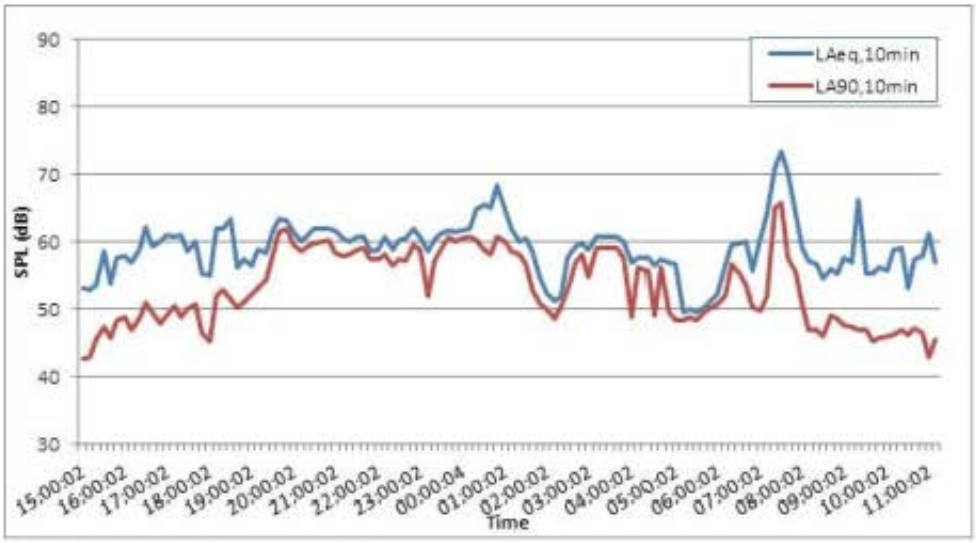


Figure 10.9: Measured Noise Levels – Ufude

The graph indicates a close correlation between measured L_{Aeq} and L_{A90} noise levels. During the evening and night-time, the difference between measured L_{Aeq} and L_{A90} noise levels is typically less than 5 dB indicating a relatively consistent noise environment with few noisy events.

Measured noise levels in the night-time period are relatively consistent and in the range 50 to 60 dB. A spike in noise levels occurs between 06:50 and 08:00, coinciding with an increase in animal and human activity during and shortly after sunrise. During the daytime the measured L_{A90} values typically did not exceed 50 dB, with measured L_{Aeq} values remaining close to the night-time level of 60 dB.

The lowest measured noise levels are presented in Table 10.10.

Table 10.10: Lowest Average Hourly Measured Noise Levels - Ufude

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	05:00	06:00	52.2	49.0
Day	14:00	15:00	58.8	44.6

10.5.2.8 Saliquenhe

Monitoring of baseline noise levels at Saliquenhe was undertaken between 12 and 13 September 2012 (Figure 10.10).

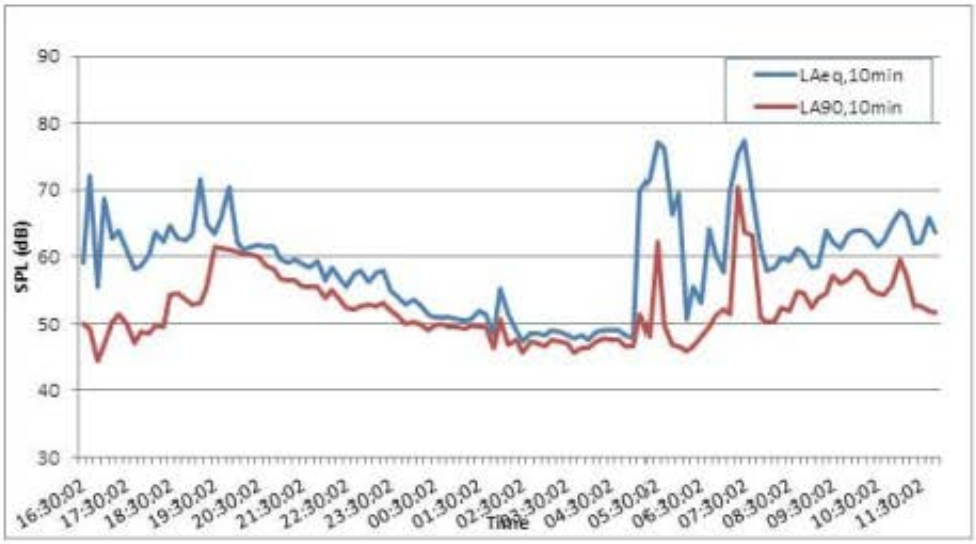


Figure 10.10: Measured Noise Levels – Saliquenhe

The graph indicates a close correlation between ambient (L_{Aeq}) and background (L_{A90}) noise levels, with both indices more closely correlated during the night than during daytime.

A trend in noise levels is observed throughout the monitoring period, with noise levels remaining relatively loud during late afternoon and evening, decreasing during the night-time period, before increasing again during the morning period. It is anticipated that the spikes in measured noise levels in the morning relate to operation of machinery or vehicle engines in proximity to the monitoring site. During daytime it was noted that birdsong was dominant. The Village Weaver is a common species in Central and West Africa, and is most often associated with trees in villages where they maintain very large communities.

When comparing monitoring results to the limits prescribed in the IFC EHS Guidelines, ambient noise levels are generally higher than the daytime limit of 55 dB L_{Aeq}, with night time levels above the night-time limit of 45 dB L_{Aeq}.

The lowest measured noise levels are presented in Table 10.11.

Table 10.11: Lowest Average Hourly Measured Noise Levels – Saliquenhe

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	03:00	04:00	48.4	46.9
Day	17:00	18:00	63.8	49.3

10.5.2.9 Sancalanco

Monitoring of baseline noise levels at Sancalanco was undertaken between 13 and 14 September 2012 (Figure 10.11).

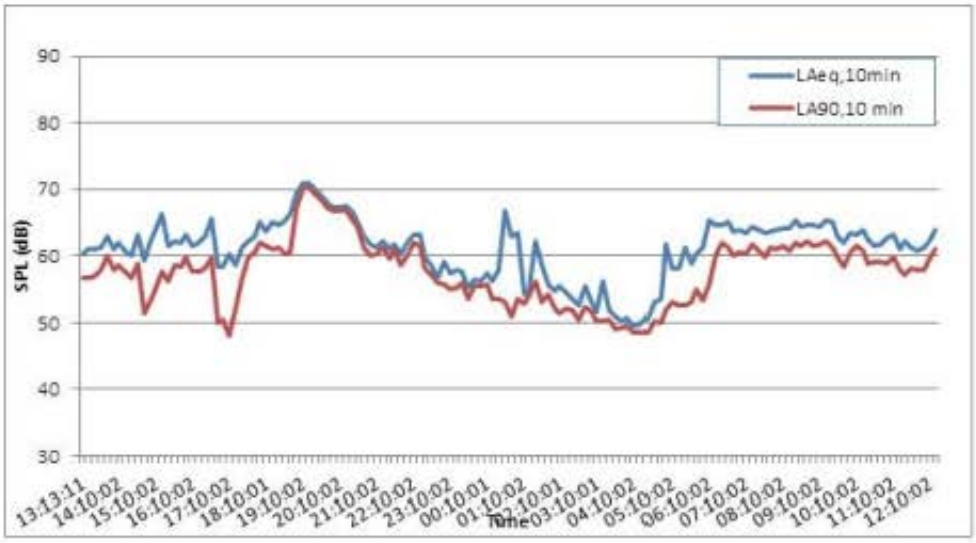


Figure 10.11: Measured Noise Levels – Sancalanco

The graph indicates a close correlation between measured L_{Aeq} and L_{A90} noise levels, with little difference between measured L_{Aeq} and L_{A90} noise levels indicating a consistent noise level for most of the period.

Measured L_{Aeq} levels remain above 60 dB for most of the day. Whilst L_{Aeq} levels remain constant in the evening and night, measured L_{A90} levels are observed to decrease. This indicates that noise sources that are intermittent (e.g. birdsong) are the dominant noise sources in the area.

When comparing monitoring results to the limits prescribed in the IFC EHS Guidelines, ambient noise levels are consistently higher than both the daytime limit of 55 dB L_{Aeq}, and the night-time limit of 45 dB L_{Aeq}.

The lowest measured noise levels are presented in Table 10.12.

Table 10.12: Lowest Average Hourly Measured Noise Levels – Sancalanco

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	04:00	05:00	50.3	48.9
Day	17:00	18:00	61.3	54.9

10.5.2.10 Sarajobe

Monitoring of baseline noise levels at Sarajobe was undertaken between 13 and 14 September 2012 (Figure 10.12).

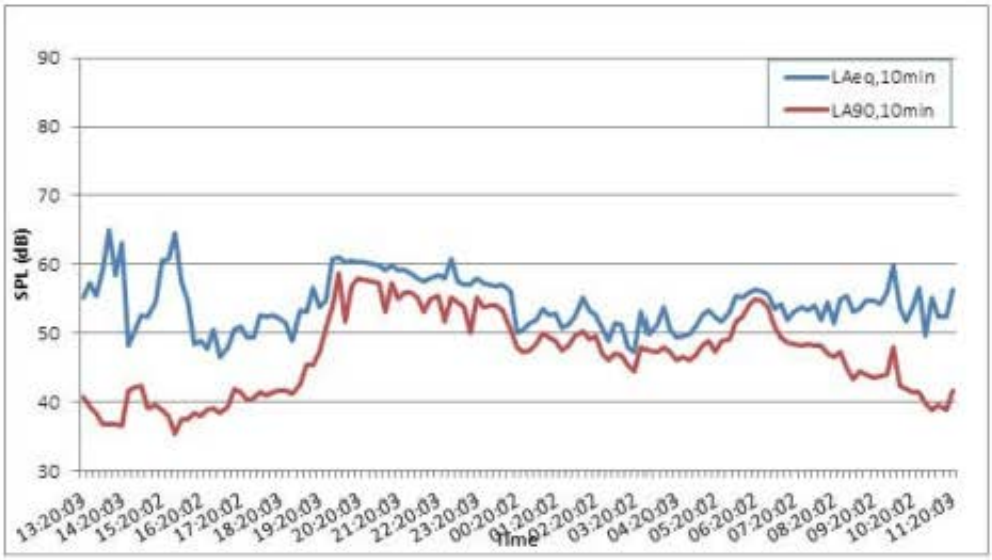


Figure 10.12: Measured Noise Levels – Sarajobe

The graph indicates a close correlation between measured L_{Aeq} and L_{A90} noise levels during the evening and night-time, but a reduced correlation during daytime hours. In daytime, the difference between measured L_{Aeq} and L_{A90} noise levels is over 10 dB, indicating a relatively non consistent noise environment with noisy events influencing measured noise levels.

The graph indicates an increase in noise levels during the evening period from 5 pm to approximately 8 pm, with noise levels remaining relatively consistent thereafter.

When comparing monitoring results to the limits prescribed in the IFC EHS Guidelines, ambient noise levels are generally lower than the daytime limit of 55 dB L_{Aeq}, and are consistently higher than the night-time limit of 45 dB L_{Aeq}.

The lowest measured noise levels are presented in Table 10.13.

Table 10.13: Lowest Average Hourly Measured Noise Levels – Sarajobe

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	03:00	04:00	50.5	46.7
Day	15:00	16:00	60.1	38.3

10.5.2.11 Canico Tumane

Monitoring of baseline noise levels at Canico Tumane was undertaken between 13 and 14 September 2012 (Figure 10.13).

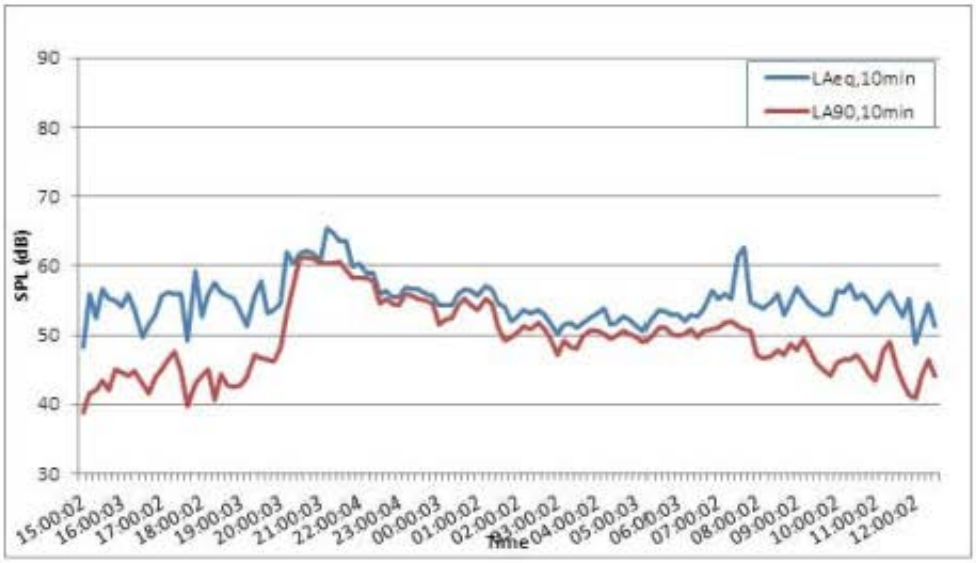


Figure 10.13: Measured Noise Levels – Canico Tumane

The graph indicates a close correlation between ambient (L_{Aeq}) and background (L_{A90}) noise levels, particularly at night. Noise levels remain largely consistent during the night periods, prior to a steady decrease through daytime until late afternoon, when noise levels are observed to increase substantially.

When comparing monitoring results to the limits prescribed in the IFC EHS Guidelines, ambient noise levels are consistently higher than the daytime and night-time limits of 55 dB L_{Aeq} and 45 dB L_{Aeq}, respectively.

The lowest measured noise levels are presented in Table 10.14.

Table 10.14: Lowest Average Hourly Measured Noise Levels – Canico Tumane

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	03:00	04:00	51.5	48.9
Day	15:00	16:00	54.6	42.5

10.5.2.12 Saliquenhedim

Monitoring of baseline noise levels at Saliquenhedim was undertaken between 13 and 14 September 2012 (Figure 10.14).

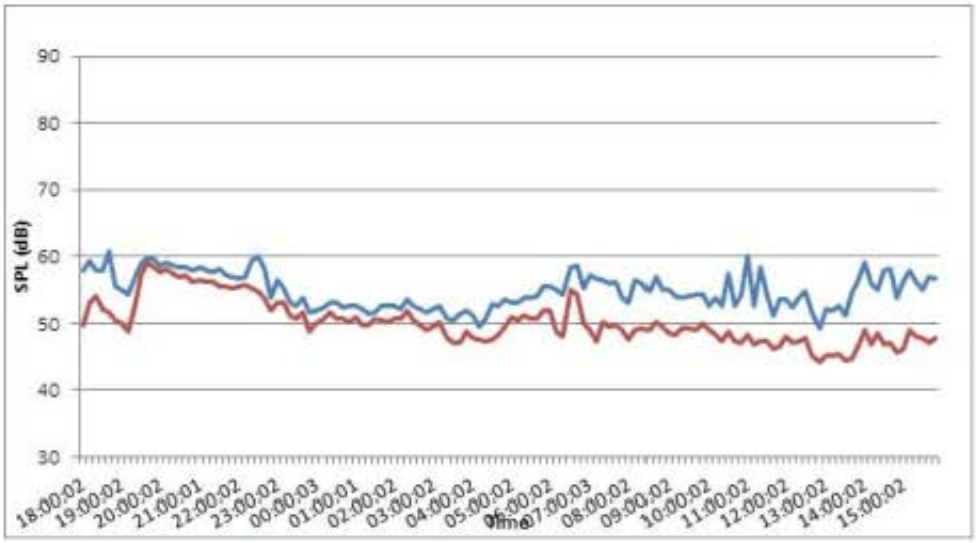


Figure 10.14: Measured Noise Levels – Saliquenhedim

The graph indicates a close correlation between ambient (L_{Aeq}) and background (L_{A90}) noise levels, with closer correlation observed during the night-time period. Measured noise levels are consistent throughout the day and typically in the range 45 and 60 dB.

When comparing monitoring results to the limits prescribed in the IFC EHS Guidelines, ambient noise levels are consistently below the daytime limit of 55 dB L_{Aeq} but above the night-time limit of 45 dB L_{Aeq}. The lowest measured noise levels are presented in Table 10.15.

Table 10.15: Lowest Average Hourly Measured Noise Levels – Saliquenhedim

Period	Start Time	End Time	dB L_{Aeq}	dB L_{A90}
Night	04:00	05:00	51.9	48.1
Day	13:00	14:00	53.5	45.3

10.5.3 Summary

Baseline noise monitoring was undertaken at twelve representative locations across the study area. In general, the monitoring results highlight an increase in noise levels during the evening period, preceding a consistent noise level during the night-time period. The higher evening noise level may be attributable to nocturnal wildlife activity, particularly toads and crickets, as was observed during the survey.

The lowest measured hourly background noise levels at each location during both the daytime and night-time periods are presented in Table 10.16.

Table 10.16: Summary of Measured Background Noise Levels, dB

Location	Lowest measured background noise level $L_{A90\ 1\ hour}$	
	Daytime (07:00 - 22:00)	Night-time (22:00 - 07:00)
Farim I	46.9	33.9
Farim II	50.7	48.4
Binta	42.3	33.6
Canico	45.5	39.1
Cansenhe	45.4	40.6
Sanjalo	39.7	46.0
Ufude	49.0	44.6
Saliquenhe	46.9	49.3
Sancalanco	48.9	54.9
Sarajobe	46.7	38.3
Canico Tumane	48.9	42.5
Saliquenhedim	48.1	45.3
IFC EHS guideline value	55.0	45.0

10.6 Abbreviations and Acronyms

ESIA	Environmental and Social Impact Assessment
IFC	International Finance Corporation
ISO	International Standards Organisation
Met	Meteorology
m/s	Metres per second
N/A	Not applicable
QA / QC	Quality Assurance / Quality Control
UKAS	United Kingdom Accreditation Service

10.7 Glossary

L_{Aeq} The value of the A-weighted sound pressure level in decibels of continuous steady sound that within a specified time interval, T, has the same mean-squared sound pressure as a sound that varies with time

L_{A90} The A-weighted sound pressure level which is that exceeded for 90% of the measurement period, indicating the noise level during quieter periods, and is often referred to as the background noise level

dB Decibel. Acoustic unit used to quantify sound levels relative to a 0 dB reference (20 micropascals sound pressure), set at the typical threshold of perception of an average human.

10.8 References

British Standards Institute (1997) BS4142:1997 Method for Rating industrial noise affecting mixed residential and industrial areas, September 1997.

International Finance Corporation (2007) Environmental, Health, and Safety (EHS) Guidelines, General EHS Guidelines: Environmental, World Bank Group, April 2007.

International Standardisation Organisation (2003) ISO 1996-1:2003 Acoustics -- Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures, 2003.

International Standardisation Organisation (2003) ISO 1996-2:2007 Acoustics -- Description, measurement and assessment of environmental noise -- Part 2: Determination of environmental noise levels, 2003.

World Health Organisation (1999) Guidelines for Community Noise, 1999.

11.0 ARCHAEOLOGY AND CULTURAL HERITAGE

11.1 Introduction

The archaeological and cultural heritage study was undertaken by Tropica Environmental Consultants (Tropica), assisted by archaeological consultants, Laboratoire d'Archéologie IFAN-UCAD of Senegal. The objective of the study was to define the archaeological and cultural heritage baseline in the study area as follows:

- Land-based elements: the mine site, waste management facilities, processing plant, run-of-mine (ROM) pad, stock pile, and barge loading facilities; and
- Marine-based elements: barging down the River Cacheu, barge marshalling area, and ship loading pontoon.

Fieldwork included interviews in local villages, followed by field reconnaissance of sites of importance identified during interviews.

This baseline will be used to inform the ESIA of the proposed development.

11.2 Baseline Study Area

The local study area comprises the proposed mine area, villages that may be directly affected by the Project and the footprint of all infrastructure. In contrast, the regional context is defined by broader processes involving the Guinea and Senegambia coasts and to some extent West Africa.

11.3 Previous Work

Tropica has conducted rapid field reconnaissance in the study area. No previous work has been identified in this study area.

11.4 Methods

To characterise the baseline archaeological and cultural heritage environment group consultation was held in four villages:

- Canico Tumana;
- Tambato;
- Saliquenheba; and
- Urqui.

Consultation involved a formal process of greeting the village chief and the village elders, followed by an address to the assembled villagers. These consultation activities elicited information on the location of sites or archaeological and cultural heritage significance, including:

- Sacred sites;
- Burial areas;

- Secret societies;
- Village history; and
- Nature of crafts people.

Sites identified orally were subsequently identified through field visits.

Rapid field reconnaissance was also conducted further north in the vicinity of the proposed Overburden Storage Area (OSA) 02, to identify any sites of archaeological or cultural heritage significance.

To characterise the archaeological and cultural heritage baseline environment along the River Cacheu, two locations were targeted.

11.4.1 International Standards

The principal conventions and guidance for this study are:

- UNESCO World Heritage Convention (1972);
- International Finance Corporation's Performance Standards on Social and Environmental Sustainability (2006), especially Performance Standard 8: Cultural Heritage; and
- World Bank Operational Policy / Bank Procedure (OP / BP) 4.11 - Physical Cultural Resources.

In the last 40 years, standards of "best practice" have developed, particularly in North America and Europe, with regard to the identification, protection, and management of cultural heritage sites and resources. UNESCO has published a series of Conventions, Declarations and Recommendations applicable to cultural heritage projects. Guinea-Bissau is a signatory to UNESCO and the UNESCO Conventions and may use those conventions as if they were national legislation. The principle relevant instruments are:

- UNESCO Convention Concerning the Protection of World Cultural and Natural Heritage (1973);
- UNESCO Operational Guidelines for the Implementation of the World Heritage Convention (2005);
- UNESCO Recommendation on International Principles Applicable to Archaeological Excavations (1956);
- UNESCO Declaration Concerning the Intentional Destruction of Cultural Heritage (2003);
- UNESCO Recommendation on the Safeguarding of Traditional Culture and Folklore (1989);
- UNESCO Recommendation for the Protection of Movable Cultural Property (1978);
- UNESCO Recommendation Concerning the Safeguarding and Contemporary Role of Historic Areas (1976); and
- UNESCO Recommendation Concerning the Safeguarding of Beauty and Character of Landscapes and Sites (1962).

The International Council on Monuments and Sites (ICOMOS) is an international non-governmental organization of professionals dedicated to the conservation of the world's historic monuments and sites. ICOMOS works for the conservation and protection of cultural heritage places. It is the only global non-government organization, dedicated to promoting the application of theory, methods and scientific techniques to the conservation of the architectural and archaeological heritage. ICOMOS has published a number of charters, of which the following are most pertinent:

- ICOMOS Charter for the Protection and Management of the Archaeological Heritage (1990; the Lausanne Charter);

- ICOMOS The Burra Charter: The Australia ICOMOS charter for the conservation of places of cultural significance (1999);
- ICOMOS Charter—Principles for the analysis, conservation, and structural restoration of architectural heritage (2003);
- ICOMOS Charter on the Built Vernacular Heritage (Mexico, 1999); and
- ICOMOS International Charter for the conservation and restoration of monuments and sites (Venice Charter; 1964).

11.4.2 Guinea-Bissau Legislation and Standards

In Article 17 of the Guinea-Bissau Constitution, the preservation of cultural heritage and identity is an important attribute of the State and is key to societal, political and economic development; however, this specific legislation is underdeveloped.

Guinea-Bissau is signatory of the Cultural Charter for Africa adopted in Port Louis, Mauritius in July 1976 and enforced in September 1990. The Cultural Charter for Africa urges all signatory states to carry out a systematic inventory of their cultural heritage in the spheres of traditions, history and arts. Article 1 (b) seeks to rehabilitate, restore, preserve and promote African Cultural Heritage.

The member states agreed to defend and develop the people's culture, rehabilitate the functions of artists and craftmen and, use information and communication technology for cultural development and raise awareness about heritage resources.

In 2006, the Charter of African Cultural Renaissance replaced the 1976 Cultural Charter for Africa. Under this new charter, member states commit to defend minorities and their culture to promote cultural diversity, to protect and develop tangible and intangible heritage and use cultural heritage resources to build Pan-Africanism. This Charter urges member states to take all necessary measures for the establishment of African World Heritage Fund. In Article 31, African states agreed to build capacities, particularly for the specialised institutions of African Union Commission to enable it to coordinate, monitor, evaluate and harmonise best practices and policies concerning programs and networks.

In addition to African Union, Guinea-Bissau is signatory of the Cotonou Agreement (2000) that was revised in Luxembourg in 2005. The Joint Declaration XI on the ACP expresses the common will of signatory States for the preservation and enhancement of the cultural heritage at the international, bilateral and private level to promote the development of exchange information on the culture heritage of ACP States. Member States also expressed the usefulness of providing assistance in training for the preservation, protection and exhibition of culture heritage properties, monuments, and objects and, the promulgation and enforcement of adequate legislation.

Since 2006, the Republic of Guinea-Bissau is also a signatory to United Nations Educational, Scientific and Cultural Organization (UNESCO) and the UNESCO Conventions and may use those conventions as if they were national legislation.

11.4.3 Limitations of Baseline Studies

In some locations, surveys were impeded by adverse ground condition, comprising dense secondary forest or fallow fields with very dense ground-cover grasses and bushes (Figure 11.1). This made the observation of archaeological sites extremely difficult during a simple walkover.

Figure 11.1: High grasses and vegetation, reducing surface visibility in study areas

This effect was observed to be exacerbated during the wet season, during which minimal ground surface visibility was achieved, particularly in the area of the proposed OSA 02, due to a combination of dense vegetation and pools of stagnant water. In order to penetrate survey areas, dirt track roads were located, from which only archaeological sites in close proximity were identified.

11.5 Results and Discussion

11.5.1 Farim Area

11.5.1.1 General Overview

The villagers practice subsistence level agriculture, and are 'governed' by a village chief. Traditionally each village may have had one of several sacred bushes but with conversion to Islam most of the sacred bushes were abandoned. Traditionally, the sacred bush was the geographic place where the most secret ceremonies are conducted. Secret societies such as the *Kankourang* still exist in most of the villages and until recently had a secret bush in each.

The roles of the secret societies (especially *Kankourang* among the men) and their respective 'Sacred Bushes', are probably the single most important elements of society in the Farim region. Although *Kankourang* society associated with male initiation has undergone profound changes over the past decades, it is still omnipresent; in everyday village life, and in social and political organization. *Kankourang* is traditionally a Malinke secret society. However, in the Project, in addition to Malinke, most other ethnic groups including Peul, Manjack, and Balante have adopted *Koukourang* practices, which reflect a strong presence of Malinke socio-political institutions in the villages of the Project area. *Fambodi*, another masked figure that is more powerful than the *Kankourang* according the villagers has not appeared in many years. This figure generally appears during difficult times and is a powerful social regulator whose role is to re-establish peace, security, discipline and order when these are threatened.

Kankourang has recently been added on UNESCO World Heritage list, which means that it is critical to record this practice in multiple social contexts and preserve both the cultural and physical environment it is associated with.

According to traditions thus far collected in the Project area, Canico Tumana is one of the oldest settlements in the area. The date of establishment is not known but would fall anytime in between the 13th century and the arrival of Portuguese settlers. Farim Sané is understood to have been the founder of the village and gave his name to the town of Farim. If Farim Sané encounter with Portuguese seafarers after AD 1500 is correct, then the foundation of Canico Tumana would be much later and would not predate the 15th century. In any case, material culture observed in most archaeological sites and traditions collected in all the villages suggests that most villages in the area were established between the 17th and the early 20th century.

The villages are, overwhelmingly inhabited by Malinke speakers; other groups including Peul, Balante, Manjack are also present. However, some villages such Urqui, are almost exclusively inhabited by Peul speakers. While inter-ethnic marriage is not rare in the villages, some groups such as Peul speakers we

interviewed in Urqui said that although they marry with Balante, they do not with the Malinke. The fact that some villages, such as Urqui, are ethnically homogeneous (also Peul speakers) suggests that information on ethnicity might prove useful to the Farim phosphate company in community sustainability works. However, the fact that most of the ethnic groups have adopted Malinke social institutions such as the *Kankourang*, suggest some degree of interaction and exchange has happened in the past.

There is also from the interviews evidence of ethnic tensions between the Peul and the others (Malinke in particular) during Moussa Molo (an ethnic Peul) war in the 19th and early 20th century.

During interviews cases of conflicts between villages for the control of farmlands were documented: these occurred in the recent past and have resulted in death (e.g. Tambato and Canico; Saliquenheba and Tambota in the 1990s).

Ethnographic meetings and interviews conducted in the four villages in the vicinity of the mine site and associated infrastructure resulted in the discovery and location of 40 cultural heritage sites/places, including:

- 26 archaeological sites, comprising abandoned ancestral sites; and
- 14 sacred sites, mainly dominated by cemeteries.

A lack of adequate recording has resulted in these sites remaining undated. A preliminary overview of these sites suggests a history of subsistence agriculture, habitation (sedentary or seasonal settlements), and ritual activities (sacred bush, burials).

The communities seem to know, and to value these sites, which they interpret (often correctly) as 'ancestral villages' which are part of the villagers' heritage. These sites appear to be relatively recent (i.e., within the last 500 to 600 years). However, because earlier sites have not been found it does not mean the Project area was not occupied prior to the fifteenth century.

The location of 26 sites using overview methods suggests that a greater number of sites of archaeological and cultural heritage significance are present. Sites of archaeological and cultural heritage significance identified in the vicinity of the four target villages are listed in Table 11.1.

Table 11.1: Village History and Sacred Sites

Village name	Village founder name	Date of Foundation	Sacred sites	Coordinates	Observations
Saliquenheba	Mouhamadou Lamine Touré also called Courtouba	17th century			Village's chief is 4th generation of descendants from founder. Malinké are predominant, followed by Balantes and Mankagne. Most important events in village's life include initiation ceremonies following circumcision of boys and excision of girls.
			Ancient cemetery (GBS1)	0472010 1379382	Cemetery of Saliquenheba: identification of the grave of Fodé Biyaya, first imam of the mosque. He died in 1912. Pilgrims from Dakar, Bissau, Gambia, Ziguinchor come pray here during that annual ceremony called *Gamou*.
			Sacred tree (GBS2)		Sacred tree in the village of Saliquenheba. Leaves or barks used by women immediately after giving birth.
			Place for prayers called Sousoutoto (GBS3)	0471636 1379398	Place of prayers at times of problems. It is strictly prohibited of cutting trees here.
			Sacred site and sacred tree (GBS4)	0471403 1378766	Site where excision of aged girls takes place. There are two sacred trees, one called *Dialla* and the other Santanwkoto not in use anymore
Canico Lenque Croto			Present day cemetery (GBS 5)	0470357 1377441	Muslim cemetery used by Malinké speakers from Canico.
			Ancient Malinké cemetery (GBS 6)	0471231 1377321	Old cemetery of Canico Lenque Croto
			Ancient Mandjak cemetery (GBS7)	0471626 1376947	Ancient Manjak cemetery
Tambato	Toumani Dabo	Around the 17th century			Tambato contemporaneous of Saliquenheba. In the 1990s, tensions between the two villages for the control of farmlands resulted in death. Similar tensions opposed Tambato and Canico villages for the exploitation of wood in farmlands.
			Ancient cemetery (GBS 8)	0468584 1378986	Ancient cemetery of Tambato
			Modern cemetery (GBS 9)	0470100 1380037	Ancient Muslim cemetery of Tambato, It is possible that it was established on an archaeological site as potsherds were observed there.

Village name	Village founder name	Date of Foundation	Sacred sites	Coordinates	Observations
Temanto	Kedjan Danfa and Dianko Sadio	Second half of 20th century			Temanto is inhabited by Balante speakers including both Muslims and Christians. It was a refuge site during the colonial war against Portugal and was burnt at that time; populations fled to Tanaf (Senegal). Circumcision of boys and excision of girls are practiced.
			Sacred tree called *Mboué* (GBS10)	0463728 1378943	Balante speakers come to pray at the foot of this tree and make sacrifices.
Canico Tumana	Farim Sané	Between 13th and 17th century?			Oldest village in area. Inhabited by Malinké and founded by Farim Sané who allegedly met the Portuguese at their arrival in the region around the 17th century. Prior to their definitive settlement it this area, many wars followed by displacements opposed the populations and Moussa Molo in the 19th century. Later in 1963, war broke out against the Portuguese. In the past, diseases, famine and wild fire have had disastrous consequences on village lives.
			Ancient cemetery (GBS 11)	0473025 1384999	Old cemetery of Canico Tumana
Urqui	Sidy Mballo	19th century			Peul
			Ancient cemetery (GBS 12)	0471712 1384487	Ancient cemetery of Urqui.
			Modern cemetery (GBS 13)	0471779 1384441	Modern cemetery of Urqui

Traditional healers are present in all the villages visited, but their knowledge and use of plants from 'the bush' is very poorly understood. The cultural roles and activities of the traditional healers (who deal with the majority of health issues at a local level) are unrecorded.

In most of the villages in the study area, craft activity is poorly developed; some have neither a blacksmith, potter, a weaver, *griot*, nor leatherworker. Itinerant woodcarvers move between villages. The prestige associated with craft activities typical in regions with a strong influence of Malinke sociopolitical institutions is missing. Although griot's roles are well known in all the villages visited, it is of interest to note that they are almost absent. Notable is the rarity of craft specialists particularly for Malinke and Peul societies.

The villages are predominately Muslim. It is also apparent that all villagers continue to practice some elements of traditional African religion, as is apparent though the continuing practice of *kankourang* and the combination of Islamic and traditional African prayers used in traditional healing practices. It is apparent that most villages have some form of cemetery for the burial of the dead. The fate of the physical remains after death is very much a secondary concern (to that of the 'soul') and that the cemetery serves a more functional role, one which can be moved to new / alternative locations should the need arise. Seasonal or yearly festivals and ceremonies have only been recorded thus far. These ceremonies are however consistently stressed as being of great importance for village health and wealth. However, beyond the physical elements of cemeteries and sacred bushes there are few if any direct impacts upon religious customs.

The political structures of the societies living in the Project area are largely influenced by Malinke organization. In theory, Malinke society is strongly stratified and individuals are generally locked into social categories. The presence of European trade goods including imported ceramics, glass beads, glass bottles, etc., indicates that inhabitants of the Farim region had contact with wider regional cultural trends and events (Figure 11.2).

Figure 11.2: European trade goods found in the Project area

Attention was drawn to some of the archaeological sites by villagers who have either noted the presence of visible potsherds during the course of their farming activities or have learned from elders or lived on those sites in the course of their lives (Figure 11.3).

Figure 11.3: Pottery observed at many sites in the Project area

Two of the sites (each composed at least of two surface scatters) were identified as potential Portuguese colonial settlements. These sites (GBA 07, GBA 09 and; GBA 22, GBA 23) are, characterised by significant ruins (Figure 11.4). According to local information, each scatter corresponds to a specific activity including a residential area, a factory for the processing of sugar cane, etc. Some of these structures may have been re-used at different moments in history as our informants suggested a re-occupation by the military at an unknown period of one of these sites.

Figure 11.4: European (probably Portuguese) colonial settlement in the Project area

11.5.2 OSA 02

In the area of the proposed OSA 02, six archaeological sites have been identified, comprising four areas of scattered remains, and two isolated finds Table 11.2

Table 11.2: Archaeological sites and isolated finds in O2 area of proposed overburden storage dump

Sites	Coordinates	Material present	Observations
GBA 27	0471360 1383835	Pottery and metal	Light scatter of material culture on dirt road.
GBA 28	0471302 1383773	Pottery	Light scatter of material culture on dirt road.
GBA 29	0470836 1383433	Pottery	Light scatter of material culture on dirt road.
GBA 30	0471739 1383025	Pottery	Light scatter of material culture on dirt road.
ISO 3	0472376 1382849	1 potsherd	Isolated find of one potsherd on dirt road.
ISO 4	0470863 1383444	Potsherds	Isolated find of one several potsherds probably from a single vessel on dirt road.

All archaeological sites and isolated finds found are light scatters probably corresponding to short-term or seasonal occupations sites.

The potential exists for these sites to have greater archaeological significance than initially observed. Further investigation of the survey area is required.

The location of sites of archaeological and cultural heritage sites in the area of Farim are shown in .

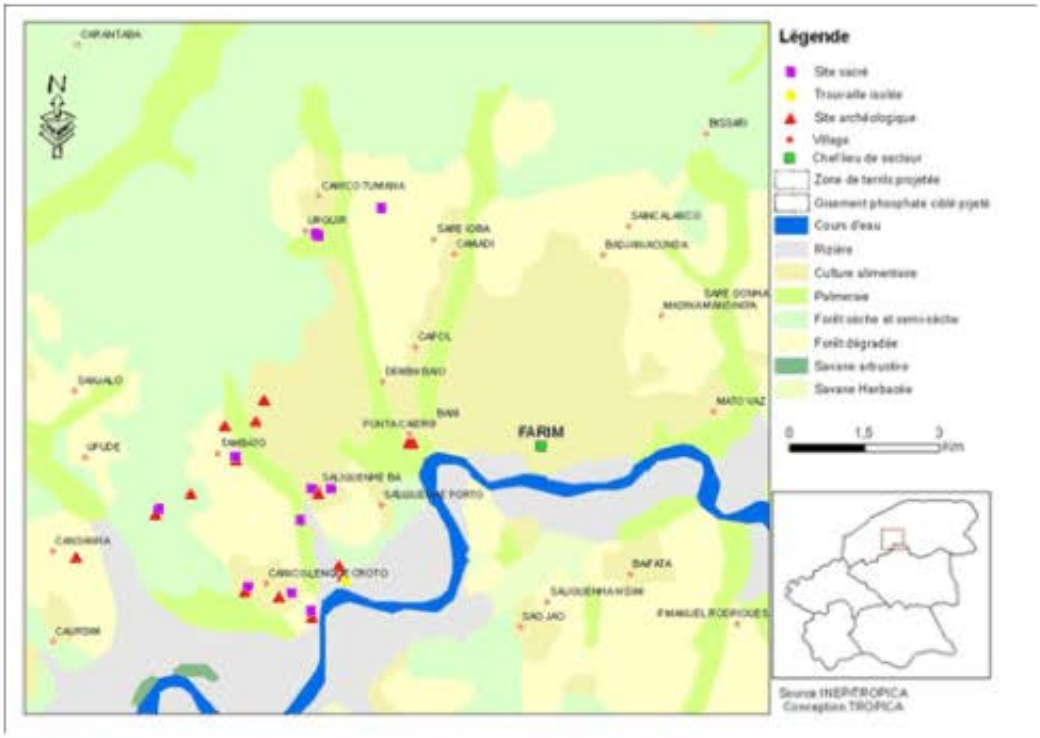


Figure 11.5: Distribution of archaeological and sacred sites within the Project area

11.5.3 River Cacheu

On the basis of available historical records and recorded data, the likelihood of sites of archaeological and cultural heritage significance being located along the River Cacheu corridor is high.

For example, the Balanta living along the mangrove swamps of the River Cacheu established defensive villages or tabancas to resist to slave raiding during the Atlantic era. Capitalising on the increased circulation of iron from the Atlantic commerce, they developed and refined highly sophisticated paddy-rice production techniques. These techniques rapidly spread in the River Cacheu region by the mid-to late seventeenth century and in the Rio Geba region in the eighteenth century. Although the Balanta resided near the powerful slave trading state of Gabou, they were able to maintain political independence by refashioning the structure of their social organisation and by adopted new crops and new farming techniques. They capitalised on their social structures, organization of labor and farming techniques to thrive at a restless political time.

Balanta growth was supported by important technical innovations that were also noted among other groups such as the Manjack (Lauer). Rice cultivation grew in lands between the Lower Rios Geba and Cacheu, and was supported by technical innovations such as the 'metal cap on the blade of the kadyendo [digging tool very similar to the Balanta kebinde] used in rice cultivation' by 1,450 with increased demand for this cereal by Europeans settlers and merchants on the Senegambia and Guinea Coasts.

On the basis of this information it is anticipated that sites of archaeological and cultural heritage significance will be located throughout the study area. This might include European / Portuguese outposts (commercial or military). These can become important tourist attractions for the African Diaspora (and a source of revenue) but also could yield educational material on the history of the slave trade and slavery. Therefore caution must be observed particularly on both the estuarine, and the mining area of the river corridor.

Two villages were identified along the River Cacheu as being of particular archaeological and cultural heritage significance; Binta and Cacheu. Interviews conducted in both villages were followed by field survey to geo-locate identified sites, assisted by local informants.

During interviews, a total of eleven sites were recorded, of which nine were located in Binta and, two in Cacheu (Table 11.3).

Table 11.3: Sacred Sites in Binta and Cacheu

Site	Coordinates	Village Associated	Observations
Sacred tree	0465227 1373039	Binta	Village founder, Kéba Sagna, a hunter, received a revelation from his dog while under the sacred tree.
Ancient cemetery and PAIGC military camp	0465398 1373151	Binta	Villagers said site was heavily vegetated and served as military camp and cemetery during liberation war.
Grave of colonel Faye Cissé	0465414 1373082	Binta	Faye Cissé is a renowned liberation fighter, killed by a mine in 1973.
Old Cemetery	0465251 1372906	Binta	First cemetery of the village at the time of the founders.
Planted wood	0465218 13733016	Binta	Woodland plantation dating to the time of the founder of the village. Protect village.
Sacred tree	0465220 1373012	Binta	Tree identified as "jujubier" allegedly planted since the time of the founder.
Kankourang sacred grove for male initiation	0464884 1373142	Binta	Place where kankourang is dressed and where male initiates camp.

Site	Coordinates	Village Associated	Observations
Female excision site	0465059 1372824	Binta	Female excision is performed at this place since foundation of village.
Mosque	0465194 1373047	Binta	Mosque is considered as sacred due to the reported burial of the village founder and some of his descendants there.
Sacred sites near port	0373193 1357614	Cacheu	Place where fishermen perform sacrifices to prevent misfortune including drowning, illness, etc.
Entrance of port	0373254 1357658	Cacheu	Place on the left side of the entrance of the port where sacrifices are performed to calm water spirits.

11.5.4 Binta

Of the nine sites recorded in Binta, the majority are sufficiently distant from the barge loading facility at Farim, thus reducing the potential for effects from the Project. These include sites where kankourang and initiation of young males take place, and also the location where female excision is undertaken. Other sites in Binta include the mosque in which the founder of the village is buried, two sacred trees and woodland plantations, and two ancient cemeteries. Important historical ruins are present in the area surrounding the port (Photograph 12.2). These likely date to the late colonial period, likely in the late nineteenth and early-to-mid-20th century. It was evident that villagers still retain vivid memories of events related these ruins and therefore they are important for both local and national history, as they concern the development of the legitimate trade that succeeded the Atlantic commerce when humans were a commodity; the liberation war still resonates profoundly in local memories.

Figure 11.6: Ruins in close proximity to the port in Binta

In addition to these ruins and sacred places, villagers are very concerned about performing activities that may anger the water spirits of the River Cacheu. Villagers reported that drowning is common and too often is the result of unhappy spirits; these can be appeased by performing the appropriate sacrifices, which might involve slaughtering a bull and / or, a sheep.

11.5.5 Cacheu

Several ruins are distributed spread throughout the town of Cacheu (see Photograph 12.3). Areas used for sacrificial purposes were also located in close proximity to and at the entrance of the port, and due to their significance must be managed with due care and sensitivity. The ruins in Cacheu have local, national and even international importance. Some are certainly related to Atlantic slavery and are important to both local

and national populations as well as to the African Diaspora of North America, Brazil and areas influenced by slavery.

Figure 11.7: Ruins in Cacheu

During the survey, a family was observed performing sacrifices at the ruins of an old house (Photograph 12.4). Although unconfirmed by field study, Cacheu may have been settled by African populations prior to the onset of Atlantic slavery. Observations made on site support this theory, suggesting that the area was populated by Floups, a subgroup of Diola speakers, at the time when Europeans arrived. Ruins of Atlantic and colonial history are apparent in the town's landscape in the present day, and any Project activity there must treat this history and any artifacts sensitively as they have fashioned and continue to influence local and national society.

Figure 11.8: A family observed performing sacrifices at an ancestral house in Cacheu

11.6 Conclusions and Recommendations

The latest phase field investigation confirms our initial findings (of March 2011 in mine area) that both archaeology and heritage are significant issues in the Project. Although finds in the location of the proposed OSA 02 are of limited value, this may be due to extremely low surface visibility.

Interviews with populations in both Binta and Cacheu connect these localities with important events in local, national and international (Atlantic) history. Historical ruins will need to be managed in consultation with communities because of their importance for local, national and Atlantic histories and memories. In both locations, a number of sacred places that must be dealt with sensitively were identified.

12.0 LANDSCAPE AND VISUAL AMENITY

12.1 Introduction

This section presents the landscape and visual baseline environment for the Project.

The baseline for the landscape and visual impact assessment (LVIA) considers the visual and aesthetic qualities of the region, the sensitivity of the landscape and identifies potential receptors that may be susceptible to the visual effects of the proposed mine development.

There are two main parts to the LVIA baseline study:

- **Landscape baseline** - establishing the key characteristics and sensitivity of the landscape to be affected, to identify areas / features worthy of protection; and
- **Visual baseline** - identifying potential visual receptors, particularly local villages, from which the Project may be visually intrusive.

Identification of sensitive landscapes and visual receptors at an early stage will help inform effective mitigation measures required to minimise the visual impact of the proposed development.

12.2 Baseline Study Area

Regional Study Area

The Regional Study Area (RSA) for the landscape and visual baseline is centred on the proposed mine development, west of Farim township, in the central north part of Guinea-Bissau, approximately 25 km south of the Senegal border, and some 120 km northeast of Bissau.

The RSA extends 10 km from the outer edge of the Project area, which comprises two open extraction pits, overburden storage areas, tailings management facilities, a processing plant, workers accommodation and a barge loading point for transport via the River Cacheu.

A proposed barge area located on the River Cacheu approximately 100 km downstream of Farim is not included in the baseline study or the RSA. The boundary of the RSA is shown on Drawing 550-12.1.

Local Study Area

The local study areas (LSAs) the for the landscape and visual study have been defined through 'viewshed' analysis, using dedicated computer software to calculate the zone of theoretical visibility (ZTV), i.e. locations from which the Project would be theoretically visible. The analysis is made on the basis of topography alone, using the preliminary design proposals for the the Beneficiation Option.

ZTVs produced for the overburden storage areas (OSAs), the largest and potentially most prominent elements of the Project, indicate those areas within 10 km from which the mounds may be visible and define the LSA:

- Drawing 550-12.2 ZTV OSA 01; and
- Drawing 550-12.3: ZTV OSA 02.

Whilst the ZTVs suggest that theoretical views of the mounds would be possible from distances in excess of 10 km, this is unlikely to be the case in reality due to the screening effects of the existing vegetation.

It is considered that receptors located more than 5 km from the proposed mine would not be unduly affected and have not been included in the baseline study.

The preliminary viewshed analysis will be reassessed when the design for the mine and associated infrastructure (e.g. OSAs) is finalised.

12.3 Previous Work

This study is based solely on information obtained in 2012 (data collection and field surveys); there have been no previous studies on landscape or visual aspects in relation to the Project.

12.4 Methods

12.4.1 International Standards

The assessment of landscape quality and visual amenity as a discipline has no established international standards or guidance.

Guidelines produced by the International Finance Corporation (IFC) for the assessment of mining projects (Environmental, Health and Safety Guidelines for Mining, 2007) include the following in relation to visual impacts of mining:

> *"Mining operations, and in particular surface mining activities, may result in negative visual impacts to resources associated with other landscape uses such as recreation or tourism. Potential contributors to visual impacts include highwalls, erosion, discolored water, haul roads, waste dumps, slurry ponds, abandoned mining equipment and structures, garbage and refuse dumps, open pits, and deforestation. Mining operations should prevent and minimise negative visual impacts through consultation with local communities about potential post-closure land use, incorporating visual impact assessment into the mine reclamation process. Reclaimed lands should, to the extent feasible, conform to the visual aspects of the surrounding landscape. The reclamation design and procedures should take into consideration the proximity to public viewpoints and the visual impact within the context of the viewing distance. Mitigation measures may include strategic placement of screening materials including trees and use of appropriate plant species in the reclamation phase as well as modification in the placement of ancillary facilities and access roads."*

The methodology employed for this assessment is based on current UK and USA guidance, namely:

- Landscape Institute with the Institute of Environmental Management and Assessment. *Guidelines for Landscape and Visual Impact Assessment, Second Edition* (GLVIA 2002); and
- United States Department of the Interior, Bureau of Land Management (BLM). *Visual Resource Inventory*. (BLM 1986a).

The methodology amalgamates the best of both systems, using standardised criteria for identifying and assessing the sensitivity of the existing landscape and potential visual receptors. It is applicable to large scale projects, where characterisation and sensitivity of the existing landscape resource has not been mapped previously and where there are no in-country standards for LVIA.

Fundamental to the assessment process is the distinction between landscape and visual effects:

- Landscape effects are the result of a change to the fabric, character, or quality of the landscape as a result of proposed development. They do not have to be seen; and
- Visual effects result from a change in views currently experienced by local residents, visitors, or workers within a study area.

There may be substantial landscape effects but little visual effect if the site is remote with no people to view it.

Whilst landscape and visual issues are intrinsically linked, they are considered separately in this baseline report.

The landscape and visual assessment should use a transparent assessment process with auditable scoring criteria. There is an element of subjectivity in establishing a landscape quality baseline. The landscape quality assigned is based on professional judgement, which may vary between individuals according to

personal values and background. The proposed development may also be perceived differently by the local inhabitants or mine workers, whose opinion may be influenced by financial, cultural, or other priorities.

12.4.2 Guinea-Bissau Legislation and Standards

The NFSP does not specifically reference landscape or visual amenity.

12.4.3 Methodology

Landscape Methodology

The characteristics of the existing landscape were defined to assess its sensitivity, or scenic value, to identify areas worthy of protection and to inform mine design.

Information was obtained through desk studies and site surveys. Maps, geographic information systems data (GIS) and aerial photographs were used to define landscape character areas (LCAs). LCAs are made up of recognisable patterns or elements (physical and perceptual) that occur consistently in a particular area and define the landscape character, or 'sense of place'. These include:

- **Landform** - generally topography becomes more interesting as it gets steeper, more massive, or more severely sculptured. Computer-generated slope analysis was used to identify sloping or undulating ground, which provides greater scenic variation than flat ground;
- **Vegetation** - vegetation patterns usually contribute positively to the scenic value of a landscape. Consideration has been given to the variety, pattern, form, and textures created by vegetation. Generally, landscapes displaying a wide variety of species, age and density are considered to be of higher scenic value than areas with little variation in vegetation type and cover;
- **Water** - adds movement or serenity to a scene; a watercourse or water body provides visual interest and increases the recreational value of an area. Areas in and around the periphery of the water courses / bodies are generally considered to be of higher scenic value. Typically, natural water features (e.g. rivers and waterfalls) tend to be of greater value than man-made features (e.g. canals and reservoirs);
- **Built form** - (existing development) adds variety to a landscape. Depending on the nature and scale of the development it may promote visual harmony, or it may result in disharmony in the landscape. A small group of traditional houses made of local material are likely to enhance landscape, where as a large scale industrial plant is likely to detract from a scene;
- **Historical/cultural associations** - landscape may be of historical or cultural interest (either directly or by association). Historical features (or remains), along with culturally important sites, may influence the perception of a landscape, contributing positively to the scenic variety and / or its potential for tourism;
- **Tranquillity** - generally tranquil areas with low noise levels and low levels of human activity are perceived as being calmer, more relaxing environments and therefore more pleasant landscapes to stay, whilst busy or noisy landscapes tend to be less inviting. Natural sounds are generally preferable to man-made sounds;
- **Scarcity** - scarcity or rarity of a landscape increases its importance. Landscapes which are 'one of a kind', unusually memorable, or are rare within a country or region are generally more valuable as a geographical resource than common place landscapes; and
- **Condition** - pristine landscapes (either natural or man-made), or those with little human intervention are generally more valuable scenically than those that have been severely degraded or are in a poor state of repair.

The landscape within and adjacent to the Project was assessed in relation to the above criteria to produce a series of discreet LCAs, each with their own identifiable characteristics and scenic qualities.

Designated areas protected by international, national, or regional policy are also a key consideration in the assessment of the landscape characteristics, although because there is no implicit or direct link between a designation and its scenic value or landscape sensitivity landscape designations were not included in the scoring criteria.

Landscape Sensitivity

The sensitivity or scenic value of each LCA was assessed in relation to its capacity to accommodate change of a particular type and scale without unacceptable adverse effects on the existing landscape character. The extent to which a landscape can accept such change is dependent on the physical characteristics of the landscape and the scale and nature of the change to the receiving environment. Landscape sensitivity is also dependent on the relative importance of the landscape values identified within each LCA.

The scenic value and sensitivity of the LCAs was calculated by applying a score to the individual elements or characteristics using the criteria in Table 12.1 allowing the combination of factors to define the overall quality, sensitivity, and boundaries of the LCA.

Table 12.1: Criteria for Assessing Landscape Sensitivity

	Rating Criteria and Score					
Landform	High vertical relief such as prominent cliffs, spires, rock outcrops, or severe surface variation or highly eroded formations including major badlands or dune systems; or detail features dominant and exceptionally striking and intriguing, such as glaciers		Undulating landscape displaying a variety of gradients and orientation; or detail features which are interesting though not dominant or exceptional		Flattish ground with little topographical variation	
	5	**4**	**3**	**2**	**1**	**0**
Vegetation	A variety of vegetative types as expressed in interesting forms, textures, and patterns		Some variety of vegetation, but only one or two major types		Little or no variety or contrast in vegetation	
	5	**4**	**3**	**2**	**1**	**0**
Water	A dominant component of the landscape. Clear and clean. Still or cascading white water		Flowing, or still, but not a dominant in the landscape		Absent, or present but not noticeable	
	5	**4**	**3**	**2**	**1**	**0**
Built Form	Built form (existing development) if present adds favourably to the variety and scenic value of the landscape. It promotes visual harmony in the landscape, or no development to detract from the natural landscape		Built form adds some visual variety to the area, but does not enhance the scenic quality of the landscape		Built form is very discordant and promotes strong disharmony in the landscape, or significant visual detractors present	
	5	**4**	**3**	**2**	**1**	**0**
Historical / Cultural Associations	Landscape is of historical or cultural interest (either directly or by association). Historical / cultural features (or remains) have a major influence on the landscape, contributing positively to the scenic variety and / or the 'sense of place'		Historical / cultural features present, but they are not a notable component of the landscape and have only a minor influence on the 'sense of place'		Historical features or cultural associations are not present, or do not contribute to the 'sense of place'	

	Rating Criteria and Score					
	5	4	3	2	1	0
Tranquillity	Very remote area with virtually no human activity. Very tranquil (natural sounds only). Lack of moving objects		Some human activity and movement in the landscape, but not disruptive		Busy active landscape, (typically urban areas) with lots of noise and human activity. Significant movement of vehicles / pedestrians	
	5	4	3	2	1	0
Scarcity	One of a kind; unusually memorable or very rare landscape within country or region		Distinctive landscape, though somewhat similar to others within the region		Landscape fairly common place within the region	
	5	4	3	2	1	0
Condition	Pristine landscape (either natural or man-made). Without human intervention or highly maintained man-made landscape in good condition		Generally well maintained landscape but with localised degradation of features		Severely degraded landscape in poor state of repair and / or in poor condition; lacking integrity and cohesion	
	5	4	3	2	1	0

The score for each landscape component was combined to provide a total which defines the scenic quality of the LCAs (Table 12.2). The higher the score, the higher the scenic value and degree of landscape sensitivity.

Table 12.2: Landscape Sensitivity Rating

Score	Landscape Sensitivity Rating
35 or higher	Very high sensitivity
30 to 34	High sensitivity
25 to 29	Medium to high sensitivity
20 to 24	Medium sensitivity
15 to 19	Low to medium
10 to 14	Low sensitivity
9 or less	Very low sensitivity

Visual Methodology

The baseline study considers changes in views experienced by people living, working within, or passing through the study area, including indigenous (traditional) communities, local residents, transient groups, recreational visitors, tourists, occupational workers, and other groups of viewers.

Viewshed analysis and site inspections were used to identify potential visual receptors within the study area. Views from residential properties, settlements, and other key locations within the ZTV (e.g. roads, gathering points, and places of cultural heritage significance) were recorded photographically in accordance with the Landscape Institute guidelines (2002).

The relative sensitivity of the visual receptors within the study area was assessed using the scoring criteria given in Table 12.3.

Table 12.3: Criteria for Assessing the Sensitivity of Visual Receptors

Key Factors	Rating Criteria and Score							
Receptor type	Local residents, who live in a permanent, well established settlement. Where existing views are integral to the setting of the dwelling or settlement		Local people or visitors experiencing views from cultural / historic sites, or communal gathering points which are not permanent places of residence		Road users and travellers experiencing views from transport routes; including roads, rivers, railways, tracks or paths. People working on or moving through the landscape (i.e. engaged in farming hunting, shooting)		Users of commercial / industrial areas, taking part in activities not involving an appreciation of the views	
	8	7	6	5	4	3	2	1
Number of Receptors	Large numbers of receptors. Settlements with 200+ households (i.e. busy towns or large villages), or busy transport routes (main roads or railways)		Medium groups of receptors (typically medium sized villages with 50 to 200 households). Transport routes (local roads with frequent travellers)		Small groups of receptors (typically small villages with 25-50 dwellings), or transport routes (local roads with infrequent travellers)		Isolated residents (typically less than 25 households), or infrequent visitors. Very occasional travellers, on quiet tracks	
	8	7	6	5	4	3	2	1

The sensitivity of each receptor is dependent on both the type and size of the group and activity of the viewers. For example, a large group of residents in a well-established village could be highly sensitive to the visual effects of a development; however, the same group travelling along a road is considered to be less sensitive to visual effects, because the viewer is transient. Similarly, individual / isolated receptors are considered less visually sensitive than villages where whole communities may be affected by a proposed development.

The numbers of visual receptors (households) within each village were calculated using aerial imagery to count the number of buildings (it was assumed that one building represents one household). Estimates for numbers and frequency of road users were based on the 'perception of use' obtained during site visits. Detailed traffic counts were not undertaken, or considered, as part of the landscape and visual study.

The combined score for receptor type and the receptor number was used to define the degree of sensitivity (Table 12.4).

Table 12.4: Visual Sensitivity Rating

Score	Visual Sensitivity Rating
15 or higher	Very high sensitivity
13 to 14	High sensitivity
11 to 12	Medium to high sensitivity
9 to 10	Medium sensitivity
7 to 8	Low to medium
6 or less	Low sensitivity
3 or less	Very low sensitivity

Visualisation Techniques

Site Photographs

Site photographs were taken from key viewpoints, including the majority of villages within the ZTV, to illustrate typical views experienced by local inhabitants and / or visitors.

A Sony NEX-5 digital camera was used, using panoramic mode and automatic aperture and shutter speed settings. The focal length (amount of zoom) for each photograph varies between 18 and 38 mm, according to the extent of foreground detail required to readily identify the viewpoint location.

The photographs are presented as a series of individual viewpoint record sheets which include details of the viewpoint location, distance, and direction from the mine area, and a summary of the receptor size / type.

3D Topographical Modelling

A virtual 3D topographical model of the existing landform (and proposed OSAs) was constructed using modelling software (AutoDesk 3DS Max). This allowed the landscape to be viewed from any location, irrespective of visibility or climatic condition and permitted an initial appreciation of the location and approximate extent of the Project.

Viewshed Analysis

Computer-generated ZTVs were produced to establish the approximate envelope from which the Project would be visible; they were generated using 'Resoft Windfarm' software using ASTER DEM data. Above ground features were removed to produce bare-earth elevation values (i.e. it depicts the landform without vegetation or built structures).

Site Survey

The objectives of the site visits were:

- To verify the extent of the ZTVs (as defined by the viewshed analysis);
- To document the views from nearby settlements and other receptors groups;
- To assess the relative sensitivity of the visual receptors; and
- To record and assess the sensitivity of the existing landscape within the concession and the surrounding lowlands.

The site survey was undertaken from publicly accessible roads / paths or from privately owned land (with permission of landowners / village elders).

12.5 Results and Discussion

12.5.1 Landscape Baseline

The main features of the landscape within the study area are described under the following headings:

Topography

Within the study area topographical variation is fairly small, ranging from approximately 8 m above sea level (ASL) in the southwest of the study area to a maximum height of 55 m ASL in the north. The town of Farim is located around the 9 m contour. Drawing 550-12.4 shows the main part of the study area is dominated by the flat low-lying valley through which the River Farim meanders in a generally westerly direction. There are a number of shallow side valleys which join the Farim valley, to the west of Farim town. However, these are comparatively shallow and are relatively indistinct features. Throughout the study area the landform is best described as flat to gently undulating and does not contribute greatly to the 'sense of place'. Throughout the study area dense vegetation cover serves to mask landform variation. It is likely that topographical effects are greater during the dry season when there is less vegetation and the hills / valleys are more pronounced.

Generally the lack of topographical range makes successful integration of stockpiles, tailings facilities and OSAs more difficult, requiring careful consideration of the design to avoid alien looking features in the flat low-lying areas.

Vegetation Cover

Much of the northern part of the study area is covered in dense tropical forest, although in many areas forest has been cleared, or partially cleared to make way for permanent or seasonal cultivation of crops, such as rice, cashew nuts, peanuts, corn and millet.

The most intact tracts of tropical forest are located on higher ground to the north of the study area, where as the low-lying valleys, which are prone to flooding, are largely devoid of trees.

With the exception of the wetland areas in the river valleys large trees are abundant throughout the study area. Even within the villages, where demand for firewood and construction materials is high, mature trees have been retained to provide shade and in some villages large trees have become the focus of the village defining a central meeting point under which villagers gather. Some villages such as Tambadinto have been named after the large tree in the centre of the village.

In many places the giant baobab trees create striking landmark features, as do the numerous stands of clear stemmed date palms which contrast with the rich textures of the native woodland.

The abundance of trees means that villages are frequently screened from the wider landscape. The trees and forest would undoubtedly screen views of the proposed mine from many of the villages.

The variety and disposition of forest and agricultural areas, creates a diverse and varied landscape with areas of dense vegetation and more open areas adjacent to the rivers.

Agricultural production tends to be concentrated into regions according to the water requirements of the crops. The majority of the flat valleys in the study area are given over to the production of rice, utilising the river water to irrigate the paddy fields, whereas the higher more sandy ground to the north is better suited to the production of cashew nuts and peanuts.

Crop production in the study area is generally undertaken at a local scale, mostly for domestic consumption (subsistence farming).

Watercourses

The main watercourse in the study area is the River Cacheu (also known as the River Farim east of Farim town). The river, which comprises a series of gentle bends, varies in width between 150 to 350 m and is navigable to small ships. There is a small jetty and quayside at Farim (referred to as Farim Port). The water is tidal, with a range of between 2 and 3 m. Much of the low-lying land either side of the river is subject to seasonal flooding.

Within the study area there are no bridges across the river (the nearest bridge at Sao Vicente is located approximately 100 km downstream). Vehicular and pedestrian ferries at Farim provide the main means of crossing the river for many kilometres in either direction.

Despite its size there are comparatively few opportunities to view the river from within the study area due to the dense vegetation along the river banks and the wetlands in the river valley which restrict access from the nearby villages.

Four smaller rivers discharge into the River Cacheu to the west of the town:

- Rio de Caur;
- Rio de Cavaras;
- Rio de Bunga; and
- Rio de Banim.

With the exception of Rio de Caur, which remains a permanent watercourse throughout the year, the smaller tributaries tend to be seasonal in nature. The tributaries provide a water source for the irrigation of crops, particularly rice and are a notable feature of the study area.

The water courses are shown on Drawing 550-12.4.

Settlement and Infrastructure

The main settlement within the study area is Farim. The town has a population of approximately 4,000 (based on the number of dwellings visible on aerial imagery). The town comprises shops, administrative buildings, schools and churches with many rendered buildings, including a former swimming pool, some two storey buildings dating back to the pre-independence days when the country was administered by Portugal. More recent buildings tend to comprise mud structures with small windows, verandas and corrugated tin roofs. Many buildings are in a poor state of repair. The main streets have street lights (although no electricity) and the roads are not surfaced.

During the day the town is busy with shoppers, pedestrians, cycles and animals, contributing to the impression of a vibrant township.

Elsewhere in the study area settlements are much smaller, varying in size from 7 to 70 huts and comprising mostly rectangular dwellings with tin, or occasionally thatched, roofs. The villages are generally quieter than Farim, with a peaceful ambience. The villages vary in shape and density. Most comprise an organic cluster of buildings connected by dirt tracks, with field / animal enclosures, large mature trees, patches of cultivated ground, a village well and a central gathering place. Some villages (e.g. Saliquinhe and Cansenhe) have developed along the road and are more linear in form. Larger villages are accessible by road, although many of the smaller more remote settlements were only accessible by foot.

The following villages are located within the study area:

Town / Village	Approximate Number of Dwellings
Bani	17
Bissari	17
Bolumbato	33
Canico	50
Canico Tumane	65
Cansenha	20
Farim Township	1,250
Cabo Seco (Ponta Capsec)	11
Ponta Zeca	16
Saliquinhe	67
Saliquinhe Porto	7
Sancalanco	33
Sangal	24
Sara Lobe	10
Sintchan Maunde	14
Tabandinto	62
Tambato	18
Ulude (Ufude)	27
Sincha Seidi (Urqui)	59

The population of each village has been estimated by counting the number of dwellings visible on aerial imagery, May 2011, assuming one household per dwelling. Based on anecdotal evidence, obtained from villages in September 2012, a typical village dwelling can accommodate up to ten family members.

There are five main roads within the study area radiating out from Farim:

- Farim to Bigene (west of Farim);
- Farim to Dungal and the Senegal boarder, (northwest of Farim);
- Farim to Jumbembem (northeast of Farim);
- Farim to Bricama (east of Farim); and
- Farim to Saliquinhedim (south of Farim across the Rio de Cacheu).

Roads in the study area are mostly unsurfaced dirt tracks and are poorly maintained. The roads are mainly used by villagers walking between settlements, with only occasional cars buses or lorries travelling to or from Farim.

Landscape Designations

There are a number of national parks and protected areas within Guinea- Bissau. None of these are located within the LVIA study area.

The protected area closest to the Project area is the Natural Park of mangroves Cacheu, created by Decree No. 12/2000. Cacheu National Park a protected mangrove area is located on the River Cacheu, approximately 70 km downstream of Farim.

The National Strategy and Action Plan for Biodiversity (2004) sets out the national guidance and areas for conservation and sustainable use of biological diversity including National Forest Management Plan, which is applicable to the study area.

There are no national or local designations specifically relating to the protection of landscapes, views or visual amenity within the study area.

No tourist or visitor attractions were noted within the study area and there were no landmark features or nationally important geographical or historical features to attract visitors to the region.

12.5.2 Landscape Character Areas

Across the study area there is a notable variation in the character or scenic quality of the landscape, although variations are mostly subtle and are determined primarily by the type and density of vegetation cover, which ranges from native forest to cultivated land, or a mixture of the two. Five broad LCAs were identified within the study area:

Table 12.5: Landscape Character Areas Identified

LCA	Name	Refer to table:
LCA 1	River Corridor	10.6
LCA 2	Cultivated River Valley	10.7
LCA 3	Undulating Farmland and Woodland	10.8
LCA 4	Dense Forest	10.9
LCA 5	Settlement	10.10

The defined boundaries of the LCAs may change if extensive vegetation clearance takes place, or if any other notable changes to the existing landscape (e.g., creation of new settlements). The boundaries do not

indicate an abrupt change in landscape characteristics; the transition between the different areas is usually gradual.

Within an LCA or subtype, there may be considerable variation in characteristics at a local level. This study is concerned with the broader landscape characteristics to inform the siting of large scale infrastructure, rather than the micro-siting of mine infrastructure which would require more detailed site-specific work.

The LCAs within the study area (Drawing 550-12.5) are described below along with the assessment of landscape sensitivity (Drawing 550-12.6), based on the criteria outlined in Table 12.1 and 12.2.

Landscape Character Area: LCA1 River Corridor

The River corridor LCA is defined by the River Cacheu which flows through the southern part of the study area in south westerly direction.

Figure 12.1: Landscape Character Area LCA1: River Corridor (Farim: Golder Sept 2012)

Table 12.6 summarises the key features of the LCA using the scoring criteria given in Table 12.1 and Table 12.2 to determine the landscape sensitivity.

Table 12.6: Landscape Sensitivity Rating: LCA 1 River Corridor

	Description of Key Components	Sensitivity Rating
Landform	The river corridor is essentially flat with little topographical variation.	1
Vegetation	The LCA comprises mostly open water without trees. The river banks support dense vegetation either side of the river (apart from at Farim). A key feature of the corridor is the row of mature trees on the river bank, which are taller than the surrounding trees. These taller trees help define the river alignment from within the adjacent LCAs. Where possible should be retained to maintain integrity of the river corridor.	3
Water	Water is a key element of the LCA but is not readily accessible, or particularly noticeable from the surrounding LCAs. The water apart from being an integral part of the ecosystem and a source of foods for local inhabitants it adds visual interest to the town of Farim and has long term potential to attract tourism to the area in the future.	4
Built Form	With the exception of Farim Port the river corridor is largely undeveloped. Flooding and inhospitable ground conditions means settlements are generally set back from the riverside. Farim port is a focal point on the river providing some visual interest to the area and marginally enhances the scenic quality of the landscape.	3

	Description of Key Components	Sensitivity Rating
Historical / Cultural Associations	There are currently no tourist destinations and no obvious historical remains or features within the LCA. Rivers in Guinea-Bissau often have spiritual significance to local inhabitants. (To date the findings of the field work undertaken by the social specialists have not been considered in this assessment. The presence and location of historical / cultural sites of importance to the local population are not known at this stage).	2
Tranquillity	For the most part the river is very tranquil, with the exception of the busy river crossing at Farim Port there is very little sound or evidence of human activity.	4
Scarcity	The river corridor is fairly typical of main watercourses within Guinea-Bissau and West Africa. i.e. it is a distinctive landscape, though somewhat similar to others within the region. Lower reaches of the river, beyond the study area are flanked by protected mangrove swamps.	3
Condition	The river corridor LCA for the most part appears to be in good condition. (An assessment of water quality is not included in the LVIA baseline study). Apart from Farim there is very little human intervention on or adjacent to the landscape.	4
	Total	**24**
	Scenic value and landscape sensitivity	**Medium**

Landscape Character Area: LCA2 Cultivated River Valley

The LCA is defined by the shallow valleys of the Rio de Caur, Rio de Cavaras, Rio de Bunga, and Rio de Banim and encompasses the low lying areas adjacent to the River Cacheu, which are prone to flooding.

Figure 12.2: Landscape Character Area LCA 2: Cultivated River Valley (Rio de Cavaras valley: Golder Sept 2012)

Table 12.7 summarises the key features of the LCA using the scoring criteria given in Table 12.1 and Table 12.2 to determine the landscape sensitivity.

Table 12.7: Landscape Sensitivity Rating: LCA 2 Cultivated River Valley

	Description of Key Components	Sensitivity Rating
Landform	The Cultivated River Valley LCA comprises flattish low-lying land adjacent to the Rio de Farim and land in the shallow valleys to the north associated with the Rio de Caur; Rio de Cavaras; Rio de Bunga; and Rio de Banim. The valleys are enclosed by higher ground in the adjacent LCAs.	2
Vegetation	The flat valley landscape is largely devoid of trees. The land is given over to either open grassland or to the production of crops, including rice which is irrigated from the adjacent watercourses. The contrast between the cultivated areas and the woodland in the adjacent LCAs has resulted in an attractive aesthetically pleasing landscape which dispalys a variety of colour and texture. The lack of trees provides the rare opportunity for long distance views, which are not possible elsewhere due to the abundant forest.	4
Water	Water is a key element of the LCA giving rise to crop production through extensive irrigation of the land. The Rio de Caur is a large and apparent watercourse. The Rio de Cavaras; Rio de Bunga; and Rio de Banim are smaller and less obvious, but contribute significantly to the character of the landscape.	4
Built Form	Villages are mostly located on higher ground away from the low-lying areas which are prone to flooding. Within the LCA the most obvious manmade structures are the bunded paddy fields, irrigation channels and the occasional pedestrian or vehicular bridge. The development is low key and enhances the scenic value of the valleys.	3
Historical / Cultural Associations	There are currently no tourist destinations and no obvious historical remains or features within the LCA. (To date the findings of the field work undertaken by the social specialists have not been considered in this assessment. The presence and location of historical / cultural sites of importance to the local population are not known at this stage).	2
Tranquillity	The cultivated areas are a focus for human activity. The fields are attended by villagers, which reduces the sense of remoteness and sense of isolation experienced in other parts of the study area. Activity is generally low key, typically comprising an occasional solitary worker, using hand implements only. Occasionally roads cut across the valleys, although traffic is occasional and does not reduce the tranquillity of the areas. Overall the LCAs are very peaceful and tranquil.	3
Scarcity	The cultivated river valleys are reasonably common in Guinea-Bissau and West Africa. Although in terms of land area they occupy a very small percentage of the country. (The majority of the land within the study area and the wider region is forested).	3
Condition	The Cultivated River Valley LCA is well maintained as a productive landscape consequently it is in good condition.	4
	Total	**25**
	Scenic value and landscape sensitivity	**Medium to High**

Landscape Character Area: LCA3 undulating Farmland and Woodland

The LCA is defined by the higher ground north of the River Cacheu and comprises a mix of forest, trees and farmland.

Figure 12.3: Landscape Character Area LCA 3: Undulating Farmland and Woodland (North of Farim): Golder Sept 2012)

Table 12.8 summarises the key features of the LCA using the scoring criteria given in Table 12.1 and Table 12.2 to determine the landscape sensitivity.

Table 12.8: Landscape Sensitivity Rating: LCA 3 Undulating Farmland and Woodland

	Description of Key Components	Sensitivity Rating
Landform	The Undulating Farmland and Woodland LCAs occupy higher ground, away from the low-lying valleys. The LCA displays a greater variety in topographical range than the valleys, although landform is not an obviously recognisable feature of the landscape (partly due to the vegetation cover which masks the underlying topography). The slightly greater variety of gradients and slope orientations are visually interesting though not dominant or exceptional	3
Vegetation	The LCA comprises woodland interspersed with cultivated land and orchards. There is greater variety of vegetation than the adjacent LCAs, resulting in a patchwork of different textures, colours with areas of light and shade. In many places fruit or nut trees have been planted in forest clearings. Generally the vegetation cover is less dense than the native forest areas.	4
Water	The LCA occupies higher ground away from the water in the valley bottoms. No water bodies or water courses were recorded in the Undulating Farmland and Woodland LCA. Crops in these areas are more tolerant to drought.	1
Built Form	Away from the settlements there is very little built form. Apart from a number of paths and tracks which provide access to the fields and cultivated area the only signs of human intervention are the fields themselves which have been ploughed and support rows of crops or trees. There are no field enclosures (i.e. fences or walls) or structures outside of the villages.	2

	Description of Key Components	Sensitivity Rating
Historical / Cultural Associations	There are currently no tourist destinations and no obvious historical remains or features within the LCA. (To date the findings of the field work undertaken by the social specialists have not been considered in this assessment. The presence and location of historical / cultural sites of importance to the local population are not known at this stage).	2
Tranquillity	The LCA is very tranquil. Human activity is restricted to occasional farm workers attending the cultivated land, or cattle. There are some roads in the area although traffic is occasional and does not reduce the tranquillity of the areas. Overall there is some human activity and movement in the landscape, but it is not disruptive and the LCAs are quiet and peaceful.	3
Scarcity	The landscape comprising woodland interspersed with farmland is common place within the country and the landscape could be easily replicated.	1
Condition	The Undulating Farmland and Woodland LCA is well maintained as a productive landscape and therefore it is in good condition, although the integrity of the native forest has been compromised by the removal of trees to facilitate	3
	Total	**19**
	Scenic value and landscape sensitivity	**Low to Medium**

Landscape Character Area: LCA4 Dense Forest

The Dense Forest LCA is defined by the dense forest mostly occupying higher ground in the northern part of the study area.

Figure 12.4: Landscape Character Area: LCA 4 Dense Forest. (Carico Tumané: Golder, Sept 2012)

Table 12.9 summarises the key features of the LCA using the scoring criteria given in Table 12.1 and Table 12.2 to determine the landscape sensitivity.

Table 12.9: Landscape Sensitivity Rating: LCA 4 Dense Forest

	Description of Key Components	Sensitivity Rating
Landform	The Dense Forrest LCAs mostly occupy higher ground, to the north of the study area away from the low-lying valleys. The LCAs displays a greater variety in topographical range than the valleys, although landform is not an obviously recognisable feature of the landscape (partly due to the vegetation cover which masks the underlying topography). The slightly greater variety of gradients and slope orientations are interesting though not dominant or exceptional.	3
Vegetation	The vegetation cover is the defining feature of the LCA. Dense forest comprises a wide variety of species, including ground flora, under-storey shrubs and a dense canopy layer. The forest displays a wide variety of colour, texture and leaf patterns. The density and of the forest varies according to the location, increasing further the scenic value of the LCA. It should be noted that the boundaries between the LCA 4 Dense Forest and the adjacent LCA 3 Undulating Farmland and Woodland are not easily defined as the transition between natural forest and farmland is gradual and is constantly changing according to demands, and activity, of the local inhabitants,(i.e. the amount of clearance taking place).	4
Water	Water is not an apparent feature of the LCA. There are no obvious water courses or water bodies within the forest areas. (Although high rainfall levels are an integral part of the forest eco-system).	1
Built Form	Forests are largely uninhabited, with few, if any built form, or signs of human intervention.	3
Historical / Cultural Associations	There are currently no tourist destinations and no obvious historical remains or features within the LCA. (To date the findings of the field work undertaken by the social specialists have not been considered in this assessment. The presence and location of historical / cultural sites of importance to the local population are not known at this stage).	2
Tranquillity	The LCAs are peaceful and remote. Sounds are predominantly natural (i.e. birdsong). Apart from the occasional villager gathering wood or hunting there are few signs of human activity. The remaining forest areas are mostly located away from areas of habitation, which further increases the sense of remoteness.	4
Scarcity	The forest areas are abundant throughout Guinea-Bissau (It is the main land-cover in the region), although anecdotal evidence suggests the forest is reducing due to the demand for agricultural land, construction materials and firewood.	2
Condition	The Dense Forest LCA is mostly in good condition. Areas without human intervention are considered to be more valuable and score more highly (in terms of condition) than those that have been modified or where the species composition has been altered.	4
	Total	**23**
	Scenic value and landscape sensitivity	**Medium**

Landscape Character Area: LCA5 Settlements

The fragmented Settlements LCA is defined by the settlement boundaries and includes the township of Farm.

Figure 12.5: Landscape Character Area LCA 5: Settlements (Farim: Golder, Sept 2012)

Table 12.10 summarises the key features of the LCA using the scoring criteria given in Table 12.1 and Table 12.2 to determine the landscape sensitivity.

Table 12.10: Landscape Sensitivity Rating: LCA 5 Settlements

	Description of Key Components	Sensitivity Rating
Landform	The landform is not the defining characteristic of the LCA. The villages are generally built on flattish or gently sloping ground with little topographical variation.	2
Vegetation	Large mature trees are a feature of the villages. Unlike other west African counties where trees have been cut down for firewood and / or building materials the villages are well vegetated. There appears to be a good relationship between the inhabitants and the surrounding forest. The small scale cultivation of subsistence crops adds variation texture colour to the villages.	4
Water	Water is generally not an apparent feature in the villages. Each village has a communal well, but there are no water bodies or water courses within or immediately adjacent to any of the settlements. The township of Farim is built on the banks of the River de Farim, but the majority of the town is orientated away from the water and has no physical or visual links to it.	1
Built Form	There is a notable difference between the Portuguese inspired 'colonial' style architecture in Farm township and the vernacular huts in the village, which are mostly constructed from local materials. The huts in the villages are functional and growth / layout appear to be determined by the size of the population, availability of land and the local site conditions. The size, scale and appearance of the villages are appropriate to their settings and it is considered that they do not detract visually from the 'natural' surroundings.	3
Historical / Cultural Associations	There are currently no tourist destinations and no obvious historical remains or features within the LCA. (To date the findings of the field work undertaken by the social specialists have not been considered in this assessment. The presence and location of historical / cultural sites of importance to the local population are not known at this stage).	2

	Description of Key Components	Sensitivity Rating
Tranquillity	The tranquillity of the villages is directly related to their size. Farim is a busy town with frequent movement which detracts from the more peaceful surroundings. The villages tend to be much quieter with fewer people. Some noise is generated by children and animals, but this does not detract significantly from the peaceful surroundings.	2
Scarcity	The villages within the study area are relatively commonplace in the region and in Guinea-Bissau. The buildings are constructed from local materials and could be replaced comparatively easily. There are very few old or historic buildings in the villages vested.	1
Condition	The landscape around the villages has been modified though human activity. Intervention is fairly low scale and has not caused irreversible damage to the landscape. The buildings are maintained, although during the site visit a number of damaged or collapsed huts were noted. Many of the buildings in Farim are in a poor state of repair, but have the potential to be attractive structures.	2
	Total	**17**
	Scenic value and landscape sensitivity	**Low to Medium**

The scenic value / landscape sensitivity of the LCAs is summarised in Table 12.11.

Table 12.11: Predicted Landscape Sensitivity

LCA		Scenic Value / Landscape Sensitivity
LCA 1	River Corridor	Medium
LCA 2	Cultivated River Valley	Medium to High
LCA 3	Undulating Farmland and Woodland	Low to Medium
LCA 4	Dense Forest	Medium
LCA 5	Settlement	Low to Medium

It is considered that the most attractive and therefore most sensitive parts of the landscape are the Cultivated River Valleys of the Rio de Caur, Rio de Cavaras, Rio de Bunga, and Rio de Banim that feed in to the Cacheu valley west of Farim and which support verdant crops and grasslands during the wet season.

12.5.3 Visual Baseline

The visual baseline has identified settlements or views from roads or publically accessible places from which the proposed mine and associated infrastructure would be theoretically visible. Table 12.12 lists the settlements which fall within the ZTV for the key 'above ground elements' of the proposed mine (i.e. the overburden storage mounds) which are likely to be the most prominent features of the Project.

Table 12.12: Settlements within the Zone of Theoretical Visibility

Settlement	Settlements Within the Mine ZTV	
	Overburden Storage Area O1. (Beneficiation Option)	Overburden Storage Area O2
Cansenha	✓	
Farim Township	✓	
Army base at Farim	✓	✓
Cabo Seco (Ponta Capsec)		✓

Settlement	Settlements Within the Mine ZTV	
	Overburden Storage Area O1. (Beneficiation Option)	Overburden Storage Area O2
Ponta Zeca	✓	✓
Saliquinhe	✓	✓
Saliquinhe Porto	✓	✓
Sancalanco		
Sangal	✓	
Sara Lobe	✓	✓
Sintchan Maunde	✓	
Tabandinto	✓	
Tambato	✓	✓
Ulude (Ufude)	✓	
Sincha Seidi (Urqui)		✓
Canico	✓	✓
Falaco	✓	
Canico Tumané		✓

Preliminary viewshed analysis shows that:

- 14 villages would have potential views of the Overburden Storage Area O1 (Beneficiation Option); and
- 10 villages would have potential views of the Overburden Storage Area O2.

These settlements were visited in September 2012 to assess the degree of visibility and amount of screening afforded by vegetation and / or intervening structures. (A detailed impact assessment would be undertaken at a later date when the Project design is finalised.)

Preliminary assessment suggests that the dense vegetation reduces opportunities for distant views and many villages are visually contained by dense vegetation, potentially obscuring views of the mine development from many areas of habitation.

Photographs (Drawings 550-12.8 and 550-12.9) were taken from the identified villages, or other strategic locations, where gaps in vegetation, and landform afforded inhabitants potential views of the Project area. The photograph locations are shown on Drawing 550-12.7. (It should be noted that some photographs were taken to illustrate potential alternative sites for OSAs and tailings management facilities, the location of which had not been finalised, prior to undertaking the site visit).

Table 12.13 (to be read in conjunction with the site photographs), provides a brief description of each view and an appraisal of visual sensitivity using the scoring criteria given in Table 12.3 and Table 12.4

Table 12.13: Visual Sensitivity

Photo-graph Ref.	Grid Co-ordinates (WGS84, UTM28N)		Photograph Location / Visual Receptor	Elevation (m)	Description of View	Receptor Type	Receptor Size	Combined Score	Visual Sensitivity
	East	North							
1	467290	1377573	Cansenhe Village	13 m	View from the village, looking northeast along the Farim Road towards the proposed overburden storage area 01. Dense vegetation prevents long distance views.	Residents living in a permanent well established village. Road users and travellers on the Farim to Bigene road. Score: 8	Small numbers of dwellings Score: 4	**12**	**Medium to High**
2	467432	1377635	Cansenhe Village	12 m	Northeasterly view from a vantage point on the Farim Road, east of Cansenhe, looking across the shallow Rio de Caur valley towards and the proposed overburden storage area (01) on the higher ground beyond.	Road users and travellers on the Farim to Bigene road. Score: 4	Road with infrequent travellers. Score: 4	**10**	**Medium**
3	467726	1377765	Rio de Caur Bridge	6 m	Northeast along the Farim Road from the bridge across the Rio de Caur looking towards the proposed overburden storage area (01).	Road users and travellers on the Farim to Bigene road. Score: 4	Road with infrequent travellers. Score: 4	**8**	**Low to Medium**
4	467960	1377867	Rio de Caur Bridge	5 m	Northeasterly view along the Farim Road, approximately 180 m northeast of the Rio de Caur bridge, looking towards the proposed overburden storage area (01). Roadside vegetation partially obscures distant views.	Road users and travellers on the Farim to Bigene road. Score: 4	Road with infrequent travellers. Score: 4	**8**	**Low to Medium**
5	470603	1377699	Canico	22 m	Northwesterly view across the football pitch at Canico looking towards the proposed overburden storage area (01), from the northern end of the village.	Residents living in a permanent well established village. Score: 8	Medium numbers of dwellings Score: 5	**13**	**High**

Photo-graph Ref.	Grid Co-ordinates (WGS84, UTM28N)		Photograph Location / Visual Receptor	Elevation (m)	Description of View	Receptor Type	Receptor Size	Combined Score	Visual Sensitivity
	East	North							
6	471157	1376387	Canico	9 m	Southeast of Canico. Easterly view from the edge of the wetlands looking towards the approximate location of the proposed processing plant on the banks of the Rio de Cacheu. (Behind the taller trees on the horizon).	People working in or moving through the landscape (i.e., engaged in farming or hunting) Score: 4	Occasional farmers. Score: 1	5	Low
7	469916	1379950	Tambato	26 m	Northerly views from the edge of Tambato village looking towards the proposed edge of the northern pit. Mature trees prevent long distance views.	Residents living in a permanent well established village. Score: 8	Small group of dwellings. Score: 4	12	Medium to High
8	467346	1379981	Ufude	17 m	Southerly view, from the edge of Ufude village, looking between houses and trees towards the proposed overburden storage area (01).	Residents living in a permanent well established village. Score: 8	Small group of dwellings. Score: 4	12	Medium to High
9	465889	1381569	Tambadinto (Previously Sangal II)	16 m	Northerly view across cultivated land from the northeastern edge of Tambadinto village. The building in the middle distance appears to be an old religious building.	Residents living in a permanent well established village. Score: 8	Medium sized village. Score: 5	11	Medium to High
10	474063	1383514	Sara Lobe	21 m	View from the Farim road adjacent to Sara Lobe, looking across lower ground to the northeast.	Residents living in a permanent well established village. Score: 7	Small group of dwellings. Score: 3	10	Medium
11	473321	1384125	Sara Lobe	37 m	Easterly view from a high point on the road approximately 1 km northwest of Sara Lobe. Long distance views may be possible in the dry season when the vegetation is less dense.	Road users and travellers experiencing views from the Farim to Dungal road (and to the Senegal boarder). Score: 4	Road with infrequent travellers. Score: 4	8	Low to Medium

Photo-graph Ref.	Grid Co-ordinates (WGS84, UTM28N)		Photograph Location / Visual Receptor	Elevation (m)	Description of View	Receptor Type	Receptor Size	Combined Score	Visual Sensitivity
	East	North							
12	472382	1384573	Canico Tumané	21 m	Northerly views to the north looking across the rice fields of the Rio de Bunja valley (southeast of Canico Tumané)	Road users and travellers experiencing views from the Farim to Dungal road (and to the Senegal boarder). Score: 4	Road with infrequent travellers. Score: 4	8	**Low to Medium**
13	469232	1385672	Sintchan Maundé	31 m	Easterly view of Sintchan Maundé-situation on high ground, affording long distance views to the east.	Residents living in a permanent well established village and road users. Score: 8	Small group of dwellings. Score: 4	10	**Medium**
14	470441	1385240	Sintchan Maundé	52 m	Look distance views to southwest from the highest point on the road mid way between Sintchan Maundé and Canico Tumané	Road users and travellers experiencing views from the Farim to Dungal road (and to the Senegal boarder). Score: 4	Road with infrequent travellers. Score: 4	8	**Low to Medium**
15	471673	1384497	Urqui	35 m	Southerly view from the eastern edge of Urqui village, looking across lower ground to the south.	Residents living in a permanent well established village. Score: 7	Medium sized village. Score: 5	11	**Medium to High**
16	471342	1383865	Urqui	29 m	Southerly view from track south of Urqui. Long distance views across the low-lying ground to the south are screened by foreground vegetation.	Villagers moving through the landscape engaged in farming or hunting. Score: 4	Very occasional traveller / farmer. Score: 1	5	**Low**
17	478810	1384785	Sancalanco	34 m	Northerly view from the track to north of Sancalanco village looking northwards across cultivated ground.	Villagers moving through the landscape engaged in farming or hunting. Score: 4	Very occasional traveller / farmer. Score: 1	5	**Low**
18	478674	1384245	Sancalanco	23 m	Northerly view of the village well and open ground from the northern edge of Sancalanco village.	Residents living in a permanent well established village. Score: 7	Small village Score: 4	11	**Medium to High**

Photo-graph Ref.	Grid Co-ordinates (WGS84, UTM28N)		Photograph Location / Visual Receptor	Elevation (m)	Description of View	Receptor Type	Receptor Size	Combined Score	Visual Sensitivity
	East	North							
19	467103	1377492	Cansenhe Village	15 m	Northerly views from the village well in Cansenhe are restricted by dense vegetation.	Residents living in a permanent well established village. Road users and travellers on the Farim to Bigene road. Score: 8	Medium number of receptors. Score: 2	10	**Medium**
20	471116	1379318	Rio de Cavaras Marinhos	13 m	North easterly view across rice fields from the Farim road at the crossing of the Rio de Cavaras Marinhos (close to edge of the proposed northern pit).	Road users and travellers on the Farim to Bigene road. Score: 4	Road with infrequent travellers. Score: 4	8	**Low to Medium**
21	472954	1379911	Ponta Zeca (North)	12 m	Northerly view across the football pitch on the north side of Ponta Zeca (south of the Farim to Bigene road).	Residents living in a permanent well established village. Score: 8	Small village Score: 4	12	**Medium to High**
22	472873	1380060	Ponta Zeca (south)	12 m	South side of Ponta Zeca (North) looking in a southerly direction towards a small group of 4 -5 houses: Ponta Zeca South	Residents living in a permanent well established village. Score: 7	Small group of dwellings. Score: 3	10	**Medium**
23	473042	1379504	Ponta Zeca	6 m	Northerly view across rice fields between Ponta Zeco North and Ponta Zeco South (looking north)	Villagers moving through the landscape engaged in farming or hunting. Score: 7	Very occasional travellers, on quiet tracks. Score:1	8	**Low to Medium**
24	473055	1379201	Ponta Zeca (South)	14 m	Boabab trees south of Ponta Zeca (South) looking in a southerly direction towards the Rio de Cacheu.	Villagers moving through the landscape engaged in farming or hunting. Score: 3	Very occasional travellers, on quiet tracks. Score: 1	4	**Low**
25	473226	1378575	Selaquinhe Porto	11 m	Southerly view from south of Selaquinhe Porto (small group of old huts) looking towards the river and an old well in the foreground.	Villagers moving through the landscape engaged in farming or hunting. Score: 4	Very occasional travellers, on quiet tracks. Score: 1	5	**Low**

Photo-graph Ref.	Grid Co-ordinates (WGS84, UTM28N)		Photograph Location / Visual Receptor	Elevation (m)	Description of View	Receptor Type	Receptor Size	Combined Score	Visual Sensitivity
	East	North							
26	473265	1378325	Selaquinhe Porto	6 m	Palm trees to the south of Selaquinhe Porto, on the edge of the wetlands looking south towards the river, (defined by the tall trees on the horizon).	Villagers moving through the landscape engaged in farming or hunting. Score: 3	Very occasional travellers, on quiet tracks. Score: 1	4	Low
27	473238	1378672	Selaquinhe Porto	13 m	Central area in the small and remote settlement of Selaquinhe Porto.	Residents living in a permanent village. Score: 7	Isolated dwellings Score: 2	9	Medium
28	472118	1379865	Saliquinne	19 m	Southwesterly view along the Farim-Bigene road through Saliquinne, flanked by rows of large mature trees.	Residents living in a permanent well established village. Road users and travellers on the Farim to Bigene road. Score: 8	Medium sized village. Score: 5	13	High
29	469796	1378680	Saliquinne	34 m	The Farim-Bigene road southwest of Saliquinne. Southwesterly view from the highest point on the road, looking towards the proposed overburden storage area 01.	Road users and travellers experiencing views from the Farim-Bigene road Score: 8	Road with infrequent travellers. Score: 4	12	Medium to High
30	472487	1382001	Ponta Capsec	16 m	Rice fields in the low-lying Rio de Bunga valley immediately east of Ponta Capsec. (The village lies within the proposed boundary of the northern pit).	Residents living in a permanent well established village Score: 7	Small group of dwellings. Score: 3	10	Medium
31	473693	1380549	Banim	10 m	Northerly view of Benim a small village north of the Farim - Bigene road, between the Rio de Bunga and the Rio de Banim.	Residents living in a permanent well established village. Score: 7	Small group of dwellings. Score: 3	10	Medium
32	474823	1380565	Farim	14 m	Westerly view along the Bigene road, showing houses on the western edge of Farim. The proposed mine pits would be located beyond the trees on the horizon.	Residents living in a permanent township and road users. Score: 8	Large settlement with large number of dwellings Score: 7	15	Very High

Photo-graph Ref.	Grid Co-ordinates (WGS84, UTM28N)		Photograph Location / Visual Receptor	Elevation (m)	Description of View	Receptor Type	Receptor Size	Combined Score	Visual Sensitivity
	East	North							
33	475924	1380248	Farim	6 m	Southerly view across rice fields in Farim. The township is divided by a central cultivated strip of low lying land, part of which is prone to flooding.	Residents living in a permanent township and road users. Score: 8	Large settlement with large number of dwellings Score: 7	15	Very High
34	475881	1382201	Farim	40 m	Farmland and plantations on high ground north of Farim, looking towards the site of the proposed accommodation camp. Vegetation obscures long distance views to the south across Farim.	Villagers moving through the landscape engaged in farming or hunting. Score: 3	Occasional travellers, on quiet tracks. Score: 2	5	Low
35	476064	1381160	Farim	26 m	Westerly view towards the prominent telecommunication mast from houses on northern edge of Farim, (east of the army base).	Residents living in a permanent township Score: 7	Large settlement with large number of dwellings Score: 7	14	High
36	475925	1379602	Farim Port	9m	Southerly view of Farim Port (Farim Township) and the River Cacheu (River crossing).	Travellers experiencing views from Farim Port and the River Cacheu. Score: 4	Busy transport Route with frequent travellers Score: 5	9	Medium

12.6 Limitations of Baseline Studies

The landscape and visual site reconnaissance was undertaken in September 2012, towards the end of the rainy season, when the vegetation was especially dense. At this time of year there are very few opportunities for long distance views within the study area. The perception is of a lush, well vegetated landscape, which is visually enclosed. Anecdotal evidence suggests the landscape is much more open during the dry season and distant views are possible from many locations, especially the higher ground to the northeast. The difference in visual enclosure between the wet and the dry seasons should be an important consideration when considering the visual effects of the scheme, but has not been fully assessed in this study.

The viewshed model and three dimensional (3D) visualisations are based on digital terrain data and mapping available for the Project. Additional data to the southwest of the study area would have given the study drawings more context but is unlikely to change the findings of the baseline assessment.

The value a community places on a locality is an important consideration in the visual assessment. It is likely that there are many unrecorded sites where the visual setting is important to the local population; these should be considered in future community consultation and social management plans.

Professional judgement has been used to moderate the scoring criteria and to ensure the visual sensitivity rating is appropriate, and where possible, consistent with other schemes. Inevitably, there is an element of subjectivity in the scoring process and caution should be used when comparing the findings of this assessment with other similar mine projects.

Despite the limitations, a thorough and robust landscape and visual baseline study has been completed.

12.7 Summary

Summary of Landscape Baseline

The landscape within the study area is varied. It is generally in good condition, and apart from Farim township is tranquil with a sense of remoteness. However, the landscape is not particularly rare; it is not located within a National Park and is not protected by international, national or local designations. There are no important geographical / landmark features, known historical associations or visitor attractions (although it may have potential for tourism in the future).

The scenic quality and landscape sensitivity as a whole is considered to be 'Medium', with some localised variations. The most attractive parts are considered to be valleys of the Rio de Caur, Rio de Cavaras, Rio de Bunga, and Rio de Banim that feed in to the Cacheu valley and which support verdant crops and grasslands during the wet season. The River Cacheu is an important geographical feature, characterised by large trees on river banks.

The town of Farim with its Portuguese style architecture, has a certain colonial charm and has the potential to attract visitors in the future, but is currently in a poor state of repair.

There are many very old trees, including giant Baobab trees within the study area, which have become the focus of the villages and the surrounding area. Some villages such as Tabandinto have been named after local tree species. Anecdotal evidence suggests that some of these mature specimens may have spiritual and or cultural significance.

Summary of Visual Baseline

The most sensitive visual receptors in the study area are predicted to be the local residents, particularly those residing within the larger settlements including the township of Farim. Visual sensitivity is increased by the number of inhabitants whose views may be affected by the proposals. However, preliminary viewshed analysis suggests that many of the residents in the larger villages would be outside the zone of visual influence and would not be affected by the proposals.

Many villages within the ZTV, which are afforded theoretical views of the Project area, are currently screened, or partially screened by dense forest adjacent to the settlements. Where unobstructed views of the Project area are possible from nearby villages and roads it does not necessarily imply a substantial visual effect will occur.

Viewshed analysis undertaken for the alternative mine designs suggests that OSA 02 would be more easily screened than OSA 01, which is located in flat low-lying land and is surrounded by fewer trees.

A key consideration in the assessment of views is the climatic conditions that can affect visibility. During the wet season, visibility is frequently reduced by rain or mist. During the dry season, dust and airborne particulates can reduce the visibility dramatically, often creating a haze which can prevent long distance views.

Another consideration in the LVIA is the ever-changing baseline, particularly in relation to the amount and type of vegetation cover. There was a notable difference in vegetation cover between the wet and the dry seasons. The vegetation was more lush and more dense during the rainy months, which increases the amount of screening and serves to reduce the openness and the apparent scale of the landscape.

Examination of the aerial imagery (2005) and more recent imagery (May 2011) shows significant changes to forest have occurred. Large areas of forest have been cleared, presumably for farming. If this practice continues many areas and some villages currently surrounded by vegetation may become (visually) exposed to the Project.

Similarly aerial photos show a significant increase in the size of villages. Since 2005 many villages have doubled in size and new settlements have appeared and the boundaries / location of some villages has changed.

It is recommended that the visual baseline study is updated at the impact assessment stage to confirm the precise size and location of residential settlements and other potential visual receptors.

It is important to protect the setting of spiritual / sacred sites, burial grounds and religious sites. The effects on these sites would be assessed at the impact assessment stage, although to date the location and impotence of these features will not be known until the findings of the community surveys are known.

12.8 Abbreviations, Acronyms and Glossary

12.8.1 Abbreviations and Acronyms

2D	two dimensional
3D	three dimensional
ASTER	advanced spaceborne thermal emission and reflection radiometer
DEM	digital elevation model
DTM	digital terrain model
EHS	environmental, health, and safety (guidelines)
ESIA	environmental and social impact assessment
GIS	geographic information system
GPS	global positioning system
IFC	International Finance Corporation
km	kilometre
LSA	local study area

LVIA	landscape and visual impact assessment
m	metre
mm	millimetre
RSA	regional study area
ZTV	zone of theoretical visibility

12.8.2 Glossary

ASTER imagery	ASTER (advanced spaceborne thermal emission and reflection radiometer). Aerial imagery derived from the space shuttle or satellites.
digital elevation model	A digital model or 3D representation of a terrain's surface using digital contours or more commonly digital spot heights.
viewshed	A viewshed is an area of land, water, or other element that is visible to the human eye from a fixed vantage point.
viewshed analysis	Viewshed analysis is the objective process of determining the visibility of an object in the surrounding landscape. Areas of visibility or non-visibility are determined by computer software using a digital elevation dataset. The output from the analysis is used to create a map showing a zone of theoretical Visibility (ZTV) which illustrates the potential (or theoretical) visibility of an object in the landscape. The phrase "potential visibility" is used to describe the result because the analysis does not take into account any landscape artefacts such as trees, woodland or buildings. The analysis is made on the basis of topography alone.
zone of theoretical visibility (ZTV)	Output from viewshed analysis. An area of land, water, or other element from which it is predicted a proposed development would be visible (sometimes referred to as a visual envelope).
visual receptor	A visual receptor is a person or group of people (residents, visitors, travellers or workers), whose view or outlook would be affected by a proposed development.
landscape character	Landscape character means the distinct and recognisable pattern of elements that occurs consistently in a particular type of landscape, and how these are perceived by people. It reflects particular combinations of geology, landform, soils, vegetation, land use and human settlement. It creates the particular sense of place for different areas of the landscape.
landscape character areas	These are single, unique areas and are discreet geographical areas of a particular landscape type. Each has its own individual character and identity even though it shares similar generic characteristics with other similar areas.
visual amenity	This is the value of a particular area or view in terms of what is seen. Visual amenity relates to the quality of, pleasantness or attractiveness of views towards, from and in between areas. Landscape elements that increase attractiveness or value will contribute to visual amenity as will development and changes to landscape elements.

representative views	Views which are typically experienced by people living, working or travelling through an area. Representative viewpoints are locations from which views are most commonly experienced.
scenic quality	A measure of the 'attractiveness' of an area or view based on an assessment landform, vegetation, water, built form, historical / cultural associations tranquillity, scarcity and condition. (Based on professional judgement.)

12.9 References

United States Department of the Interior, Bureau of Land Management (BLM). 1986. *Visual Resource Inventory.*

Landscape Institute with the Institute of Environmental Management and Assessment. *Guidelines for Landscape and Visual Impact Assessment. Second Edition 2002.*

IFC / World Bank Group. 10 December 2007. *Environmental, Health and Safety Guidelines for Mining.*

Guinea-Bissau Government: The National Environmental Management Plan (NFSP), 2004, include: *National Forest Management Plan*. (Decree-Law N ° 4-A/91 29 October approved the Forestry Law).

13.0 TRAFFIC

13.1 Introduction

The objective of the baseline traffic study, as part of the overall ESIA, is to characterise the existing baseline conditions in the proposed study area. Existing traffic will be taken into account when predicting what impacts are likely to occur during construction, operation and closure stages of the Project.

Data on traffic rates in the local study area (LSA) have been collected at seven locations to establish road usage by motorised, non-motorised and pedestrian traffic. This information will be a reference for the project design. The information on traffic will enable road infrastructure and safety procedures to be developed, for all phases of the Project (construction, operation, and closure).

13.2 Baseline Study Area

Traffic surveys were undertaken at locations considered to represent key routes and / or interchanges in the Regional Study Area (RSA) and Local Study Area (LSA).

The traffic baseline RSA comprises the area between Farim, Cacheu and Bissau. The traffic baseline LSA is focused on the mine component and the area that will be directly affected (i.e. Farim and surrounding settlements; Drawing 550-13.1).

13.3 Previous Work

Preliminary baseline traffic counts were taken at two locations in September 2012:

- Location 1 Farim (12 September 2012 outside GB Minerals office in Farim); and
- Location 2 Sarajobe (13 September 2012 on the road bypassing Sarajobe village, northwest bound towards the Senegal).

Traffic was monitored over a 12 hour period, from 07:30 until 19:30, based on sunrise and sunset times (06:50 and 19:00 respectively[1]). Traffic volume prior to and after these times was assumed to be lower. GB Minerals' on-site technicians collected the traffic data following training by Golder Associates (UK) Ltd (Golder).

Golder learned of a fuel shortage affecting the Bissau and Farim areas at the time of these surveys. The results of these surveys indicated that the data was not reliable and Golder is of the opinion that traffic levels in the area of Farim are likely to have been affected during the period of the survey. As such, the data could not be relied on as representative of baseline conditions and therefore has been excluded in this report.

13.4 Method

13.4.1 International Standards

The traffic baseline study aligns with the IFC Performance Standards (PSs) (IFC 2012a). IFC Guidance Note 4, G11, Community Health, Safety and Security states (IFC 2012b):

> *GN11. According to the UN Global Status Report on Road Safety (2009), approximately 1.3 million people die each year on the world's roads, and between 20 and 50 million sustain non-fatal injuries. A significant proportion of these fatalities and injuries involve pedestrians, cyclists and motorcyclists. Private sector entities whose commercial activities depend on the use of owned or contracted road vehicle fleets for the transport of goods or provision of services have a particularly important role and responsibility in preventing road accidents to safeguard the lives of community residents along transport routes as well as the lives of their own employees. The role of companies is even more important in jurisdictions with poor quality infrastructure (i.e., lack of proper signalling and illumination, poor road surfaces, lack of proper pedestrian walkways and cross-walks, urban congestion, etc.), poor driver regulations and enforcement (i.e., weak driver licensing rules and enforcement and poor enforcement of road safety rules such as speed limits), and inadequate emergency response infrastructure (i.e., lack of emergency ambulatory and trauma care). Therefore, the client should implement driver and traffic safety programs proportional to the scope and nature of project activities according to the principles described in the General EHS Guidelines Section 3.4 Traffic Safety). Where transport-related activities are performed by subcontractors, clients should use commercially reasonable efforts to influence the safety of these service providers, contractually requiring traffic safety risk analysis and adoption and implementation of driver safety programs. Management programs should include traffic emergency preparedness and response plans that address contingencies for emergency assistance to the driver and to third parties alike, particularly in remote locations or situations with little capacity to address emergencies involving trauma cases and other serious injuries.*

13.4.2 Guinea Bissau Legislation

In the absence of in-country legislation and regulations, the traffic baseline aligns with international good practice.

13.4.3 Limitations of Baseline Studies

The traffic baseline results reflect traffic during the wet season. Road conditions vary seasonally, and during higher volumes of rainfall, some roads are susceptible to becoming waterlogged and developing potholes. This results in some routes becoming unsuitable for travel however this was not the case during the time of the surveys.

A football tournament was occurring in Farim during the time of surveying (September 2013). The tournament began in August 2013 and was understood to finish in October 2013. This on-going event may have raised traffic levels to and from Farim and internally, during the time of the surveys.

[1] Sunrise and sunset times in Guinea-Bissau: http://www.timeanddate.com/worldclock/astronomy.html?n=40 (2012).

13.4.4 Methods Used for Traffic Counting Assessment of Existing Traffic

For the purpose of this study, "traffic" includes pedestrians, bicycles, and transport using animals such as horses and mules. This broader definition is especially relevant to the sparsely populated and rural context of the Project area.

The following transport options were included in the survey:

- Personal car;
- Taxi car;
- Passenger bus;
- Single rear-axel pickup truck;
- Double rear-axle truck;
- Backhoe, bulldozer, tractor;
- Motorcycle;
- Bicycle;
- Travel by animal and cart;
- Pedestrian; and
- Other.

Traffic counts for this revised survey were altered based on lessons learnt from the previous work. The revised counts took place over a 12 hour period between 07:00 and 19:00, based on the sun rise and sunset times of 06:50 and 18:45 respectively. Surveys were taken by 14 local GB Minerals technicians, with two people per location, alternating between 07:00 to 13:00 and 13:00 to 19:00. Survey training was provided by a Golder employee with the support of a GB Minerals manager (Figure 13.1). The technicians used a tally system to record data on a survey sheet (Appendix H).

Figure 13.1: Traffic survey training session

Each location was surveyed three times: 5 September 2013, 6 September 2013 and 8 September 2013. Surveys were taken on these days to account for weekly activities including:

- On weekday mornings, the ferry delivers produce to the market. This usually occurs between 07:00 and 08:00;
- School days are Monday to Friday with morning classes taking place from 8:00 to 12:00 and afternoon classes from 15:00 to 18:00;
- On Fridays, Islamic prayer occurs in the afternoon, generally between 15:00 and 17:00. Before, during and after this period, local people are expected to travel between villages in the LSA and other locations;
- The main market day is on Fridays in Farim and attracts visitors from outside of the township. This usually occurs between 08:00 and 13:00; and
- On Sundays, Catholic prayer is for one hour and occurs between 12:00 and 13:00. Before, during and after this period, local people are expected to travel between villages in the LSA and other locations.

The seven locations are described in Table 13.1.

Table 13.1: Traffic Survey Locations

Survey Location	Description	Coordinates	Comments
T1	Farim North Access Road	E: 476006.6924 N: 1381606.194	This location accounts for the existing traffic flows to and from Farim via the north access road.
T2	Sarajobe Village	E: 475027.3284 N: 1381598.513	This location accounts for the existing traffic flows to and from Farim, northeast to Senegal, by-passing Sarajobe village. This location also accounts for the traffic flows between Farim and Sarajobe, Canico Tumane, and Sintchan Maunde villages. These villages are sensitive receptors and could potentially be affected by construction traffic routing from Senegal to the proposed mine site.
T3	Farim Through Road	E: 476185.0838 N: 1379994.723	This survey is on one of the main roads in Farim and accounts for existing local traffic movements within the township.
T4	Farim River Crossing – North Side	E: 475942.242 N: 1379637.96	This location accounts for the existing traffic flows entering and exiting Farim from the ferry and to the market area.
T5	Farim River Crossing - South Side	E: 475799.7208 N: 1379181.256	This location accounts for the existing traffic flows on the main route between Farim and Bissau, south of the river and north of Saliquinhedium, Construction traffic could potentially route from Bissau.
T6	Sancalanco Village	E: 478432.4433 N: 1382351.822	This location accounts for the existing traffic flows on the main road from Farim, northeast bound to the Senegalese border, bypassing Sancalanco village.
T7	Farim West Access Road	E: 473964.4546 N: 1380566.707	This location accounts for the existing traffic flows between Farim, southwest to Cacheu. This road currently provides access between Farim and Cacheu for a number of villages located north and south of this route, including Cansenha, Tambato, Saliquinhe, Ponta Zeca, and Bani.

A practice run was taken at the seven locations with all technicians involved on 4 September 2013. Results revealed that location T3 by the church and T4 by the port showed extremely high pedestrian and bicycle traffic flows in comparison with the other locations. Here, the technicians were asked to switch to tallies of 25 where each line represented 5 persons.

13.4.5 Methods for Assessing the Sensitivity of Receptors

Traffic is considered an environmental issue, as it relates to changes in noise and dust, and a health and safety issue, as it relates to a potential increase in accidents and emissions.

Traffic sensitive receptors are classified as local villages and public buildings such as schools, hospitals and markets. Those which are in the projects surrounding areas, and are located on or near the main access routes.

The sensitivity of receptors will be determined during the impact assessment phase of the ESIA; there will be discussions between the relevant disciplines leads (e.g., social, air quality and noise).

13.5 Results and Discussion

13.5.1 Road Conditions

In Guinea-Bissau, out of the 3,455 km of roadways, 965 km are paved (CIA, 2002). The Trans-West African Coastal Highway crosses Guinea-Bissau, connecting 12 West African coastal nations. Rivers are navigable for some distances; ports and terminals are established at Bissau, Buba, Cacheu and Farim (CIA, 2012).

Roads through the capital, Bissau, contain a combination of tarmac and dirt surfaces. A section of the Bissau to Farim road, from Monsoa to Farim south of the river (approximately 51 km in length) was resurfaced between 2012 and 2013 (Photograph 6). Prior to this resurfacing, the travel time in the wet season from the capital was previously three and a half hours, to cover approximately 100 km.

Within the LSA roads are unpaved. These dirt roads can be eroded by surface water run-off during the wet season (Photograph 9). During the survey period, the following rainfall was recorded:

- Thursday 5 September – light rain;
- Friday 6 September – heavy rain between 10:00 and 13:00; and
- Sunday 8 September – light rain for a short period at 13:30, then again between 15:00 and 18:00.

Photographs 2 to 8 illustrate the road conditions at the traffic survey locations.

Figure 13.2: T1 dirt road north of Farim

Figure 13.3: T2 dirt road past Sarajobe Village

Figure 13.4: T3 dirt road through Farim township

Figure 13.5: T4 Farim river crossing north side

Figure 13.6: T5 tarmacked road south of river crossing at Farim

Figure 13.7: T6 dirt road past Sancalanco village

Figure 13.8: T7 dirt road west of Farim to Cacheu

Figure 13.9: Dirt road damaged by surface water erosion

13.5.2 Accident Rates

There are no available data on traffic accidents.

13.5.3 Traffic Levels

Data survey locations were mostly located on the main routes leading into Farim to capture traffic moving from surrounding communities and regional destinations including Senegal, Cacheu, and Bissau. Traffic survey data are presented in Appendix H.

Traffic data from the seven survey locations over three observation days are shown in tables 2, 3 and 4. Overall, traffic in the LSA (T1 to T7) was approximately 20% higher on Friday than on Thursday and approximately 13% higher on Sunday than Thursday. In relation to traffic levels in the LSA, the findings of the survey are:

- Highest traffic levels were observed at T3 Farim through road (total at all locations over three days: 10,687) and T4 Farim river crossing north side (total at all locations over 3 days: 5,218). These locations account for traffic coming in and out of Farim and internal traffic within Farim. Daily and weekly destinations include, but are not limited to, the market, religious buildings (church and mosque), the port, a cinema, a motorbike repair shop, water supply wells, schools, a hospital, and football pitches;
- The lowest traffic levels were observed at T1, north access road into Farim. This may be explained by the poor quality of road surface on this route (Photograph 2). Consequently, it can be concluded that travelers prefer to use the two main roads east (T6) and west (T2) of this location;
- Data shows from Thursday to Friday traffic increased by 20% and Thursday to Sunday traffic increased by 13% (total includes all locations over three days). This reflects main market traffic and Islamic holy day traffic on the Friday and Catholic prayer traffic on Sunday;
- Data showed that on Islamic holy day (Friday) T2 traffic increased by 58% from Thursday, a regular weekday. On Sunday, the Catholic holy day, T2 traffic increased by 38% from Thursday. This road provides access between Farim, northeast to Senegal, by-passing Sarajobe village;
- Data showed that on Islamic holy day (Friday) T7 traffic increased by 25% from Thursday, a regular weekday. Also at T7 traffic increased by 58% from Thursday to Sunday, Catholic holy day. This road provides access between Farim and Cacheu for a number of villages located north and south of this route, including Cansenha, Tambato, Saliquinhe, Ponta Zeca, and Bani;
- T1, T4 and T7 locations showed decreases in traffic levels during and around the time of Catholic prayer (12:00 to 13:00) and peaks in traffic before and after;
- Most locations surveyed (T3, T4, T5, T6, and T7) do not show a decrease in traffic levels during the time of Islamic prayer (Friday 15:00 to 17:00). Instead, they show a second peak in traffic in the late afternoon. The main market day is on Fridays in Farim and attracts visitors from outside of the township. This second peak in traffic could be explained by visitors leaving Farim after market.
- The main roads leading from Farim include the two routes to Senegal (T2 and T6), a route to Bissau (T5) and a route to Cacheu (T7). Higher traffic volumes were observed at location T2, the Farim to Senegal route (total for three days 4931), then T7 (3042), T5 (2421), and lowest traffic volumes were observed on the second Farim to Senegal route T6 (1432); and
- At T5 to the south of the Farim river crossing, data showed that generally from Thursday to Friday traffic levels increased by 24% and Thursday to Sunday traffic levels decreased by 24% (total includes all locations over three days). Here, traffic waiting for the boat congregates and local people sell produce on the side of the road.

Table 13.2, Table 13.3 and Table 13.4 below show results from the traffic surveys undertaken. Data shown includes all traffic counted, motorised and non-motorised. Figure 13.10 to Figure 13.16 how total travel over three observation days at each location.

Table 13.2: Thursday Total Traffic Counts

Time	T1	T2	T3	T4	T5	T6	T7	Total
7:00 – 8:00	18	100	192	76	32	30	69	517
8:00 – 9:00	33	188	262	165	60	36	101	845
9:00 – 10:00	40	188	322	144	80	27	71	872
10:00 – 11:00	15	183	488	179	65	25	57	1012
11:00 – 12:00	4	75	400	203	71	37	66	856
12:00 – 13:00	23	117	288	142	55	24	59	708
13:00 – 14:00	21	105	249	142	98	32	56	703
14:00 – 15:00	18	61	186	125	77	32	53	552
15:00 – 16:00	17	69	244	144	86	44	80	684
16:00 – 17:00	34	70	298	112	46	48	58	666
17:00 – 18:00	7	53	186	121	86	37	67	557
18:00 – 19:00	10	34	201	144	53	54	57	553
Total	**240**	**1243**	**3316**	**1697**	**809**	**426**	**794**	**8525**

Table 13.3: Friday Total Traffic Counts

Time	T1	T2	T3	T4	T5	T6	T7	Total
7:00 – 8:00	6	350	175	156	76	35	103	901
8:00 – 9:00	33	346	358	224	112	75	91	1239
9:00 – 10:00	23	221	566	227	102	47	102	1288
10:00 – 11:00	15	236	583	231	87	44	73	1269
11:00 – 12:00	7	97	215	100	29	6	45	499
12:00 – 13:00	8	96	102	81	41	20	31	379
13:00 – 14:00	15	81	209	128	51	22	65	571
14:00 – 15:00	17	90	168	140	89	28	33	565
15:00 – 16:00	15	128	267	253	162	38	119	982
16:00 – 17:00	10	140	385	147	115	57	108	962
17:00 – 18:00	10	83	267	161	101	67	100	789
18:00 – 19:00	8	101	234	215	35	47	125	765
Total	**167**	**1969**	**3529**	**2063**	**1000**	**486**	**995**	**10209**

Table 13.4: Total Sunday Traffic Counts

Time	T1	T2	T3	T4	T5	T6	T7	Total
7:00 – 8:00	18	126	220	131	61	35	158	749
8:00 – 9:00	23	171	460	150	76	48	133	1061
9:00 – 10:00	25	130	490	175	50	46	129	1045
10:00 – 11:00	19	130	500	179	49	41	79	997
11:00 – 12:00	29	106	287	113	45	41	93	714
12:00 – 13:00	4	90	322	140	45	42	76	719
13:00 – 14:00	14	116	348	97	52	46	84	757
14:00 – 15:00	31	187	282	83	26	46	58	713
15:00 – 16:00	10	110	139	48	30	36	102	475
16:00 – 17:00	20	149	187	138	66	26	117	703
17:00 – 18:00	17	195	127	92	69	58	100	658
18:00 – 19:00	19	209	480	112	43	55	124	1042
Total	**229**	**1719**	**3842**	**1458**	**612**	**520**	**1253**	**9633**

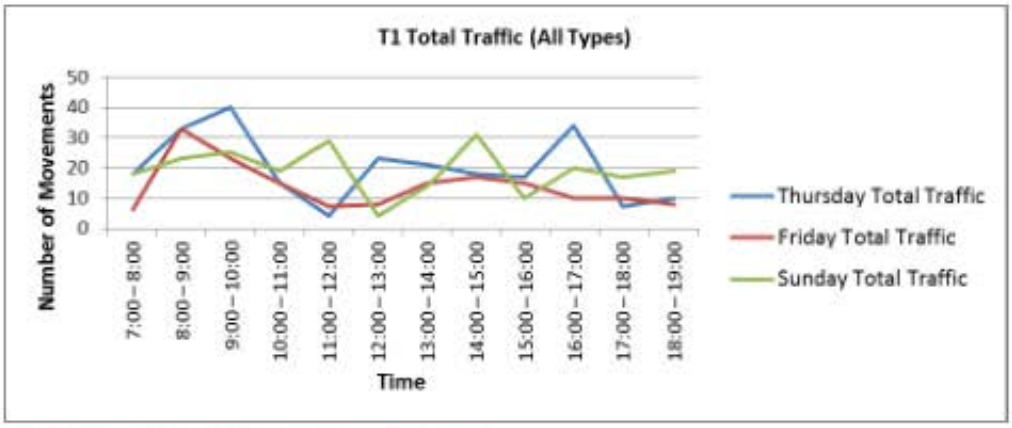


Figure 13.10: T1 total traffic for three observation days

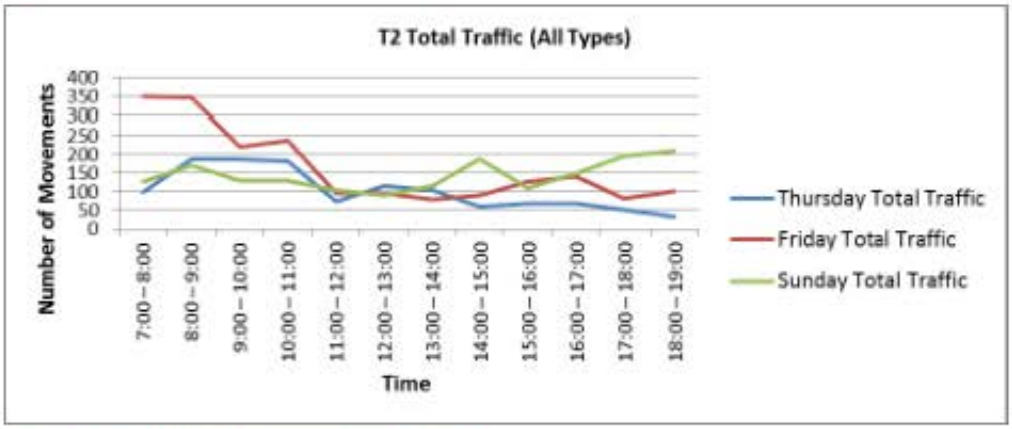


Figure 13.11: T2 total traffic for three observation days

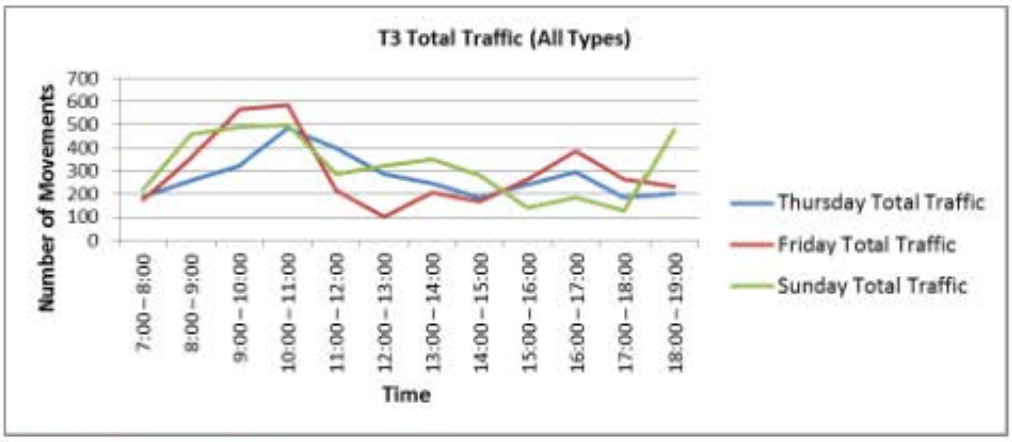


Figure 13.12: T3 total traffic for three observation days

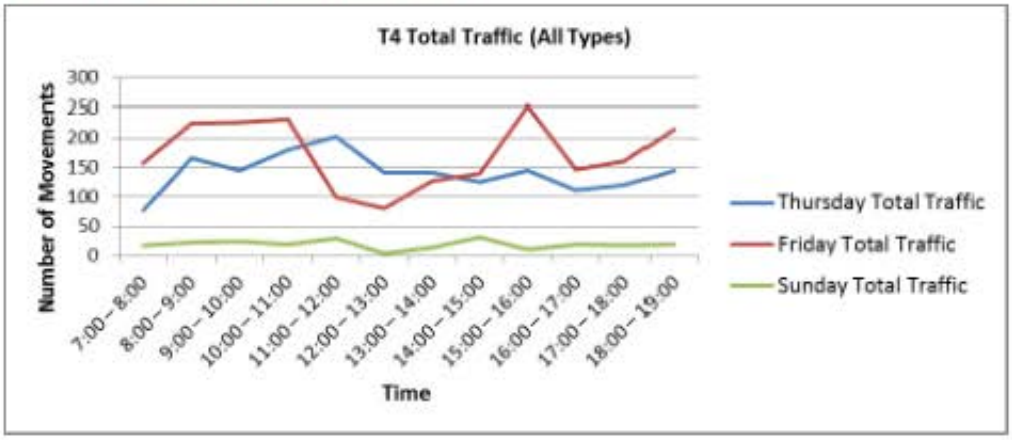


Figure 13.13: T4 total traffic for three observation days

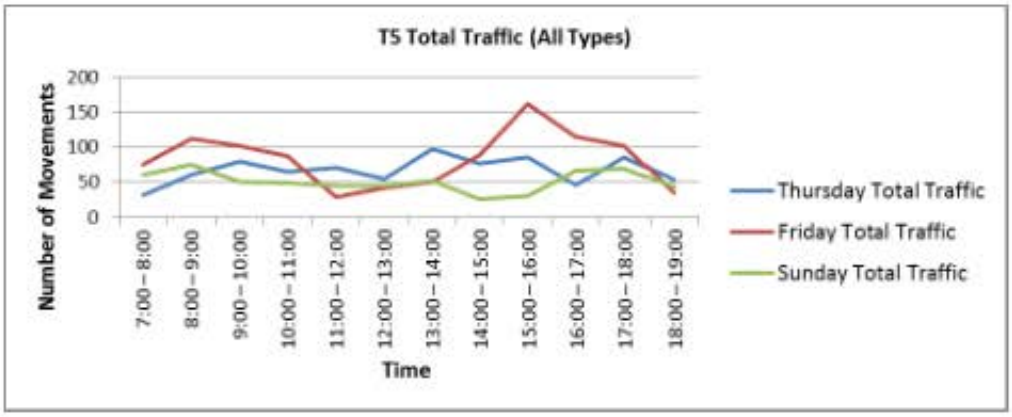


Figure 13.14: T5 total traffic for three observation days

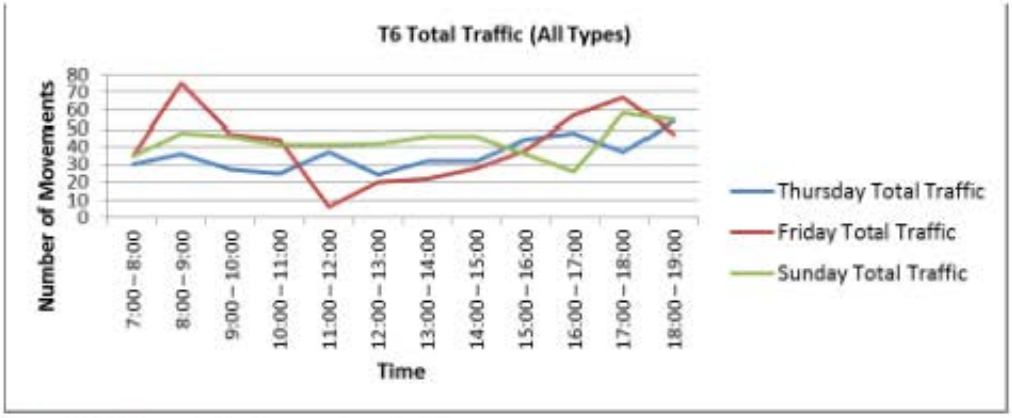


Figure 13.15: T6 total traffic for three observation days

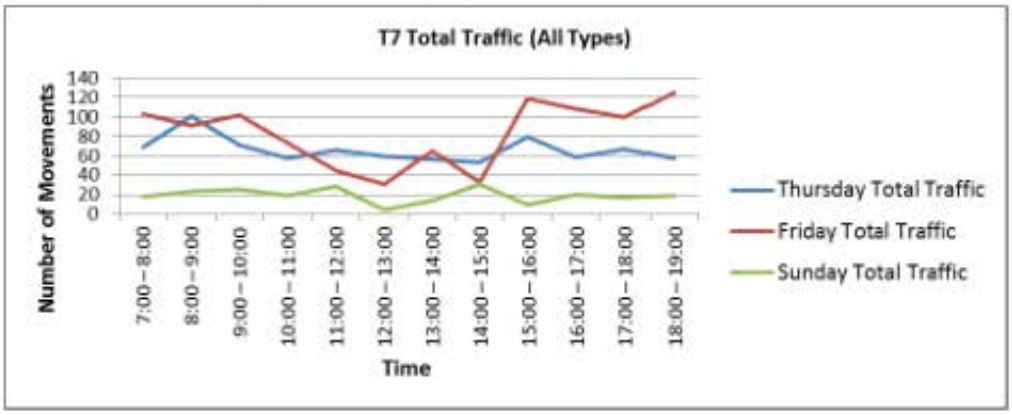


Figure 13.16: T7 total traffic for three observation days

13.5.4 Traffic Type

In relation to the type of traffic observed in the LSA, the findings of the survey are:

- Pedestrians make up approximately 56% of the total LSA traffic, and 39% and 21% of total pedestrian traffic was observed at locations T3 and T4, respectively. Pedestrian travel was observed to be highest on the Friday (36%), then Sunday (34%) and lowest on Thursday (29%);
- Bicycles make up approximately 32% of the total LSA traffic. 39% of total bicycle traffic was observed at location T3, and 19% and 13.7% at T2 and T4 respectively. Travel by bicycle was observed to be highest on the Friday (35%), then Sunday (34%) and lowest on Thursday (31%);
- Motorbikes are the most frequently used form of motorised travel and make up approximately 7% of total traffic in the LSA. Travel by motorbike was observed to be highest on a Friday (39%), then Sunday (31%) and lowest on Thursday (30%);
- Travel by animals makes up approximately 3% of the total LSA traffic;
- The lowest levels of traffic were from personal car (1.3%), taxi (0.1%), passenger bus (0.7%), Single Rear-axel Pickup Truck (0.3%), Double Rear-axle Truck (0.1%), Backhoe, Bulldozer, Tractor (0.01%) and other (0.2%); and
- The sum total of single and double rear-axel pickup truck at all survey locations on Thursday weekday was 31 and this almost doubled to 57 on the Sunday.

Traffic levels at each survey location for the three survey days are presented on Figures 1 to 7. Overall, peak flows of traffic occurred mainly between 10:00 and 11:00 on Thursday, 09:00 to 10:00 on Friday, and 08:00 to 09:00 on Sunday. Between locations, peak flows of traffic occurred between 08:00 and 09:00 and between 10:00 and 11:00 at most locations, and at 07:00 and 08:00 at T7. T5, T6 and T7 have another rush hour near the end of the day. These results suggest that changes in traffic patterns are not closely linked to prayer times. This could be explained by visitors leaving Farim after market and heading home to neighbouring villages before sunset.

Motorbikes are commonly used to transport people (for personal use and as a taxi) and goods in the LSA. Accidents are fairly common as motorbikes are often overloaded; most people do not use helmets and road conditions are poor.

Table 13.5 shows traffic volumes by type and location for the three observation days and is presented in Figure 13.17.

Table 13.5: Traffic by Type and Location for All Observation Days

Location	Day	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, Bulldozer, Tractor	Motorcycle	Bicycle	Travel by Animal and Cart	Other	Pedestrian	Total	Percentage Change Between Thursday and Friday [%]	Percentage Change Between Thursday and Sunday[%]
T1	Thursday	0	0	0	0	0	0	11	78	5	0	146	240		
	Friday	0	0	0	0	0	0	14	90	5	0	58	167	-30%	-5%
	Sunday	0	0	0	0	0	0	8	88	8	0	125	229		
T2	Thursday	0	0	5	0	1	0	115	449	81	0	592	1243		
	Friday	4	0	2	1	2	0	230	630	140	0	960	1969	58%	38%
	Sunday	9	0	3	0	8	0	188	583	113	17	798	1719		
T3	Thursday	66	6	0	9	0	0	217	1196	40	0	1782	3316		
	Friday	56	0	4	11	1	0	241	1070	31	0	2115	3529	6%	16%
	Sunday	45	0	3	29	0	0	196	1206	45	0	2318	3842		
T4	Thursday	31	3	1	1	4	0	78	421	97	0	1061	1697		
	Friday	30	3	1	3	1	0	82	483	98	0	1362	2063	22%	-14%
	Sunday	20	4	3	0	11	0	39	326	112	1	942	1458		
T5	Thursday	43	4	51	5	1	0	63	212	2	0	428	809		
	Friday	37	7	67	23	2	1	43	257	5	0	558	1000	24%	-24%
	Sunday	18	8	43	6	0	2	30	171	12	0	322	612		
T6	Thursday	3	0	1	0	0	0	53	174	10	2	183	426		
	Friday	2	0	0	1	0	0	83	192	10	3	195	486	14%	22%
	Sunday	7	0	2	3	0	1	53	202	11	18	223	520		
T7	Thursday	2	0	0	0	10	0	36	285	17	2	442	794		
	Friday	2	0	1	0	0	0	60	393	16	0	523	995	25%	58%
	Sunday	3	0	0	0	0	0	79	452	22	7	690	1253		
Total	**Thursday**	**145**	**13**	**58**	**15**	**16**	**0**	**573**	**2815**	**252**	**4**	**4634**	**8525**		
Total	**Friday**	**131**	**10**	**75**	**39**	**6**	**1**	**753**	**3115**	**305**	**3**	**5771**	**10209**		
Total	**Sunday**	**102**	**12**	**54**	**38**	**19**	**3**	**593**	**3028**	**323**	**43**	**5418**	**9633**		
Total	**3 days**	**378**	**35**	**187**	**92**	**41**	**4**	**1919**	**8958**	**880**	**50**	**15823**	**28367**		

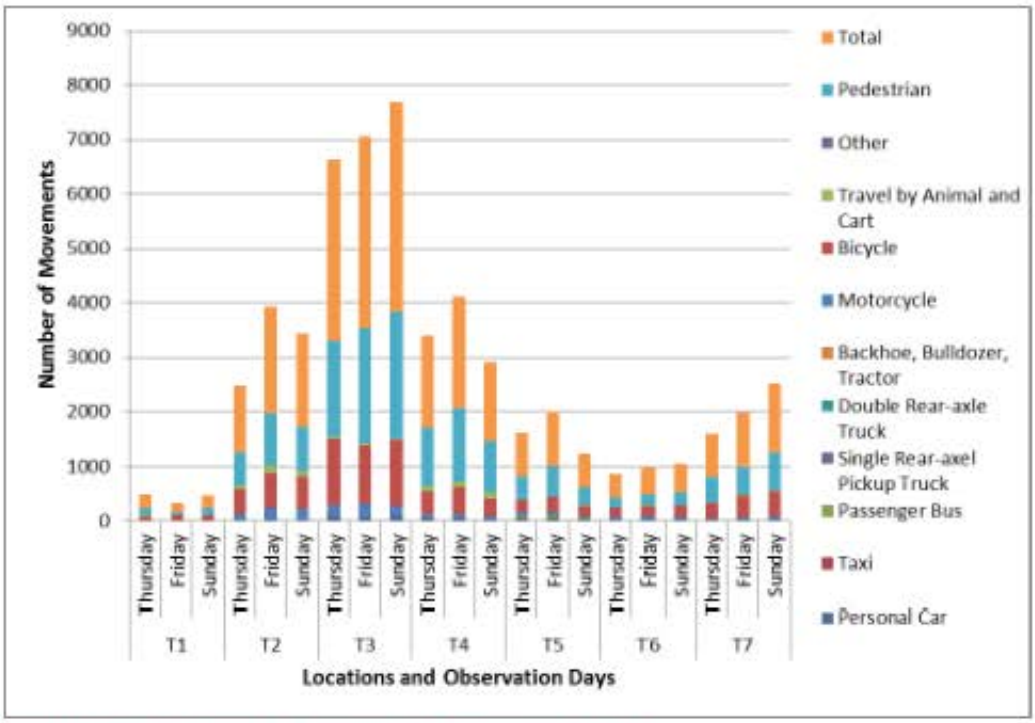


Figure 13.17: Traffic Type at Each Survey Location for all Observation Days

13.5.5 Summary

Roads in the LSA are generally unpaved dirt roads, with the exception of the recently resurfaced Monsoa to Farim section of the main Bissau-Farim road.

The highest volumes of traffic were observed at the main street through Farim and at the port (T3 and T4). Farim attracts daily visitors from surrounding villages due to the services it provides such as mosques, churches, health care, education, recreation, and opportunities through business such as buying and selling at the market.

Data from the traffic survey showed that traffic increased by 20% from Thursday to Friday and by 13% from Thursday to Sunday (total includes all locations over three days). Only half of the locations surveyed (T1, T4 and T7) showed decreases in traffic during times of Catholic prayer on the Sunday, and most locations showed increases in traffic during the time of Islamic prayer on the Friday. Consequently, it can be concluded that travel for religious prayer does not impact the traffic levels as originally proposed. Late afternoon traffic levels on the Friday coincided more with market, school and work related travel.

Pedestrian travel was observed to be highest mode of travel in the LSA and motorbikes were the most frequently used form of motorised travel. Walking and cycling are commonplace within Farim and in its surrounding communities.

13.6 Abbreviations and Acronyms

ESIA Environmental and Social Impact Assessment;

LSA local study area;

RSA regional study area;

IFC International Finance Corporation; and

PS performance standards.

13.7 Glossary

Baseline	A surveyed or predicted condition that serves as a reference point to which later surveys are coordinated or correlated.
Baseline data	Data gathered during the social and environmental assessment used to describe the relevant existing conditions of the project, such as physical, biological, socio-economic, and labour conditions, including any changes before the project commences. (Source: IFC 2012)
Local study area	A defined area of land within which baseline conditions are described
Regional study area	Represents the area of study for the assessment of regional and cumulative (combined) effects of the Project and other past, existing or planned developments
Traffic	The movement or transportation of persons and vehicle along a road or path
Movement	One pass at the survey location

13.8 References

CIA (Central Intelligence Agency). 2002: *The World Factbook: Guinea Bissau*, Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/pu.html. Accessed: October 2012.

CIA (Central Intelligence Agency). 2012: *The World Factbook: Guinea Bissau, Roadways*. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/pu.html. Accessed: 23 September 2012.

IFC (International Finance Corporation). 2012a: *Performance Standards and Guidance Notes - 2012 Edition* (online). Available at: http://www1.ifc.org/wps/wcm/connect/115482804a0255db96fbffd1a5d13d27/PS_English_2012_Full-Document.pdf?MOD=AJPERES. Accessed: October 2012.

IFC (International Finance Corporation). 2012b. *International Finance Corporation's Guidance Notes: Performance Standards on Environmental and Social Sustainability* (online). Available at: http://www.ifc.org/wps/wcm/connect/e280ef804a0256609709ffd1a5d13d27/GN_English_2012_Full-Document.pdf?MOD=AJPERES. Accessed: 23 September 2012.

14.0 SOCIO-ECONOMICS

14.1 Introduction

The study was undertaken by environmental consultancy, Tropica Environmental Consultants (Tropica), to define the socio-economic baseline conditions of populations in the vicinity of all elements of the Project:

- Land-based elements: the mine site, waste management facilities, processing plant, ROM pad, stock pile, and barge loading facilities; and
- Marine-based elements: barging down the River Cacheu, barge marshalling area, and ship loading pontoon.

This baseline will be used to inform the ESIA of the proposed development.

During field investigation, focus has been given to the measurement of a number of 'well-being' factors, which can be used to define socio-economic conditions of targeted populations.

These factors include:

- Various human resources in the targeted villages and their social organisation;
- The interrelationships between human resources and those of the physical environment;
- The presence of infrastructures and technical services or development support;
- Historical profiles of the villages that are likely to be affected;
- Available socio economic infrastructures; and
- Livelihood.

Particular emphasis was given to investigation of land availability and land tenure, farming systems and commercial cultivation, fisheries, salt production and its importance to female livelihood, and availability of competing markets from which to sell produce.

14.2 Study Area

The Regional Study Area (RSA) can be defined as the Oio and Cacheu regions, encompassing each of the villages in which field study has been undertaken, including the River Cacheu corridor.

The Local Study Area (LSA) can be focussed on those locations in which development is proposed. The LSA therefore includes Farim and surrounding villages, and the villages lining each side of the River Cacheu.

14.3 Previous Work

Tropica[2] has conducted a baseline study for the Project area among populations and villages in the vicinity of Farim, and along the River Cacheu. Baseline study work has also previously been undertaken in the vicinity of now redundant elements of the Project, and will not be referenced in this baseline report.

Field study in the vicinity of Farim was conducted in March 2012, during which questionnaires were administered to 301 households in the locality. Field study along the River Cacheu took place in September 2012, at nine villages along the River Cacheu, and an additional two villages in the vicinity of the mine site and associated infrastructure. In total, field studies represented approximately 22% of a total of 1,378 homesteads / compounds, according to 2008 census data.

[2] All information presented in this report was collected, analysed and compiled in two separate reports by Tropica: *Rapport general de l'esab, 2011 and Socioeconomic Baseline Report (draft), 2012.*

Data was collected by means of qualitative and quantitative research methods. Qualitative methods entailed village meetings and focus groups, using structured discussion guides, with youth, women and men, as well as key informant interviews and direct observations. Secondary data (sectoral policy documents incorporating descriptions of the situation in the sectors concerned) were collected and analysed.

Villages featuring in surveys were selected based on a number of factors. Villages in the vicinity of the mine site and associated infrastructure were selected primarily on account of their proximity to areas proposed for development, while villages located along the River Cacheu were selected on the basis of three interrelated criteria:

- The proximity to the River Cacheu;
- Dependence on fisheries; and
- Population size.

14.4 Methods

14.4.1 International Standards

For the purposes of the Socio-economic baseline, cognisance has been given to the IFC PSs on Environmental and Social Sustainability, with particular reference to:

- PS 1 – Assessment and Management of Environmental and Social Risks and Impacts;
- PS 4 – Community Health, Safety, and Security; and
- PS 7 – Indigenous Peoples.

In addition consideration has been given to the social sustainability guidance in the International Council on Mining and Metals (ICMM) Community Development Toolkit.

14.4.2 Guinea-Bissau Legislation and Standards

One of the main facets of the Guinea-Bissau Environmental Assessment Law (October 2011) is to protect the lives of people living in areas in which development projects are planned. For this purpose it is essential to obtain detailed knowledge of the social-economic baseline of these communities, in order to identify and assess the potential impacts a proposed development may have on these.

14.4.3 Assessment Methodology

14.4.3.1 Limitations of Baseline Studies

Limitations of the baseline studies include:

- The absence or inaccessibility of existing published data specific to the regions of Oio, Farim, and to individual villages;
- Data obtained to help define the baseline is, in many instances, outdated;
- The survey coincided with the campaign period for presidential election, thus people were either engaged in political activities, or did not attend group meetings believing that these meetings were political; and
- Facilitators of qualitative surveys used the services of translators, which can lead to a loss of accuracy in interpretation.

14.4.3.2 Methods for Assessment of Existing Socio-Economic Conditions

The socio-economic survey combined qualitative and quantitative methods.

- Quantitative: a questionnaire including all the subjects of concern was drafted and translated into Portuguese; 10 field workers were hired, trained and tested to administer questionnaires; a sample of 301 households was selected by using computerised survey programming[3] for sampling. A statistical computer program was used to process the data collected through the questionnaire; and
- Qualitative: conducted through a combination of several techniques and research tools including: village assemblies; Focus group discussions (with men, women, young, professional groups); key informants and observations.

14.5 Results and Discussion

14.5.1 Oio Region

14.5.1.1 Population Demographics

The population of the Oio region, in which Farim is located, is estimated to 215,259 inhabitants of whom 52% are female. Approximately 85% of the population of Oio is rural, compared to 60% of the national population. The population is very young with 53% of the population below the age of 21 and 83% of the population below the age of 40.

The area is characterised by a diverse range of eight ethnic groups; the Mandingas represent 66% of the population followed by the Mansonkas with 17%, then Fulas (7.6%) and Balantes (6%). Minority groups such as the Manjak, Pepel and Mancagnes are also represented in the area.

The area is characterised by permanent residents and 91% of households are resident whilst 7.4% are absent. The population in the districts lives predominantly in rural villages and each district has only one or two towns.

Farim

Farim (district), with 48,264 inhabitants (42% of the population of the Oio region) is the most populated district in the region after Bissora which accounts for 26.3%. The region's population is relatively young with over 50% under the age of 18 years.

Outside the town of Farim, which has a population of 8,661 inhabitants, the population in the villages rarely exceeds 500 (Table 14.1). The residential areas are spatially dispersed. Houses are often built by young people and consist of a single building with several rooms. Houses were predominantly built (84%) with clay; 72% of structures had from four to seven rooms and 19% of the houses had between eight and 11 rooms. Nearly 80% of homes had corrugated iron roofing and 15% had thatched roofs.

With regard to ownership, 25% of households held land title, 11% an occupancy permit while more than half (55%) held traditionally determined residential authorization.

Households have an average size of 10 members and the area is predominantly inhabited by Mandingo (40%) followed by the Fulani (27.6%) and Balante (21.5%).

Mobility

Considerable mobility is experienced in Farim and its surrounding villages, especially among the young adult population. Mobility is often driven by a search for employment in Bissau, neighbouring countries (e.g., to Senegal, Gambia, and Cape Verde) and Europe (Portugal and France). The villages of Tambato, Canico, Tumana, Salikénié and Farim town are mostly affected by migration.

[3] Available at http://www.surveyguy.com/SGcalc.htm

Religion

Islam is the predominant religion (71%) in the area and practiced by the Mandingo and Fulani. Christians represent 25% of the population while paganism is practiced by 4% of the population. The last two religions are mainly practiced by the Balante.

Table 14.1: Villages and Population Figures in the Mining Area

Locality	Female (official)	Male (official)	Population estimates		Number of compounds	
			Village chiefs	Official	Village chiefs	Official
Mining Area (Farim)						
Farim	4,397	4,264	-	8,661	-	1,005
Saliquenhe Ba	362	305	1,339	667		72
Tambato	157	143	500	300	30	18
Canico Lenque croto	362	304	666	666	23	59
Canico Tu Manna	236	217	850	453	12	26
Unfude	105	100	360	205	11	11
Sandjal 1 et 2	272	249		521		46
Cabiceque	46	47	200	93	9	8
Demba Baio	12	12	19	24	1	1
Ponta Caiero (Kilakiyala)	37	44	80	81	3	7
Saliquenhe Porto (Ponta Seaca)	131	125	200	256	11	24
Sintchã Seidi (Urque)	228	220	400	448	20	35
Total: Mining Area	**6,545**	**6,230**		**12,375**		**1,312**

14.5.1.2 Social Organisation

Compounds or homesteads are often shared by more than one related family headed by a 'chief' who is the father or the grandfather. Besides sharing living arrangements in the compound, families also share the agricultural land which they cultivate collaboratively.

Monogamy is more common (51.8% of respondents) than polygamy. In general, women and youths have the responsibility for most domestic tasks, and thus constitute the backbone of the family but, in contrast, have little influence on decision making.

Decision-Making

Decision-making is primarily through consensus facilitated by the village leaders or committees. The village chief (or committee) invites the heads of families and youth representatives and, in some cases, women's representatives when matters need to be discussed and decided on. Decisions are made only after ample discussion and when each had the opportunity to express their opinion. Male opinion dominates the decision-making process, in particular that of heads of families and the village head; their views are very prominent and have a significant influence in the deliberations.

Heads of villages are under the authority of the administrator of the district to which they report. The status of village head is usually held by the founding family of the village and is transferred within the family over generations.

14.5.1.3 Social Infrastructure / Amenities

Social Services

The Oio Region is one of the poorest of the country. The population's poverty in the locality of the Project is accentuated by the fact that it generally lacks basic social infrastructure.

Education

In most of these localities there are no primary schools and where they exist, they fail to meet demands for places. Moreover, schools in the Project area are mostly temporary shelters. This, in addition to other factors, results in a very low enrolment rate.

Health

The Project area is characterised by the prevalence of contagious diseases which is associated with poor living conditions, environmental issues, poor diet and deficiencies in the health system. A basic hospital in Farim provides the health services in the mining area and has been supported by the Project proponent to improve facilities.

Water and Sanitation

Villages and Farim town use traditional wells and hand pump-operated boreholes for domestic water. There is no reticulated sewerage system in the area and domestic (solid) waste is dumped in uncontrolled spaces to the detriment of the environment and particularly water from wells.

14.5.1.4 Economic Activities

Access to Land

The Land Law (Lei No. 5/98 to 23 April 2012) states that land is the property of the State and the heritage of the population. However, land is administered following traditional law by customary authorities. Thus, the law has changed the basis of ownership through the integration of customary land management practices with legal forms of ownership.

In the traditional system common in rural areas, the "ax right" allows a person to (a) clear land not previously occupied before they register it with the village chief or (b) upon allocation by the chief when the owner can clear the land. Similarly, the land owner may sell part of it to a third party and declare the "transaction" with the village chief. In contrast, in urban areas such as Farim, land concessions for residential purposes must be registered with the administration and land transactions are more formally recognised.

Regarding land use for agriculture, 93% of surveyed households claimed to be actively cultivating land. Only 13% reported having land title while 55% gained access to land through traditional administrative means; 3% have fields without any recognised authorisation.

Subsistence Agriculture

Maize, millet, sorghum, rice and fonio are commonly grown in the area for consumption with maize the most important crop cultivated by more than 51% of the households. The proportion of households involved in other crops (millet, beans, etc.) is between 3% and 15%. Rice, although a staple food, is cultivated by only 12% of households.

Food gardens are kept in several villages, mostly by women who have their gardens either around water sources (ponds, wells or boreholes) or in their own compound. They also take advantage of the fields to grow vegetables such as okra and tomatoes intercropped with the main crops.

Food Security and Income Generation

Food deficit was widely reported by households and appears to be common despite the availability of farmland. Food shortages are caused, among other, by limited access to agricultural equipment and fertilisers.

Some of the produce that is cultivated in home gardens and fields is consumed by the growers and the remainder sold. Peanuts, cassava pulp, and beans are particularly grown as cash crops. Peanuts and

cashews are almost entirely grown as cash crops. The Project area is among the most important producing regions in the country for peanuts and the crop is primarily sold in Senegal through a complex network of traders from neighbouring countries.

Production of Salt

Almost all women in the mining area are engaged in salt harvesting during the dry season, between February and May. Using rudimentary equipment, the salt is mined from sand taken from rice fields that became salt-affected (*tann*) as a result of saltwater flooding. The sale of the product provides cash to women to meet daily family needs (food, purchase of school supplies, clothing).

Livestock

In the mine area, livestock rearing remains an important activity. Almost 93% of surveyed households had livestock (cattle, sheep, and goats). Pig farming is generally practiced by the Balante and Manjak women, with an average of ten animals per household. Family ceremonies create the main opportunity for the sale of livestock.

Fisheries

Artisanal fishery is practiced in the areas by 31% of households. Daily catches vary between 10 kg and 15 kg per individual expedition and between 400 kg and 450 kg for group expeditions. There are about 43 fishermen grouped in an association in Farim and the fleet consists of 15 canoes.

Natural Resource Harvesting

Forest products used in the Project area can be classified as food products, home building material, and medicinal products. Edible fruit (baobab fruit, palm fruit) is harvested in season, as are fibres, leaves (baobab leaf), sap extracts (palm wine), wood (90% of domestic energy), honey, and several medicinal plants. Products that are used and marketed include charcoal, baobab fruit, palm wine and palm fruit.

Housing architecture mirrors the building material directly harvested from the natural surroundings (e.g., thatch, palm leafs, wooden stakes for fences and watchtowers).

14.5.2 River Cacheu

14.5.2.1 Population Demographics

Field study revealed that the majority of villages studied were founded between 200 and 300 years ago. Major events in recent history common to villages in the region include the famine of 1985, and displacement due in part to the liberation war, and escape of adverse living conditions.

Outside the village of Tancroal which is located in Olossato Sector or District, Oio region, other localities, including Cacheu, Boulol, Apidjiou and Sao Vicente, depend administratively on the Cacheu region.

Demographically, the city of Cacheu is the only capital of the study area that has a population of over 8,000 inhabitants (Table 14.2). Of the other localities, only Sao Vicente has more than 1,500 inhabitants.

Several ethnic groups live in the communities targeted by the field study. Ethnic groups with greatest representation are Manjack, Balantas, Floups, and Pepels. Manjacks are the majority in Cacheu.

Mobility

Several common migratory movements were noted in the study area. In general, both young men and women travel to capital cities Dakar, Banjul and Bissau in search of employment and improved standards of social welfare. The flow of these movements varies according to ethnicity and gender. Migrants contribute usually to increase the household incomes by financing agricultural activities.

Religion

The dominant religion within the communities who live along the River Cacheu is animism, practiced mostly by Manjacks, Floups, Balantas on whom Christianity has had a minimal impact.

Table 14.2: Demographic Characteristics of the Study Area

Location	Village age	Population size	Number of concessions	Ethnic groups present	Religions practiced
Cacheu	424 years *	8,585*	-	Manjak, Floup, Pepel	Animist Christian Muslim
Boulol	+ than 300 years	775	45	Floup	Animist
Sao Vicente	92	1920	13	Balanta, Mancagne, Floup, Mandinga, Foula, Pepel, Manjak, Bambara	Christian Muslim
Apidjiou	+100	750	54	Diola, Mandingue Mancagne, Fulani, Balante, Pepel, Manjak	Christian Muslim
Tancroal	Nearly 200 years	Plus de 500	-	Mandinga	Muslim
Kantouré	90	63	06	Mandinga Balanta,	Muslim Christian
Bigène	247	967	08	Balanta, Mandingo, Manjak, Fulani , Mancagne	Muslim Christian
Binta	309	1,348	09	Mandinga, Balanta	Muslim Christian
Tambato Mandinka	700	580	07	Mandinga,	Muslim

Source *: Complementary study EIES Projet Phosphate de Farim, September 2012*
**Data obtained from studies involving local populations*

14.5.2.2 Social Organisation

In villages located in the study area, the chief represents the local authority and is commonly elected by local village populations. The chief's role is to provide an interface between people and the local administration. While in some villages the position of chief is transmitted hereditarily, in some others it can be held by any family. At Cacheu, neighborhood leaders administer populations and serve as an interface between these populations and the local administration.

In some localities, including Boulol, the social hierarchy includes a king in addition to a chief, and the local administration. The role of the king is commonly to preside over the organisation of cultural and religious ceremonies. This function, unlike that of the village chief, is devoted to a specific family and is passed down hereditarily.

Patriarchs also play an important role in the social organization of some villages and are consulted on all matters relating to the management of particular cultural aspects of the village.

In general, the social organisation is based on an egalitarian system in most localities covered by the study. Indeed, there is no class and caste system within Balantas, Floups and Pepels. In Mandingo communities, there is a social stratification based on caste, however those belonging to the low caste are not discriminated against. Indeed, community management within Mandingos involves all social strata including young men and women. Male domination is exercised through the monopolising of the means of production and the power in which women have little influence.

The Role of Women in the Community

Women constitute a crucial fringe in community dynamics through their involvement in the production systems, the role played in community life, and their involvement in the decision making process. Women are seen as pillars of society, particularly in family structure in that they have a fundamental responsibility for

family welfare. Indeed, women provide the bulk of food production and business activities (processing of fishery products, rice, salt production, gardening, crafts, etc). Some of these products are sold at nearby markets while much is reserved for domestic needs.

Women contribute greatly to establish the household food security and they invest in the health and education of their children through economic practices such as trade and agriculture. Culturally, the organization of certain ceremonies depends exclusively on women who perform rituals at places in which they control access.

The process by which women make decisions is very participatory, involving consultation prior to making any decision. Decisions relating to wider community life are taken at meetings where all community members (men, women and youths) are present, and are often the result of a dialogue which leads to consensus. Decision making within the household is also often taken after extensive consultation, particularly when it comes to the future of children.

However, it is paramount to note that even if women are involved in the process of decision making, because of the mode of socialisation and the inherently male dominated nature of the communities in question, their influence remains very limited in the final decision. The same situation applies to economics. Limited availability of equipment restricts production, and therefore remains a handicap for women despite the crucial role they play.

The Role of the Youth

Young people are actively involved in the communities and are regularly consulted in the decision making process. In all the surveyed villages, young people are deeply involved in the economic, cultural and associative activities.

However, the youth face major constraints mainly associated with lack of training and employment, and low incomes which result in outward migration.

Dynamic Association

In all survey locations, the existence of ethnic, professional but also generational associations between villages were noted. However in most localities these associations are often informal and are only involved in collective farming work and sports. In Sao Vicente and Cacheu, associations are quite structured and dynamic. Age classes form profit associations and offer their services to operators for performing plowing, harvesting wok, etc.

Fishermen are organised in association in several localities like Cacheu, Sao Vicente and Kantouré. There is an association of fishermen composed of 10 villages which collectively practice fishery activities; the president of this association is based in Kantouré. Apart from fishing, professional associations are almost non-existent in the villages studied. For example, in Cacheu, the only association mentioned by the locals is that which unites to fight cattle theft.

In almost all localities women are grouped into female promotion group (FPG) practicing gardening and / or processing activities and sale of fishery products as it is the case in Cacheu. It was also noted the existence of ethnic based associations; for example in Apidjiou, Diola, Balanta and other ethnic groups have created associations; there are also associations formed on the basis of the place of origin.

Similarly, development associations are identified in some localities as in Bigène with the presence of seven community based organizations with one formal (AJED) that works with the FAO and the Bissau State in the field of HIV / AIDS prevention and border conflict prevention.

14.5.2.3 Access to Basic Social Infrastructure

Health

The provision of health services in the study area is found to be of a low standard. Health monitoring is difficult due to the remoteness of some villages, the scarcity of transportation, and particularly the non-functionality of the few health posts that exist in the villages. Health problems are numerous among the covered villages and arise in terms of accessibility. Most villages have no health facilities; and of those with

the means to support such facilities, these have neither the personnel nor the medication to support the needs of the population.

To obtain medication, some local residents of Tancroal village resort to vendors and resellers in the villages of Apidjiou and others. Therapeutic itineraries include traditional medicine with the use of plants known for their medicinal properties. Patients are mostly evacuated to urban centers including Olossato or Bula, located approximately 15 - 16 km away. The problems of isolation and poor trail conditions are influencing factors in seeking medical attention, especially during the wet season. In some villages, the rotation schedule of medical attention is weekly.

According to local people, the lack of local health facilities has a detrimental effect on their health in terms of lost time and income, but also risks associated with not achieving timely medical evacuation. This situation hinders social and economic advancement of women, but especially has disastrous consequences on their health and that of their children.

Education

The education sector is characterised by the lack of school infrastructure. With the exception of Cacheu, all other localities, including the village of Sao Vicente, Apidjiou, and Tancroal do not have school structures. The few schools that have been identified in these villages have only a few classes that are temporary shelters built by local people who also have responsibility for the payment of teachers. Cycles are not complete; schools have only three or four classes. When children finish the first round, they are sent to Bula, Bissora or Bissau, where they continue their studies while living with their family members. In some cases women migrate to Bissau to support and care for their children who continue their studies. At Boulol, children attend the nearest school located approximately at three kilometers from the village.

In summary, it is important to note that access to education in rural communities remains a major constraint. Adequate infrastructures are either absent or too remote from human settlements. Nursery equipment to support children who have not yet reached the school attendance age is also nonexistent in almost all study areas. In addition, the low level of education among women was also noted. In general, those who have been to school are a minority and have not surpassed the primary school level, some ceased attending after three years of schooling, others after five years.

The presence of religious schools is noted in Muslim communities.

Water

In villages located in the study area, access to drinking water is a major concern. In most villages, the main sources of supply are hand pumps and wells which often dry up during the dry season. Women responsible for fetching water stressed their lack of access to adequate supplies, they also highlighted the difficulty of the task and the time devoted to the chore of obtaining and transporting water.

Miscellaneous Infrastructure

With regard to other basic social infrastructure such as markets, and recreational areas for children and young people, these are almost non-existent in the villages visited. Moreover, it is important to highlight the lack of equipment relief work of women in almost all the villages surveyed. This hardship situation contributes to increased female vulnerability and impedes socio-economic welfare.

14.5.2.4 Economic Activities

Agriculture

The local economy in the study area is mainly based on agriculture, which is afforded important status. Agriculture is practiced by all social classes during the rainy season with rudimentary means. It is characterised by the diversity of speculation; the main products are rice, corn, beans and millet, which are intended for consumption. Peanuts and soybeans are farmed as marketable products.

In most localities, gardening is an activity reserved for women, although some men are becoming increasingly involved. Cereals and groundnut production is intended for consumption; cashew, peanut, cowpea production is sold locally or in weekly markets.

Furthermore, constraints have been identified in the agricultural sector and pertain to soil salinisation including rice (Faro) used mostly by women, loss of soil due to mahogany production, difficult access to inputs and seeds, arable land reduction which is a consequence of population increase. Thus, agricultural production can no longer meet the population nutritional needs. Soil depletion, lack of input, lower rainfall and reduced arable land remain major constraints.

Fishing

Fishing is the second most productive economic activity in most areas and supersedes agriculture in Kantouré and Sao Vicente. In localities along the River Cacheu, an important fringe of the population is involved in fishing activities. Cacheu and Sao Vicente are among the biggest fishing localities of the country. Men (young and old) capture fish while women are specialised in the catching of oysters and shellfish in the mangroves. They are also specialised in the transformation of artisanal fishery products (drying and smoking).

The traditional fishing technique 'Armadigue' is the most used fishing technique and is practiced with a net attached to two pieces of wood; however, some fishermen still practice angling.

The main species caught are the Fro, Thialo, Koudialo, Felta, Sesso, Bacro Koukélong, Batamo, Fourfourlo, Wanka etc. They are partly intended for sale locally and in weekly markets at Bissora, Maké, Mores and Bissau. Women are involved in the resale and fish processing.

The fishing sector is still facing constraints related to lack of equipment and capital that prevent fishermen to fish on high seas. Some of them travel to Senegal to obtain quality materials, especially lines.

Plantation

The exploitation of cashew mobilises almost the entire population in the study area with exception of Boulol village. It is a significant source of income for people who cultivate the crops between March and May in conjunction with other activities.

Breeding

Livestock is the third most productive economic activity after agriculture and fishing, and consists predominantly of sheep, goat, and cattle farming. Breeding is practiced alongside agriculture. Almost all ethnic groups practice to a varying degree breeding cows, sheep and goats; only Catholics or animists rear pigs. However, because of repeated thefts, sheep farming has become less important and it is very rare to large herds in the areas studied. Production is generally intended for home consumption; with only a portion sold when required.

The existence of forests considered as very valuable fodder reserves, as well as numerous water ponds and backwaters especially in the Project area is an asset for the development of this activity.

Salt Exploitation

It is an activity practiced by women in the surveyed villages. Production is usually marketed locally and in weekly markets further afield. Income from this activity contributes to the wellbeing of households.

Other Activities

Trade is fairly developed and vibrant in the area. Trade activities are practiced in weekly markets commonly referred to as 'luma'. These 'luma' remain a privileged location for populations with regard to their food supply but also for the sale of their products such as vegetables from gardening, salt and fishery products. Each weekly market polarises at least all the villages that lie within a radius of 30 km.

Means of transport that are mostly used in the Project area are bicycles and carts, with very rare occurrence of motor vehicle transport. Such means of transportation are both for passenger and freight; the heavyweights provide the bulk of freight and agro-sylvopastoral.

Other less important activities are developed in the study area where live very few qualified people who practice masonry, pottery, woodwork and metal, forging, etc.

Report Signature Page

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Carl Nicholas Senior ESIA Practitioner	Darren King Project Manager

Date: 21 February 2014

Authors: MS/CN/MT/DAK/te

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solutions@golder.com
www.golder.com

Golder Associates (UK) Ltd
1 Alie Street
London
E1 8DE
UK
T: [+44] (0) 20 7423 0940

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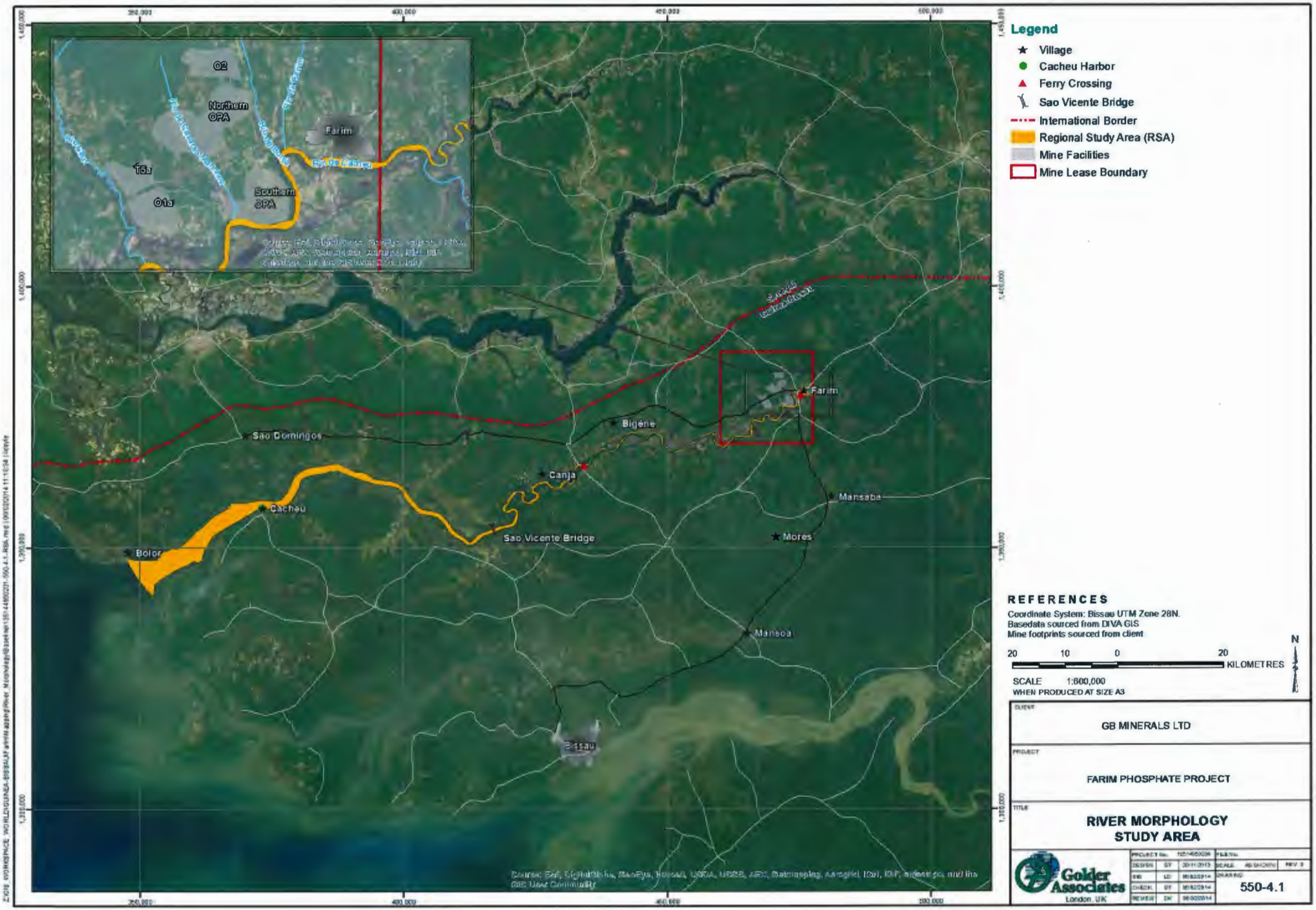
DRAWINGS


Legend
Village
Cacheu Harbor
Ferry Crossing
Sao Vicente Bridge
International Border
Regional Study Area (RSA)
Mine Facilities
Mine Lease Boundary
O2
Northern OPA
Farim
T5a
O1a
Southern OPA
Sao Domingos
Bigéne
Canja
Cacheu
Bolor
Sao Vicente Bridge
Mansaba
Mores
Mansoa
Bissau
REFERENCES
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Mine footprints sourced from client
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WHEN PRODUCED AT SIZE A3
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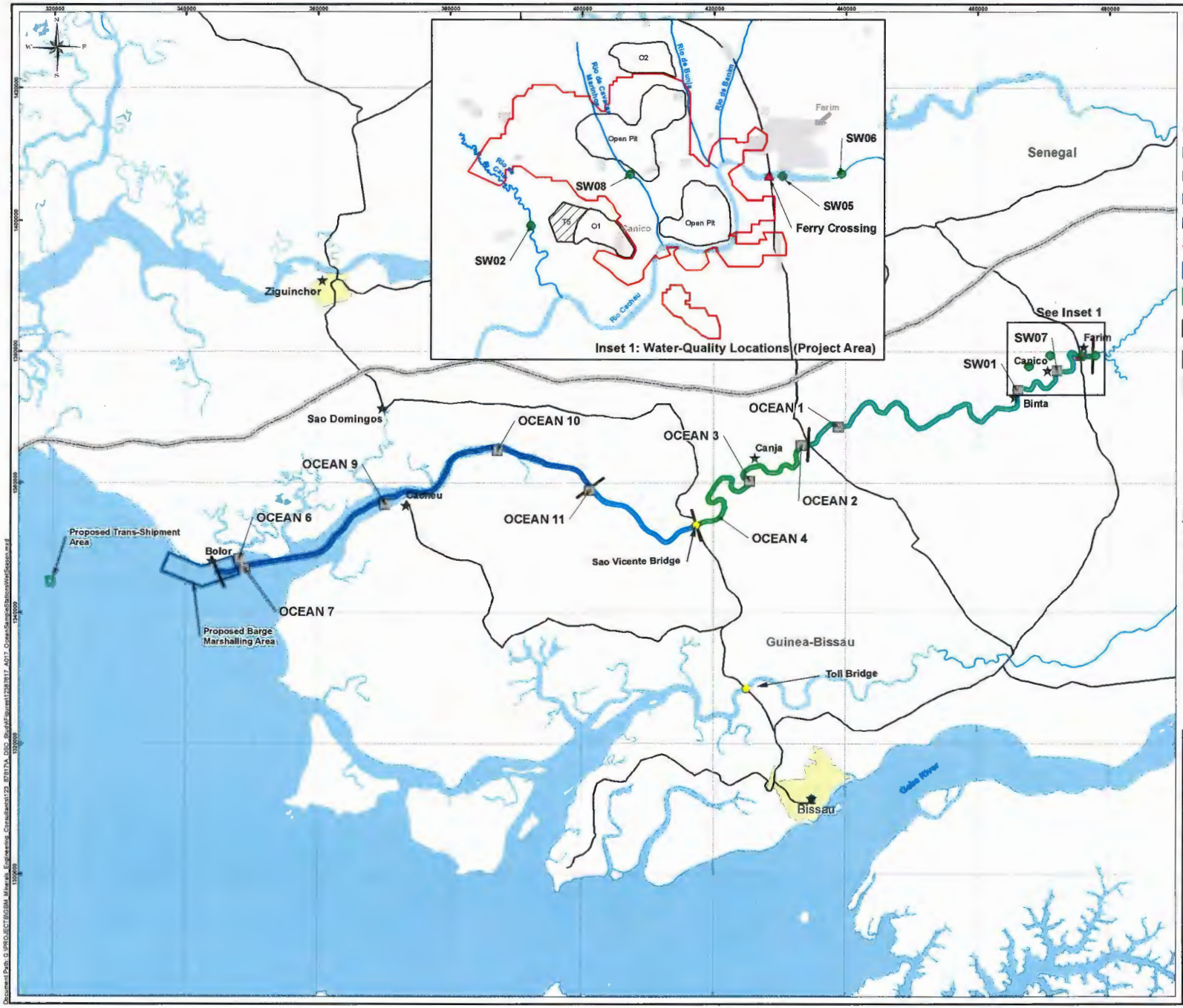

Legend

- Towns
- Bridge
- Ferry Crossing
- Country Border
- River Reach 1
- River Reach 2
- River Reach 3
- River Reach 4
- Project Area
- Proposed Barge Marshalling Area
- Proposed Trans-Shipment Area
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility
- Populated Settlements

Sample Stations

- Sediment
- Water Quality
- Water Quality, Sediment

Notes

Study Area Developed by Golder Associates Inc., 2012
Base Map Supplied By ESRI Inc. ©2010 and its Data Suppliers. Accessed 1/29/2014
Sediment Sample Locations and Salinity Measurement Locations are approximate. Collected during May 2013 field visit by Golder Associates Inc.

Coordinate System: WGS 1984 UTM Zone 28N
Projection: Transverse Mercator
Datum: WGS 1984

0 13 26
Kilometers

Client: GB Minerals Ltd			
Project: Farim Phosphate Project			
Title: River Cacheu Study Area Wet Season Monitoring Program			
Created by: NRL	Project Manager: BS	Reviewer: BD	Date: 01/29/14
File No.: 12387617_A017		Project No.: 13514950200	
Size: A3	Scale: 1:551,000	Status: Report Issue	
Drawing No.: 550-4.2			Rev: 0

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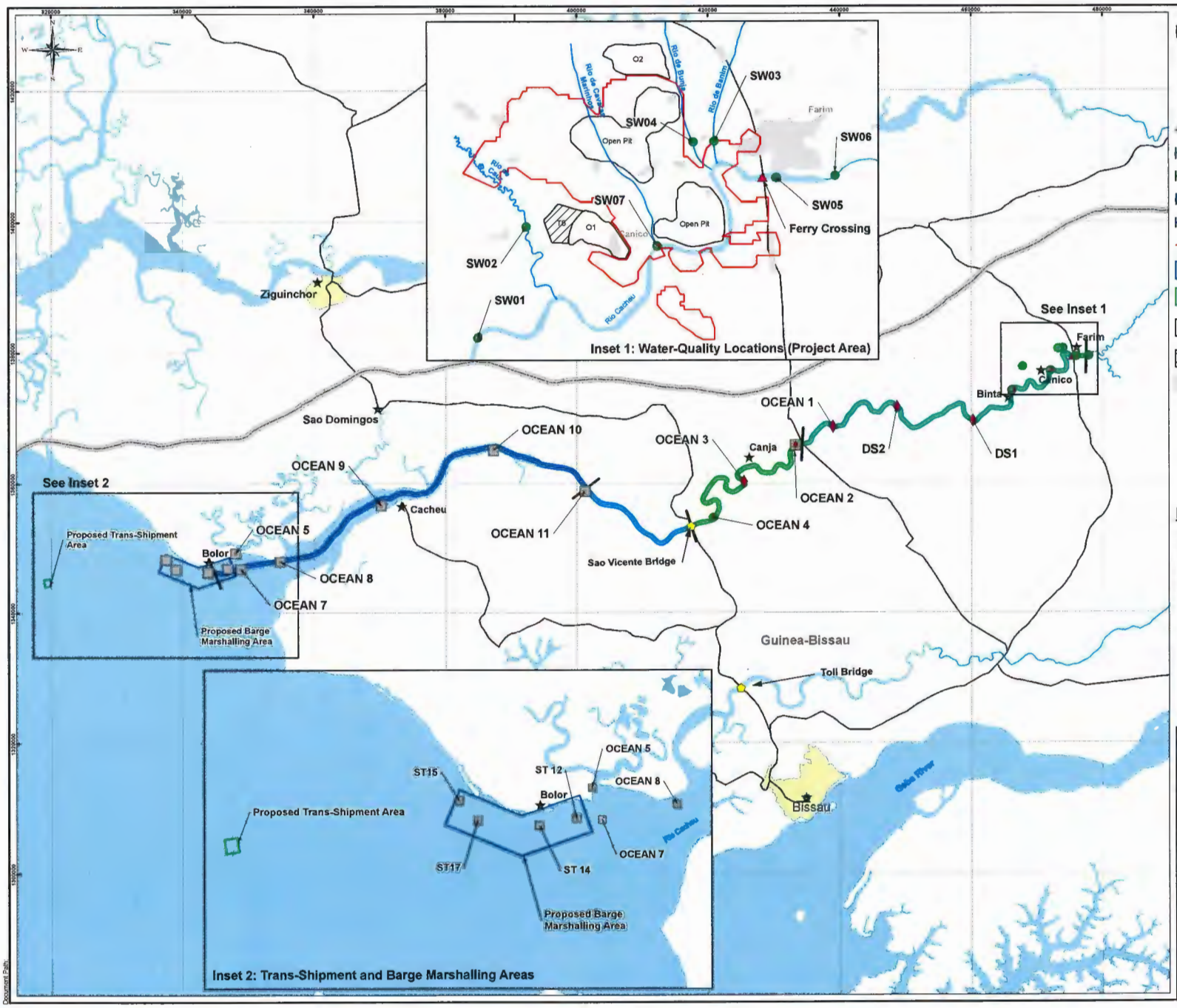

Legend

- Towns
- Bridge
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- River Reach 1
- River Reach 2
- River Reach 3
- River Reach 4
- Project Area
- Proposed Barge Marshalling Area
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- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility
- Populated Settlements

Sample Stations

- River Cross Section
- Sediment
- Sediment, River Cross Section
- Water Quality
- Water Quality, River Cross Section
- Water Quality, Sediment
- Water Quality, Sediment, River Cross Section

Guinea-Bissau

Notes

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Kilometers

Client	GB Minerals Ltd
Project	Farim Phosphate Project
Title	River Cacheu Study Area Dry Season Monitoring Program
Created by	NRL
Project Manager	BS
Reviewer	BD
Date	01/29/14
File No.	12387617_A016
Project No.	13514950200
Size	A3
Scale	1:551,000
Status	Report Issue
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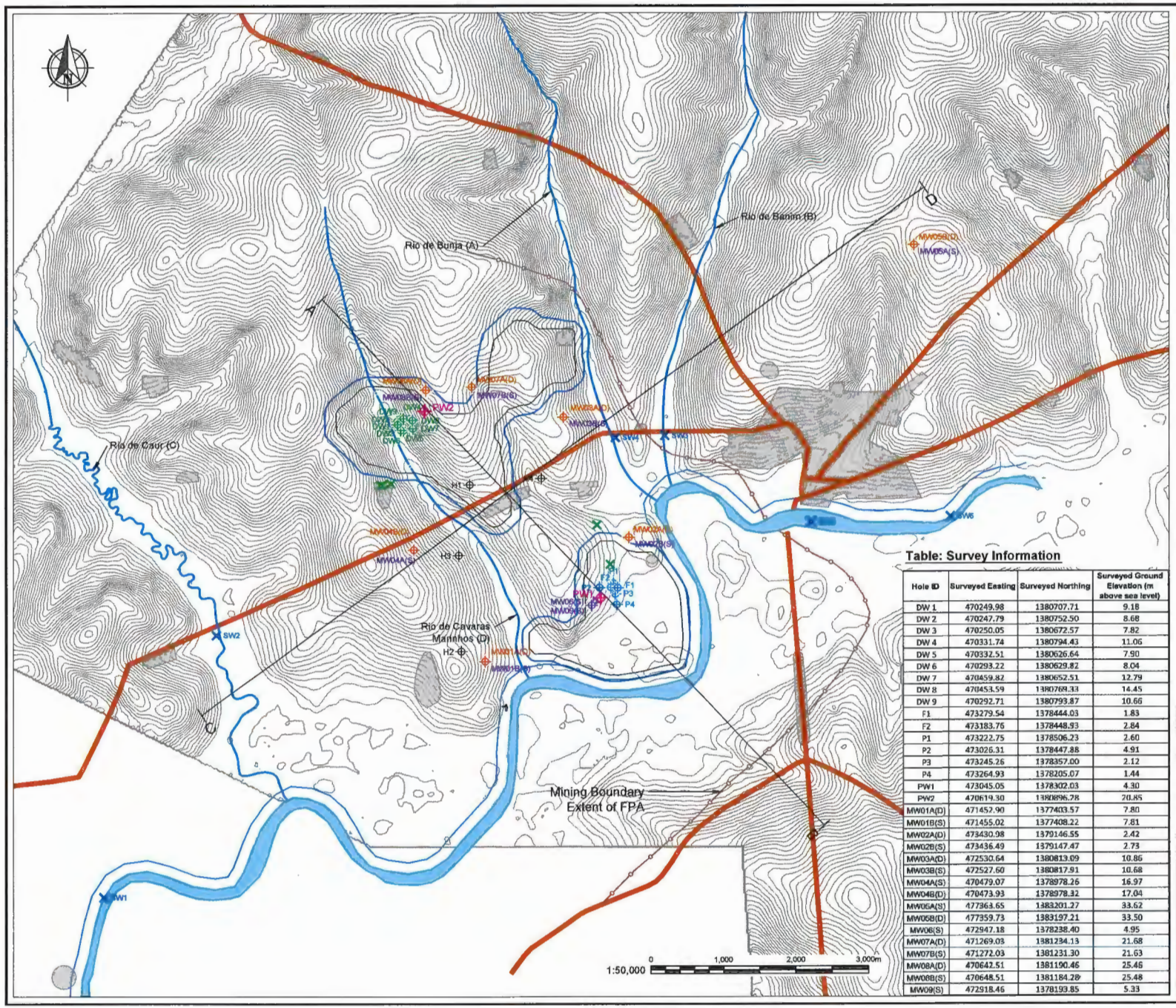

Legend

- Existing main roads
- Mining boundary, extent of FPA
- Populated settlements
- Extent of mining area
- Deep boreholes installed 2011
- Shallow boreholes installed 2011
- Boxcut boreholes installed 2007
- Pumptest boreholes installed 2008/9
- Dewatering well locations 2011
- Approximate location of BRGM pumping test boreholes 1985 now lost
- Local wells
- Location of hydrogeological cross section
- Surface water monitoring location

Table: Survey Information

Hole ID	Surveyed Easting	Surveyed Northing	Surveyed Ground Elevation (m above sea level)
DW 1	470249.98	1380707.71	9.18
DW 2	470247.79	1380752.50	8.68
DW 3	470250.05	1380672.57	7.82
DW 4	470331.74	1380794.43	11.06
DW 5	470332.51	1380626.64	7.90
DW 6	470293.22	1380629.82	8.04
DW 7	470459.82	1380652.51	12.79
DW 8	470453.59	1380769.33	14.45
DW 9	470292.71	1380793.87	10.66
F1	473279.54	1378444.03	1.83
F2	473183.76	1378448.93	2.84
P1	473222.75	1378506.23	2.60
P2	473026.31	1378447.88	4.91
P3	473245.26	1378357.00	2.12
P4	473264.93	1378205.07	1.44
PW1	473045.05	1378302.03	4.30
PW2	470619.30	1380896.78	20.85
MW01A(D)	471452.90	1377403.57	7.80
MW01B(S)	471455.02	1377408.22	7.81
MW02A(D)	473430.98	1379146.55	2.42
MW02B(S)	473436.49	1379147.47	2.73
MW03A(D)	472530.64	1380813.09	10.86
MW03B(S)	472527.60	1380817.91	10.68
MW04A(S)	470479.07	1378978.26	16.97
MW04B(D)	470473.93	1378978.32	17.04
MW05A(S)	477363.65	1383201.27	33.62
MW05B(D)	477359.73	1383197.21	33.50
MW06(S)	472947.18	1378238.40	4.95
MW07A(D)	471269.03	1381234.13	21.68
MW07B(S)	471272.03	1381231.30	21.63
MW08A(D)	470642.51	1381190.46	25.46
MW08B(S)	470648.51	1381184.28	25.48
MW09(S)	472918.46	1378193.85	5.33

Notes

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Project

Title: Borehole Location Plan

Created by	Requested by	Proj Manager	Reviewer	Date
ECS	MS	CN	CN	31/01/14

File No. 5110002 | Project No. 13514950200

Size A3 | Scale 1 : 50,000 | Status Report Issue

Drawing No. 550-5.1 | Rev -

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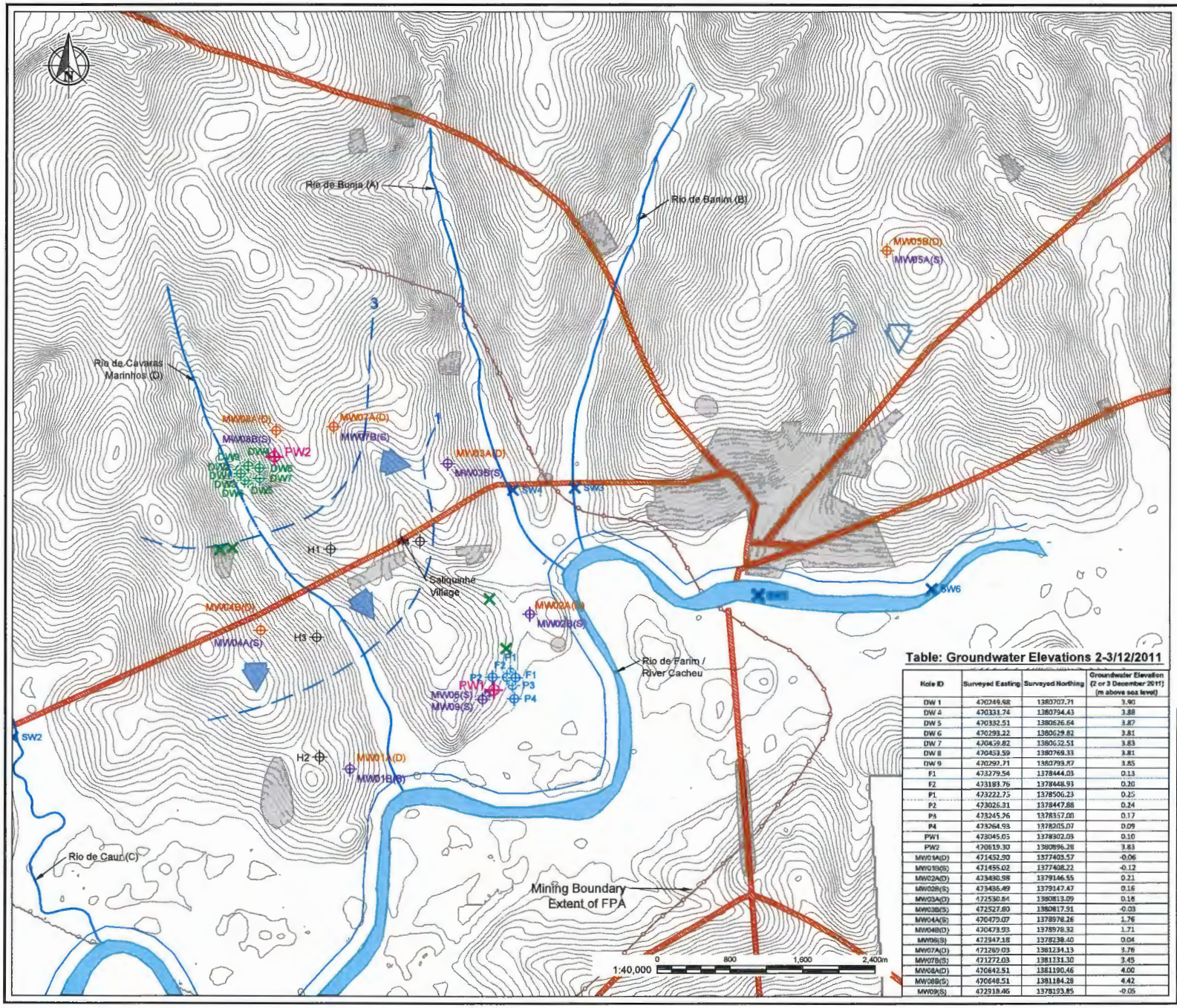

Legend

- Existing main roads
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- Pumptest boreholes installed 2008/9
- Dewatering well locations 2011
- Approximate location of BRGM pumping test boreholes 1985 now lost
- Local wells
- Surface water monitoring location
- Groundwater elevation contour (masl)
- Inferred groundwater flow direction
- Groundwater flow direction indicated

Table: Groundwater Elevations 2-3/12/2011

Hole ID	Surveyed Easting	Surveyed Northing	Groundwater Elevation (2 or 3 December 2011) (m above sea level)
DW 1	470249.68	1380707.71	3.90
DW 4	470331.74	1380794.43	3.88
DW 5	470332.51	1380626.64	3.87
DW 6	470293.22	1380629.82	3.81
DW 7	470459.82	1380632.51	3.83
DW 8	470453.59	1380769.33	3.81
DW 9	470299.71	1380799.87	3.85
F1	473279.54	1378444.03	0.13
F2	473193.76	1378448.93	0.20
P1	473222.75	1378506.23	0.25
P2	473026.31	1378447.88	0.24
P3	473245.26	1378357.00	0.17
P4	473264.93	1378205.07	0.09
PW1	473045.05	1378302.03	0.10
PW2	470619.30	1380896.28	3.83
MW01A(D)	471452.90	1377403.57	-0.06
MW01B(S)	471455.02	1377408.22	-0.12
MW02A(D)	473480.98	1379146.55	0.21
MW02B(S)	473485.49	1379147.47	0.16
MW03A(D)	472530.84	1380813.09	0.18
MW03B(S)	472527.80	1380817.91	-0.03
MW04A(S)	470472.07	1378978.26	1.76
MW04B(D)	470473.93	1378978.32	1.71
MW06(S)	472947.18	1378238.40	0.04
MW07A(D)	471269.03	1381234.13	3.76
MW07B(S)	471272.03	1381231.30	3.45
MW08A(D)	470642.51	1381190.46	4.00
MW08B(S)	470648.51	1381184.28	4.42
MW09(S)	472918.45	1378193.85	-0.05

Notes

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Project

Title: Groundwater Flow Directions

Created by	Requested by	Proj Manager	Reviewer	Date
ECS	MS	CN	CN	31/01/14

File No.: 5110003 | Project No.: 13514950200

Size: A3 | Scale: 1 : 40,000 | Status: Report Issue

Drawing No.: 550-5.2 | Rev: -

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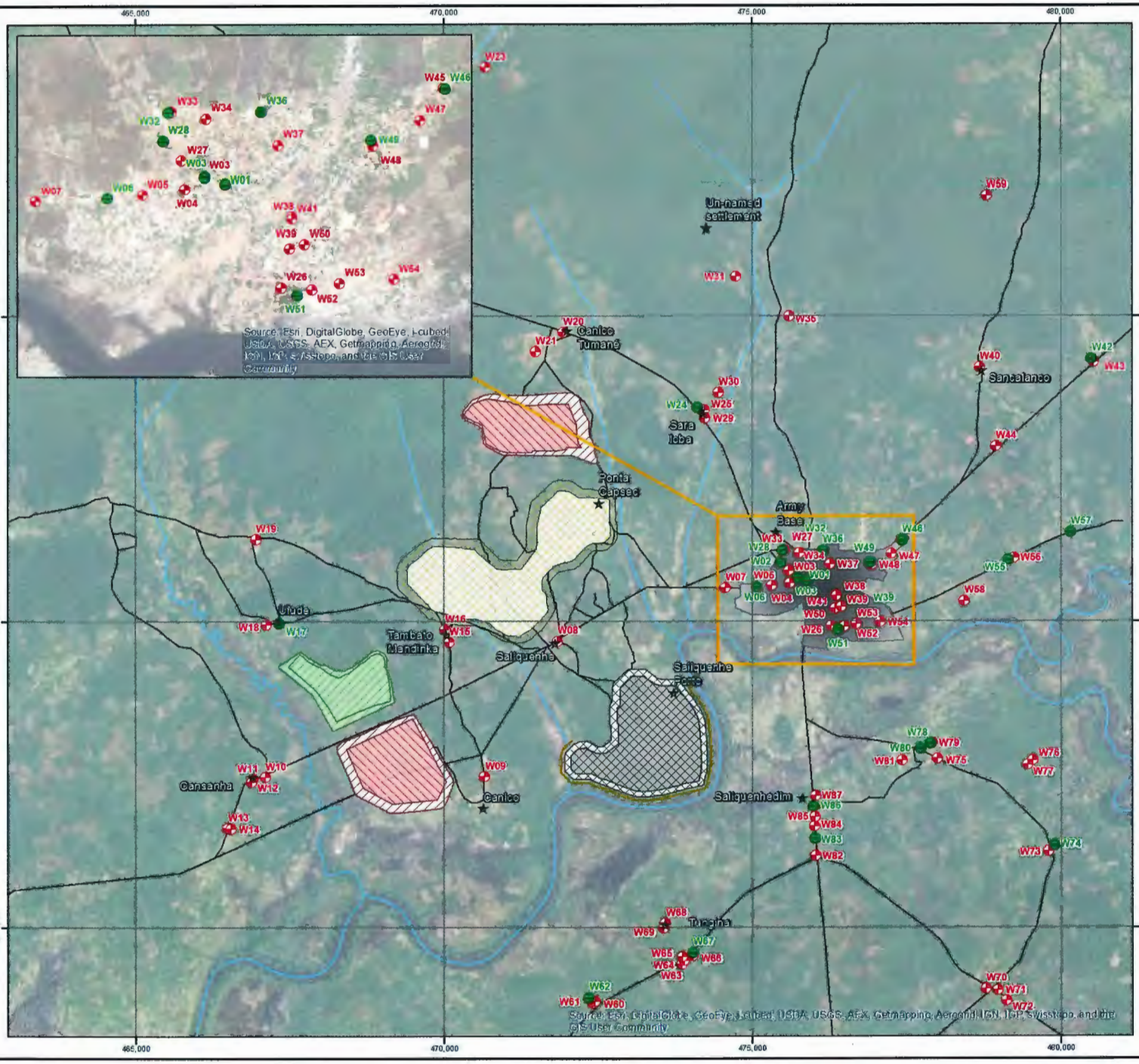
London
E1 8DE
+44 (0)20 7423 0940



Legend

- Village
- Hydrocensus Well With Recordable Water Level
- Hydrocensus Well With Unrecordable Water Level
- Existing Road
- Watercourse
- Farim

Mine Facilities

- Proposed Flood Bund Centreline
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility
- Northern Pit Area Crest
- Northern Pit Area Toe
- Southern Pit Area Crest
- Southern Pit Area Toe

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Mine footprints sourced from client

2 1 0 2 KILOMETRES

N

SCALE 1:60,000
WHEN PRODUCED AT SIZE A3

CLIENT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
HYDROCENSUS WELL LOCATIONS

Golder Associates
London, UK

PROJECT No.	1361495200		FILE No.	
DESIGN	HC	20/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	05/02/2014	DRAWING	550-5.3
CHECK	HC	05/02/2014		
REVIEW	DK	05/02/2014		

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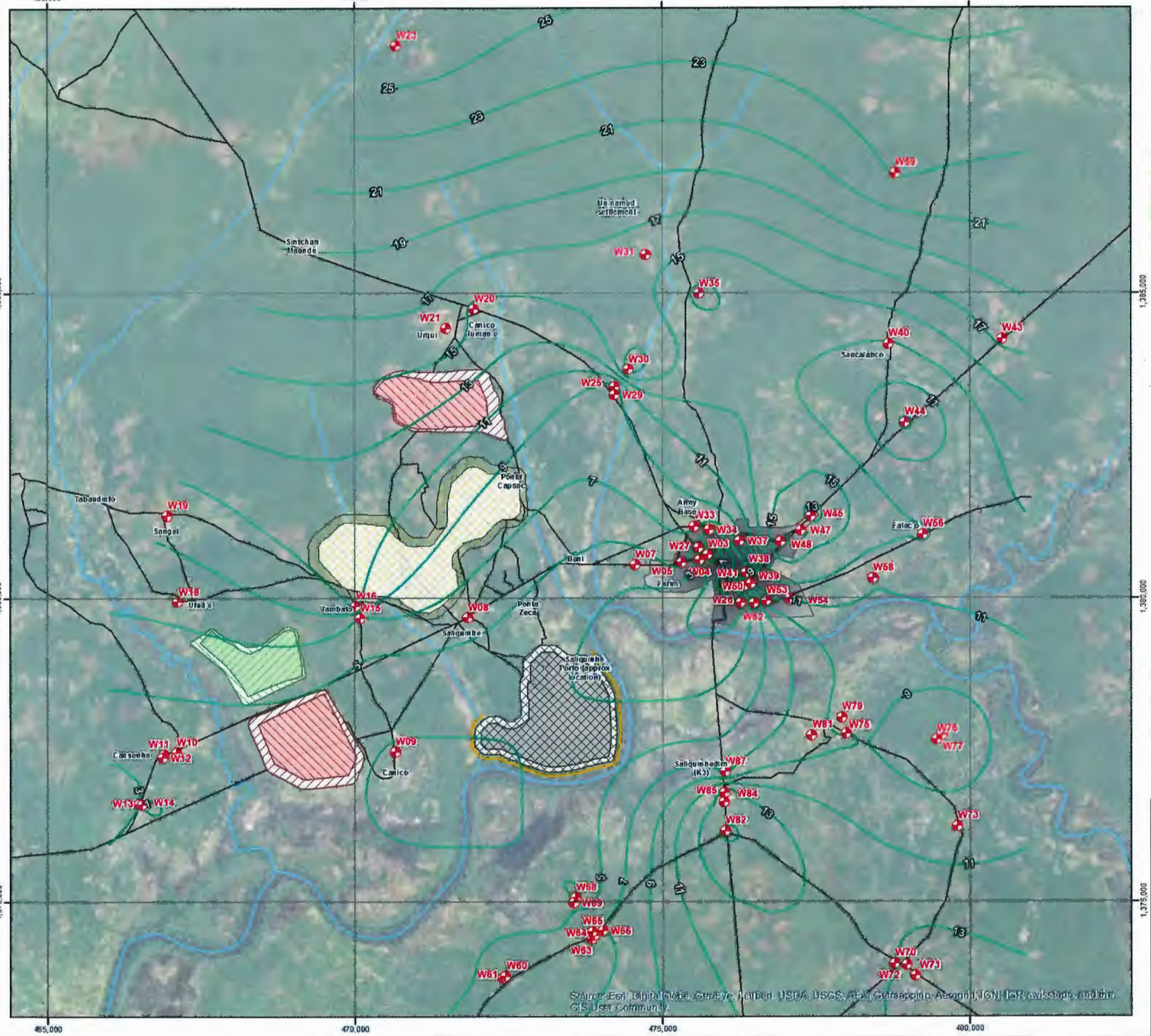

Legend

- Hydrocensus Well With Recordable Water Level
- Approximate Groundwater Elevation Contour February 2012 (m asl)
- Existing Road
- Watercourse
- Farim

Mine Facilities

- Proposed Flood Bund Centreline
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility
- North Pit Area Crest
- North Pit Area Toe
- South Pit Area Crest
- South Pit Area Toe

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Mine footprints sourced from client

2 1 0 2 KILOMETRES

N

SCALE 1:60,000
WHEN PRODUCED AT SIZE A3

CLIENT: GB MINERALS LTD

PROJECT: FARIM PHOSPHATE PROJECT

TITLE: **GROUNDWATER CONTOURS FEBRUARY 2012 FROM HYDROCENSUS WELLS**

Golder Associates
London, UK

PROJECT No.	1351466009		FILE No.	
DESIGN	HC	29-11-2013	SCALE AS SHOWN	REV 0
GIS	LD	05-02-2014	DRAWING	
CHECK	HC	05-02-2014	550-5.4	
REVIEW	DK	05-02-2014		

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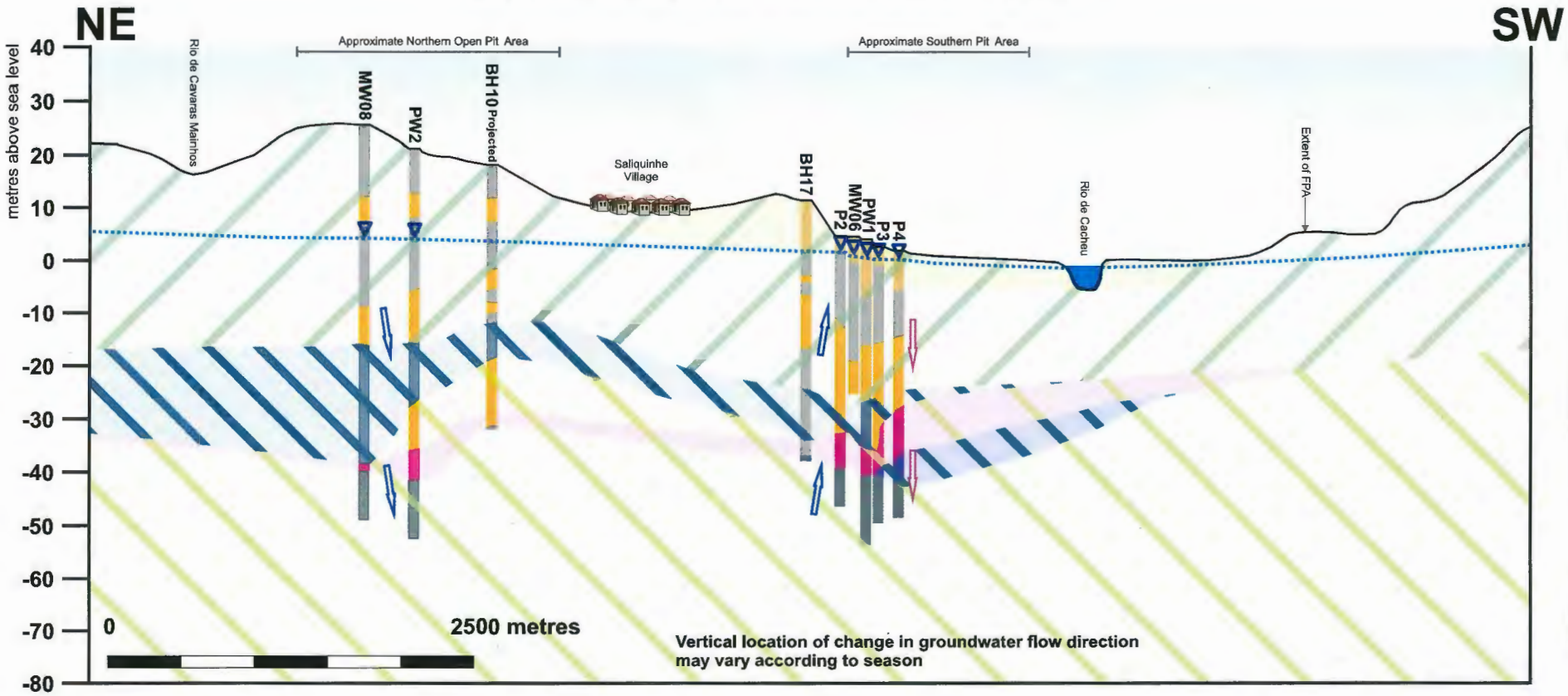
Conceptual Groundwater Flow Model



Legend

- Gravel / Laterite (Known / Inferred)
- Sand (Known / Inferred)
- Clay (Known / Inferred)
- Blue Grey Clay (Known / Inferred)
- FPA (Known / Inferred)
- Dolomitic Limestone (Known / Inferred)
- FPB (Known / Inferred)
- Limestone (Known / Inferred)

UPPER - Overburden aquifer (Consisting of confined lenses of water)

AQUITARD - (Low permeability)

LOWER - Limestone/Phosphate Aquifer (consisting of confined aquifer)

- Water table
- Groundwater elevation measured 2 or 3 December 2011
- Vertical groundwater flow direction in dry season
- Vertical groundwater flow direction in wet season

Client: GB Minerals Ltd				
Project: Farim Phophate Project				
Title: Conceptual Groundwater Flow Model				
Created by: AD	Requested by: MS	Proj Manager: DAK	Reviewer: DAK	Date: 28/01/14
File No.: 5235260		Project No.: 13514950200		
Size: A3	Scale: As Shown	Status: Report Issue		
Drawing No.: 550-5.5				Rev: 0

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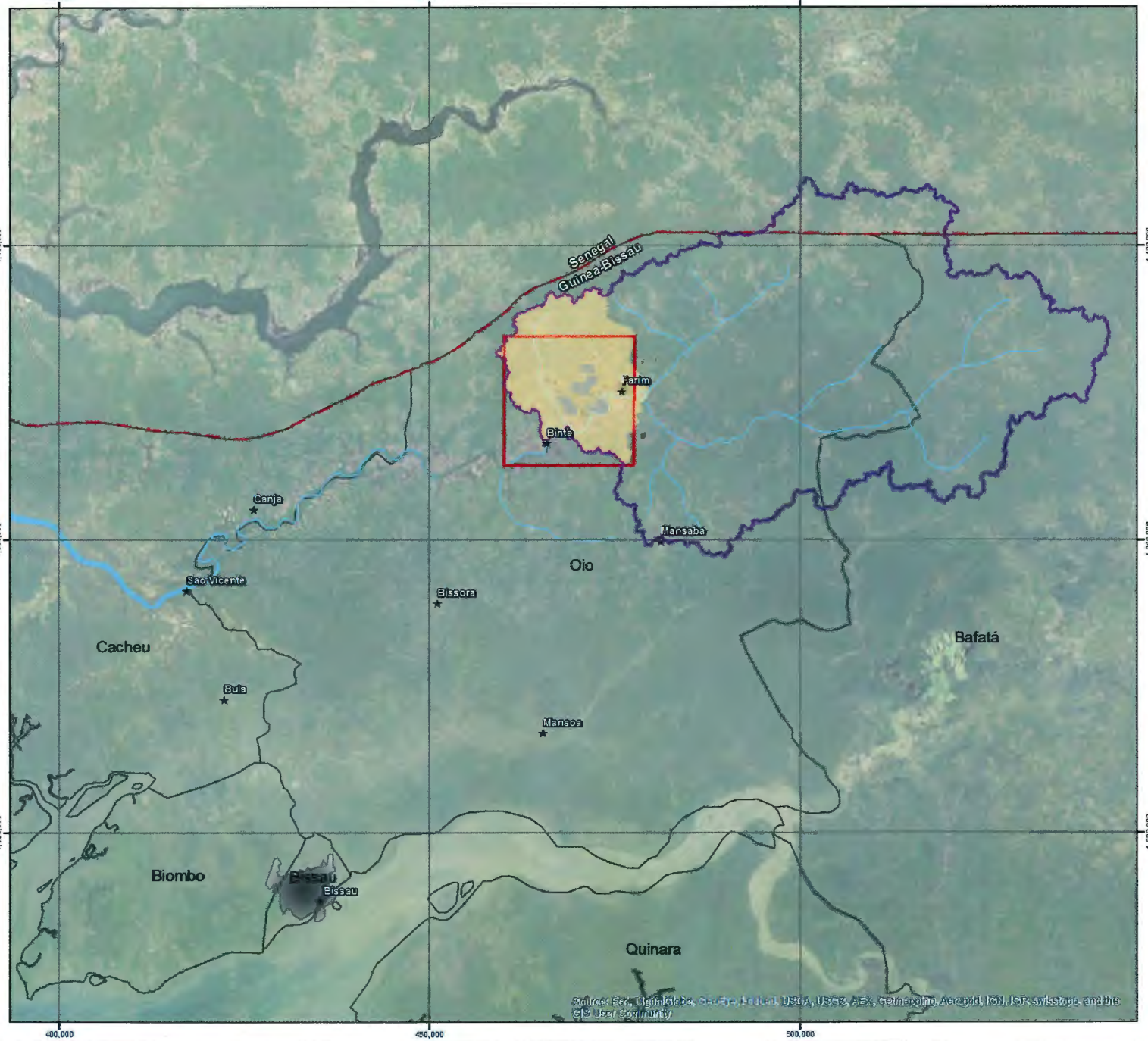
E1 8DE
+44 (0)20 7423 0940



Legend

- Village
- Watercourse
- Administrative Boundary
- International Border
- Local Study Area (LSA)
- Regional Study Area (RSA)
- Mine Lease Boundary
- Mine Facilities

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Mine footprints sourced from client

10 5 0 10 KILOMETRES

SCALE 1:500,000
WHEN PRODUCED AT SIZE A3

N

PROJECT: GB MINERALS LTD

PROJECT: FARIM PHOSPHATE PROJECT

TITLE: **SURFACE WATER LOCAL AND REGIONAL STUDY AREAS**

Golder Associates
London, UK

PROJECT No.	1351456/200		FILE No.	
DESIGN	EH	21/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	21/02/2014	DRAWING	550-6.1
CHECK	EH	21/02/2014		
REVIEW	DK	21/02/2014		

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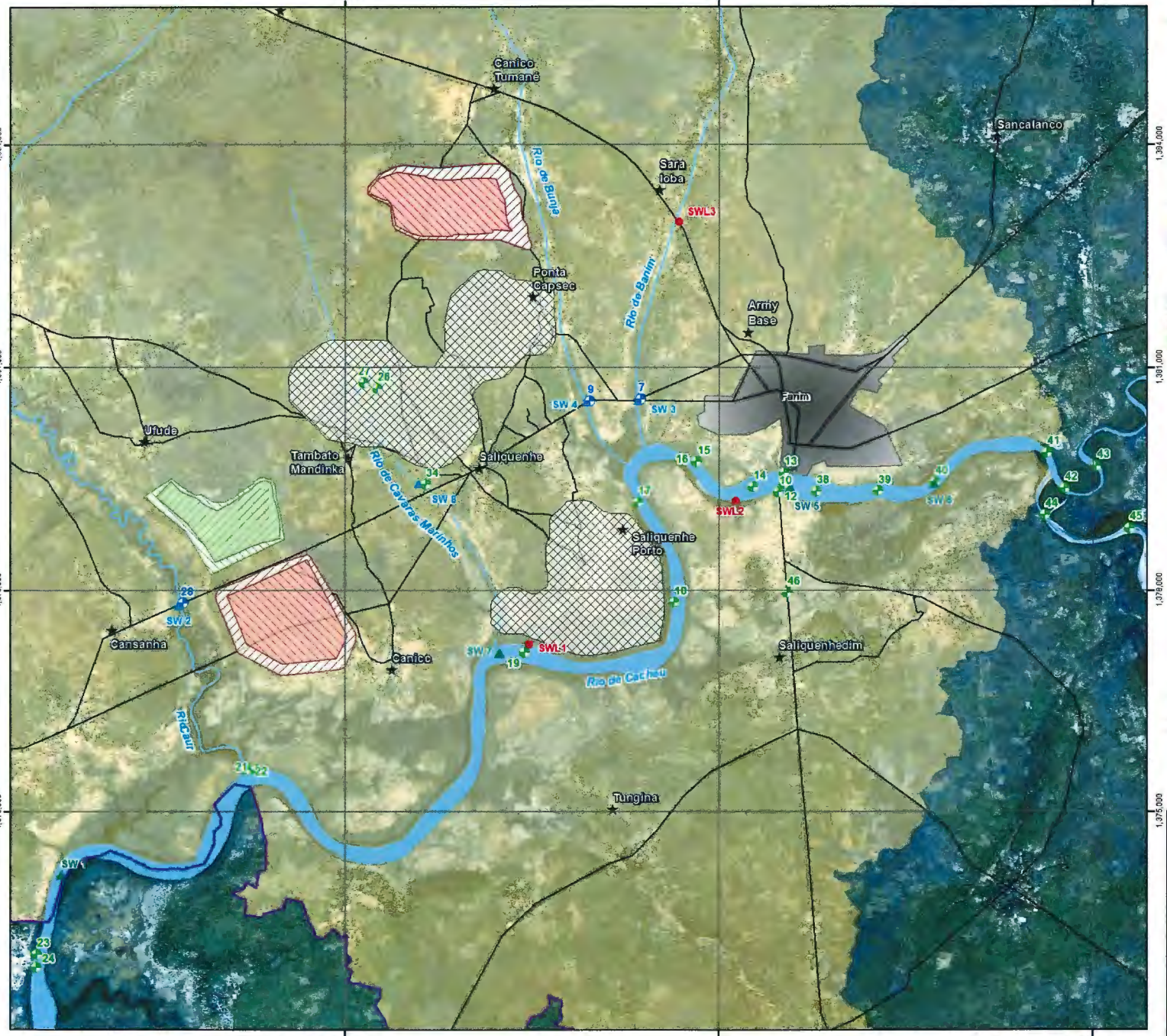

Legend

- Village
- SWL Location
- RSA samples collected for laboratory analysis
- LSA samples collected for laboratory analysis
- Regional Study Area Insitu Sample Site
- Local Study Area Insitu Sample Site
- Watercourse
- Watercourse Ephemeral
- Existing Road
- Local Study Area (LSA)
- Regional Study Area (RSA)
- Farim

Mine Facilities

- Proposed Open Pit Area
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Imagery and mine footprints sourced from client

1.5 0.75 0 1.5 KILOMETRES

SCALE 1:50,000
WHEN PRODUCED AT SIZE A3

N

PROJECT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
SURFACE WATER QUALITY SAMPLING LOCATIONS

Golder Associates
London, UK

PROJECT No.	1351495200		FILE No.	
DESIGN	EH	21/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	05/02/2014	DRAWING	
CHECK	EH	05/02/2014	550-6.2	
REVIEW	DK	05/02/2014		

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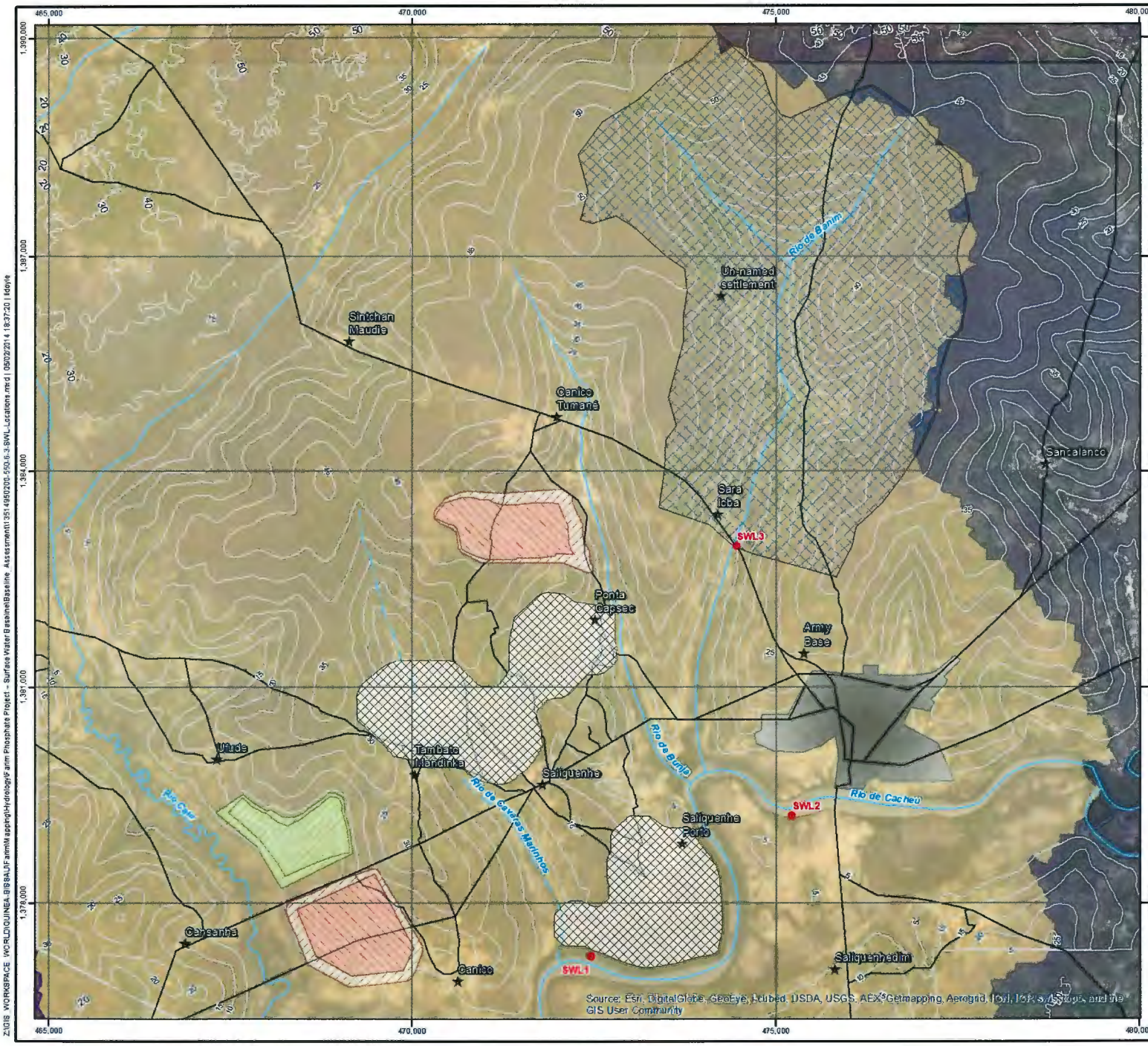

Legend

- Village
- SWL Location
- Watercourse
- Watercourse Ephemeral
- 5 Metre Contour
- Existing Road
- Monitored Catchment
- Local Study Area (LSA)
- Regional Study Area (RSA)
- Farim

Mine Facilities

- Proposed Open Pit Area
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Mine footprints sourced from client

1 0.5 0 1 KILOMETRES

SCALE 1:50,000
WHEN PRODUCED AT SIZE A3

N

PROJECT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
SURFACE WATER LEVEL MONITORING LOCATIONS

Golder Associates
London, UK

PROJECT No.	1351450230		FILE No.	
DESIGN	EH	21/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	05/02/2014	DRAWING	
CHECK	EH	05/02/2014	550-6.3	
REVIEW	DK	05/02/2014		

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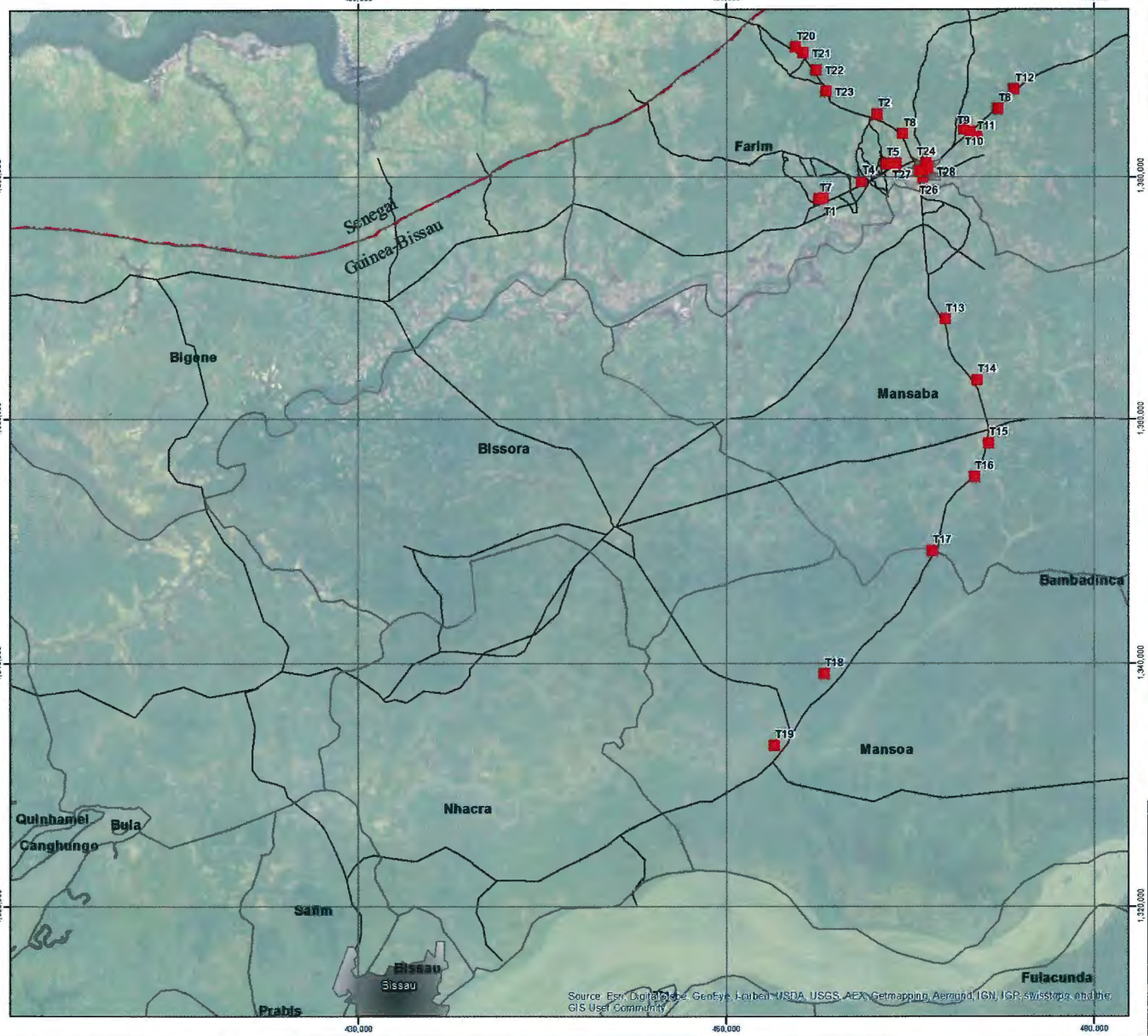

Legend

- Terrestrial Field Survey Site
- Existing Road
- Administrative Boundary
- International Border

REFERENCES

Coordinate System: Bissau UTM Zone 28N.

10 5 0 10 KILOMETRES

N

SCALE 1:300,000
WHEN PRODUCED AT SIZE A3

CLIENT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
ECOLOGICAL MONITORING SITES (TERRESTRIAL)

Golder Associates
London, UK

PROJECT No.	1351495/0201		FILE No.	
DESIGN	PW	29/10/2014	SCALE AS SHOWN	REV 0
GIS	LD	11/02/2014	DRAWING	
CHECK	PW	11/02/2014	550-8.1	
REVIEW	DK	11/02/2014		

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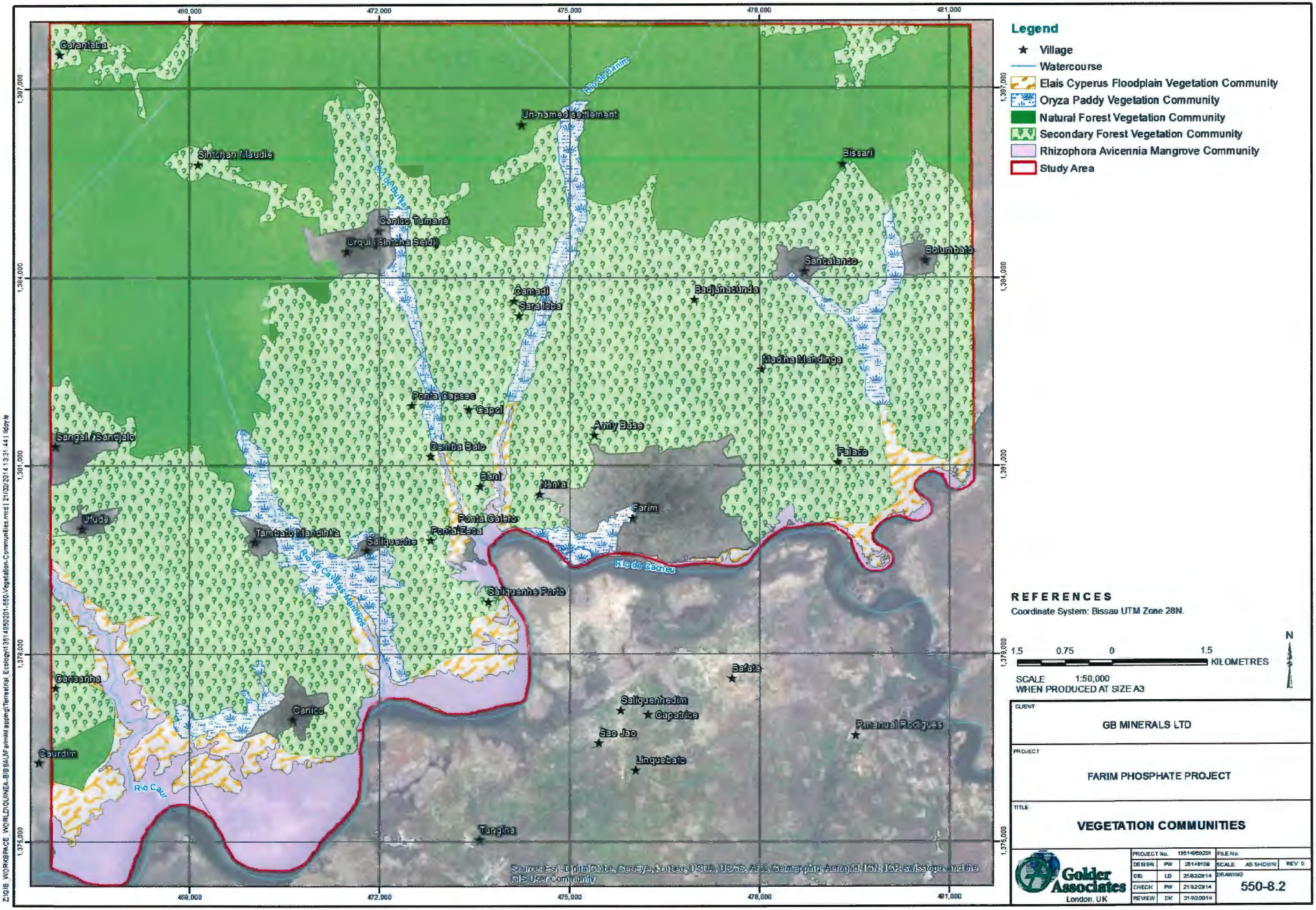
Legend
Village
Watercourse
Elais Cyperus Floodplain Vegetation Community
Oryza Paddy Vegetation Community
Natural Forest Vegetation Community
Secondary Forest Vegetation Community
Rhizophora Avicennia Mangrove Community
Study Area
REFERENCES
Coordinate System: Bissau UTM Zone 28N.
1.5 0.75 0 1.5 KILOMETRES
SCALE 1:50,000
WHEN PRODUCED AT SIZE A3
N
CLIENT
GB MINERALS LTD
PROJECT
FARIM PHOSPHATE PROJECT
TITLE
VEGETATION COMMUNITIES
Golder Associates
London, UK
PROJECT No. 1351495020
FILE No.
DESIGN PW 21/02/2014
SCALE AS SHOWN
REV 0
GIS LD 21/02/2014
DRAWING
CHECK PW 21/02/2014
REVIEW DK 21/02/2014
550-8.2
469,000
472,000
475,000
478,000
481,000
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1,384,000
1,381,000
1,378,000
1,375,000
Rio de Farim
Rio de Cacheu
Rio Caur
Rio de Canhas Manhiros
Rio Buffa
Caranabca
Sintchan Maudie
Un-named settlement
Bissari
Canjac Tumane
Urqui / Sintcha Seidi
Sancalanao
Bolumbato
Camadi
Saraloba
Badjanacunda
Madina Mandinga
Ponta Capsoe
Capel
Army Base
Sangal / Sancjalo
Demba Balo
Palace
Bani
Nemai
Farim
Ponta Galero
Ponta Zecai
Tamtato Mandinka
Salquenhe
Salquenhe Porto
Bafata
Carisanha
Canico
Salquenhedim
Capatrice
Pimanual Rodrigues
Sao Jao
Caurdim
Linquebato
Turgina
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
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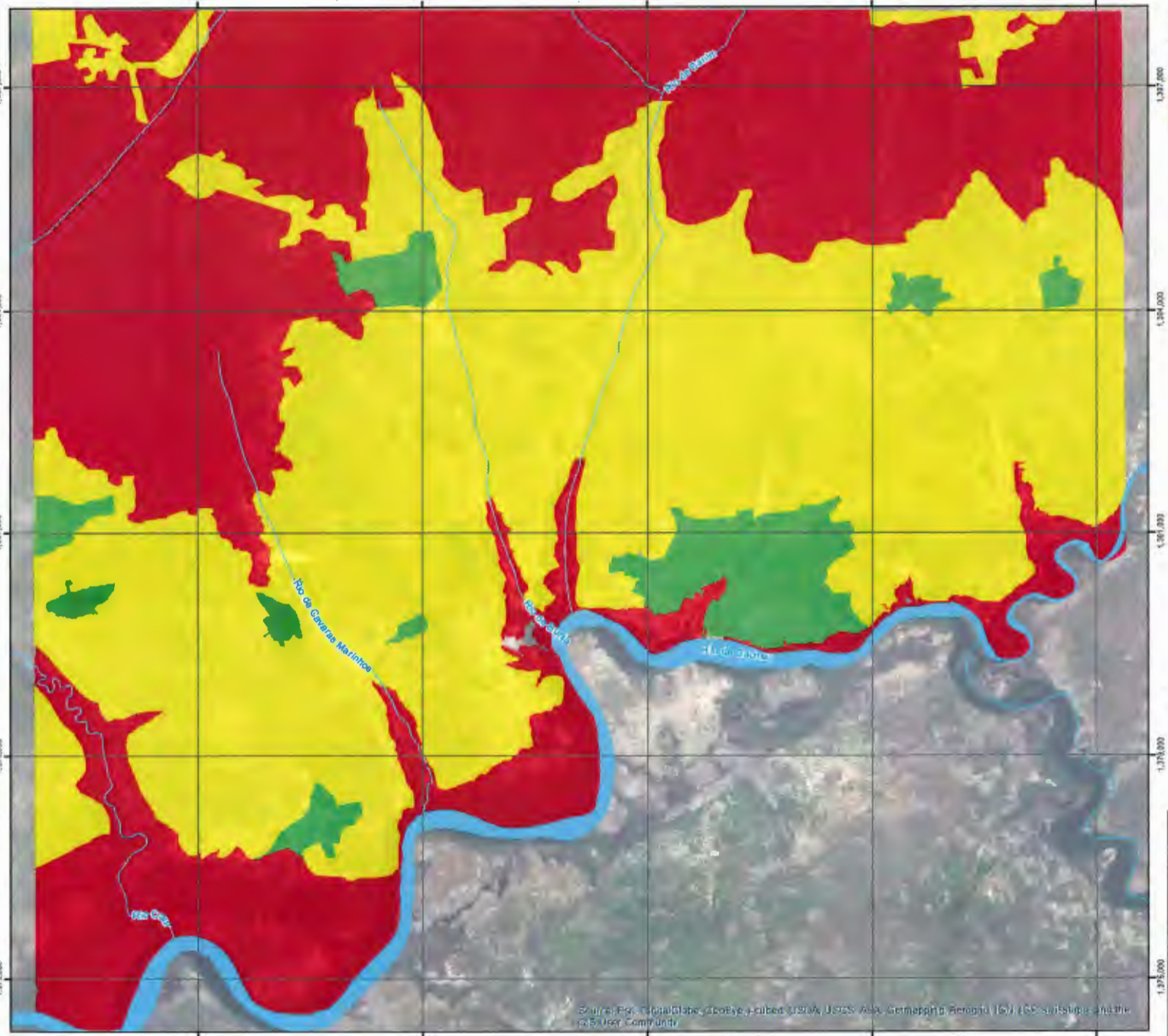

Legend

Watercourse

Ecological Integrity

- High
- Moderate
- Low

REFERENCES

Coordinate System: Bissau UTM Zone 28N.

1.5 0.75 0 1.5 KILOMETRES

N

SCALE 1:50,000
WHEN PRODUCED AT SIZE A3

CLIENT

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PROJECT

FARIM PHOSPHATE PROJECT

TITLE

ECOLOGICAL INTEGRITY

Golder Associates
London, UK

PROJECT No.	1351466G01	FILE No.	
DESIGN	PW	28/10/2014	SCALE AS SHOWN	REV 0
DR	LE	11/02/2014	DRAWING
CHECK	PW	11/02/2014	550-8.3
REVIEW	DK	11/02/2014	

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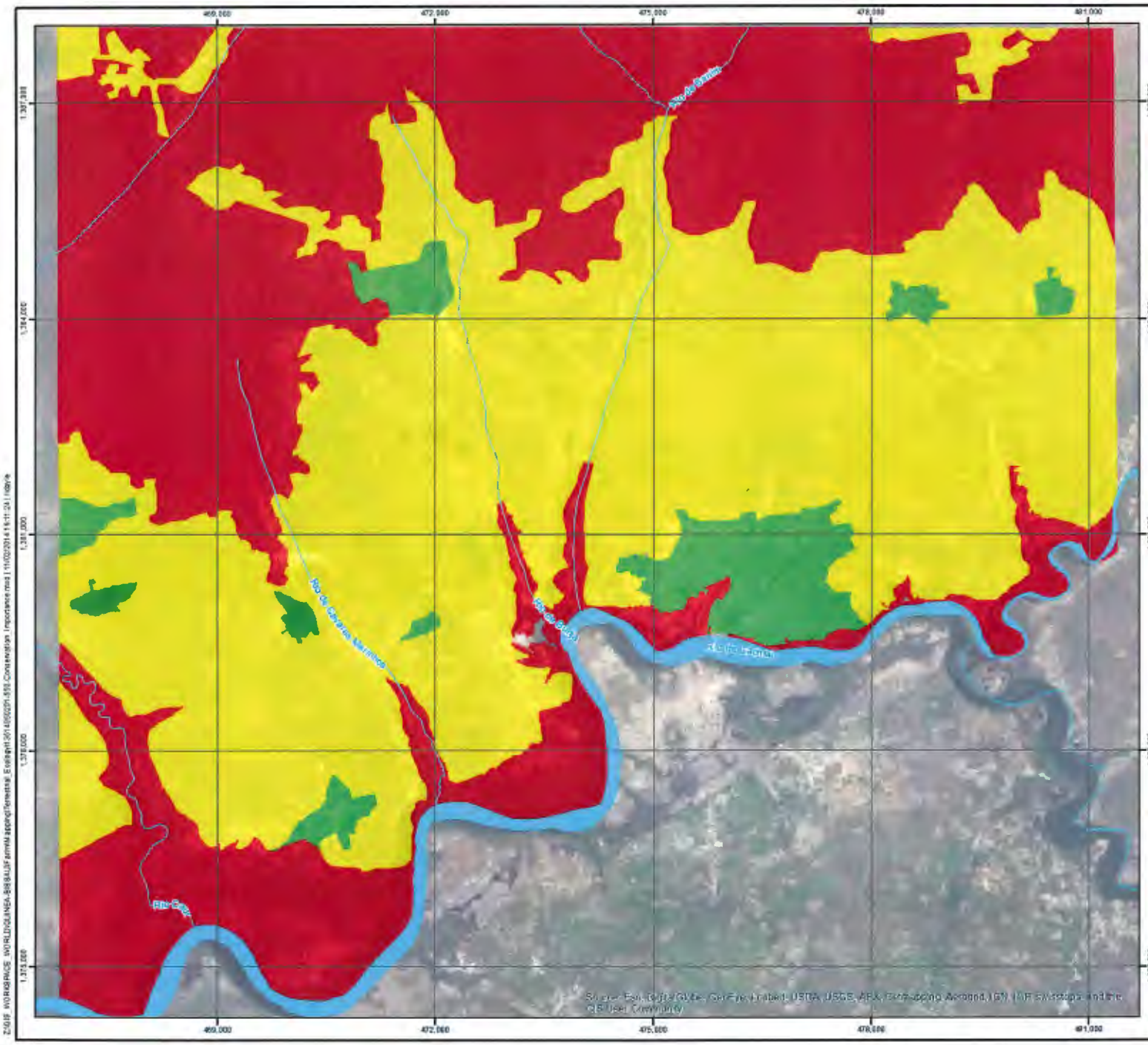

Legend

- ★ Village
- Watercourse / Curso De Água

Conservation Importance

- High
- Moderate
- Low

REFERENCES

Coordinate System: Bissau UTM Zone 28N.

1.5 0.75 0 1.5 KILOMETRES

SCALE 1:50,000
WHEN PRODUCED AT SIZE A3

N

CLIENT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
CONSERVATION IMPORTANCE

Golder Associates
London, UK

PROJECT No.	1061466001		FILE No.	
DESIGN	PW	2014/02/06	SCALE AS SHOWN	REV 2
GIS	LD	11/02/2014	DRAWING	
CHECK	PW	11/02/2014	550-8.4	
REVIEW	DK	11/02/2014		

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Legend

- Settlement Extent
- Parks
- Study Area
- Potential Seagrass Habitat
- Administrative Boundary
- International Border

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Mine footprints sourced from client

15 7.5 0 15 KILOMETRES

SCALE 1:500,000
WHEN PRODUCED AT SIZE A3

N

CLIENT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
PROPOSED STUDY AREA

Golder Associates
London, UK

PROJECT No.	1351495201		FILE No.	
DESIGN	PW	29149108	SCALE AS SHOWN	REV 0
GIS	LD	11/02/2014	DRAWING	
CHECK	PW	11/02/2014	550-8.5	
REVIEW	DK	11/02/2014		

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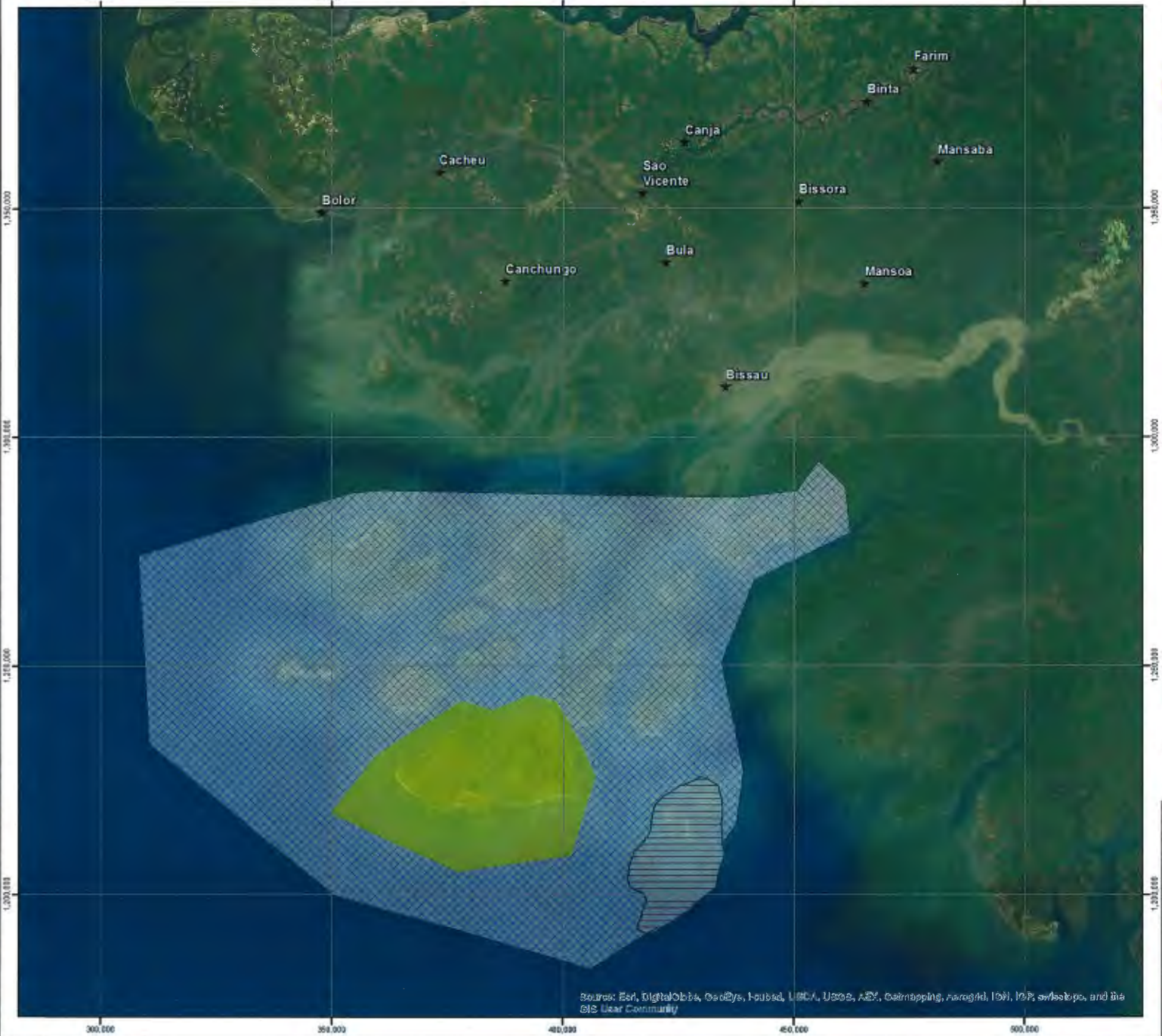

Legend

★ Village

Protected Areas For Turtles

- Orango National Park
- Joao Vieira - Poilao Marine National Park
- Coastal Protect Areas Boloma-Bijagos Marine Biosphere

REFERENCES

Coordinate System: Bissau UTM Zone 28N.

20 10 0 20 KILOMETRES

SCALE 1:800,000
WHEN PRODUCED AT SIZE A3

N

PROJECT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
PROTECTED AREAS FOR TURTLES

Golder Associates
London, UK

PROJECT No.		FILE No.	
DRAWN	AH	26/11/2013	SCALE AS SHOWN REV 0
GIS	LD	05/02/2014	DRAWING
CHECK	AH	05/02/2014	550-8.6
REVIEW	DK	05/02/2014	

Legend

- ★ Village
- Study Area Investigated For Turtle Activity

REFERENCES

Coordinate System: Bissau UTM Zone 28N.t

10 5 0 10 KILOMETRES

N

SCALE 1:300,000
WHEN PRODUCED AT SIZE A3

CLIENT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
STUDY AREA INVESTIGATED FOR TURTLE ACTIVITY

Golder Associates
London, UK

PROJECT No.	1351495200		FILE No.	
DESIGN	AH	28/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	05/02/2014	DRAWING	
CHECK	AH	05/02/2014	550-8.7	
REVIEW	DK	05/02/2014		

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Legend

- ★ Village
- Study Area Investigated For Crocodile Activity

REFERENCES

Coordinate System: Bissau UTM Zone 28N.

10 5 0 10 KILOMETRES

SCALE 1:500,000
WHEN PRODUCED AT SIZE A3

N

CLIENT: GB MINERALS LTD

PROJECT: FARIM PHOSPHATE PROJECT

TITLE: **STUDY AREA INVESTIGATED FOR CROCODILE ACTIVITY**

Golder Associates
London, UK

PROJECT No.	1361-4950200		FILE No.	
DESIGN	AH	28/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	05/02/2014	DRAWING	
CHECK	AH	05/02/2014	550-8.8	
REVIEW	DK	06/02/2014		

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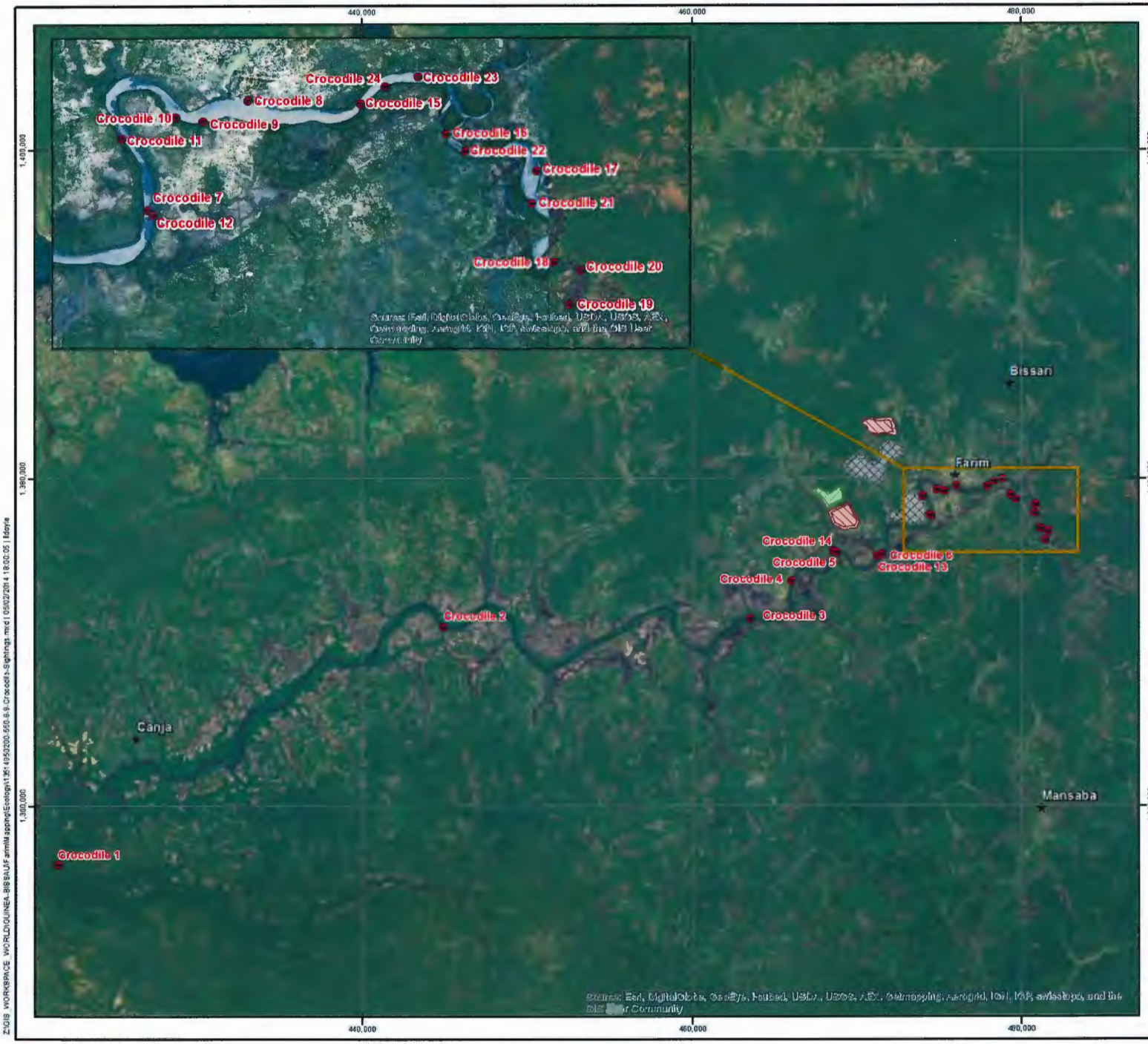

Legend

- ★ Village
- ● Crocodile Sighting

Mine Facilities

- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility
- Proposed Open Pit Area

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Inset image and mine footprints sourced from client

5 2.5 0 5 KILOMETRES

SCALE 1:220,000
WHEN PRODUCED AT SIZE A3

N

CLIENT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
CROCODILE SIGHTINGS

Golder Associates
London, UK

PROJECT No.	1351405029		FILE No.	
DESIGN	AH	28/11/2013	SCALE AS SHOWN	REV 0
GIS	LD	05/02/2014	DRAWING	
CHECK	AH	05/02/2014	550-8.9	
REVIEW	DK	06/02/2014		

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Legend

- Village
- Vulture Sighting

Mine Facilities

- Proposed Overburden Storage Facility
- Proposed Tailings Managment Facility
- Proposed Open Pit Area

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Mine footprints sourced from client

1.5 0.75 0 1.5 KILOMETRES

SCALE 1:50,000
WHEN PRODUCED AT SIZE A3

N

CLIENT: GB MINERALS LTD

PROJECT: FARIM PHOSPHATE PROJECT

TITLE: VULTURE STUDY SITES

Golder Associates
London, UK

PROJECT No.	1351466028	FILE No.	
DESIGN	AH	28.11.2013	SCALE AS SHOWN REV 0
GIS	LD	05/02/2014	DRAWING
CHECK	AH	06/02/2014	550-8.10
REVIEW	DK	06/02/2014	

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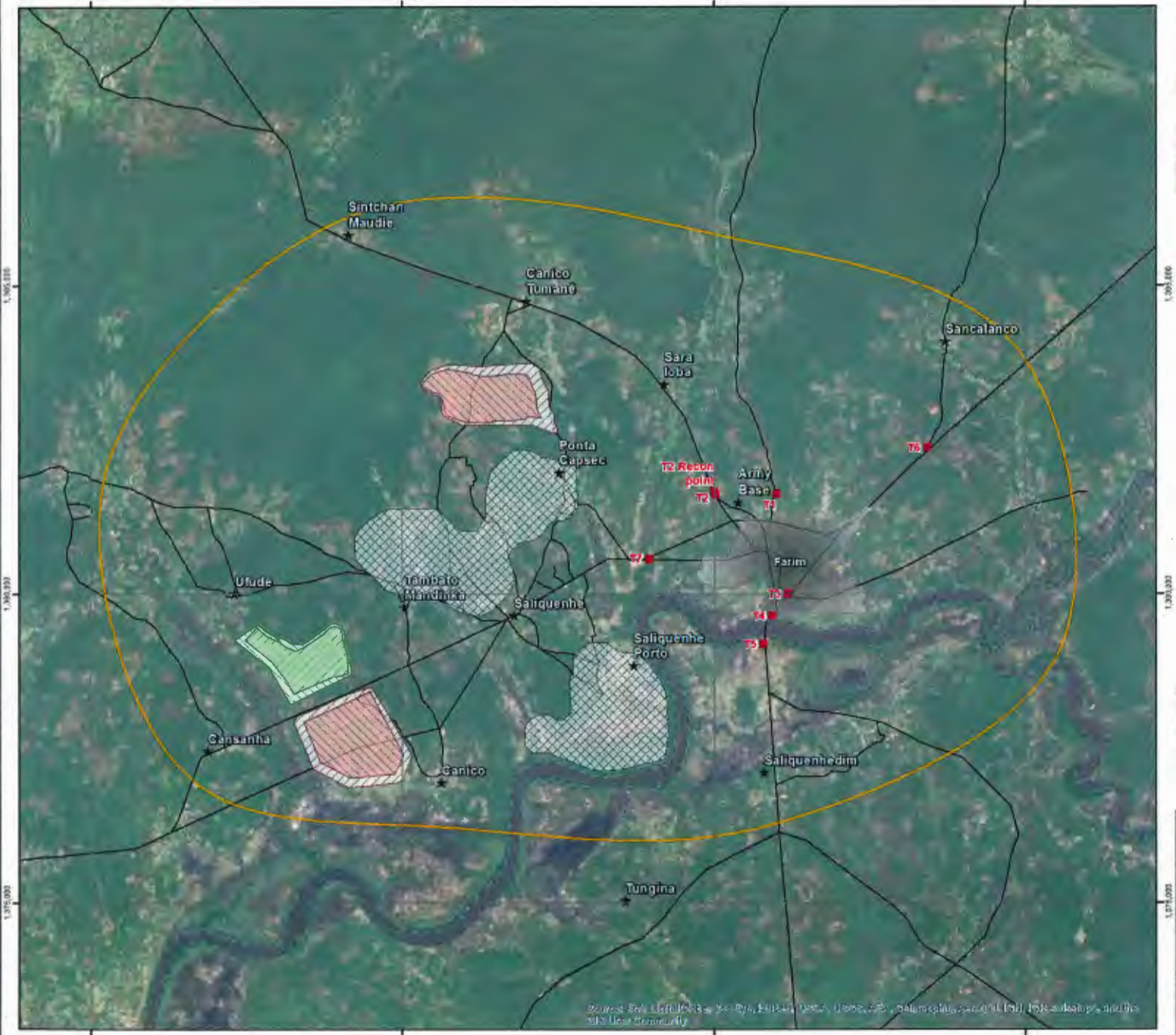


Legend

- Village
- Traffic Survey Location
- Local Study Area
- Farim

Mine Facilities

- Proposed Open Pit Area
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Basedata sourced from DIVA GIS
Mine footprints sourced from client>.

2 1 0 2 KILOMETRES

N

SCALE 1:60,000
WHEN PRODUCED AT SIZE A3

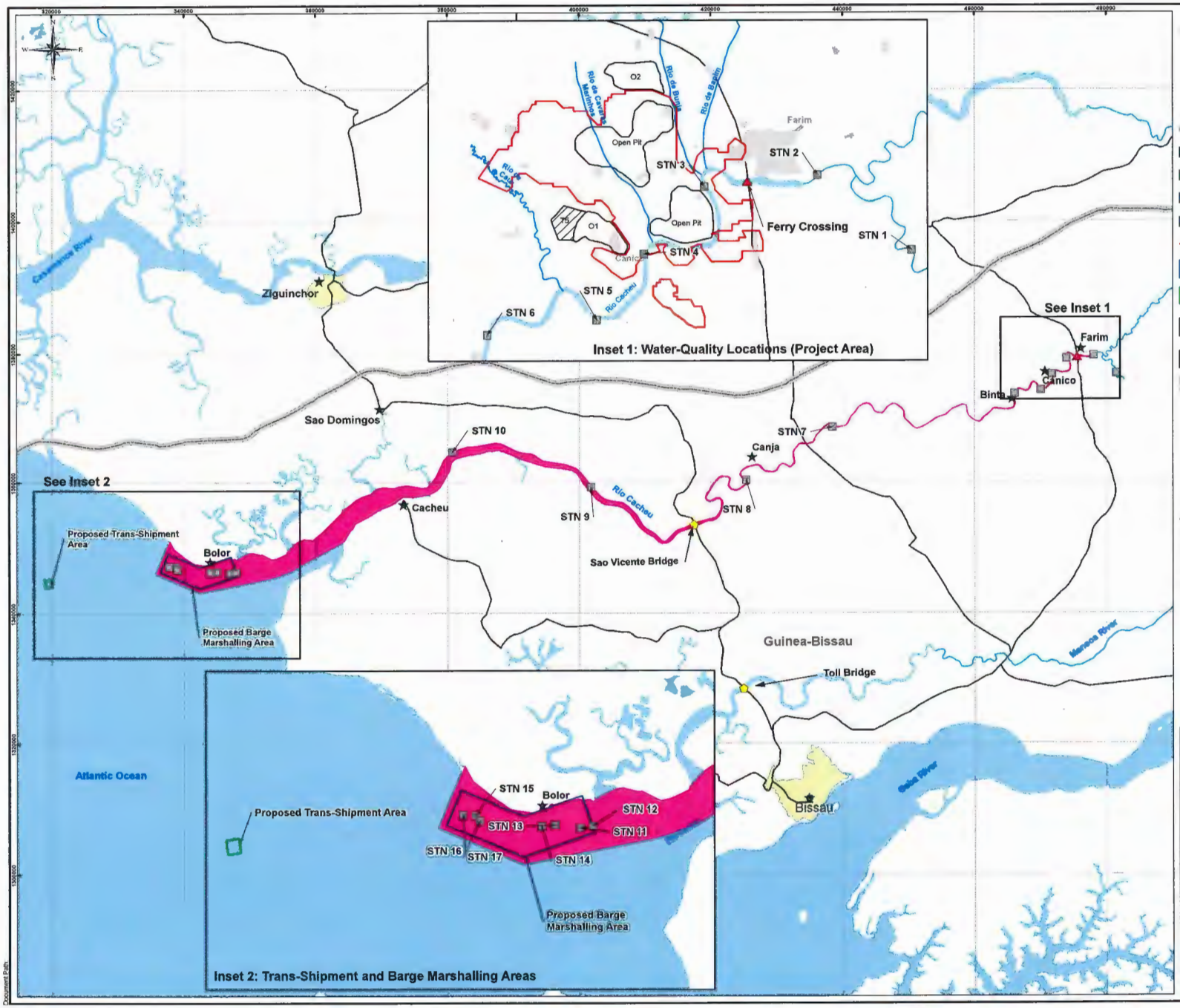
PROJECT
GB MINERALS LTD

PROJECT
FARIM PHOSPHATE PROJECT

TITLE
TRAFFIC LOCAL STUDY AREA

Golder Associates
London, UK

PROJECT No.	1551-650009		FILE No.	
DESIGN	AH	28-11-2013	SCALE AS SHOWN	REV 0
DR	LD	05/02/2014	DRAWING	
CHECK	AH	28/02/2014	550-13.1	
REVIEW	DK	28/02/2014		



Legend

- Towns
- Bridge
- Ferry Crossing
- Country Border
- River Reach 1
- River Reach 2
- River Reach 3
- River Reach 4
- Project Area
- Proposed Barge Marshalling Area
- Proposed Trans-Shipment Area
- Proposed Overburden Storage Facility
- Proposed Tailings Management Facility
- Populated Settlements

Sample Stations

- River Cross Section
- Sediment
- Sediment, River Cross Section
- Water Quality
- Water Quality, River Cross Section
- Water Quality, Sediment
- Water Quality, Sediment, River Cross Section

Guinea-Bissau

Notes

Study Area Developed by Golder Associates Inc., 2012
Base Map Supplied By ESRI Inc. ©2010 and its Data Suppliers. Accessed 1/29/2014
Sediment Sample Locations and Salinity Measurement Locations are approximate. Collected during May 2013 field visit by Golder Associates Inc.

Coordinate System: WGS 1984 UTM Zone 28N
Projection: Transverse Mercator
Datum: WGS 1984

0 13 26
Kilometers

Client	GB Minerals Ltd.
Project	Farim Phosphate Project
Title	River Cacheu and Estuary Study Area Sampling Stations
Created by	NRL
Project Manager	ICJ
Reviewer	BJ
Date	01/29/14
File No.	12387617_C002
Project No.	13514950200
Size	A3
Scale	1:551,000
Status	Report Issue
Drawing No.	550-9.1
Rev	0

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London
E1 8DE
UK
+44 (0)20 7423 0940

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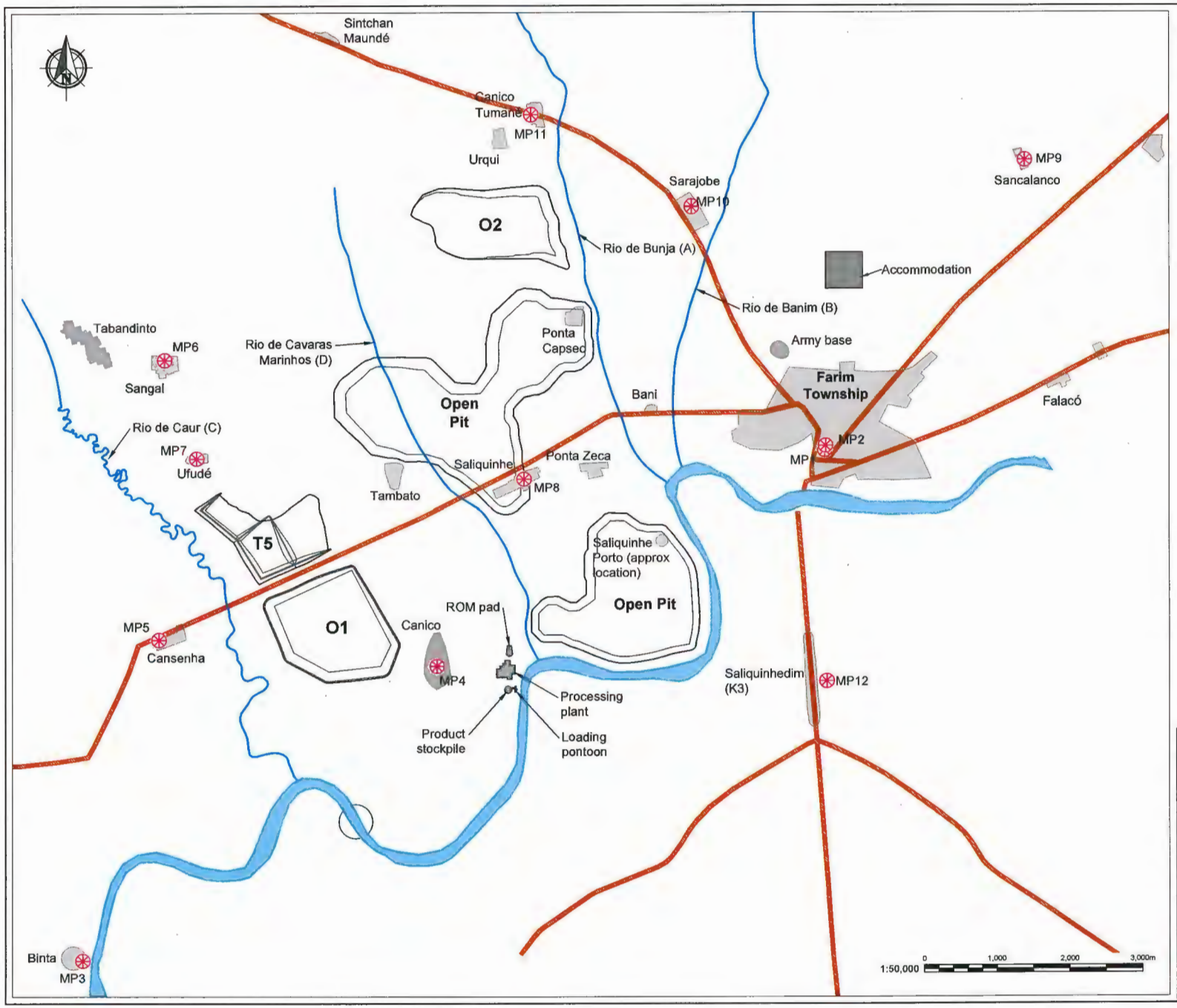

Legend

- T — Proposed TMF Site
- O — Proposed Overburden Storage Facility
- Populated settlement
- Noise monitoring location

Note

Grid coordinates are in WGS84, UTM28N.

Client: GB Minerals Ltd				
Project: Farim Phosphate Project				
Title: Noise and Vibration Local Study Area and Monitoring Locations				
Created by: ECS	Requested by: MS	Proj Manager: CN	Reviewer: CN	Date: 31/01/14
File No.: 5110001		Project No.: 13514950200		
Size: A3	Scale: 1:50,000	Status: Report Issue		
Drawing No.: 550-10.1				Rev: -

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1 Alie Street
London
E1 8DE
+44 (0)20 7423 0940

Note

Guinea Bissau/Senegal border

Regional Study Area

Note

1. Grid coordinates are in WGS84, UTM28N.

Client: GB Minerals Ltd				
Project: Farim Phosphate Project				
Title: LVA Regional Study Area				
Created by: ECS	Requested by: MS	Proj Manager: CN	Reviewer: CN	Date: 30/01/14
File No.: 5110000		Project No.: 13514950200		
Size: A3	Scale: 1:125,000	Status: Report Issue		
Drawing No.: 550-12.1				Rev: -

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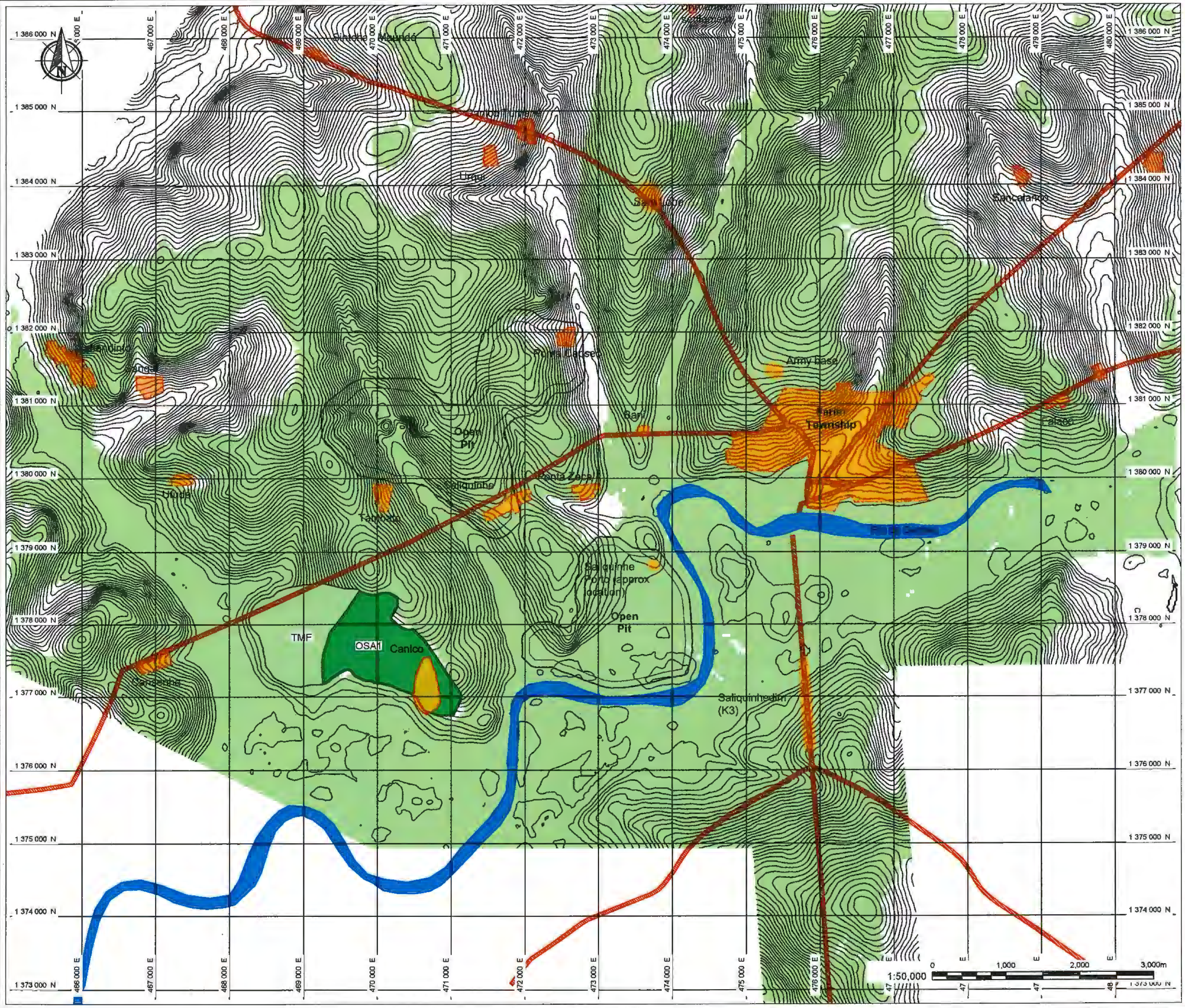

Legend

- Proposed Overburden Storage Area
- Populated settlement
- Existing main roads

Zone of Theoretical Visibility

- Areas where OSA 1 is visible

1. Grid coordinates are in WGS84, UTM28N.

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Project

Title: Zone of Theoretical Visibility Overburden Storage Area 1

Created by	Requested by	Proj Manager	Reviewer	Date
AD	MS	DAK	DAK	28/01/14

File No.	Project No.
5235252	13514950200

Size	Scale	Status
A3	1:50,000	Report Issue

Drawing No. **550-12.2** Rev **0**

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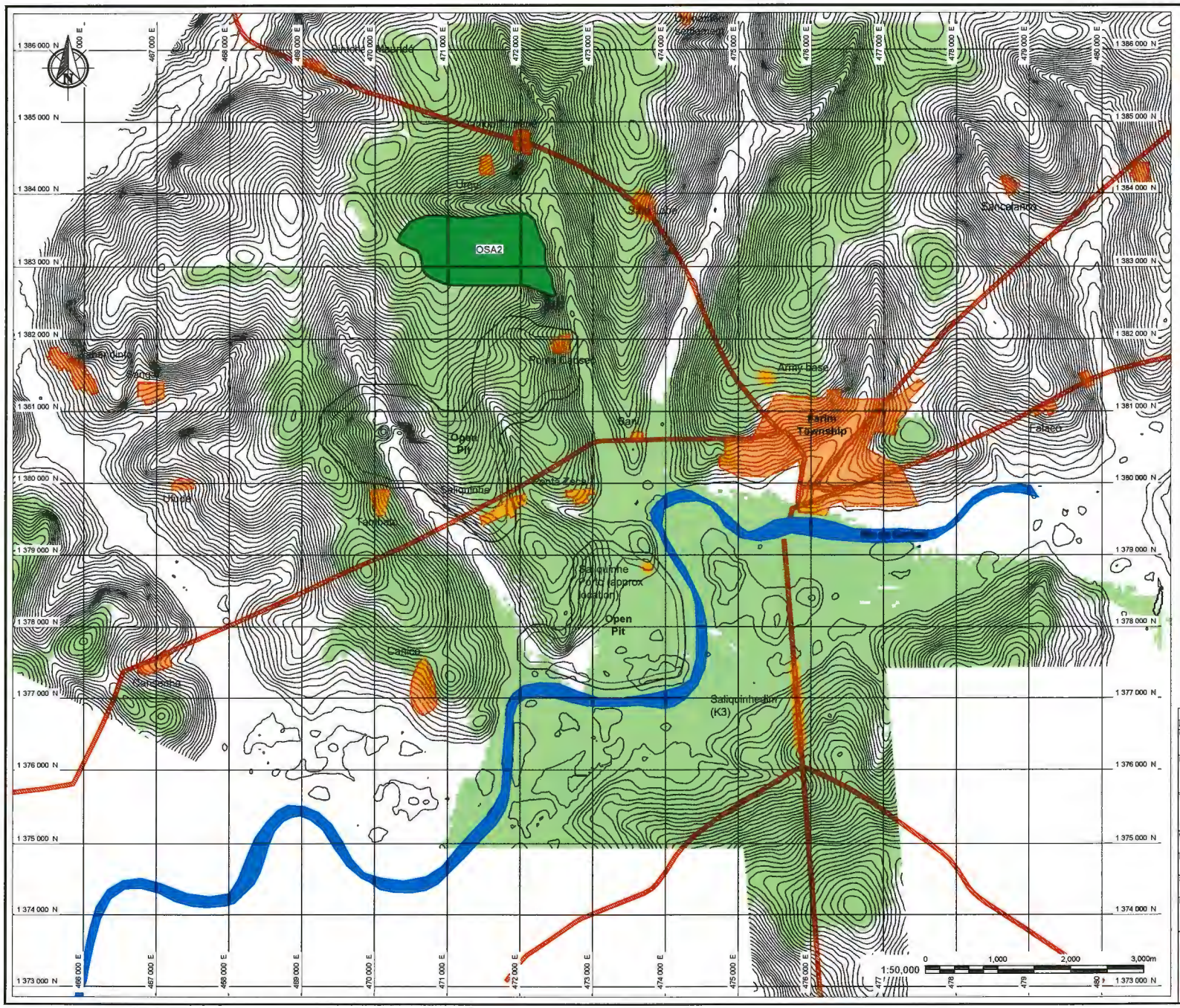

Legend

- Proposed Overburden Storage Area
- Populated settlement
- Existing main roads

Zone of Theoretical Visibility

- Areas where OSA 2 is visible

1. Grid coordinates are in WGS84, UTM28N.

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Project

Title: Zone of Theoretical Visibility Overburden Storage Area 2

Created by	Requested by	Proj Manager	Reviewer	Date
AD	MS	DAK	DAK	28/01/14

File No. 5235253 | Project No. 13514950200

Size A3 | Scale 1:50,000 | Status Report Issue

Drawing No. 550-12.3 | Rev 0

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London
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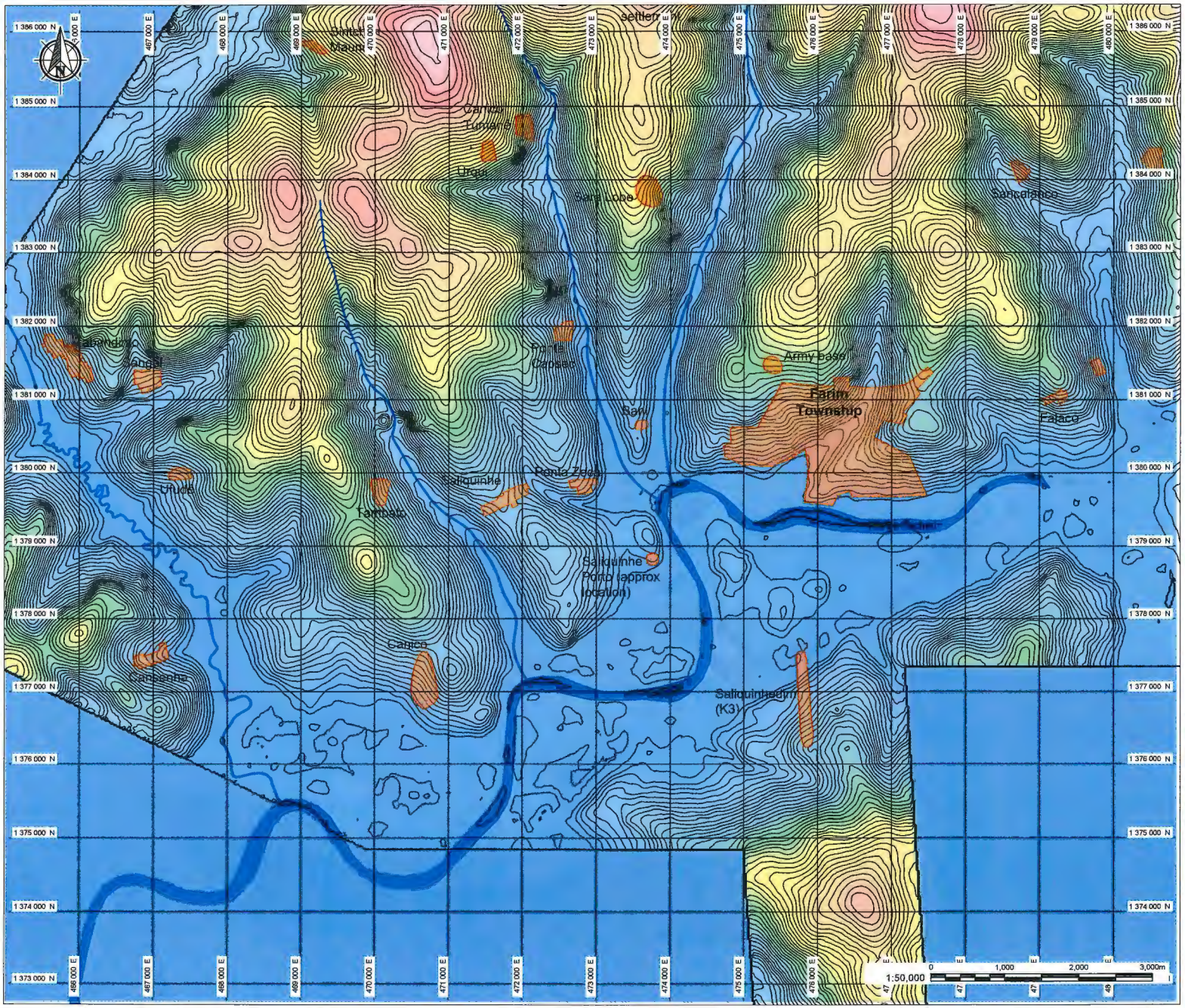
+44 (0)20 7423 0940



Legend

- 49 metres above sea level
- 0 metres
- 1m Contours
- Watercourses
- Populated settlement

Notes
1. Grid coordinates are in WGS84, UTM 28N

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Project

Title: Topography Plan

Created by	Requested by	Proj Manager	Reviewer	Date
AD	MS	DAK	DAK	28/01/14

File No.	Project No.
5235254	13514950200

Size	Scale	Status
A3	1:50,000	Report Issue

Drawing No. 550-12.4 Rev 0

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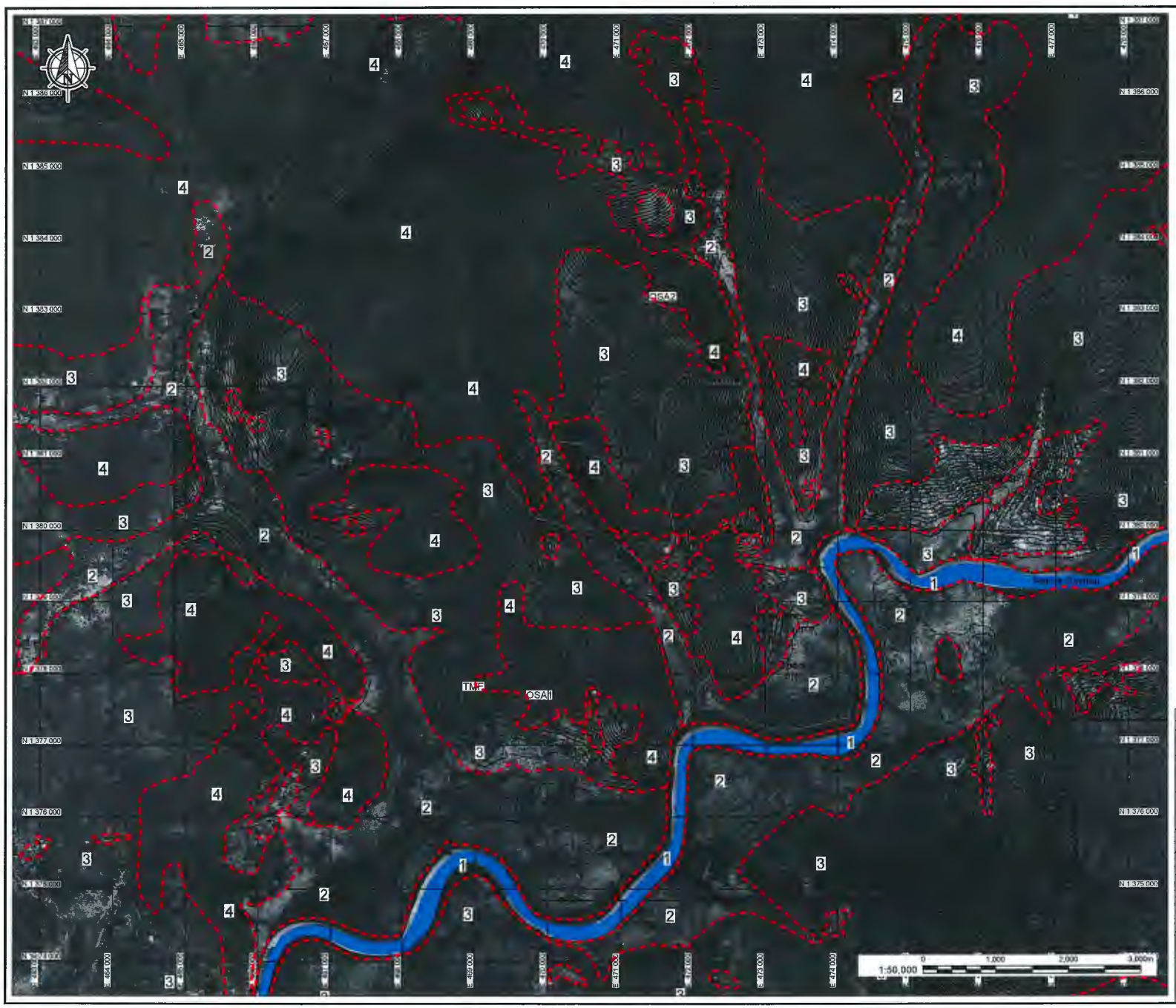
1 ALIE STREET
LONDON
E1 8DE
+44 (0)20 7423 0940



Legend

Landscape Character Area Boundaries

LCA1. River Corridor
LCA2. Cultivated River Valley
LCA3. Undulating Farmland and Woodland
LCA4. Dense Forest
LCA5. Settlements

1m Contours

1. Grid coordinates are in WGS84, UTM28N.
2. Includes material © CNES 2012, Distribution Spot Image S.A., France, all rights reserved

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Facility

Title: Landscape Character Areas

Created by	Requested by	Proj Manager	Reviewer	Date
AD	MS	DAK	DAK	28/01/14

File No. 5235255 | Project No. 13514950200

Size A3 | Scale 1:50,000 | Status Report Issue

Drawing No. 550-12.5 | Rev 0

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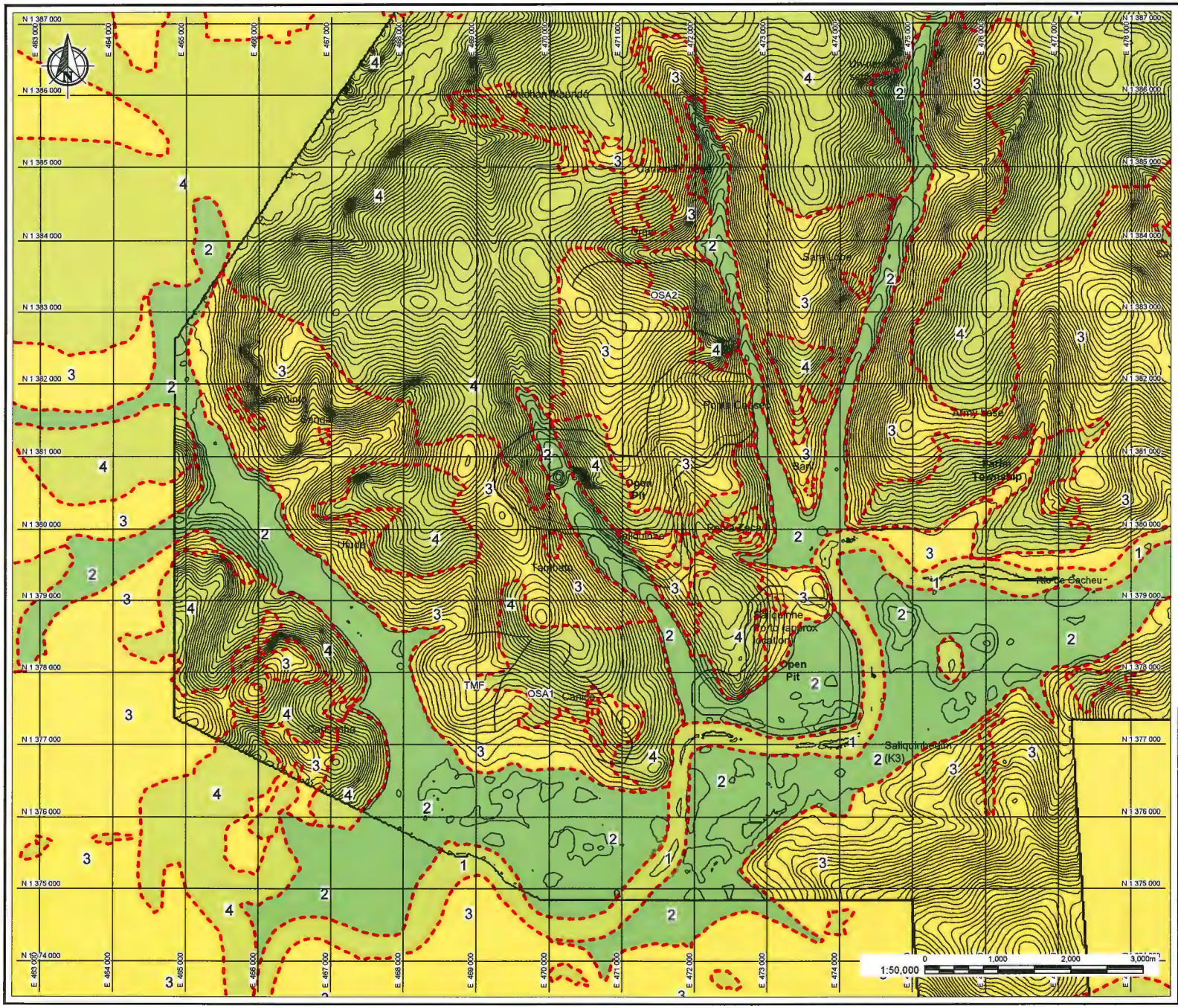

Legend

- Landscape Character Area Boundaries

Landscape Sensitivity

- Medium to High
- Medium
- Low to Medium
- 1m Contours

Notes
1. Grid coordinates are in WGS84, UTM28N.

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Facility

Title: Landscape Sensitivity

Created by	Requested by	Proj Manager	Reviewer	Date
AD	MS	DAK	DAK	28/01/14

File No. 5235256 | Project No. 13514950200

Size A3 | Scale 1:50,000 | Status Report Issue

Drawing No. 550-12.6 | Rev 0

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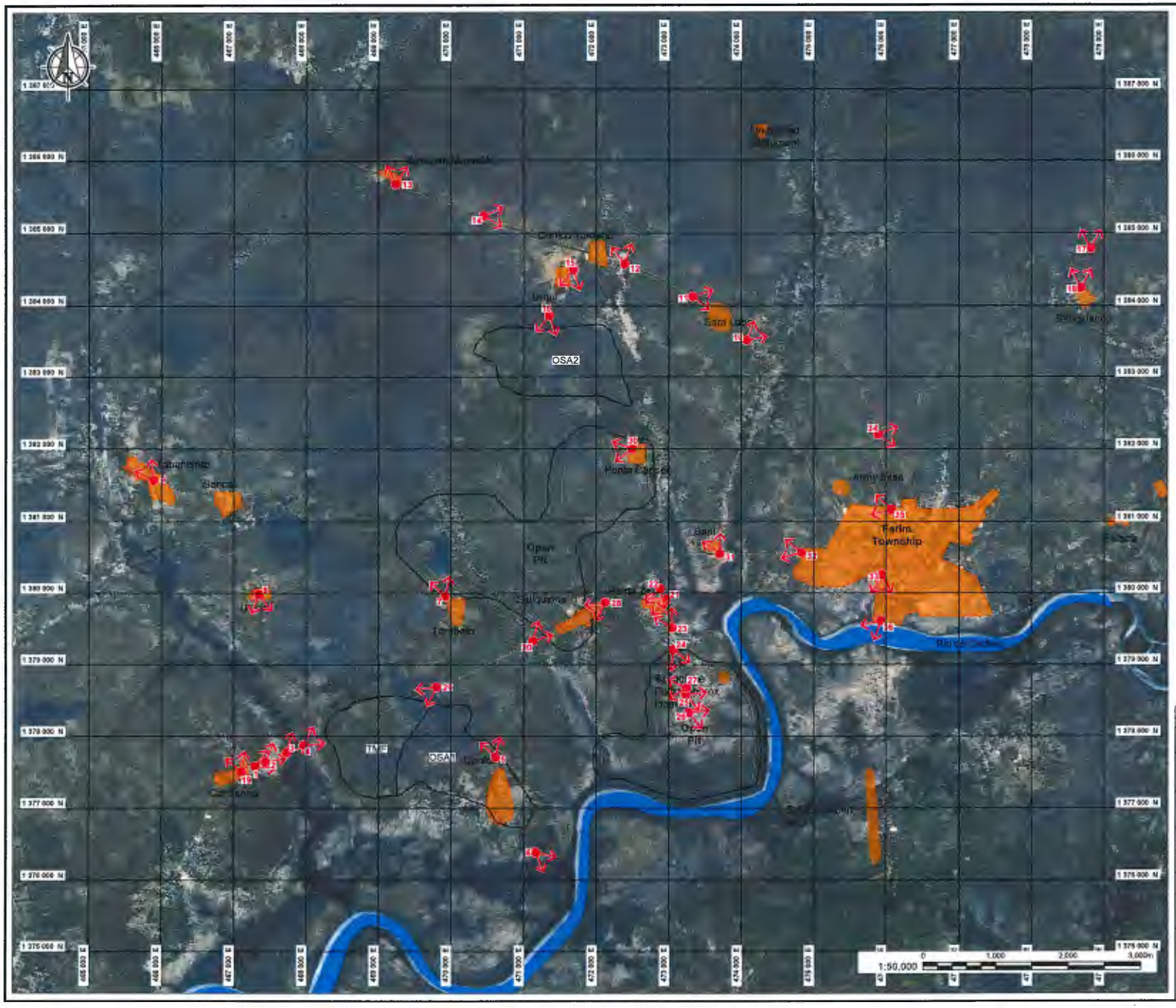
1 Alie Street
London
E1 8DE
+44 (0)20 7423 0940



Legend

Photograph Location Points

1. Grid coordinates are in WGS84, UTM28N.
2. Includes material © CNES 2012, Distribution Spot Image S.A., France, all rights reserved

Rev	Description	PM	Review	Date

Client: GB Minerals Ltd

Project: Farim Phosphate Project

Title: LVIA Photograph Location Plan

Created by	Requested by	Proj Manager	Reviewer	Date
AD	MS	DAK	DAK	28/01/14

File No.	Project No.
5235257	13514950200

Size	Scale	Status
A3	1:50,000	Report Issue

Drawing No. 550-12.7 Rev 0

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1 Alie Street
London
E1 8DE
+44 (0)20 7423 0940

APPENDIX A1

Investigative Gaseous Air Quality Monitoring Results

January 2014
Report No. 13514950200.550/B.0

1.0 INVESTIGATIVE MONITORING RESULTS FOR TRANSPORTATION ROUTE OPTIONS

1.1 Investigative Gaseous Monitoring Results

Investigative gaseous air quality monitoring was undertaken at potential road, port and pipeline locations in Guinea Bissau during November 2011 and October 2012. This baseline air quality data is expected to be utilised once the transportation options of phosphate ore are finalised.

Table A.1 describes the investigative monitoring locations are also represented in Figures A.1 and A.2. A plan showing the baseline monitoring locations is provided in Appendix E.

Table A.1: Investigative Baseline Air Quality Monitoring Stations

Location	Description	Comments
Location GB 6	Mansaba 12°18'1.37"N 15°10'21.06"W	One of the largest village locations within the proposed pipeline construction area. The station is situated on unfarmed land approximately 40 m away from the main road.
Location GB 7	Monsoa 12° 3'48.25"N 15°19'6.76"W	The largest village location within the proposed pipeline area. The station is situated on un-used land, located approximately 124 m away from the main road and south of the Monsoa township.
Location GB 8	Diuja (Bissau) 11°56'52.75"N 15°26'11.86"W	Village upwind of the port area representing Diuja. The station is located on agricultural land located 93 m south of Diuja village and 770 m north of the proposed port area. (triplicate quality assurance location).
Location DSO 1	Cacheu 12°16'41.38"N 16° 9'53.95"W	100 m to the south of the river adjacent to residential dwellings, in an open area in close proximity to residential amenity areas.
Location DSO 2	Sao Vicente 12°14'19.74"N 15°45'36.37"W	50 m from the south bank of the river, approximately 100 m downstream of the bridge spanning the River Cacheu in an open area on a slight raised platform to protect against flooding.
Location DSO 3	Balor 12°11'59.98"N 16°23'56.58"W	Monitoring station situated on the outskirts of the village, 30 m from river in close proximity to a number of small residences.
Location DSO 4	Binta Port 12°25'10.07"N 15°18'52.31"W	Monitoring station deployed approximately 50 m to the west of the river at a suitable distance away from direct port activities.
Location DSO 5	Canico Village 12°27'15.96"N 15°16'16.70"W	West of River Cacheu, monitoring station was installed on the outskirts of Canico village in an open agricultural area away from direct sources of pollutants. Considered a sensitive receptor and in close proximity to the FPH area operations.

Data collection was undertaken for the following periods:

- GB 6 to GB 7 for six months between November 2011 and April 2012;
- GB 8 for eight months between November 2011 to April 2012 and September 2012 to October 2012; and
- DSO 1 to DSO 5 for two months between September 2012 and October 2012.

The purpose of this investigative monitoring was to determine whether pollutant concentrations are similar spatially. The monitored data during the two month monitoring period at the DSO locations demonstrate similar concentrations as monitored within the mine area during the same period.

GB 6 Mansaba

GB 7 Monsoa

GB 8 Chugue/ Diuja Port

Figure A.1: Air Quality Stations GB 6 Mansaba, GB 7 Monsoa and GB 8 Chugue/ Diuja Port

DSO 1 Cacheu

DSO 2 Sao Vicente

DSO 3 Balor

DSO 4 Binta

DSO 5 Canico Village (left)

DSO 5 Canico Village (right)

Figure A.2: Investigative Air Quality Stations DSO 1 to DSO 5

Tables A.2 and A.3 present the investigative monitoring results for both investigative monitoring areas.

Table A.2: Summary of Investigative Baseline Gaseous Data

Location	Value	NO_X	NO_2	SO_2	O_3
		µg/m³			
GB 6 Mansaba^	average	5.99	5.71	1.11	61.11
	minimum	4.26	2.58	0.46	47.40
	maximum	9.22	7.82	1.90	81.76
GB 7 Monsoa^	average	7.63	5.81	1.71	67.74
	minimum	4.67	3.32	0.95	46.88
	maximum	11.68	7.57	2.71	86.68
GB 8 Chugue/Diuja>	average	6.08	2.87	1.54	77.48
	minimum	2.24	1.05	0.93	61.36
	maximum	9.63	5.15	2.03	104.85

^ Result based on six monthly datasets averaged over six months > Result based on eight monthly datasets averaged over eight months

Table A.3: Summary of Investigative DSO Baseline Gaseous Data

Location	Value	NO_X	NO_2	SO_2	Location
		µg/m³			
DSO 1>	average	9.89	1.81	2.96	75.35
	minimum	9.30	1.06	1.07	69.30
	maximum	10.47	2.56	4.84	81.40
DSO 2>	average	8.20	1.02	1.41	100.98
	minimum	7.82	0.72	1.41	88.39
	maximum	8.57	1.31	1.41	113.56
DSO 3>	average	9.46	1.85	1.22	68.33
	minimum	8.81	1.33	1.22	67.31
	maximum	10.11	2.36	1.22	69.34
DSO 4>	average	7.83	1.48	1.28	71.27
	minimum	5.57	0.99	1.28	69.96
	maximum	10.08	1.96	1.28	72.57
DSO 5>	average	8.10	1.38	LOD	59.35
	minimum	6.00	1.13	LOD	53.50
	maximum	10.19	1.62	LOD	65.19

> Result based on two monthly datasets averaged over two months

1.1.1 Investigative Gaseous Triplicate Monitoring Data

GB 8 was a quality assurance station and all gaseous pollutants were monitored in triplicate; reported concentrations for this station are an average of three samples for each pollutant and individual results are presented in Table A.3 below.

Table A.4: Summary of Investigative Baseline Gaseous Data

GB – 8 Location	Value	NO_X	NO_2	SO_2	O_3
		µg/m^3			
November 2011	1	2.58	2.45	1.94	80.9
	2	2.27	2.21	2.07	52.26
	3	2.43	2.19	2.07	71.05
December 2011	1	2.71	2.85	1.01	67.1
	2	1.42	2.67	0.86	75.85
	3	2.6	2.81	1.14	68.56
January 2012	1	4.02	3.98	1.02	33.78
	2	3.12	3.86	1.49	86.35
	3	3.69	3.98	1.69	63.95
February 2012	1	8.08	5.1	2.03	82.05
	2	6.52	5.25	1.36	68.5
	3	5.87	5.09	2.31	51.94
March 2012	1	9.51	3.99	1.00	73.74
	2	8.94	4.23	2.24	83.83
	3	10.44	4.14	2.55	85.39
April 2012	1	8.58	1.94	1.07	113.53
	2	9.85	2.43	1.53	96.17
	3	7.53	2.43	2.26	-
September 2012	1	7.97	1.16	0.89	81.72
	2	5.61	1.31	0.97	104.65
	3	6.66	0.67	0.92	72.9
October 2012	1	10.66	1.52	LOD	78.24
	2	8.11	1.24	LOD	70.51
	3	6.85	LOD	LOD	91.76

1.2 Investigative Dust Monitoring Results

Investigative deposited dust data was also collected at a range of potential road, port and pipeline locations in Guinea Bissau during November 2011 and September 2012. Baseline dust data is presented in Tables A.4 and A.5 below.

Table A.5: Summary of Investigative Roads Baseline Deposited Dust Data

Location	Value	Deposited Dust
		mg/m^2/day
GB 6 Mansaba^	average	135
	minimum	70
	maximum	252
GB 7 Monsoa^	average	114
	minimum	39
	maximum	164
GB 8 Chugue/Diuja>	average	78
	minimum	23
	maximum	143

^ Result based on six monthly datasets averaged over six months > Result based on eight monthly datasets averaged over eight months

Table A.5 Summary of Investigative DSO Baseline Deposited Dust Data

Location	Value	Deposited Dust
		mg/m^2/day
DSO 1>	average	40
	minimum	38
	maximum	42
DSO 2>	average	40
	minimum	7
	maximum	73
DSO 3>	average	56
	minimum	42
	maximum	70
DSO 4>	average	35
	minimum	21
	maximum	49
DSO 5>	average	37
	minimum	34
	maximum	39

>Result based on two monthly datasets averaged over two months

1.3 Baseline Results Interpretation

1.3.1 Gaseous Air Quality

Monthly data for each monitoring location were averaged and represent long-term annual background concentrations. Results were compared to the project AQS and the current contribution towards these standards are assessed.

To allow the comparison between monthly data and standards based on short-term averaging periods (*i.e. 24 hour and 1 hour*), the United Kingdom Environment Agency guidance (Environment Agency, 2010) is sued and for the 10 minute average period, the Ontario Ministry of the Environment, Canada (2008) methodology. The long-term annual average concentration is taken as the mean of the monthly monitored data. The following assumptions were applied:

- The annual average concentration x 2 = hourly average concentration;
- The hourly average concentration x 0.59 = 24 hour average concentration;
- The hourly average concentration x 0.7 = 8 hour average concentration; and
- The hourly average concentration x 1.65 = 10 minute average concentration.

For example:

- The monitored long-term average SO_2 concentration at GB 6 for the baseline monitoring period was 1.11 µg/m^3.
- Therefore the hourly average SO_2 concentration was estimated to be 2.22 µg/m^3 (i.e., 1.11 µg/m^3 x 2).
- 24 hour average concentration = 1.31 µg/m^3 (i.e., 2.40 µg/m^3 x 0.59); and
- 10 minute average concentration = 3.66 µg/m^3 (i.e., 2.22 µg/m^3 x 1.65).

Tables A.6 to A.13 compare the monitored average baseline concentrations to the Project AQS. Any pollutant concentration which is greater than the relevant AQS is highlighted in bold.

Table A.6: Background Monitored and Estimated Gaseous Concentrations

GB 6 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m^3			
NO_2 Annual	5.71	5.71	14%	40
NO_2 1 hour	5.71	11.41	6%	200
SO2 10 minute	1.11	3.66	1%	500
SO_2 24 hour	1.11	1.31	7%	20
O_3 8 hour daily max	61.11	85.55	86%	100

Table A.7: Background Monitored and Estimated Gaseous Concentrations

GB 7 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	5.81	5.81	15%	40
NO_2 1 hour	5.81	11.61	6%	200
SO2 10 minute	1.71	5.63	1%	500
SO_2 24 hour	1.71	2.01	10%	20
O_3 8 hour daily max	67.74	94.83	95%	100

Table A.8: Background Monitored and Estimated Gaseous Concentrations

GB 8 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	2.87	2.87	7%	40
NO_2 1 hour	2.87	5.74	3%	200
SO2 10 minute	1.54	5.09	1%	500
SO_2 24 hour	1.54	1.82	9%	20
O_3 8 hour daily max	77.48	108.48	**108%**	100

Table A.9: Background Monitored and Estimated Gaseous Concentrations

DSO 1 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 2nnual	1.81	1.81	5%	40
NO_2 1 hour	1.81	3.62	2%	200
SO2 10 minute	2.96	9.75	2%	500
SO_2 24 hour	2.96	3.49	17%	20
O_3 8 hour daily max	75.35	105.49	**105%**	100

Table A.10: Background Monitored and Estimated Gaseous Concentrations

DSO 2 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m³			
NO_2 Annual	1.02	1.02	3%	40
NO_2 1 hour	1.02	2.03	1%	200
SO2 10 minute	1.41	4.65	1%	500
SO_2 24 hour	1.41	1.66	8%	20
O_3 8 hour daily max	100.98	141.37	**141%**	100

Table A.11: Background Monitored and Estimated Gaseous Concentrations

DSO 3 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m^3			
NO_2 Annual	1.85	1.85	5%	40
NO_2 1 hour	1.85	3.69	2%	200
SO2 10 minute	1.22	4.03	1%	500
SO_2 24 hour	1.22	1.44	7%	20
O_3 8 hour daily max	68.33	95.66	96%	100

Table A.12: Background Monitored and Estimated Gaseous Concentrations

DSO 4 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m^3			
NO_2 Annual	1.48	1.48	4%	40
NO_2 1 hour	1.48	2.95	1%	200
SO2 10 minute	1.28	4.22	1%	500
SO_2 24 hour	1.28	1.51	8%	20
O_3 8 hour daily max	71.27	99.77	**100%**	100

Table A.13: Background Monitored and Estimated Gaseous Concentrations

DSO 5 - Pollutant Average Period	Monitored Average	Period Average	% of AQS	AQS
	µg/m^3			
NO_2 Annual	1.38	1.38	3%	40
NO_2 1 hour	1.38	2.75	1%	200
SO2 10 minute	0.00	0.00	0%	500
SO_2 24 hour	0.00	0.00	0%	20
O_3 8 hour daily max	59.35	83.08	83%	100

The results indicate that the majority of pollutants measured at the additional air quality monitoring stations are significantly below the Project AQS, with the exception of the following:

- 8 hour O_3 concentrations monitored at the DSO 1, DSO 2 and DSO 4 air quality stations were estimated to be greater than the Project AQS. However, O_3 is thought to be naturally occurring at the site due to lightning frequency and therefore higher levels are expected.

1.4 Investigative Deposited Metallic and VOC Analysis

Deposited dust metals and VOC sample analysis was undertaken during both the dry transition wet season periods at potential road, port and pipeline locations. Monitoring was undertaken in January (dry season) and September 2012 (transition wet season) incorporating both the significant change in seasonal weather experienced by the site.

The analysis performed on the monitoring tubes determines the key ambient VOC concentrations present at each monitored location during the month.

The laboratory analysis reports are provided in Appendix C and D. No further review or discussion is provided in respect of these data.

1.5 Combined Baseline Data

Within the air quality ESIA, existing concentrations will be required to be assessed. For example, a detailed air quality assessment using air dispersion modelling (ADM) will predict a modelled process contribution (PC) which will be combined with the existing air quality concentrations (background) to give a total predicted environmental concentration (PEC). The PEC will then be compared to the relevant project AQS.

For less complex sites, a single existing concentration may be representative of the whole study area and it is often not practical to include all the minor variations in the pollutant concentrations measured at each location. Data was combined for two specific investigative development areas and include the main access roads between Bissau and Farim (GB 6 to GB 8) and the River Cacheu receptors (DSO 1 to 5) stations.

The maximum pollutant concentrations for each location are used to derive the combined gaseous, dust and fine particulate concentrations for the two development areas (Table A.14). In the absence of site specific particulate monitoring at representative locations along the road, port and pipeline locations, the maximum 24 hour average monitored concentration is used as for the mine pit areas (GB 4).

Table A.14: Proposed Baseline Concentrations for Development Areas

Pollutant/ Development Area	NO_2	SO_2	O_3	PM_{10}	$PM_{2.5}$	Deposited Dust
	µg/m3					mg/m^2/day
FPM access Roads (GB 6 to GB 8)	6.85	2.21	91.10	123.41	23.90	186
DSO/River Cacheu Area (DSO1 to DSO 5)	1.96	1.75	80.41	123.41	23.90	55

2.0 CONCLUSIONS

This Appendix presents the results of an investigative baseline monitoring established surrounding the proposed Farim Phosphate Project at a number of representative road, port and pipeline locations.

The investigative baseline data are intended to be utilised within a future impact assessment to assist in predicting any potential impacts in relation to the current conditions. These data can also be used to assess the operational impacts of the development.

The baseline monitoring programme was commissioned during November 2011 and October 2012. The following data were collected during this period:

- 6 months gaseous NO_x, NO_2, SO_2, O_3, and deposited dust data for the mine area access roads; and
- 2 months gaseous NO_x, NO_2, SO_2, O_3, and deposited dust data for receptors located close to the River Cacheu (Appendix A).

Baseline data have been collated and compared with the applicable Project air quality standards and the following conclusions are drawn:

- NO_x, NO_2 and SO_2 concentrations are less than the project AQS for human health;
- O_3 concentrations are greater than the project AQS for human health in some monitored locations within the proposed mine area; however levels of O_3 are expected to be naturally occurring in some areas due to occurrences of lightening;
- Surrogate fine particulate (PM_{10} and $PM_{2.5}$) concentrations used for the investigative areas are monitored to be higher than the Project AQS based on the limited short term data collected. However is considered to be typical for the West African climate. Further particulate monitoring is recommended in the areas of the road, port and pipeline locations.
- Deposited dust levels are less than the project AQS.

APPENDIX A2

Gaseous Air Quality Monitoring Results

January 2014
Report No. 13514950200.550/B.0

gradko environmental
(A division of Gradko International Ltd.)

St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V. SPECTROPHOTOMETRY

REPORT NUMBER F 1152R
BOOKING IN REFERENCE No F 1152
DESPATCH NOTE No SOR 007979

CUSTOMER Golder Associates Attn.: Daniel Birkinshaw
Nottingham

DATE SAMPLES RECEIVED 13/02/2012

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_X ppb *	NO ppb * +	NO_2 µg/m^3	NO_X µg/m^3	NO µg/m^3 +	TOTAL µG NO_2	TOTAL µG NOx
563697	GB1	502971	02/01/2012	01/02/2012	720.08	1.39	1.28	<L.O.D.	2.68	2.46	<L.O.D.	0.14	0.13
563602	GB2	502378	02/01/2012	01/02/2012	720.32	1.59	1.48	<L.O.D.	3.06	2.85	<L.O.D.	0.16	0.15
563548	GB3	503065	02/01/2012	01/02/2012	721.88	1.17	1.25	0.08	2.25	2.40	0.15	0.12	0.13
563736	GB4	502562	02/01/2012	01/02/2012	719.68	2.99	3.14	0.15	5.74	6.02	0.29	0.30	0.32
563572	GB4	502616	02/01/2012	01/02/2012	719.68	3.37	3.28	<L.O.D.	6.46	6.29	<L.O.D.	0.34	0.33
563553	GB4	502689	02/01/2012	01/02/2012	719.68	3.24	3.27	0.03	6.21	6.27	0.06	0.33	0.33
563050	GB5	502446	03/01/2012	31/01/2012	679.55	1.57	1.51	<L.O.D.	3.02	2.90	<L.O.D.	0.15	0.14
563710	GB6	502492	03/01/2012	31/01/2012	678.17	3.70	3.66	<L.O.D.	7.10	7.02	<L.O.D.	0.35	0.35
563276	GB7	502422	03/01/2012	31/01/2012	676.32	3.34	3.38	0.04	6.41	6.49	0.08	0.32	0.32

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

563119	GB8	502710	03/01/2012	31/01/2012	670.95	2.07	2.09	0.02	3.98	4.02	0.04	0.19	0.20
563236	GB8	501991	03/01/2012	31/01/2012	670.95	2.01	1.62	<L.O.D.	3.86	3.12	<L.O.D.	0.19	0.15
563508	GB8	502366	03/01/2012	31/01/2012	670.95	2.07	1.92	<L.O.D.	3.98	3.69	<L.O.D.	0.19	0.18
563481	Travel Blanks	502685			721.88	0.04	0.05	0.01	0.08	0.10	0.02	0.00	0.01
	Travel Blank	502849			721.88		0.02			0.04			0.00
	Lab Blanks				721.88	0.10	1.02	0.92	0.19	1.96	1.77	0.010	0.103

Comment: Results are not blank subtracted
<L.O.D. means below the limit of detection.
Tubes GB3-GB8 exposure times were incorrect.
***NO results are derived by subtracting NO2 from NOx.**
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/- **Limit of Detection** 0.103ug NOx, 0.014ug NO2 on tube
Tube Preparation: 20%TEA/Water Analysed on UVS03 Cecil
Analyst Name J. Samuel

Date of Analysis 27/02/2012 **Date of Report** 28/02/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 1154R
BOOKING IN REFERENCE No F 1154
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

DATE SAMPLES RECEIVED 13/02/2012

GRADKO LAB REF GIL 1088-1099

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
GB 1	02/01/2012	01/02/2012	720.08	0.96	0.91	73.23	36.62
GB 2	02/01/2012	01/02/2012	720.32	0.94	0.89	71.60	35.80
GB 3	02/01/2012	01/02/2012	721.88	0.43	0.38	30.60	15.30
GB 4a	02/01/2012	01/02/2012	719.68	0.89	0.84	67.65	33.82
GB 4b	02/01/2012	01/02/2012	719.68	0.88	0.83	66.85	33.42
GB 4c	02/01/2012	01/02/2012	719.68	0.80	0.75	60.42	30.21
GB 5	03/01/2012	31/01/2012	679.55	1.20	1.15	98.02	49.01
GB 6	03/01/2012	31/01/2012	678.17	0.75	0.70	59.86	29.93
GB 7	03/01/2012	31/01/2012	676.32	0.92	0.87	74.55	37.28
GB 8a	03/01/2012	31/01/2012	670.95	0.44	0.39	33.78	16.89
GB 8b	03/01/2012	31/01/2012	670.95	1.05	1.00	86.35	43.18
GB 8c	03/01/2012	31/01/2012	670.95	0.79	0.74	63.95	31.97
Lab Blank				0.05			

(RESULTS ARE BLANK CORRECTED)
Tubes GB3-GB8c exposure times were incorrect.

Overall M.O.U 7.56% +/-
Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 14/02/2012

DATE OF REPORT 17/02/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 1153R
Booking in reference No F 1153
Despatch note No SOR 7959

Customer Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

Date samples received 13/02/2012

Gradko Lab ref GIM 2389-2401

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
GB 1	02/01/2012	01/02/2012	720.08	0.04	0.02	1.13	0.42
GB 2	02/01/2012	01/02/2012	720.32	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 3	02/01/2012	01/02/2012	721.88	0.03	0.02	1.01	0.38
GB 4a	02/01/2012	01/02/2012	719.68	0.03	0.02	0.98	0.37
GB 4b	02/01/2012	01/02/2012	719.68	0.04	0.03	1.27	0.48
GB 4c	02/01/2012	01/02/2012	719.68	0.04	0.03	1.54	0.58
GB 5	03/01/2012	31/01/2012	679.55	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 6	03/01/2012	31/01/2012	678.17	0.05	0.04	1.90	0.71
GB 7	03/01/2012	31/01/2012	676.32	0.04	0.03	1.39	0.52
GB 8a	03/01/2012	31/01/2012	670.95	0.03	0.02	1.02	0.38
GB 8b	03/01/2012	31/01/2012	670.95	0.04	0.03	1.49	0.56
GB 8c	03/01/2012	31/01/2012	670.95	0.04	0.03	1.69	0.63
Travel blank				0.03	0.02		
Lab Blank				0.01			

(RESULTS ARE BLANK CORRECTED)
<L.O.D. means below the limit of detection.
All tubes except GB1 and GB2 exposure times were incorrect.
Customer's blank was high so lab blank was used.

Overall M.O.U. 14.1%+/-
Analysed on Dionex DX100 ICU7

Limit of detection 0.030µg S

Analyst name M. Zmudzka

Date of analysis 23/02/2012

Date of report 24/02/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
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L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)

St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V. SPECTROPHOTOMETRY

REPORT NUMBER F 1816R
BOOKING IN REFERENCE No F 1816
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn.: Daniel Birkinshaw
Nottingham

DATE SAMPLES RECEIVED 16/03/2012

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_x ppb *	NO ppb * +	NO_2 µg/m³	NO_x µg/m³	NO µg/m³ +	TOTAL µG NO_2	TOTAL µG NOx
482337	GB1	489683	01/02/2012	01/03/2012	695.97	2.38	1.75	<L.O.D.	4.57	3.36	<L.O.D.	0.23	0.17
481992	GB2	489377	01/02/2012	01/03/2012	695.67	2.75	3.40	0.65	5.28	6.53	1.25	0.27	0.33
481972	GB3	489840	01/02/2012	01/03/2012	694.22	2.38	2.55	0.17	4.58	4.90	0.32	0.23	0.25
482578	GB4	489423	01/02/2012	01/03/2012	696.25	4.18	3.41	<L.O.D.	8.02	6.54	<L.O.D.	0.41	0.33
482380	GB4	490081	01/02/2012	01/03/2012	696.25	4.29	5.06	0.77	8.24	9.72	1.48	0.42	0.49
481985	GB4	489877	01/02/2012	01/03/2012	696.25	4.28	5.46	1.17	8.22	10.47	2.25	0.42	0.53
482756	GB5	489591	31/01/2012	03/03/2012	765.37	2.92	4.09	1.17	5.61	7.86	2.25	0.31	0.44
482342	GB6	490101	31/01/2012	03/03/2012	765.32	4.07	2.22	<L.O.D.	7.82	4.26	<L.O.D.	0.44	0.24

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

482679	GB7	489328	31/01/2012	03/03/2012	764.75	3.95	6.08	2.14	7.57	11.68	4.10	0.42	0.65
481988	GB8	489667	31/01/2012	03/03/2012	768.17	2.66	4.21	1.55	5.10	8.08	2.97	0.29	0.45
482030	GB8	489643	31/01/2012	03/03/2012	768.17	2.73	3.40	0.66	5.25	6.52	1.27	0.29	0.36
482512	GB8	489309	31/01/2012	03/03/2012	768.17	2.65	3.06	0.41	5.09	5.87	0.79	0.28	0.33
482302 Travel Blanks		489721			768.17	0.21	2.29	2.08	0.39	4.39	3.99	0.02	0.25
Lab Blanks					768.17	0.07	0.96	0.90	0.13	1.84	1.72	0.007	0.103

Comment: Results are not blank subtracted
<L.O.D. means below the limit of detection.
***NO results are derived by subtracting NO2 from NOx.**
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/- **Limit of Detection** 0.103ug NOx, 0.014ug NO2 on tube

Tube Preparation: 20%TEA/Water Analysed on UVS03 Cecil

Analyst Name J. Samuel

Date of Analysis 27/03/2012 **Date of Report** 29/03/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 1815R

BOOKING IN REFERENCE No F 1815

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

DATE SAMPLES RECEIVED 16/03/2012

GRADKO LAB REF GIL 1476-1487

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
GB 1	01/02/2012	01/03/2012	695.97	0.71	0.65	54.00	27.00
GB 2	01/02/2012	01/03/2012	695.67	0.91	0.85	70.65	35.32
GB 4a	01/02/2012	01/03/2012	696.25	0.49	0.43	35.71	17.86
GB 4b	01/02/2012	01/03/2012	696.25	0.54	0.48	39.86	19.93
GB 4c	01/02/2012	01/03/2012	696.25	0.62	0.56	46.51	23.25
GB 5	31/01/2012	03/03/2012	765.37	0.48	0.42	31.73	15.87
GB 6	31/01/2012	03/03/2012	765.32	0.78	0.72	54.40	27.20
GB 7	31/01/2012	03/03/2012	764.75	0.68	0.62	46.88	23.44
GB 8a	31/01/2012	03/03/2012	768.17	1.15	1.09	82.05	41.02
GB 8b	31/01/2012	03/03/2012	768.17	0.97	0.91	68.50	34.25
GB 8c	31/01/2012	03/03/2012	768.17	0.75	0.69	51.94	25.97
Travel Blank				0.06			
Lab Blank				0.06			

(RESULTS ARE BLANK CORRECTED)

Overall M.O.U	7.56% +/- Analysed on DX 100 ICU1	**LIMIT OF DETECTION**	0.114µg
ANALYST SIGNATURE		**ANALYST NAME**	M. Zmudzka
DATE OF ANALYSIS	29/03/2012	**DATE OF REPORT**	30/03/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

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tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 1814R
Booking in reference No F 1814
Despatch note No SOR 007959

Customer Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

Date samples received 16/03/2012

Gradko Lab ref GIM 3603-3614

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
GB 1	01/02/2012	01/03/2012	695.97	0.04	0.02	1.05	0.39
GB 2	01/02/2012	01/03/2012	695.67	0.04	0.02	1.03	0.39
GB 4a	01/02/2012	01/03/2012	696.25	0.06	0.04	1.87	0.70
GB 4b	01/02/2012	01/03/2012	696.25	0.05	0.02	1.12	0.42
GB 4c	01/02/2012	01/03/2012	696.25	0.04	0.02	1.07	0.40
GB 5	31/01/2012	03/03/2012	765.37	0.03	0.01	0.45	0.17
GB 6	31/01/2012	03/03/2012	765.32	0.05	0.02	1.15	0.43
GB 7	31/01/2012	03/03/2012	764.75	0.08	0.06	2.71	1.02
GB 8a	31/01/2012	03/03/2012	768.17	0.07	0.04	2.03	0.76
GB 8b	31/01/2012	03/03/2012	768.17	0.05	0.03	1.36	0.51
GB 8c	31/01/2012	03/03/2012	768.17	0.07	0.05	2.31	0.87
Travel blank				0.02			
Lab Blank				0.02			

(RESULTS ARE BLANK CORRECTED)

Overall M.O.U. 14.1%+/-
Analysed on Dionex DX100 ICU7

Limit of detection 0.030µg S

Analyst name M. Zmudzka

Date of analysis 22/03/2012

Date of report 26/03/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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Gradko International Ltd
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tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V. SPECTROPHOTOMETRY

REPORT NUMBER F 2559R
BOOKING IN REFERENCE No F 2559
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn. D. Birkinshaw
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 23/04/2012

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_X ppb *	NO ppb * +	NO_2 µg/m^3	NO_X µg/m^3	NO µg/m^3 +	TOTAL µG NO_2	TOTAL µG NOx
530533	GB 1	599188	01/03/2012	02/04/2012	768.38	2.95	4.04	1.09	5.66	7.75	2.10	0.32	0.43
530333	GB 2	598989	01/03/2012	02/04/2012	768.38	2.31	2.86	0.55	4.44	5.50	1.06	0.25	0.31
530594	GB 3	599513	01/03/2012	02/04/2012	768.08	2.33	3.74	1.41	4.48	7.18	2.70	0.25	0.40
530204	GB 4	599772	01/03/2012	02/04/2012	768.00	4.11	5.02	0.91	7.90	9.64	1.74	0.44	0.54
530561	GB 4	599423	01/03/2012	02/04/2012	768.00	4.23	5.15	0.92	8.12	9.89	1.77	0.45	0.55
530057	GB 4	599311	01/03/2012	02/04/2012	768.00	4.23	5.12	0.90	8.12	9.84	1.72	0.45	0.55
530087	GB 5	599050	03/03/2012	03/04/2012	739.00	2.38	4.23	1.85	4.56	8.12	3.56	0.25	0.44

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

	GB 6 599101	03/03/2012	03/04/2012	740.38		4.80			9.22			0.50
530531	GB 7 599316	03/03/2012	03/04/2012	743.08	2.66	3.98	1.32	5.11	7.65	2.54	0.28	0.41
530517	GB 8 599861	03/03/2012	03/04/2012	744.92	2.08	4.95	2.88	3.99	9.51	5.52	0.22	0.52
530271	GB 8 599482	03/03/2012	03/04/2012	744.92	2.20	4.66	2.45	4.23	8.94	4.71	0.23	0.48
530025	GB 8 599394	03/03/2012	03/04/2012	744.92	2.15	5.44	3.28	4.14	10.44	6.30	0.22	0.57
530068	Travel Blank599158			768.38	0.25	4.75	4.50	0.48	9.11	8.63	0.03	0.51
	Lab Blanks			768.38	0.06	0.96	0.90	0.11	1.84	1.74	0.006	0.103

Comment: Results are not blank subtracted
NO2 tube GB6 (530663) was void as it did not contain any grids.
All tubes except GB2 exposure times were incorrect.
+NO results are derived by subtracting NO2 from NOx.
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/-
Tube Preparation: 20%TEA/Water Analysed on UVS03 Cecil

Limit of Detection 0.103ug NOx, 0.014ug NO2 on tube

Analyst Name J. Samuel

Date of Analysis 26/04/2012

Date of Report 02/05/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 2557R

BOOKING IN REFERENCE No F 2557

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn. D. Birkinshaw
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 23/04/2012

GRADKO LAB REF GIL 1928-1940

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
GB 1	01/03/2012	02/04/2012	768.38	0.85	0.77	57.94	28.97
GB 2	01/03/2012	02/04/2012	768.38	1.17	1.09	82.03	41.01
GB 3	01/03/2012	02/04/2012	768.08	0.89	0.81	60.98	30.49
GB 4	01/03/2012	02/04/2012	768.00	0.87	0.79	59.48	29.74
GB 4	01/03/2012	02/04/2012	768.00	1.01	0.93	70.02	35.01
GB 4	01/03/2012	02/04/2012	768.00	0.99	0.91	68.51	34.26
GB 5	03/03/2012	03/04/2012	739.00	0.94	0.86	67.29	33.64
GB 6	03/03/2012	03/04/2012	740.38	0.93	0.85	66.38	33.19
GB 7	03/03/2012	03/04/2012	743.08	1.06	0.98	76.26	38.13
GB 8	03/03/2012	03/04/2012	744.92	1.03	0.95	73.74	36.87
GB 8	03/03/2012	03/04/2012	744.92	1.16	1.08	83.83	41.92
GB 8	03/03/2012	03/04/2012	744.92	1.18	1.10	85.39	42.69
Travel Blank				0.08			
Lab Blank				0.06			

(RESULTS ARE BLANK CORRECTED)

Tubes exposure times were incorrect except GB2.

Overall M.O.U 7.56% +/- Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 25/04/2012

DATE OF REPORT 02/05/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 2558R
Booking in reference No F 2558
Despatch note No SOR 007959

Customer Golder Associates Attn. D. Birkinshaw
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

Date samples received 23/04/2012

Gradko Lab ref GIM 5142-5154

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
GB 1	01/03/2012	02/04/2012	768.38	0.05	0.03	1.41	0.53
GB 2	01/03/2012	02/04/2012	768.38	0.06	0.05	2.20	0.83
GB 3	01/03/2012	02/04/2012	768.08	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 4	01/03/2012	02/04/2012	768.00	0.05	0.03	1.47	0.55
GB 4	01/03/2012	02/04/2012	768.00	0.05	0.04	1.68	0.63
GB 4	01/03/2012	02/04/2012	768.00	0.05	0.04	1.70	0.64
GB 5	03/03/2012	03/04/2012	739.00	0.06	0.05	2.39	0.90
GB 6	03/03/2012	03/04/2012	740.38	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 7	03/03/2012	03/04/2012	743.08	0.07	0.05	2.56	0.96
GB 8	03/03/2012	03/04/2012	744.92	0.04	0.02	1.00	0.37
GB 8	03/03/2012	03/04/2012	744.92	0.06	0.05	2.24	0.84
GB 8	03/03/2012	03/04/2012	744.92	0.07	0.05	2.55	0.96
Travel Blank				0.02			
Lab Blank				0.02			

(RESULTS ARE BLANK CORRECTED)
<L.O.D. means below the limit of detection.

Overall M.O.U. 14.1%+/-
Analysed on Dionex DX100 ICU7

Limit of detection 0.030µg S

Analyst name M. Zmudzka

Date of analysis 03/05/2012

Date of report 04/05/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V.SPECTROPHOTOMETRY

REPORT NUMBER F 3506R

BOOKING REFERENCE No F 3506

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 06/06/2012

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_X ppb *	NO ppb * +	NO_2 µg/m³	NO_X µg/m³	NO µg/m³ +	TOTAL µG NO_2	TOTAL µG NOx

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

640495	GB 1	646146	02/04/2012	10/05/2012	911.17	1.62	2.27	0.64	3.11	4.35	1.24	0.21	0.29
628451	GB 2	646320	02/04/2012	10/05/2012	911.00	0.88	2.01	1.12	1.69	3.85	2.16	0.11	0.26
627873	GB 3	646163	02/04/2012	10/05/2012	911.03	1.08	1.99	0.91	2.07	3.82	1.75	0.14	0.25
627821	GB 4	646476	02/04/2012	10/05/2012	911.00	1.17	2.90	1.73	2.25	5.57	3.32	0.15	0.37
640675	GB 4	646712	02/04/2012	10/05/2012	911.00	1.35	2.61	1.27	2.58	5.01	2.43	0.17	0.33
628065	GB 4	646034	02/04/2012	10/05/2012	911.00	1.12	2.38	1.26	2.14	4.56	2.42	0.14	0.30
627829	GB 5	646493	03/04/2012	09/05/2012	871.08	1.27	2.62	1.35	2.43	5.02	2.59	0.15	0.32
640659	GB 6	646219	03/04/2012	09/05/2012	869.92	1.34	2.36	1.01	2.58	4.52	1.95	0.16	0.29
627994	GB 7	646484	03/04/2012	09/05/2012	867.25	1.73	3.35	1.62	3.32	6.43	3.11	0.21	0.41
627916	GB 8	646644	03/04/2012	09/05/2012	865.83	1.01	4.47	3.46	1.94	8.58	6.64	0.12	0.54
640952	GB 8	646484	03/04/2012	09/05/2012	865.83	1.27	5.13	3.87	2.43	9.85	7.42	0.15	0.62
627939	GB 8	646246	03/04/2012	09/05/2012	865.83	1.27	3.92	2.66	2.43	7.53	5.10	0.15	0.47
640750	Travel Blank	646303			911.17	0.10	4.74	4.64	0.20	9.11	8.91	0.01	0.60
	Lab Blanks				911.17	0.03	0.81	0.78	0.06	1.56	1.49	0.004	0.103

Comment: Results are not blank subtracted

***NO results are derived by subtracting NO2 from NOx.**

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/- **Limit of Detection** 0.031ug NOx, 0.017ug NO2 on tube

Tube Preparation: 20%TEA/Water Analysed on UVS04 Camspec M550

Analyst Signature **Analyst Name** B. Gregory

Date of Analysis 15/06/2012 **Date of Report** 18/06/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 3505R

BOOKING IN REFERENCE No F 3505

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 06/06/2012

GRADKO LAB REF GIL 2689-2700

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
GB 1	02/04/2012	10/05/2012	911.17	1.42	1.32	83.77	41.88
GB 2	02/04/2012	10/05/2012	911.00	2.00	1.90	120.60	60.30
GB 3	02/04/2012	10/05/2012	911.03	1.51	1.41	89.49	44.75
GB 4	02/04/2012	10/05/2012	911.00	1.40	1.30	82.51	41.26
GB 4	02/04/2012	10/05/2012	911.00	1.50	1.40	88.86	44.43
GB 4	02/04/2012	10/05/2012	911.00	1.71	1.61	102.19	51.09
GB 5	03/04/2012	09/05/2012	871.08	0.88	0.78	51.78	25.89
GB 6	03/04/2012	09/05/2012	869.92	1.33	1.23	81.76	40.88
GB 7	03/04/2012	09/05/2012	867.25	1.40	1.30	86.68	43.34
GB 8	03/04/2012	09/05/2012	865.83	1.80	1.70	113.53	56.76
GB 8	03/04/2012	09/05/2012	865.83	1.54	1.44	96.17	48.08
Travel Blank				0.10			
Lab Blank				0.06			

(RESULTS ARE BLANK CORRECTED)
Third tube 8 was missing on arrival.

Overall M.O.U 7.56% +/-
Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 11/06/2012

DATE OF REPORT 18/06/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 3504R
Booking in reference No F 3504
Despatch note No SOR 007959

Customer Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

Date samples received 06/06/2012

Gradko Lab ref GIM 6717-6729

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
GB 1	02/04/2012	10/05/2012	911.17	0.06	0.05	2.02	0.76
GB 2	02/04/2012	10/05/2012	911.00	0.05	0.04	1.56	0.59
GB 3	02/04/2012	10/05/2012	911.03	0.05	0.04	1.44	0.54
GB 4	02/04/2012	10/05/2012	911.00	0.03	0.02	0.82	0.31
GB 4	02/04/2012	10/05/2012	911.00	0.05	0.04	1.48	0.56
GB 4	02/04/2012	10/05/2012	911.00	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 5	03/04/2012	09/05/2012	871.08	0.06	0.04	1.82	0.68
GB 6	03/04/2012	09/05/2012	869.92	0.04	0.03	1.05	0.39
GB 7	03/04/2012	09/05/2012	867.25	0.04	0.03	1.05	0.39
GB 8	03/04/2012	09/05/2012	865.83	0.04	0.03	1.07	0.40
GB 8	03/04/2012	09/05/2012	865.83	0.05	0.04	1.53	0.57
GB 8	03/04/2012	09/05/2012	865.83	0.07	0.05	2.26	0.85
Travel blank				0.05	0.04		
Lab Blank				0.01			

(RESULTS ARE BLANK CORRECTED)
<L.O.D. means below the limit of detection.

Overall M.O.U.	14.1%+/- Analysed on Dionex DX100 ICU7	**Limit of detection**	0.030µg S
		Analyst name	M. Witek
Date of analysis	15/06/2012	**Date of report**	19/06/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V.SPECTROPHOTOMETRY

REPORT NUMBER F 6190R

BOOKING REFERENCE No F 6190

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 29/10/2012

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_X ppb *	NO ppb * +	NO_2 µg/m³	NO_X µg/m³	NO µg/m³ +	TOTAL µG NO_2	TOTAL µG NOx
042598	DSD 1	042581	03/09/2012	15/10/2012	1008.00	0.55	5.45	4.90	1.06	10.47	9.40	0.08	0.77
042600	DSD 2	042583	03/09/2012	15/10/2012	1008.00	0.38	4.07	3.70	0.72	7.82	7.10	0.05	0.57
042599	DSD 3	042582	04/09/2012	15/10/2012	984.00	0.69	5.27	4.57	1.33	10.11	8.78	0.10	0.72
042597	DSD 4	042580	06/09/2012	17/10/2012	984.00	0.52	2.90	2.38	0.99	5.57	4.57	0.07	0.40
042595	DSD 5	042577	07/09/2012	18/10/2012	984.00	0.59	3.12	2.53	1.13	6.00	4.87	0.08	0.43
042596	GB 1	042579	06/09/2012	17/10/2012	984.00	0.47	3.58	3.11	0.89	6.87	5.97	0.06	0.49
042594	GB 2	042576	06/09/2012	18/10/2012	1008.00	0.58	3.18	2.59	1.12	6.10	4.98	0.08	0.45
042590	GB 3	042572	07/09/2012	19/10/2012	1008.00	0.20	3.46	3.26	0.38	6.63	6.25	0.03	0.49
042593	GB 4	042575	06/09/2012	18/10/2012	1008.00	0.91	3.13	2.22	1.75	6.01	4.26	0.13	0.44

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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gradko environmental
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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

042604	GB 5	042587	05/09/2012	16/10/2012	984.00	0.34	3.66	3.32	0.64	7.02	6.38	0.05	0.50
042592	GB 4	042574	06/09/2012	18/10/2012	1008.00	0.75	5.05	4.31	1.43	9.71	8.27	0.11	0.71
042591	GB 4	042573	06/09/2012	18/10/2012	1008.00	1.02	2.54	1.52	1.95	4.87	2.92	0.14	0.36
042601	GB 8	042584	05/09/2012	16/10/2012	984.00	0.60	4.15	3.55	1.16	7.97	6.81	0.08	0.57
042602	GB 8	042585	05/09/2012	16/10/2012	984.00	0.68	2.92	2.24	1.31	5.61	4.29	0.09	0.40
042603	GB 8	042586	05/09/2012	16/10/2012	984.00	0.35	3.47	3.12	0.67	6.66	5.98	0.05	0.48
	Lab Blanks				1008.00	0.07	0.15	0.08	0.14	0.29	0.15	0.010	0.021

Comment: Results are not blank subtracted

***NO results are derived by subtracting NO2 from NOx.**
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/- **Limit of Detection** 0.031ug NOx, 0.017ug NO2 on tube

Tube Preparation: 20%TEA/Water Analysed on UVS04 Camspec M550

Analyst Signature **Analyst Name** B. Gregory

Date of Analysis 08/11/2012 **Date of Report** 09/11/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 6188R

BOOKING IN REFERENCE No F 6188

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn. D. Birkinshaw
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 29/10/2012

GRADKO LAB REF GIL 4870-4885

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
042615 DSD1	03/09/2012	15/10/2012	1001.55	1.49	1.41	81.40	40.70
042617 DSD2	03/09/2012	15/10/2012	1007.48	1.62	1.54	88.39	44.19
042616 DSD3	04/09/2012	15/10/2012	983.98	1.26	1.18	69.34	34.67
042614 DSD4	06/09/2012	17/10/2012	983.50	1.27	1.19	69.96	34.98
042612 DSD5	07/09/2012	18/10/2012	983.50	0.99	0.91	53.50	26.75
042613 GB1	06/09/2012	17/10/2012	983.33	1.16	1.08	63.51	31.75
042611 GB2	06/09/2012	18/10/2012	1005.00	1.25	1.17	67.32	33.66
042607 GB3	07/09/2012	19/10/2012	1007.97	0.85	0.77	44.17	22.09
042610 GB4	06/09/2012	18/10/2012	1008.75	1.46	1.38	79.10	39.55
042621 GB5	05/09/2012	16/10/2012	984.23	0.97	0.89	52.29	26.14
042609 GB4	06/09/2012	18/10/2012	1008.75	1.22	1.14	65.35	32.67
042608 GB4	06/09/2012	18/10/2012	1008.75	1.32	1.24	71.08	35.54
042618 GB8	05/09/2012	16/10/2012	983.48	1.47	1.39	81.72	40.86
042619 GB8	05/09/2012	16/10/2012	983.50	1.86	1.78	104.65	52.32
042620 GB8	05/09/2012	16/10/2012	983.52	1.32	1.24	72.90	36.45
Travel Blank				0.08			
Lab Blank				0.07			

(RESULTS ARE BLANK CORRECTED)

Overall M.O.U 7.56% +/-
Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 06/11/2012

DATE OF REPORT 09/11/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 6192R
Booking in reference No F 6192
Despatch note No SOR 007959

Customer Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

Date samples received 29/10/2012

Gradko Lab ref GIJ 5629-5644

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
042632 DSO 1	03/09/2012	15/10/2012	1001.50	0.14	0.13	4.84	1.81
042634 DSO 2	03/09/2012	15/10/2012	1007.45	0.04	0.04	1.41	0.53
042633 DSO 3	04/09/2012	15/10/2012	984.07	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042631 DSO 4	06/09/2012	17/10/2012	983.50	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042629 DSO 5	07/09/2012	18/10/2012	983.50	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042630 GB 1	06/09/2012	17/10/2012	983.33	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042628 GB 2	06/09/2012	18/10/2012	1005.00	0.04	0.03	1.21	0.45
042624 GB 3	07/09/2012	19/10/2012	1007.97	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042627 GB 4	06/09/2012	18/10/2012	1008.75	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042638 GB 5	05/09/2012	16/10/2012	984.22	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042626 GB 4	06/09/2012	18/10/2012	1008.75	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042625 GB 4	06/09/2012	18/10/2012	1008.75	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
042635 GB 8	05/09/2012	16/10/2012	983.42	0.03	0.02	0.89	0.33
042636 GB 8	05/09/2012	16/10/2012	983.43	0.03	0.03	0.97	0.36
042637 GB 8	05/09/2012	16/10/2012	983.45	0.03	0.02	0.92	0.34
Travel Blank				0.01			
Lab Blank				0.01			

(RESULTS ARE BLANK CORRECTED)
<L.O.D. means below the limit of detection.

Overall M.O.U. 6.0%+/-
Analysed on Dionex ICS3000 ICU5

Limit of detection 0.03µg S

Analyst name M. Zmudzka

Date of analysis 06/11/2012

Date of report 12/11/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V.SPECTROPHOTOMETRY

REPORT NUMBER F 6447R

BOOKING REFERENCE No F 6447

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 19/11/2012

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_x ppb *	NO ppb * +	NO_2 µg/m³	NO_x µg/m³	NO µg/m³ +	TOTAL µG NO_2	TOTAL µG NOx
053550	DSO 1	053527	15/10/2012	09/11/2012	600.85	1.34	4.84	3.51	2.56	9.30	6.73	0.11	0.41
053548	DSO 2	053525	15/10/2012	09/11/2012	600.78	0.68	4.46	3.78	1.31	8.57	7.26	0.06	0.37
053549	DSO 3	053526	15/10/2012	09/11/2012	601.30	1.23	4.59	3.36	2.36	8.81	6.45	0.10	0.39
053543	DSO 4	053520	17/10/2012	11/11/2012	597.68	1.02	5.25	4.23	1.96	10.08	8.13	0.09	0.44
053541	DSO 5	053518	18/10/2012	11/11/2012	576.67	0.85	5.31	4.46	1.62	10.19	8.57	0.07	0.43
053542	GB 1	053519	17/10/2012	11/11/2012	597.27	0.54	4.45	3.91	1.04	8.55	7.51	0.05	0.37
053540	GB 2	053517	18/10/2012	11/11/2012	576.07	0.62	4.39	3.77	1.19	8.43	7.24	0.05	0.35
053539	GB 3	053516	19/10/2012	11/11/2012	554.17	0.34	5.39	5.06	0.65	10.35	9.71	0.03	0.42

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

053538	GB 4	053515	18/10/2012	11/11/2012	576.43	1.44	3.19	1.75	2.77	6.13	3.37	0.12	0.26
053537	GB 4	053514	18/10/2012	11/11/2012	576.62	1.48	6.46	4.98	2.84	12.41	9.57	0.12	0.52
053536	GB 4	053513	18/10/2012	11/11/2012	576.63	1.34	5.80	4.46	2.58	11.14	8.57	0.11	0.47
053544	GB 5	053521	16/10/2012	10/11/2012	596.02	0.71	4.71	4.00	1.36	9.05	7.69	0.06	0.39
053547	GB 8	053524	16/10/2012	10/11/2012	598.77	0.79	5.55	4.76	1.52	10.66	9.15	0.07	0.46
053546	GB 8	053523	16/10/2012	10/11/2012	598.78	0.65	4.22	3.58	1.24	8.11	6.87	0.05	0.35
053545	GB 8	053522	16/10/2012	10/11/2012	598.80	26.88	3.57	<L.O.D.	51.61	6.85	<L.O.D.	2.25	0.30
	Lab Blanks				601.30	0.07	0.23	0.15	0.14	0.43	0.30	0.006	0.019

Comment: Results are not blank subtracted
<L.O.D. means below the limit of detection.
NO2 tube 053545 GB8 contained a spider, contaminated and diluted to read within method calibration range.
NOX tube 053520 DSO4 contained a spider.
+NO results are derived by subtracting NO2 from NOx.
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/- **Limit of Detection** 0.031ug NOx, 0.017ug NO2 on tube

Tube Preparation: 20%TEA/Water Analysed on UVS04 Camspec M550

Analyst Signature **Analyst Name** B. Gregory

Date of Analysis 26/11/2012 **Date of Report** 28/11/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 6445R

BOOKING IN REFERENCE No F 6445

DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn. D. Birkinshaw
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

DATE SAMPLES RECEIVED 19/11/2012

GRADKO LAB REF GIL 5131-5146

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
053509 DSO1	15/10/2012	09/11/2012	600.80	0.79	0.72	69.30	34.65
053507 DSO2	15/10/2012	09/11/2012	600.83	1.25	1.18	113.56	56.78
053508 DSO3	15/10/2012	09/11/2012	601.33	0.77	0.70	67.31	33.65
053502 DSO4	17/10/2012	11/11/2012	597.60	0.82	0.75	72.57	36.28
053500 DSO5	18/10/2012	11/11/2012	576.57	0.72	0.65	65.19	32.59
053501 GB1	17/10/2012	11/11/2012	597.15	0.69	0.62	60.04	30.02
053499 GB2	18/10/2012	11/11/2012	576.10	0.54	0.47	47.17	23.59
053498 GB3	19/10/2012	11/11/2012	554.20	0.67	0.60	62.60	31.30
053497 GB4	18/10/2012	11/11/2012	576.50	0.67	0.60	60.18	30.09
053496 GB4	18/10/2012	11/11/2012	576.52	0.78	0.71	71.21	35.60
053495 GB4	18/10/2012	11/11/2012	576.53	0.74	0.67	67.20	33.60
053503 GB5	16/10/2012	10/11/2012	596.00	0.74	0.67	65.00	32.50
053506 GB8	16/10/2012	10/11/2012	598.62	0.88	0.81	78.24	39.12
053505 GB8	16/10/2012	10/11/2012	598.63	0.80	0.73	70.51	35.26
053504 GB8	16/10/2012	10/11/2012	598.67	1.02	0.95	91.76	45.88
Travel Blank				0.07			
Lab Blank				0.06			

(RESULTS ARE BLANK CORRECTED)

Overall M.O.U 7.56% +/-
Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 22/11/2012

DATE OF REPORT 28/11/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 6450R
Booking in reference No F 6450
Despatch note No SOR 007959

Customer Golder Associates
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
Nottingham

Date samples received 19/11/2012

Gradko Lab ref GIJ 6426-6443

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
053490 DSO1	15/10/2012	09/11/2012	600.75	0.03	0.02	1.07	0.40
053488 DSO2	15/10/2012	09/11/2012	600.87	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053489 DSO3	15/10/2012	09/11/2012	601.38	0.03	0.02	1.22	0.46
053477 DSO4	17/10/2012	11/11/2012	597.53	0.03	0.02	1.28	0.48
053476 DSO4	17/10/2012	11/11/2012	598.63	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053478 GB1	17/10/2012	11/11/2012	597.23	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053479 GB2	18/10/2012	11/11/2012	576.17	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053480 GB3	19/10/2012	11/11/2012	554.27	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053481 GB4	18/10/2012	11/11/2012	576.62	0.03	0.02	1.44	0.54
053482 GB4	18/10/2012	11/11/2012	576.63	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053483 GB4	18/10/2012	11/11/2012	576.65	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053574 GB5	16/10/2012	10/11/2012	596.03	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053587 GB8	16/10/2012	10/11/2012	598.53	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053585 GB8	16/10/2012	10/11/2012	598.55	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
053484 GB8	16/10/2012	10/11/2012	598.57	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
Extra:							
P4				<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
P8 053459				<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
Travel Blank				0.01			
Lab Blank				0.01			

(RESULTS ARE BLANK CORRECTED)
<L.O.D. means below the limit of detection.
Tube 053585 GB8 was wet inside. Result may be compromised.
Two extra tubes were received.

Overall M.O.U. 6.0%+/-
Analysed on Dionex ICS3000 ICU5

Limit of detection 0.03µg S

Analyst name M. Witek

Date of analysis 22/11/2012

Date of report 28/11/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V. SPECTROPHOTOMETRY

REPORT NUMBER E 6722R
BOOKING IN REFERENCE No E 6722
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn.: Daniel Birkinshaw
Nottingham

DATE SAMPLES RECEIVED 14/12/2011

NO_2	Tube Number	NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_X ppb *	NO ppb * +	NO_2 µg/m^3	NO_X µg/m^3	NO µg/m^3 +	TOTAL µG NO_2	TOTAL µG NOx
586039	GB 1	559362	31/10/2011	30/11/2011	723.18	0.68	0.87	0.19	1.31	1.67	0.36	0.07	0.09
586615	GB 2	559611	31/10/2011	30/11/2011	722.92	1.52	1.86	0.35	2.91	3.58	0.67	0.15	0.19
586444	GB 3	559347	31/10/2011	01/12/2011	735.08	0.92	1.20	0.28	1.76	2.30	0.54	0.09	0.12
586431	GB 4	559265	31/10/2011	01/12/2011	732.92	3.12	2.88	<L.O.D.	5.99	5.54	<L.O.D.	0.32	0.30
586707	GB 4	559440	31/10/2011	01/12/2011	732.92	3.02	2.20	<L.O.D.	5.80	4.22	<L.O.D.	0.31	0.23
586259	GB 4	559663	31/10/2011	01/12/2011	732.92	2.40	2.50	0.11	4.60	4.81	0.21	0.25	0.26
586136	GB 5	559283	01/11/2011	01/12/2011	709.87	2.43	1.47	<L.O.D.	4.67	2.83	<L.O.D.	0.24	0.15

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

586407	GB 6	559725	01/11/2011	01/12/2011	709.22	2.64	2.80	0.16	5.06	5.37	0.31	0.26	0.28
586705	GB 7	559584	01/11/2011	01/12/2011	708.12	3.75	4.61	0.86	7.21	8.86	1.65	0.37	0.46
586419	GB 8	559706	04/11/2011	01/12/2011	635.33	1.27	1.34	0.07	2.45	2.58	0.13	0.11	0.12
586180	GB 8	559441	04/11/2011	01/12/2011	635.33	1.15	1.18	0.03	2.21	2.27	0.06	0.10	0.11
586147	GB 8	559398	04/11/2011	01/12/2011	635.33	1.14	1.26	0.12	2.19	2.43	0.24	0.10	0.11
	Extras:												
531449		501713			735.08	0.23	0.21	<L.O.D.	0.45	0.41	<L.O.D.	0.02	0.02
	Lab Blanks				735.08	0.04	1.00	0.97	0.07	1.93	1.85	0.004	0.103

Comment: Results are not blank subtracted
<L.O.D. means below the limit of detection.
NO2 and NOX Travel Blanks were missing on arrival.
Two extra tubes were received and maximum exposure time used.
+NO results are derived by subtracting NO2 from NOx.
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/-
Tube Preparation: 20%TEA/Water Analysed on UVS03 Cecil

Limit of Detection 0.103ug NOx, 0.014ug NO2 on tube

Analyst Name J. Samuel

Date of Analysis 17/01/2012

Date of Report 18/01/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER E 6721R
BOOKING IN REFERENCE No E 6721
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

DATE SAMPLES RECEIVED 14/12/2011

GRADKO LAB REF GIJ 5892-5902, 5937-5938

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
GB 1	31/10/2011	30/11/2011	723.18	0.72	0.67	53.89	26.94
GB 2	31/10/2011	30/11/2011	722.92	1.05	1.00	80.31	40.15
GB 3	31/10/2011	01/12/2011	741.42	0.67	0.62	48.67	24.33
GB 4a	31/10/2011	01/12/2011	742.70	0.63	0.58	45.47	22.73
GB 4b	31/10/2011	01/12/2011	742.70	0.74	0.69	54.03	27.02
GB 4c	31/10/2011	01/12/2011	742.70	0.72	0.67	52.47	26.24
GB 5	01/11/2011	01/12/2011	714.38	0.73	0.68	55.36	27.68
GB 6	01/11/2011	01/12/2011	716.28	0.75	0.70	56.83	28.42
GB 7	01/11/2011	01/12/2011	717.38	0.80	0.75	60.77	30.39
GB 8a	04/11/2011	01/12/2011	646.17	0.95	0.90	80.90	40.45
GB 8b	04/11/2011	01/12/2011	646.17	0.63	0.58	52.26	26.13
GB 8c	04/11/2011	01/12/2011	646.17	0.84	0.79	71.05	35.53
Travel Blank				0.05			
Lab Blank				0.05			

(RESULTS ARE BLANK CORRECTED)
Tubes GB3-GB8c exposure times were incorrect.

Overall M.O.U 7.56% +/-
Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 16/12/2011

DATE OF REPORT 03/01/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number E 6720R
Booking in reference No E 6720
Despatch note No SOR 007959

Customer Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

Date samples received 14/12/2011

Gradko Lab ref GIK 10833-10845

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
GB 1	31/10/2011	30/11/2011	723.18	0.03	0.01	0.39	0.15
GB 2	31/10/2011	30/11/2011	722.92	0.05	0.03	1.47	0.55
GB 3	31/10/2011	01/12/2011	741.42	0.04	0.02	0.97	0.36
GB 4a	31/10/2011	01/12/2011	742.70	0.07	0.05	2.34	0.88
GB 4b	31/10/2011	01/12/2011	742.70	0.08	0.06	2.92	1.09
GB 4c	31/10/2011	01/12/2011	742.70	0.11	0.08	4.12	1.54
GB 5	01/11/2011	01/12/2011	714.38	0.04	0.02	1.04	0.39
GB 6	01/11/2011	01/12/2011	716.28	0.03	0.01	0.46	0.17
GB 7	01/11/2011	01/12/2011	717.38	0.05	0.03	1.58	0.59
GB 8a	04/11/2011	01/12/2011	646.17	0.06	0.03	1.94	0.73
GB 8b	04/11/2011	01/12/2011	646.17	0.06	0.04	2.07	0.78
GB 8c	04/11/2011	01/12/2011	646.17	0.06	0.04	2.07	0.78
Travel Blank				0.02			
Lab Blank				0.02			

(RESULTS ARE BLANK CORRECTED)

Tubes GB3-GB8c exposure times were incorrect.

Overall M.O.U. 14.1%+/-
Analysed on Dionex DX100 ICU7

Limit of detection 0.030µg S

Analyst name M. Zmudzka

Date of analysis 20/12/2011

Date of report 03/01/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)

St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

NITROGEN DIOXIDE IN DIFFUSION TUBES BY U.V. SPECTROPHOTOMETRY

REPORT NUMBER F 0744R
BOOKING IN REFERENCE No F 0744
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates Attn.: Daniel Birkinshaw
Nottingham

DATE SAMPLES RECEIVED 30/01/2012

NO_2 Tube Number		NO_x	Exposure Data Date On	Date Off	Time (hr.)	NO_2 ppb *	NO_X ppb *	NO ppb * +	NO_2 µg/m³	NO_X µg/m³	NO µg/m³ +	TOTAL µG NO_2	TOTAL µG NOx
531109	GB1	501638	30/11/2011	02/01/2012	788.57	0.76	1.20	0.44	1.47	2.30	0.84	0.08	0.13
530848	GB2	502106	30/11/2011	02/01/2012	788.63	1.23	1.29	0.06	2.36	2.48	0.12	0.14	0.14
531297	GB3	501724	01/12/2011	02/01/2012	770.87	0.86	0.81	<L.O.D.	1.66	1.55	<L.O.D.	0.09	0.09
531457	GB4	502228	30/11/2011	02/01/2012	793.32	2.48	2.72	0.24	4.75	5.22	0.47	0.27	0.30
530998	GB4	502203	30/11/2011	02/01/2012	793.32	2.53	2.52	<L.O.D.	4.86	4.84	<L.O.D.	0.28	0.28
531171	GB4	501794	30/11/2011	02/01/2012	793.32	2.75	2.67	<L.O.D.	5.27	5.13	<L.O.D.	0.30	0.30
530818	GB5	502310	01/12/2011	03/01/2012	792.78	1.43	1.04	<L.O.D.	2.74	2.00	<L.O.D.	0.16	0.12
530741	GB6	501554	01/12/2011	03/01/2012	792.85	3.11	2.90	<L.O.D.	5.97	5.57	<L.O.D.	0.34	0.32

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

530786	GB7	501579	01/12/2011	03/01/2012	792.63	2.72	2.43	<L.O.D.	5.22	4.67	<L.O.D.	0.30	0.27
531459	GB8	502077	01/12/2011	03/01/2012	792.80	1.48	1.41	<L.O.D.	2.85	2.71	<L.O.D.	0.16	0.16
531333	GB8	501577	01/12/2011	03/01/2012	792.80	1.39	0.74	<L.O.D.	2.67	1.42	<L.O.D.	0.15	0.08
531326	GB8	501789	01/12/2011	03/01/2012	792.80	1.46	1.36	<L.O.D.	2.81	2.60	<L.O.D.	0.16	0.15
	Extra:												
586355		559292			793.32	0.13	0.13	<L.O.D.	0.24	0.24	<L.O.D.	0.01	0.01
Lab Blanks					793.32	0.04	0.93	0.89	0.07	1.79	1.72	0.004	0.103

Comment: Results are not blank subtracted
<L.O.D. means below the limit of detection.
Travel blanks tubes were missing on arrival.
Extra tubes were received and maximum exposure time used.
Total hours calculated according to exposure period using our formulas.
***NO results are derived by subtracting NO2 from NOx.**
Results have been corrected to a temperature of 293K (20C)

Overall M.O.U. 7.3% +/- **Limit of Detection** 0.103ug NOx, 0.014ug NO2 on tube
Tube Preparation: 20%TEA/Water Analysed on UVS03 Cecil
Analyst Name J. Samuel

Date of Analysis 14/02/2012 **Date of Report** 15/02/2012

Analysis carried out in accordance with documented in-house Laboratory Method GLM7

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

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tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF OZONE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

REPORT NUMBER F 0745R
BOOKING IN REFERENCE No F 0745
DESPATCH NOTE No SOR 007959

CUSTOMER Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

DATE SAMPLES RECEIVED 30/01/2012

GRADKO LAB REF GIL 0829-0841

Tube Identification	Date On	Date Off	Exposure (hrs)	µg on Tube Total	µg - Blank	O3* µg/m3	O3* ppb
GB 1	30/11/2011	02/01/2012	788.57	0.69	0.62	45.46	22.73
GB 2	30/11/2011	02/01/2012	788.63	1.02	0.95	69.65	34.83
GB 3	01/12/2011	02/01/2012	770.87	0.88	0.81	60.76	30.38
GB 4a	30/11/2011	02/01/2012	793.32	0.94	0.87	63.41	31.71
GB 4b	30/11/2011	02/01/2012	793.32	0.83	0.76	55.39	27.70
GB 4c	30/11/2011	02/01/2012	793.32	0.88	0.81	59.04	29.52
GB 5	01/12/2011	03/01/2012	792.78	0.73	0.66	48.14	24.07
GB 6	01/12/2011	03/01/2012	792.85	0.72	0.65	47.40	23.70
GB 7	01/12/2011	03/01/2012	792.63	0.91	0.84	61.28	30.64
GB 8a	01/12/2011	03/01/2012	792.80	0.99	0.92	67.10	33.55
GB 8b	01/12/2011	03/01/2012	792.80	1.11	1.04	75.85	37.93
GB 8c	01/12/2011	03/01/2012	792.80	1.01	0.94	68.56	34.28
Travel Blank				0.07			
Lab Blank				0.046			

(RESULTS ARE BLANK CORRECTED)
Tubes GB3-GB8c exposure times were incorrect.
Tube GB8b was dirty inside.

Overall M.O.U 7.56% +/-
Analysed on DX 100 ICU1

LIMIT OF DETECTION 0.114µg

ANALYST SIGNATURE

ANALYST NAME M. Zmudzka

DATE OF ANALYSIS 31/01/2012

DATE OF REPORT 03/02/2012

THE ANLYSIS HAS BEEN CARRIED OUT IN ACCORDANCE WITH IN-HOUSE METHOD GLM 2

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

DETERMINATION OF SULPHUR DIOXIDE IN DIFFUSION TUBES BY ION CHROMATOGRAPHY

Report number F 0746R
Booking in reference No F 0746
Despatch note No SOR 007959

Customer Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds
Nottinghamshire NG12 5BL

Date samples received 30/01/2012

Gradko Lab ref GIM 1654-1666

Location	Date exposed	Date finished	Exposure hours	µg S Total	µgS - Blank	SO_2 µg/m^3*	SO_2 ppb*
GB 1	30/11/2011	02/01/2012	788.57	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 2	30/11/2011	02/01/2012	788.63	<L.O.D.	<L.O.D.	<L.O.D.	<L.O.D.
GB 3	01/12/2011	02/01/2012	770.87	0.03	0.02	0.84	0.31
GB 4a	30/11/2011	02/01/2012	793.32	0.03	0.02	0.88	0.33
GB 4b	30/11/2011	02/01/2012	793.32	0.03	0.02	0.92	0.35
GB 4c	30/11/2011	02/01/2012	793.32	0.04	0.03	1.41	0.53
GB 5	01/12/2011	03/01/2012	792.78	0.03	0.02	0.97	0.36
GB 6	01/12/2011	03/01/2012	792.85	0.03	0.02	0.98	0.37
GB 7	01/12/2011	03/01/2012	792.63	0.03	0.02	0.95	0.36
GB 8a	01/12/2011	03/01/2012	792.80	0.04	0.02	1.01	0.38
GB 8b	01/12/2011	03/01/2012	792.80	0.03	0.02	0.86	0.32
GB 8c	01/12/2011	03/01/2012	792.80	0.04	0.02	1.14	0.43
Travel blank				0.03	0.02		
Lab Blank				0.01			

(RESULTS ARE BLANK CORRECTED)
<L.O.D. means below the limit of detection.
Tubes GB3-Gb8c exposure times were incorrect.
Customer's blank was high so lab blank was used.

Overall M.O.U. 14.1%+/-
Analysed on Dionex DX100 ICU7

Limit of detection 0.030µg S

Analyst name M. Zmudzka

Date of analysis 02/02/2012

Date of report 03/02/2012

The analysis has been carried out in accordance with in-house method GLM1

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

APPENDIX A3

Deposited Dust and Metallic Analysis Monitoring Results

January 2014
Report No. 13514950200.550/B.0

Environmental Scientifics Group

UKAS TESTING 1205

RESULTS OF ANALYSIS
FRISBEE GAUGE SAMPLE EXTENDED ANALYSIS
(METALLIC ELEMENTS)

Golder Associates
Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: OHEM 07142
Report Number: OHEM/07142/CA/0001 (Revision 0)
Report Date: 19 Apr 2012

Method Number FD01: The Determination of Fugitive Dust based on BS 2690: part 120: 1981
(Mass of collected deposit expressed in mg is the UKAS Accredited Result reported)
The metallic analysis was carried out to a UKAS accredited method by the sub-contract laboratory employed.
Environmental Scientifics Group Limited. does not accept responsibility for the sampling associated with the results included within this report.

Dust analysed by: **Lynne Dent, Senior Analyst**
Metals analysed by: **Leszek Bielawski, Analyst - Specialist Chemistry**

Authorised By:

.....
N J Fenwick, Laboratory Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01 283 554487

TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	1
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44995**

Mass of Deposit (mg)	**98.83**
Deposition Rate (mg.m^{-2}day^{-1})	**83**

Element	Mass (mg)	Deposition Rate (mg.m^{-2}day^{-1})
Aluminium	4.7	3.940167
Arsenic	0.003	0.002515
Barium	0.03	0.02515
Cadmium	0.00007	0.000059
Calcium	2.7	2.2635
Chromium	0.0091	0.007629
Cobalt	0.0031	0.002599
Copper	0.044	0.036887
Iron	4.8	4.024
Lead	0.013	0.010898
Magnesium	0.55	0.461083
Manganese	0.23	0.192817
Mercury	<0.0004	<0.000335
Molybdenum	0.0054	0.004527
Nickel	0.0054	0.004527
Selenium	<0.0001	<0.000084
Zinc	0.54	0.4527

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	2
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44996**

Mass of Deposit (mg)	**85.73**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**72**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.4	3.688667
Arsenic	0.0023	0.001928
Barium	0.026	0.021797
Cadmium	0.00004	0.000034
Calcium	2.2	1.844333
Chromium	0.0076	0.006371
Cobalt	0.0027	0.002264
Copper	0.037	0.031018
Iron	4.2	3.521
Lead	0.0097	0.008132
Magnesium	0.52	0.435933
Manganese	0.18	0.1509
Mercury	<0.0004	<0.000335
Molybdenum	0.0054	0.004527
Nickel	0.005	0.004192
Selenium	0.0001	0.000084
Zinc	0.5	0.419167

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	3
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44997**

Mass of Deposit (mg)	**72.33**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**61**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	5.1	4.2755
Arsenic	0.00093	0.00078
Barium	0.021	0.017605
Cadmium	<0.00002	<0.000017
Calcium	0.3	0.2515
Chromium	0.01	0.008383
Cobalt	0.0015	0.001258
Copper	0.029	0.024312
Iron	3.5	2.934167
Lead	0.0024	0.002012
Magnesium	0.36	0.3018
Manganese	0.046	0.038563
Mercury	<0.0004	<0.000335
Molybdenum	0.0053	0.004443
Nickel	0.0048	0.004024
Selenium	<0.0001	<0.000084
Zinc	0.023	0.019282

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	4
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44998**

Mass of Deposit (mg)	**177.27**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**149**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	11	9.221667
Arsenic	0.0026	0.00218
Barium	0.034	0.028503
Cadmium	0.00008	0.000067
Calcium	0.58	0.486233
Chromium	0.024	0.02012
Cobalt	0.0025	0.002096
Copper	0.043	0.036048
Iron	8.2	6.874333
Lead	0.015	0.012575
Magnesium	0.49	0.410783
Manganese	0.09	0.07545
Mercury	<0.0004	<0.000335
Molybdenum	0.0056	0.004695
Nickel	0.008	0.006707
Selenium	0.0004	0.000335
Zinc	0.044	0.036887

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	5
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44999**

Mass of Deposit (mg)	**72.1**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**65**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.4	3.952143
Arsenic	0.00068	0.000611
Barium	0.022	0.019761
Cadmium	0.00003	0.000027
Calcium	0.32	0.287429
Chromium	0.0085	0.007635
Cobalt	0.0015	0.001347
Copper	0.031	0.027845
Iron	2.6	2.335357
Lead	0.0037	0.003323
Magnesium	0.36	0.323357
Manganese	0.047	0.042216
Mercury	<0.0004	<0.000359
Molybdenum	0.0054	0.00485
Nickel	0.0039	0.003503
Selenium	<0.0001	<0.00009
Zinc	0.017	0.01527

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UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	6
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**45000**

Mass of Deposit (mg)	**81.55**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**73**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.9	4.40125
Arsenic	0.0016	0.001437
Barium	0.014	0.012575
Cadmium	0.00003	0.000027
Calcium	0.23	0.206589
Chromium	0.013	0.011677
Cobalt	0.0011	0.000988
Copper	0.028	0.02515
Iron	5.4	4.850357
Lead	0.0026	0.002335
Magnesium	0.21	0.188625
Manganese	0.042	0.037725
Mercury	<0.0004	<0.000359
Molybdenum	0.0055	0.00494
Nickel	0.0035	0.003144
Selenium	<0.0001	<0.00009
Zinc	0.016	0.014371

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UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	7
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**45001**

Mass of Deposit (mg)	**122.54**
Deposition Rate (mg.m^{-2}day^{-1})	**110**

Element	Mass (mg)	Deposition Rate (mg.m^{-2}day^{-1})
Aluminium	8.3	7.455179
Arsenic	0.0021	0.001886
Barium	0.028	0.02515
Cadmium	0.00004	0.000036
Calcium	0.46	0.413179
Chromium	0.018	0.016168
Cobalt	0.0019	0.001707
Copper	0.049	0.044012
Iron	6.1	5.479107
Lead	0.0082	0.007365
Magnesium	0.45	0.404196
Manganese	0.066	0.059282
Mercury	<0.0004	<0.000359
Molybdenum	0.0057	0.00512
Nickel	0.0067	0.006018
Selenium	0.0002	0.00018
Zinc	0.035	0.031438

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	8
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**45002**

Mass of Deposit (mg)	**65.54**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**59**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.2	3.7725
Arsenic	0.00045	0.000404
Barium	0.02	0.017964
Cadmium	<0.00002	<0.000018
Calcium	0.27	0.242518
Chromium	0.0075	0.006737
Cobalt	0.0013	0.001168
Copper	0.027	0.024252
Iron	2.1	1.88625
Lead	0.0021	0.001886
Magnesium	0.35	0.314375
Manganese	0.04	0.035929
Mercury	<0.0004	<0.000359
Molybdenum	0.0051	0.004581
Nickel	0.0038	0.003413
Selenium	<0.0001	<0.00009
Zinc	0.014	0.012575

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Environmental Scientifics Group

UKAS TESTING 1205

RESULTS OF ANALYSIS
FRISBEE GAUGE SAMPLE EXTENDED ANALYSIS
(METALLIC ELEMENTS)

Golder Associates
Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: OHEM 07142
Report Number: OHEM/07142/CA/0001 (Revision 0)
Report Date: 19 Apr 2012

Method Number FD01: The Determination of Fugitive Dust based on BS 2690: part 120: 1981
(Mass of collected deposit expressed in mg is the UKAS Accredited Result reported)
The metallic analysis was carried out to a UKAS accredited method by the sub-contract laboratory employed.
Environmental Scientifics Group Limited. does not accept responsibility for the sampling associated with the results included within this report.

Dust analysed by: **Lynne Dent, Senior Analyst**
Metals analysed by: **Leszek Bielawski, Analyst - Specialist Chemistry**

Authorised By:

.....
N J Fenwick, Laboratory Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01 283 554487

TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	1
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44995**

Mass of Deposit (mg)	**98.83**
Deposition Rate (mg.m^{-2}day^{-1})	**83**

Element	Mass (mg)	Deposition Rate (mg.m^{-2}day^{-1})
Aluminium	4.7	3.940167
Arsenic	0.003	0.002515
Barium	0.03	0.02515
Cadmium	0.00007	0.000059
Calcium	2.7	2.2635
Chromium	0.0091	0.007629
Cobalt	0.0031	0.002599
Copper	0.044	0.036887
Iron	4.8	4.024
Lead	0.013	0.010898
Magnesium	0.55	0.461083
Manganese	0.23	0.192817
Mercury	<0.0004	<0.000335
Molybdenum	0.0054	0.004527
Nickel	0.0054	0.004527
Selenium	<0.0001	<0.000084
Zinc	0.54	0.4527

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	2
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44996**

Mass of Deposit (mg)	**85.73**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**72**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.4	3.688667
Arsenic	0.0023	0.001928
Barium	0.026	0.021797
Cadmium	0.00004	0.000034
Calcium	2.2	1.844333
Chromium	0.0076	0.006371
Cobalt	0.0027	0.002264
Copper	0.037	0.031018
Iron	4.2	3.521
Lead	0.0097	0.008132
Magnesium	0.52	0.435933
Manganese	0.18	0.1509
Mercury	<0.0004	<0.000335
Molybdenum	0.0054	0.004527
Nickel	0.005	0.004192
Selenium	0.0001	0.000084
Zinc	0.5	0.419167

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	3
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44997**

Mass of Deposit (mg)	**72.33**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**61**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	5.1	4.2755
Arsenic	0.00093	0.00078
Barium	0.021	0.017605
Cadmium	<0.00002	<0.000017
Calcium	0.3	0.2515
Chromium	0.01	0.008383
Cobalt	0.0015	0.001258
Copper	0.029	0.024312
Iron	3.5	2.934167
Lead	0.0024	0.002012
Magnesium	0.36	0.3018
Manganese	0.046	0.038563
Mercury	<0.0004	<0.000335
Molybdenum	0.0053	0.004443
Nickel	0.0048	0.004024
Selenium	<0.0001	<0.000084
Zinc	0.023	0.019282

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	4
Period:	02/01/2012 - 01/02/2012 (30 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44998**

Mass of Deposit (mg)	**177.27**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**149**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	11	9.221667
Arsenic	0.0026	0.00218
Barium	0.034	0.028503
Cadmium	0.00008	0.000067
Calcium	0.58	0.486233
Chromium	0.024	0.02012
Cobalt	0.0025	0.002096
Copper	0.043	0.036048
Iron	8.2	6.874333
Lead	0.015	0.012575
Magnesium	0.49	0.410783
Manganese	0.09	0.07545
Mercury	<0.0004	<0.000335
Molybdenum	0.0056	0.004695
Nickel	0.008	0.006707
Selenium	0.0004	0.000335
Zinc	0.044	0.036887

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	5
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**44999**

Mass of Deposit (mg)	**72.1**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**65**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.4	3.952143
Arsenic	0.00068	0.000611
Barium	0.022	0.019761
Cadmium	0.00003	0.000027
Calcium	0.32	0.287429
Chromium	0.0085	0.007635
Cobalt	0.0015	0.001347
Copper	0.031	0.027845
Iron	2.6	2.335357
Lead	0.0037	0.003323
Magnesium	0.36	0.323357
Manganese	0.047	0.042216
Mercury	<0.0004	<0.000359
Molybdenum	0.0054	0.00485
Nickel	0.0039	0.003503
Selenium	<0.0001	<0.00009
Zinc	0.017	0.01527

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	6
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**45000**

Mass of Deposit (mg)	**81.55**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**73**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.9	4.40125
Arsenic	0.0016	0.001437
Barium	0.014	0.012575
Cadmium	0.00003	0.000027
Calcium	0.23	0.206589
Chromium	0.013	0.011677
Cobalt	0.0011	0.000988
Copper	0.028	0.02515
Iron	5.4	4.850357
Lead	0.0026	0.002335
Magnesium	0.21	0.188625
Manganese	0.042	0.037725
Mercury	<0.0004	<0.000359
Molybdenum	0.0055	0.00494
Nickel	0.0035	0.003144
Selenium	<0.0001	<0.00009
Zinc	0.016	0.014371

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	7
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**45001**

Mass of Deposit (mg)	**122.54**
Deposition Rate (mg.m^{-2}day^{-1})	**110**

Element	Mass (mg)	Deposition Rate (mg.m^{-2}day^{-1})
Aluminium	8.3	7.455179
Arsenic	0.0021	0.001886
Barium	0.028	0.02515
Cadmium	0.00004	0.000036
Calcium	0.46	0.413179
Chromium	0.018	0.016168
Cobalt	0.0019	0.001707
Copper	0.049	0.044012
Iron	6.1	5.479107
Lead	0.0082	0.007365
Magnesium	0.45	0.404196
Manganese	0.066	0.059282
Mercury	<0.0004	<0.000359
Molybdenum	0.0057	0.00512
Nickel	0.0067	0.006018
Selenium	0.0002	0.00018
Zinc	0.035	0.031438

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 07142
Site:	Guinea, Bissau
Gauge Location:	8
Period:	03/01/2012 - 31/01/2012 (28 days)
Date Received:	15/03/2012
Dust Date Analysed:	19/03/2012
Metal Date Analysed:	30/03/2012

Sample ID № (OHEM...)	**45002**

Mass of Deposit (mg)	**65.54**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**59**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Aluminium	4.2	3.7725
Arsenic	0.00045	0.000404
Barium	0.02	0.017964
Cadmium	<0.00002	<0.000018
Calcium	0.27	0.242518
Chromium	0.0075	0.006737
Cobalt	0.0013	0.001168
Copper	0.027	0.024252
Iron	2.1	1.88625
Lead	0.0021	0.001886
Magnesium	0.35	0.314375
Manganese	0.04	0.035929
Mercury	<0.0004	<0.000359
Molybdenum	0.0051	0.004581
Nickel	0.0038	0.003413
Selenium	<0.0001	<0.00009
Zinc	0.014	0.012575

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UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 07153

Report Number: FD/ 03202

Report Date: 26/03/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

Environmental Scientifics Group Limited does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment:

Authorised by:

HELatham

.....

Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....

N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045045

Site Description Golder Associates - Guinea, Bissau

Sample 1

Date Received 16/03/2012 Sampling Period 01/02/2012 to 01/03/2012 29 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 154

Deposition ($mg.m^{-2}d^{-1}$) 134

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045046

Site Description Golder Associates - Guinea, Bissau

Sample 2

Date Received 16/03/2012 Sampling Period 01/02/2012 to 01/03/2012 29 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 148

Deposition ($mg.m^{-2}d^{-1}$) 128

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045047

Site Description Golder Associates - Guinea, Bissau

Sample 3

Date Received 16/03/2012 Sampling Period 01/02/2012 to 01/03/2012 29 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 169

Deposition ($mg.m^{-2}d^{-1}$) 147

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045048

Site Description Golder Associates - Guinea, Bissau

Sample 4

Date Received 16/03/2012 Sampling Period 01/02/2012 to 01/03/2012 29 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 194

Deposition ($mg.m^{-2}d^{-1}$) 168

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045049

Site Description Golder Associates - Guinea, Bissau

Sample 5

Date Received 16/03/2012 Sampling Period 31/01/2012 to 03/03/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 193

Deposition ($mg.m^{-2}d^{-1}$) 152

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045050

Site Description Golder Associates - Guinea, Bissau

Sample 6

Date Received 16/03/2012 Sampling Period 31/01/2012 to 03/03/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 178

Deposition ($mg.m^{-2}d^{-1}$) 140

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045051

Site Description Golder Associates - Guinea, Bissau

Sample 7

Date Received 16/03/2012 Sampling Period 31/01/2012 to 03/03/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 209

Deposition ($mg.m^{-2}d^{-1}$) 164

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03202 Job Number 07153 ID Number 045052

Site Description Golder Associates - Guinea, Bissau

Sample 8

Date Received 16/03/2012 Sampling Period 31/01/2012 to 03/03/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 175

Deposition ($mg.m^{-2}d^{-1}$) 138

Detection Limit (mg) 0.5 Date Tested 21/03/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 07482

Report Number: FD/ 03389

Report Date: 18/05/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

Environmental Scientifics Group Limited does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment:

Authorised by:

HELatham

.....

Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....

N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046948

Site Description Golder Associates - Guinea, Bissau

Sample 1

Date Received 03/05/2012 Sampling Period 01/03/2012 to 02/04/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 190

Deposition ($mg.m^{-2}d^{-1}$) 149

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046949

Site Description Golder Associates - Guinea, Bissau

Sample 2

Date Received 03/05/2012 Sampling Period 01/03/2012 to 02/04/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 166

Deposition ($mg.m^{-2}d^{-1}$) 130

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046950

Site Description Golder Associates - Guinea, Bissau

Sample 3

Date Received 03/05/2012 Sampling Period 01/03/2012 to 02/04/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 181

Deposition ($mg.m^{-2}d^{-1}$) 142

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046951

Site Description Golder Associates - Guinea, Bissau

Sample 4

Date Received 03/05/2012 Sampling Period 01/03/2012 to 02/04/2012 32 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 294

Deposition ($mg.m^{-2}d^{-1}$) 231

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046952

Site Description Golder Associates - Guinea, Bissau

Sample 5

Date Received 03/05/2012 Sampling Period 03/03/2012 to 03/04/2012 31 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 194

Deposition ($mg.m^{-2}d^{-1}$) 157

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046953

Site Description Golder Associates - Guinea, Bissau

Sample 6

Date Received 03/05/2012 Sampling Period 03/03/2012 to 03/04/2012 31 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 185

Deposition ($mg.m^{-2}d^{-1}$) 150

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046954

Site Description Golder Associates - Guinea, Bissau

Sample 7

Date Received 03/05/2012 Sampling Period 03/03/2012 to 03/04/2012 31 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 141

Deposition ($mg.m^{-2}d^{-1}$) 114

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03389 Job Number 07482 ID Number 046955

Site Description Golder Associates - Guinea, Bissau

Sample 8

Date Received 03/05/2012 Sampling Period 03/03/2012 to 03/04/2012 31 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 140

Deposition ($mg.m^{-2}d^{-1}$) 114

Detection Limit (mg) 0.5 Date Tested 09/05/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 07716

Report Number: FD/ 03512

Report Date: 21/06/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

Environmental Scientifics Group Limited does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment: Sampling period 02/04/12 - 10/05/12

Authorised by:

HELatham

.....

Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....

N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048176

Site Description Golder Associates - Guinea, Bissau

Sample 1

Date Received 07/06/2012 Sampling Period 02/04/2012 to 10/05/2012 38 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 385

Deposition ($mg.m^{-2}d^{-1}$) 255

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 03512 Job Number 07716 ID Number 048177

Site Description Golder Associates - Guinea, Bissau

Sample 2

Date Received 07/06/2012 Sampling Period 02/04/2012 to 10/05/2012 38 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 240

Deposition ($mg.m^{-2}d^{-1}$) 159

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048178

Site Description Golder Associates - Guinea, Bissau

Sample 3

Date Received 07/06/2012 Sampling Period 02/04/2012 to 10/05/2012 38 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 322

Deposition ($mg.m^{-2}d^{-1}$) 213

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048179

Site Description Golder Associates - Guinea, Bissau

Sample 4

Date Received 07/06/2012 Sampling Period 02/04/2012 to 10/05/2012 38 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 370

Deposition ($mg.m^{-2}d^{-1}$) 245

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048180

Site Description Golder Associates - Guinea, Bissau

Sample 5

Date Received 07/06/2012 Sampling Period 03/04/2012 to 09/05/2012 36 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 326

Deposition ($mg.m^{-2}d^{-1}$) 228

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048181

Site Description Golder Associates - Guinea, Bissau

Sample 6

Date Received 07/06/2012 Sampling Period 03/04/2012 to 09/05/2012 36 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 360

Deposition ($mg.m^{-2}d^{-1}$) 252

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048182

Site Description Golder Associates - Guinea, Bissau

Sample 7

Date Received 07/06/2012 Sampling Period 03/04/2012 to 09/05/2012 36 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 203

Deposition ($mg.m^{-2}d^{-1}$) 142

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 03512 Job Number 07716 ID Number 048183

Site Description Golder Associates - Guinea, Bissau

Sample 8

Date Received 07/06/2012 Sampling Period 03/04/2012 to 09/05/2012 36 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 205

Deposition ($mg.m^{-2}d^{-1}$) 143

Detection Limit (mg) 0.5 Date Tested 21/06/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 08834
Report Number: FD/ 04161
Report Date: 04/12/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

Environmental Scientifics Group Limited does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment:

Authorised by:

HELatham
.....
Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....
N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054416

Site Description Golder Associates - Guinea, Bissau

Sample GB 1

Date Received 30/10/2012 Sampling Period 06/09/2012 to 17/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 27

Deposition ($mg.m^{-2}d^{-1}$) 17

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054417

Site Description Golder Associates - Guinea, Bissau

Sample GB 2

Date Received 30/10/2012 Sampling Period 06/09/2012 to 18/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 22

Deposition ($mg.m^{-2}d^{-1}$) 13

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054418

Site Description Golder Associates - Guinea, Bissau

Sample GB 3

Date Received 30/10/2012 Sampling Period 07/09/2012 to 19/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 7

Deposition ($mg.m^{-2}d^{-1}$) 4

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054419

Site Description Golder Associates - Guinea, Bissau

Sample GB 4

Date Received 30/10/2012 Sampling Period 06/09/2012 to 18/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 41

Deposition ($mg.m^{-2}d^{-1}$) 25

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054420

Site Description Golder Associates - Guinea, Bissau

Sample GB 5

Date Received 30/10/2012 Sampling Period 05/09/2012 to 16/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 53

Deposition ($mg.m^{-2}d^{-1}$) 33

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054421

Site Description Golder Associates - Guinea, Bissau

Sample GB 8

Date Received 30/10/2012 Sampling Period 05/09/2012 to 16/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 59

Deposition ($mg.m^{-2}d^{-1}$) 36

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054422

Site Description Golder Associates - Guinea, Bissau

Sample DSO 1

Date Received 30/10/2012 Sampling Period 03/09/2012 to 15/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 64

Deposition ($mg.m^{-2}d^{-1}$) 38

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054423

Site Description Golder Associates - Guinea, Bissau

Sample DSO 2

Date Received 30/10/2012 Sampling Period 03/09/2012 to 15/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 11

Deposition ($mg.m^{-2}d^{-1}$) 7

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054424

Site Description Golder Associates - Guinea, Bissau

Sample DSO 3

Date Received 30/10/2012 Sampling Period 04/09/2012 to 15/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 69

Deposition ($mg.m^{-2}d^{-1}$) 42

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 04161 Job Number 08834 ID Number 054425

Site Description Golder Associates - Guinea, Bissau

Sample DSO 4

Date Received 30/10/2012 Sampling Period 06/09/2012 to 17/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 35

Deposition ($mg.m^{-2}d^{-1}$) 21

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 04161 Job Number 08834 ID Number 054426

Site Description Golder Associates - Guinea, Bissau

Sample DSO 5

Date Received 30/10/2012 Sampling Period 07/09/2012 to 18/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 56

Deposition ($mg.m^{-2}d^{-1}$) 34

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

Environmental Scientifics Group

UKAS TESTING 1205

RESULTS OF ANALYSIS
FRISBEE GAUGE SAMPLE EXTENDED ANALYSIS
(METALLIC ELEMENTS)

Golder Associates
Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: OHEM 08834
Report Number: OHEM/08834/CA/0001 (Revision 0)
Report Date: 04 Dec 2012

Method Number FD01: The Determination of Fugitive Dust based on BS 2690: part 120: 1981
(Mass of collected deposit expressed in mg is the UKAS Accredited Result reported)
The metallic analysis was carried out to a UKAS accredited method by the sub-contract laboratory employed.
Environmental Scientifics Group Limited. does not accept responsibility for the sampling associated with the results included within this report.

Dust analysed by: **Dawn Harris, Analyst**
Metals analysed by: **Leszek Bielawski, Analyst - Specialist Chemistry**

Authorised By:

.....
N J Fenwick, Laboratory Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01 283 554487

TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 1
Period:	06/09/2012 - 17/10/2012 (41 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54416**

Mass of Deposit (mg)	**26.73**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**16**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0086	0.005275
Cadmium	0.00002	0.000012
Calcium	0.12	0.07361
Chromium	0.0025	0.001534
Cobalt	0.00043	0.000264
Copper	0.018	0.011041
Iron	0.74	0.453927
Lead	0.0019	0.001165
Magnesium	0.089	0.054594
Manganese	0.018	0.011041
Molybdenum	0.0041	0.002515
Nickel	0.003	0.00184
Zinc	0.02	0.012268

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 2
Period:	06/09/2012 - 18/10/2012 (42 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54417**

Mass of Deposit (mg)	**21.54**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**13**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0067	0.004012
Cadmium	0.00001	0.000006
Calcium	0.089	0.053294
Chromium	0.0018	0.001078
Cobalt	0.00032	0.000192
Copper	0.021	0.012575
Iron	0.51	0.305393
Lead	0.00074	0.000443
Magnesium	0.054	0.032336
Manganese	0.013	0.007785
Molybdenum	0.004	0.002395
Nickel	0.0024	0.001437
Zinc	0.023	0.013773

Environmental Scientifics Group Limited
Registered office: ESG House, Bretby Business Park, Ashby Road, Burton on Trent DE15 0YZ Registered in England no. 2880501
Telephone: 01283 554400 Fax: 01283 554422
www.esg.co.uk
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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 3
Period:	07/09/2012 - 19/10/2012 (42 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54418**

Mass of Deposit (mg)	**6.58**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**4**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0049	0.002934
Cadmium	0.000006	0.000004
Calcium	0.04	0.023952
Chromium	0.00074	0.000443
Cobalt	0.00012	0.000072
Copper	0.013	0.007785
Iron	0.2	0.119762
Lead	0.00036	0.000216
Magnesium	0.021	0.012575
Manganese	0.0041	0.002455
Molybdenum	0.0021	0.001258
Nickel	0.001	0.000599
Zinc	0.0045	0.002695

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 4
Period:	06/09/2012 - 18/10/2012 (42 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54419**

Mass of Deposit (mg)	**40.83**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**24**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.012	0.007186
Cadmium	0.00003	0.000018
Calcium	0.16	0.09581
Chromium	0.0038	0.002275
Cobalt	0.00054	0.000323
Copper	0.025	0.01497
Iron	1.3	0.778452
Lead	0.002	0.001198
Magnesium	0.21	0.12575
Manganese	0.021	0.012575
Molybdenum	0.0041	0.002455
Nickel	0.0059	0.003533
Zinc	0.014	0.008383

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 5
Period:	05/09/2012 - 16/10/2012 (41 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54420**

Mass of Deposit (mg)	**52.88**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**32**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0098	0.006011
Cadmium	0.00002	0.000012
Calcium	0.11	0.067476
Chromium	0.0046	0.002822
Cobalt	0.00041	0.000252
Copper	0.023	0.014109
Iron	1.8	1.104146
Lead	0.0024	0.001472
Magnesium	0.15	0.092012
Manganese	0.01	0.006134
Molybdenum	0.0041	0.002515
Nickel	0.0025	0.001534
Zinc	0.0093	0.005705

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 8
Period:	05/09/2012 - 16/10/2012 (41 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54421**

Mass of Deposit (mg)	**59.15**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**36**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.01	0.006134
Cadmium	0.00002	0.000012
Calcium	0.15	0.092012
Chromium	0.0039	0.002392
Cobalt	0.00059	0.000362
Copper	0.031	0.019016
Iron	1.3	0.797439
Lead	0.0016	0.000981
Magnesium	0.2	0.122683
Manganese	0.011	0.006748
Molybdenum	0.0042	0.002576
Nickel	0.0031	0.001902
Zinc	0.0083	0.005091

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-END OF REPORT-

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 08834
Report Number: FD/ 04161
Report Date: 04/12/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

Environmental Scientifics Group Limited does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment:

Authorised by:

HELatham
.....
Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....
N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054416

Site Description Golder Associates - Guinea, Bissau

Sample GB 1

Date Received 30/10/2012 Sampling Period 06/09/2012 to 17/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 27

Deposition ($mg.m^{-2}d^{-1}$) 17

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054417

Site Description Golder Associates - Guinea, Bissau

Sample GB 2

Date Received 30/10/2012 Sampling Period 06/09/2012 to 18/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 22

Deposition ($mg.m^{-2}d^{-1}$) 13

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054418

Site Description Golder Associates - Guinea, Bissau

Sample GB 3

Date Received 30/10/2012 Sampling Period 07/09/2012 to 19/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 7

Deposition ($mg.m^{-2}d^{-1}$) 4

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054419

Site Description Golder Associates - Guinea, Bissau

Sample GB 4

Date Received 30/10/2012 Sampling Period 06/09/2012 to 18/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 41

Deposition ($mg.m^{-2}d^{-1}$) 25

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054420

Site Description Golder Associates - Guinea, Bissau

Sample GB 5

Date Received 30/10/2012 Sampling Period 05/09/2012 to 16/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 53

Deposition ($mg.m^{-2}d^{-1}$) 33

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054421

Site Description Golder Associates - Guinea, Bissau

Sample GB 8

Date Received 30/10/2012 Sampling Period 05/09/2012 to 16/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 59

Deposition ($mg.m^{-2}d^{-1}$) 36

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054422

Site Description Golder Associates - Guinea, Bissau

Sample DSO 1

Date Received 30/10/2012 Sampling Period 03/09/2012 to 15/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 64

Deposition ($mg.m^{-2}d^{-1}$) 38

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054423

Site Description Golder Associates - Guinea, Bissau

Sample DSO 2

Date Received 30/10/2012 Sampling Period 03/09/2012 to 15/10/2012 42 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 11

Deposition ($mg.m^{-2}d^{-1}$) 7

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04161 Job Number 08834 ID Number 054424

Site Description Golder Associates - Guinea, Bissau

Sample DSO 3

Date Received 30/10/2012 Sampling Period 04/09/2012 to 15/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 69

Deposition ($mg.m^{-2}d^{-1}$) 42

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 04161 Job Number 08834 ID Number 054425

Site Description Golder Associates - Guinea, Bissau

Sample DSO 4

Date Received 30/10/2012 Sampling Period 06/09/2012 to 17/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 35

Deposition ($mg.m^{-2}d^{-1}$) 21

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

UKAS TESTING 1205

Report Number FD/ 04161 Job Number 08834 ID Number 054426

Site Description Golder Associates - Guinea, Bissau

Sample DSO 5

Date Received 30/10/2012 Sampling Period 07/09/2012 to 18/10/2012 41 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 56

Deposition ($mg.m^{-2}d^{-1}$) 34

Detection Limit (mg) 0.5 Date Tested 21/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

Environmental Scientifics Group

UKAS TESTING 1205

RESULTS OF ANALYSIS
FRISBEE GAUGE SAMPLE EXTENDED ANALYSIS
(METALLIC ELEMENTS)

Golder Associates
Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: OHEM 08834
Report Number: OHEM/08834/CA/0001 (Revision 0)
Report Date: 04 Dec 2012

Method Number FD01: The Determination of Fugitive Dust based on BS 2690: part 120: 1981
(Mass of collected deposit expressed in mg is the UKAS Accredited Result reported)
The metallic analysis was carried out to a UKAS accredited method by the sub-contract laboratory employed.
Environmental Scientifics Group Limited. does not accept responsibility for the sampling associated with the results included within this report.

Dust analysed by: **Dawn Harris, Analyst**
Metals analysed by: **Leszek Bielawski, Analyst - Specialist Chemistry**

Authorised By:

.....
N J Fenwick, Laboratory Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01 283 554487

TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 1
Period:	06/09/2012 - 17/10/2012 (41 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54416**

Mass of Deposit (mg)	**26.73**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**16**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0086	0.005275
Cadmium	0.00002	0.000012
Calcium	0.12	0.07361
Chromium	0.0025	0.001534
Cobalt	0.00043	0.000264
Copper	0.018	0.011041
Iron	0.74	0.453927
Lead	0.0019	0.001165
Magnesium	0.089	0.054594
Manganese	0.018	0.011041
Molybdenum	0.0041	0.002515
Nickel	0.003	0.00184
Zinc	0.02	0.012268

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 2
Period:	06/09/2012 - 18/10/2012 (42 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54417**

Mass of Deposit (mg)	**21.54**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**13**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0067	0.004012
Cadmium	0.00001	0.000006
Calcium	0.089	0.053294
Chromium	0.0018	0.001078
Cobalt	0.00032	0.000192
Copper	0.021	0.012575
Iron	0.51	0.305393
Lead	0.00074	0.000443
Magnesium	0.054	0.032336
Manganese	0.013	0.007785
Molybdenum	0.004	0.002395
Nickel	0.0024	0.001437
Zinc	0.023	0.013773

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TEST REPORT

UKAS TESTING 1205

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CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 3
Period:	07/09/2012 - 19/10/2012 (42 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54418**

Mass of Deposit (mg)	**6.58**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**4**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0049	0.002934
Cadmium	0.000006	0.000004
Calcium	0.04	0.023952
Chromium	0.00074	0.000443
Cobalt	0.00012	0.000072
Copper	0.013	0.007785
Iron	0.2	0.119762
Lead	0.00036	0.000216
Magnesium	0.021	0.012575
Manganese	0.0041	0.002455
Molybdenum	0.0021	0.001258
Nickel	0.001	0.000599
Zinc	0.0045	0.002695

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 4
Period:	06/09/2012 - 18/10/2012 (42 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54419**

Mass of Deposit (mg)	**40.83**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**24**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.012	0.007186
Cadmium	0.00003	0.000018
Calcium	0.16	0.09581
Chromium	0.0038	0.002275
Cobalt	0.00054	0.000323
Copper	0.025	0.01497
Iron	1.3	0.778452
Lead	0.002	0.001198
Magnesium	0.21	0.12575
Manganese	0.021	0.012575
Molybdenum	0.0041	0.002455
Nickel	0.0059	0.003533
Zinc	0.014	0.008383

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TEST REPORT

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OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 5
Period:	05/09/2012 - 16/10/2012 (41 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54420**

Mass of Deposit (mg)	**52.88**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**32**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.0098	0.006011
Cadmium	0.00002	0.000012
Calcium	0.11	0.067476
Chromium	0.0046	0.002822
Cobalt	0.00041	0.000252
Copper	0.023	0.014109
Iron	1.8	1.104146
Lead	0.0024	0.001472
Magnesium	0.15	0.092012
Manganese	0.01	0.006134
Molybdenum	0.0041	0.002515
Nickel	0.0025	0.001534
Zinc	0.0093	0.005705

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TEST REPORT

UKAS TESTING 1205

OCCUPATIONAL HYGIENE & ENVIRONMENTAL MONITORING LABORATORY

CHEMICAL ANALYSIS OF ENVIRONMENTAL DUST GAUGE SAMPLE DEPOSITS (ICP METHODS)

Job Number:	OHEM 08834
Site:	Guinea, Bissau
Gauge Location:	GB 8
Period:	05/09/2012 - 16/10/2012 (41 days)
Date Received:	30/10/2012
Dust Date Analysed:	21/11/2012
Metal Date Analysed:	04/12/2012

Sample ID № (OHEM...)	**54421**

Mass of Deposit (mg)	**59.15**
Deposition Rate ($mg.m^{-2}day^{-1}$)	**36**

Element	Mass (mg)	Deposition Rate ($mg.m^{-2}day^{-1}$)
Barium	0.01	0.006134
Cadmium	0.00002	0.000012
Calcium	0.15	0.092012
Chromium	0.0039	0.002392
Cobalt	0.00059	0.000362
Copper	0.031	0.019016
Iron	1.3	0.797439
Lead	0.0016	0.000981
Magnesium	0.2	0.122683
Manganese	0.011	0.006748
Molybdenum	0.0042	0.002576
Nickel	0.0031	0.001902
Zinc	0.0083	0.005091

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-END OF REPORT-

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 08969
Report Number: FD/ 04145
Report Date: 03/12/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

Environmental Scientifics Group Limited does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment:

Authorised by:

HELatham

.....
Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....
N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055185

Site Description Golder Associates - Guinea, Bissau

Sample GB 1

Date Received 16/11/2012 Sampling Period 17/10/2012 to 11/11/2012 25 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 43

Deposition ($mg.m^{-2}d^{-1}$) 43

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055186

Site Description Golder Associates - Guinea, Bissau

Sample GB 2

Date Received 16/11/2012 Sampling Period 18/10/2012 to 11/11/2012 24 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 24

Deposition ($mg.m^{-2}d^{-1}$) 25

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055187

Site Description Golder Associates - Guinea, Bissau

Sample GB 3

Date Received 16/11/2012 Sampling Period 18/10/2012 to 11/11/2012 24 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 26

Deposition ($mg.m^{-2}d^{-1}$) 27

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055188

Site Description Golder Associates - Guinea, Bissau

Sample GB 4

Date Received 16/11/2012 Sampling Period 18/10/2012 to 11/11/2012 24 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 75

Deposition ($mg.m^{-2}d^{-1}$) 79

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055189

Site Description Golder Associates - Guinea, Bissau

Sample GB 5

Date Received 16/11/2012 Sampling Period 18/10/2012 to 11/11/2012 24 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 77

Deposition ($mg.m^{-2}d^{-1}$) 81

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055190

Site Description Golder Associates - Guinea, Bissau

Sample GB 8

Date Received 16/11/2012 Sampling Period 16/10/2012 to 10/11/2012 25 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 52

Deposition ($mg.m^{-2}d^{-1}$) 52

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055191

Site Description Golder Associates - Guinea, Bissau

Sample DSO 1

Date Received 16/11/2012 Sampling Period 15/10/2012 to 09/11/2012 25 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 42

Deposition ($mg.m^{-2}d^{-1}$) 42

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055192

Site Description Golder Associates - Guinea, Bissau

Sample DSO 2

Date Received 16/11/2012 Sampling Period 15/10/2012 to 09/11/2012 25 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 73

Deposition ($mg.m^{-2}d^{-1}$) 73

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055193

Site Description Golder Associates - Guinea, Bissau

Sample DSO 3

Date Received 16/11/2012 Sampling Period 15/10/2012 to 09/11/2012 25 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 70

Deposition ($mg.m^{-2}d^{-1}$) 70

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055194

Site Description Golder Associates - Guinea, Bissau

Sample DSO 4

Date Received 16/11/2012 Sampling Period 17/10/2012 to 11/11/2012 25 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 49

Deposition ($mg.m^{-2}d^{-1}$) 49

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

TEST REPORT

1205

Report Number FD/ 04145 Job Number 08969 ID Number 055195

Site Description Golder Associates - Guinea, Bissau

Sample DSO 5

Date Received 16/11/2012 Sampling Period 18/10/2012 to 11/11/2012 24 Days

Method FD01 **Gauge Type** Frisbee deposit gauge

Dust mass (mg) 37

Deposition ($mg.m^{-2}d^{-1}$) 39

Detection Limit (mg) 0.5 Date Tested 29/11/2012

Method

Result **LOD** **Date Tested**

Test / Direction	Measured Value	Units	Reported Result	Units
No additional tests requested				

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 06729
Report Number: FD/ 02944
Report Date: 16/01/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

ESG Ltd does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment:

Authorised by:

HELatham

.....
Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....
N J Fenwick, Laboratory Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042650

Site Description Golder Associates - Guinea, Bissau

Sample 1

Date Received 04/01/2012 Dates Sampled 31/10/2011 to 30/11/2011 30 Days

Dust mass (mg) 34

Deposition ($mg.m^{-2}d^{-1}$) 29

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042651

Site Description Golder Associates - Guinea, Bissau

Sample 2

Date Received 04/01/2012 Dates Sampled 31/10/2011 to 30/11/2011 30 Days

Dust mass (mg) 36

Deposition ($mg.m^{-2}d^{-1}$) 30

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042652

Site Description Golder Associates - Guinea, Bissau

Sample 3

Date Received 04/01/2012 Dates Sampled 31/10/2011 to 01/12/2011 31 Days

Dust mass (mg) 38

Deposition ($mg.m^{-2}d^{-1}$) 31

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042653

Site Description Golder Associates - Guinea, Bissau

Sample 4

Date Received 04/01/2012 Dates Sampled 31/10/2011 to 30/11/2011 30 Days

Dust mass (mg) 91

Deposition ($mg.m^{-2}d^{-1}$) 76

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042654

Site Description Golder Associates - Guinea, Bissau

Sample 5

Date Received 04/01/2012 Dates Sampled 01/11/2011 to 01/12/2011 30 Days

Dust mass (mg) 44

Deposition ($mg.m^{-2}d^{-1}$) 37

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042655

Site Description Golder Associates - Guinea, Bissau

Sample 6

Date Received 04/01/2012 Dates Sampled 01/11/2011 to 01/12/2011 30 Days

Dust mass (mg) 83

Deposition ($mg.m^{-2}d^{-1}$) 70

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042656

Site Description Golder Associates - Guinea, Bissau

Sample 7

Date Received 04/01/2012 Dates Sampled 01/11/2011 to 01/12/2011 30 Days

Dust mass (mg) 47

Deposition ($mg.m^{-2}d^{-1}$) 39

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 02944 Job Number 06729 ID Number 042657

Site Description Golder Associates - Guinea, Bissau

Sample 8

Date Received 04/01/2012 Dates Sampled 02/11/2011 to 01/12/2011 29 Days

Dust mass (mg) 27

Deposition ($mg.m^{-2}d^{-1}$) 23

Detection Limit (mg) 0.5 Date Tested 12/01/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

Environmental Scientifics Group

UKAS TESTING 1205

OCCUPATIONAL HYGIENE AND ENVIRONMENTAL MONITORING LABORATORY

TEST REPORT

Site:
Golder Associates - Guinea, Bissau

Client:
Mr D Birkinshaw
Air Quality Consultant
Golder Associates (UK Ltd)
Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire
NG12 5BL

Job Number: 06891

Report Number: FD/ 03046

Report Date: 21/02/2012

Method N°. FD01: The determination of Fugitive Dust Based on BS 872: 2005 (Mass of dust (mg) is the UKAS accredited test.)

ESG Ltd does not accept any responsibility for the sampling associated with the results reported below.
The dust samples will be retained at the laboratory for a period of 6 months in case extended analysis is required in future. Liquids associated with dust samples are not normally retained at the laboratory.

Report Comment: No analysis carried out on sample 7 due to contamination

Authorised by:

HELatham

.....

Helen Latham, Senior Analyst
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554486

Approved by:

.....

N J Fenwick, Technical Manager
Occupational Hygiene & Environmental Monitoring
Direct Dial: 01283 554487

TEST REPORT

1205

Report Number FD/ 03046 Job Number 06891 ID Number 043575

Site Description Golder Associates - Guinea, Bissau

Sample 1

Date Received 06/02/2012 Dates Sampled 30/11/2011 to 02/01/2012 33 Days

Dust mass (mg) 54

Deposition ($mg.m^{-2}d^{-1}$) 41

Detection Limit (mg) 0.5 Date Tested 09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 03046 Job Number 06891 ID Number 043576

Site Description Golder Associates - Guinea, Bissau

Sample 2

Date Received 06/02/2012 Dates Sampled 30/11/2011 to 02/01/2012 33 Days

Dust mass (mg) 74

Deposition ($mg.m^{-2}d^{-1}$) 56

Detection Limit (mg) 0.5 Date Tested 09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number	FD/ 03046	Job Number	06891	ID Number	043577
Site Description	Golder Associates - Guinea, Bissau				
Sample	3				
Date Received	06/02/2012	Dates Sampled	01/12/2011 to 02/01/2012	32	Days

Dust mass (mg) 68

Deposition ($mg.m^{-2}d^{-1}$) 53

Detection Limit (mg) 0.5 Date Tested 09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 03046 Job Number 06891 ID Number 043578

Site Description Golder Associates - Guinea, Bissau

Sample 4

Date Received 06/02/2012 Dates Sampled 30/11/2011 to 02/01/2012 33 Days

Dust mass (mg) 223

Deposition ($mg.m^{-2}d^{-1}$) 170

Detection Limit (mg) 0.5 Date Tested 09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number	FD/ 03046	Job Number	06891	ID Number	043579
Site Description	Golder Associates - Guinea, Bissau				
Sample	5				
Date Received	06/02/2012	Dates Sampled	01/12/2011 to 03/01/2012		33 Days

Dust mass (mg) 59

Deposition ($mg.m^{-2}d^{-1}$) 45

Detection Limit (mg) 0.5 Date Tested 09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number FD/ 03046 Job Number 06891 ID Number 043580

Site Description Golder Associates - Guinea, Bissau

Sample 6

Date Received 06/02/2012 Dates Sampled 01/12/2011 to 03/01/2012 33 Days

Dust mass (mg) 164

Deposition ($mg.m^{-2}d^{-1}$) 125

Detection Limit (mg) 0.5 Date Tested 09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

TEST REPORT

1205

Report Number	FD/ 03046	Job Number	06891	ID Number	043582
Site Description	Golder Associates - Guinea, Bissau				
Sample	8				
Date Received	06/02/2012	Dates Sampled	01/12/2011 to 03/01/2012	33	Days

Dust mass (mg)	78		
Deposition ($mg.m^{-2}d^{-1}$)	59		
Detection Limit (mg)	0.5	Date Tested	09/02/2012

Test / Direction	Method	LOD	Value	Units	Result	Value	Units	Date Tested
No additional tests requested								

APPENDIX A4

Gaseous VOC Monitoring Results

January 2014
Report No. 13514950200.550/B.0

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

AMENDMENT TO LABORATORY REPORT

REPORT NUMBER	F1155R
CUSTOMER	Golder Associates Attenborough House Browns Lane Business Park Stanton-on-the-wolds Nottinghamshire NG12 5BL
GRADKO LAB REFERENCE	GMSG0307-0319
DATE SAMPLES RECEIVED	13.02.12
DESPATCH REF.NUMBER	SOR007959
JOB NUMBER	Bissau
BOOKING IN REF.	F1155

QUANTITATIVE ANALYSIS FOR BTEX AND SEMI-QUANTITATIVE ANALYSIS FOR TOP 33 VOC'S ON TENAX DIFFUSION TUBES BY GC/MS
Analysis has been carried out in accordance with in-house method GLM 13

Tube Number	**GRA 06149**
Sample ID	**BLANK**

BTEX	**ng on tube**
Benzene	6.89
Toluene	<LOD
Ethylbenzene	<LOD
m/p-Xylene	<LOD
o-Xylene	<LOD

Top 33 VOC'S Compounds	**ng on tube**
Pentadecane	6.05

1 Compound detected

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 04476**
Exposure Time(mins)	**43205**
Sample ID	**GB1**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	1053	12	83
2,4-Dimethyl-1-heptene	574.39	6.65	33.50
Decane	295.17	3.42	19.40
Dodecane	255.52	2.96	20.11
Toluene	240.88	2.79	10.26
Heptane, 4-methyl-	225.38	2.61	11.89
Styrene	211.96	2.45	10.20
1-Pentene, 2-methyl-	207.59	2.40	8.07
Cyclohexanone	202.40	2.34	9.18
Tridecane	166.45	1.93	14.18
2,2,4,4-Tetramethyloctane	146.30	1.69	11.51
Pentane	133.28	1.54	4.44
2-Propanol, 2-methyl-	127.89	1.48	4.38
Nonane, 4-methyl-	108.80	1.26	7.15
Undecane	105.78	1.22	7.64
Decane, 4-methyl-	101.44	1.17	7.33
Pentane, 2-methyl-	92.28	1.07	3.67
Decane, 2,6,6-trimethyl-	91.69	1.06	7.81
Heptane, 2,4-dimethyl-	91.19	1.06	5.40
Octane, 4-methyl-	87.98	1.02	5.21
Octane	83.22	0.96	4.39
Decane, 3,6-dimethyl-	74.30	0.86	5.85
Octane, 3,5,6-trimethyl-	72.42	0.84	5.23
2-Propanol, 1-methoxy-	70.53	0.82	2.94
Nonane, 2,6-dimethyl-	69.01	0.80	4.98
Caprolactam	68.85	0.80	3.60
m/p-Xylene	67.64	0.78	3.32
Limonene	67.11	0.78	4.22
2-Undecene, 4-methyl-	65.63	0.76	5.10
5-Undecene, 3-methyl-	61.20	0.71	4.76
Hexane	61.10	0.71	2.43
Benzene, (1-methylethyl)-	47.48	0.55	2.64
Benzene	39.08	0.45	1.41

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REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 05735**
Exposure Time(mins)	**43219**
Sample ID	**GB2**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	830.21	9.60	65.31
2,4-Dimethyl-1-heptene	515.47	5.96	30.06
Decane	279.70	3.24	18.38
Dodecane	210.47	2.43	16.56
Cyclohexanone	207.69	2.40	9.42
Toluene	203.12	2.35	8.65
Heptane, 4-methyl-	203.12	2.35	10.72
1-Pentene, 2-methyl-	189.94	2.20	7.38
Styrene	185.69	2.15	8.94
Decane, 3,6-dimethyl-	161.88	1.87	12.73
Pentane	124.43	1.44	4.15
2,2,4,4-Tetramethyloctane	115.29	1.33	9.07
2-Propanol, 2-methyl-	109.95	1.27	3.77
Caprolactam	109.49	1.27	5.73
Decane, 4-methyl-	90.09	1.04	6.50
Pentane, 2-methyl-	86.46	1.00	3.44
Nonane, 4-methyl-	84.70	0.98	5.57
Undecane	83.67	0.97	6.04
Heptane, 2,4-dimethyl-	82.72	0.96	4.90
Hexane, 2,4-dimethyl-	73.30	0.85	3.87
Octane	73.30	0.85	3.87
Decane, 2,6,6-trimethyl-	72.48	0.84	6.17
Octane, 4-methyl-	67.72	0.78	4.01
2-Propanol, 1-methoxy-	67.10	0.78	2.79
Limonene	64.68	0.75	4.07
Nonane, 2,6-dimethyl-	63.75	0.74	4.60
m/p-Xylene	57.76	0.67	2.83
2-Undecene, 4-methyl-	56.48	0.65	4.39
Hexane	56.00	0.65	2.23
5-Undecene, 3-methyl-	54.24	0.63	4.22
Benzene, 1-ethyl-3-methyl-	45.90	0.53	2.55
Tetradecane	39.07	0.45	3.58
Oxetane, 2,2-dimethyl-	37.68	0.44	1.50

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
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Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 05978**
Exposure Time(mins)	**43313**
Sample ID	**GB3**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	1363	16	107
2,4-Dimethyl-1-heptene	670.31	7.74	39.00
Decane	333.20	3.85	21.85
Dodecane	280.55	3.24	22.02
Heptane, 4-methyl-	264.61	3.05	13.93
Cyclohexanone	259.03	2.99	11.72
Toluene	252.64	2.92	10.73
Styrene	249.16	2.88	11.97
1-Pentene, 2-methyl-	215.87	2.49	8.37
Tridecane	195.23	2.25	16.59
2,2,4,4-Tetramethyloctane	190.85	2.20	14.98
Caprolactam	164.21	1.90	8.57
Decane, 3,6-dimethyl-	149.65	1.73	11.75
Pentane	136.91	1.58	4.55
Nonane, 4-methyl-	136.23	1.57	8.93
Undecane	132.44	1.53	9.54
Decane, 4-methyl-	117.21	1.35	8.44
Decane, 2,6,6-trimethyl-	115.32	1.33	9.80
Pentane, 2-methyl-	107.55	1.24	4.27
Octane, 4-methyl-	106.32	1.23	6.28
Heptane, 2,4-dimethyl-	105.25	1.22	6.22
Octane	99.23	1.15	5.22
2-Propanol, 2-methyl-	97.69	1.13	3.34
Decane, 2,6,7-trimethyl-	90.31	1.04	7.67
2-Undecene, 4-methyl-	85.41	0.99	6.63
2-Propanol, 1-methoxy-	81.84	0.94	3.40
5-Undecene, 3-methyl-	81.44	0.94	6.32
Nonane, 2,6-dimethyl-	77.24	0.89	5.56
m/p-Xylene	74.20	0.86	3.63
Limonene	72.85	0.84	4.57
Hexane	62.41	0.72	2.48
Benzene, 1-ethyl-3-methyl-	59.84	0.69	3.32
Tetradecane	50.89	0.59	4.65

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Those results obtained using exposure data shall be indicated by an asterisk. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd.

REPORT OFFICIALLY CHECKED

Gradko International Ltd
This signature confirms the authenticity of these results
Signed.....
L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 03730**
Exposure Time(mins)	**43181**
Sample ID	**GB4**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	914.16	10.59	71.98
2,4-Dimethyl-1-heptene	663.09	7.68	38.70
Decane	321.00	3.72	21.11
Dodecane	302.27	3.50	23.80
Toluene	267.33	3.10	11.39
Heptane, 4-methyl-	264.20	3.06	13.95
Styrene	235.57	2.73	11.35
1-Pentene, 2-methyl-	223.98	2.59	8.71
Tridecane	211.40	2.45	18.02
Cyclohexanone	199.83	2.31	9.07
Decane, 3,6-dimethyl-	191.82	2.22	15.10
Pentane	138.01	1.60	4.60
Undecane	133.38	1.54	9.64
2,2,4,4-Tetramethyloctane	123.95	1.44	9.76
Limonene	109.30	1.27	6.88
Heptane, 2,4-dimethyl-	105.06	1.22	6.23
Octane, 4-methyl-	104.04	1.20	6.17
Decane, 4-methyl-	103.52	1.20	7.48
2-Propanol, 2-methyl-	101.19	1.17	3.47
Pentane, 2-methyl-	100.45	1.16	4.00
Caprolactam	94.41	1.09	4.94
Octane	91.44	1.06	4.83
Hexane, 3-methyl-	83.69	0.97	3.88
m/p-Xylene	82.48	0.96	4.05
Nonane, 4-methyl-	82.14	0.95	5.40
Decane, 2,6,6-trimethyl-	79.02	0.91	6.73
2-Undecene, 4-methyl-	78.85	0.91	6.14
2-Propanol, 1-methoxy-	76.96	0.89	3.21
5-Undecene, 3-methyl-	76.62	0.89	5.96
Nonane, 2,6-dimethyl-	72.70	0.84	5.25
Hexane	67.32	0.78	2.68
Undecane, 5-methyl-	61.16	0.71	4.82
Tetradecane	52.28	0.61	4.79

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L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)
St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 02215**
Exposure Time(mins)	**43181**
Sample ID	**GB4**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	760.63	8.81	59.89
2,4-Dimethyl-1-heptene	514.28	5.95	30.01
Decane	236.22	2.74	15.54
Hexadecane	227.73	2.64	23.84
Dodecane	219.35	2.54	17.27
Cyclohexanone	214.42	2.48	9.73
Toluene	210.26	2.43	8.96
Heptane, 4-methyl-	201.60	2.33	10.64
Styrene	199.23	2.31	9.60
1-Pentene, 2-methyl-	195.05	2.26	7.59
Heptadecane	183.25	2.12	20.37
Caprolactam	171.39	1.98	8.97
Tridecane	161.63	1.87	13.77
Pentane	123.08	1.43	4.10
2-Propanol, 2-methyl-	101.83	1.18	3.49
2,2,4,4-Tetramethyloctane	96.52	1.12	7.60
Pentane, 2-methyl-	89.07	1.03	3.55
Undecane	88.05	1.02	6.36
Heptane, 2,4-dimethyl-	81.22	0.94	4.82
Decane, 4-methyl-	76.63	0.89	5.54
Octadecane	68.21	0.79	8.02
Octane, 4-methyl-	66.73	0.77	3.96
2-Propanol, 1-methoxy-	65.88	0.76	2.75
Nonane, 4-methyl-	65.81	0.76	4.33
Limonene	65.34	0.76	4.12
m/p-Xylene	62.96	0.73	3.09
Pentadecane	57.62	0.67	5.66
Hexane	54.77	0.63	2.18
Nonane, 2,6-dimethyl-	53.77	0.62	3.88
2-Undecene, 4-methyl-	51.79	0.60	4.03
Tetradecane	49.58	0.57	4.55
Benzene	49.26	0.57	1.78
5-Undecene, 3-methyl-	48.77	0.56	3.79

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gradko environmental
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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 08009**
Exposure Time(mins)	**43181**
Sample ID	**GB4**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	1069	12	84
2,4-Dimethyl-1-heptene	586.69	6.79	34.24
Decane	299.93	3.47	19.73
Dodecane	267.11	3.09	21.03
Toluene	243.65	2.82	10.38
Heptane, 4-methyl-	233.17	2.70	13.82
1-Pentene, 2-methyl-	206.48	2.39	8.03
Styrene	201.27	2.33	9.69
Tridecane	190.85	2.21	16.26
Cyclohexanone	174.75	2.02	7.93
2,2,4,4-Tetramethyloctane	142.78	1.65	11.24
Pentane	130.31	1.51	4.35
Caprolactam	127.65	1.48	6.68
Undecane	127.59	1.48	9.22
Decane, 3,6-dimethyl-	124.49	1.44	9.80
Nonane, 4-methyl-	119.42	1.38	7.85
2-Propanol, 2-methyl-	105.62	1.22	3.62
Decane, 4-methyl-	101.23	1.17	7.31
Heptane, 2,4-dimethyl-	95.61	1.11	5.67
Octane, 4-methyl-	92.01	1.07	5.45
Pentane, 2-methyl-	91.24	1.06	3.63
Octane	84.96	0.98	4.49
Limonene	76.17	0.88	4.80
2-Undecene, 4-methyl-	73.42	0.85	5.71
2-Propanol, 1-methoxy-	73.00	0.85	3.04
m/p-Xylene	71.69	0.83	3.52
5-Undecene, 3-methyl-	71.64	0.83	5.57
Nonane, 2,6-dimethyl-	67.98	0.79	4.91
Hexane	61.76	0.72	2.46
Undecane, 5-methyl-	57.70	0.67	4.54
Tetradecane	46.89	0.54	4.30
Benzene	43.24	0.50	1.56
Benzene, 1-ethyl-3-methyl-	42.20	0.49	2.35

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 09780**
Exposure Time(mins)	**40773**
Sample ID	**GB5**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	1215	15	101
2,4-Dimethyl-1-heptene	659.83	8.09	40.78
Decane	314.23	3.85	21.89
Heptane, 4-methyl-	272.18	3.34	15.22
Dodecane	256.70	3.15	21.41
Toluene	254.76	3.12	11.50
Cyclohexanone	249.27	3.06	11.98
1-Pentene, 2-methyl-	244.18	2.99	10.06
Styrene	240.73	2.95	12.28
Tridecane	182.43	2.24	16.47
2,2,4,4-Tetramethyloctane	165.32	2.03	13.79
Pentane	138.95	1.70	4.91
Nonane, 4-methyl-	122.65	1.50	8.54
Undecane	121.68	1.49	9.31
Decane, 4-methyl-	114.15	1.40	8.74
Limonene	113.34	1.39	7.56
Heptane, 2,4-dimethyl-	109.05	1.34	6.85
Octane	108.38	1.33	6.06
Decane, 2,6,6-trimethyl-	107.29	1.32	9.68
Octane, 4-methyl-	105.01	1.29	6.59
Pentane, 2-methyl-	103.44	1.27	4.36
Caprolactam	95.86	1.18	5.31
2-Propanol, 1-methoxy-	82.08	1.01	3.62
Decane, 3,6-dimethyl-	80.46	0.99	6.71
2-Propanol, 2-methyl-	79.97	0.98	2.90
Nonane, 2,6-dimethyl-	78.09	0.96	5.98
Hexane	76.94	0.94	3.25
m/p-Xylene	73.54	0.90	3.82
2-Undecene, 4-methyl-	72.92	0.89	6.01
5-Undecene, 3-methyl-	68.09	0.84	5.61
Benzene, 1-ethyl-3-methyl-	54.79	0.67	3.23
Undecane, 5-methyl-	52.36	0.64	4.37
Propane, 2-ethoxy-2-methyl-	45.54	0.56	2.28

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gradko environmental
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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 09182**
Exposure Time(mins)	**40690**
Sample ID	**GB6**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	1414	17	118
2,4-Dimethyl-1-heptene	646.41	7.94	40.03
Decane	289.91	3.56	20.23
Dodecane	279.46	3.43	23.35
Toluene	254.04	3.12	11.49
Heptane, 4-methyl-	252.92	3.11	14.17
Caprolactam	238.39	2.93	13.24
Styrene	227.59	2.80	11.63
1-Pentene, 2-methyl-	221.66	2.72	9.15
Cyclohexanone	220.65	2.71	10.63
Tridecane	193.63	2.38	17.51
2,2,4,4-Tetramethyloctane	188.84	2.32	15.78
Nonane, 4-methyl-	147.18	1.81	10.27
Undecane	125.25	1.54	9.60
Decane, 2,6,6-trimethyl-	124.48	1.53	11.26
Pentane	117.16	1.44	4.15
Octane	107.61	1.32	6.03
Heptane, 2,4-dimethyl-	105.00	1.29	6.61
Octane, 4-methyl-	100.75	1.24	6.34
Decane, 4-methyl-	100.08	1.23	7.67
Pentane, 2-methyl-	99.55	1.22	4.21
Limonene	93.06	1.14	6.22
2-Propanol, 1-methoxy-	82.38	1.01	3.64
2-Undecene, 4-methyl-	82.26	1.01	5.58
m/p-Xylene	76.82	0.94	4.00
Nonane, 3-methyl-	73.60	0.90	5.14
Decane, 3,8-dimethyl-	70.28	0.86	6.36
2-Propanol, 2-methyl-	68.86	0.85	2.50
Oxetane, 2,2-dimethyl-	67.82	0.83	2.87
Nonane, 2,6-dimethyl-	65.73	0.81	5.04
Hexane	63.83	0.78	2.70
Benzene	57.65	0.71	2.21
Benzene, 1-ethyl-3-methyl-	54.89	0.67	3.24

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gradko environmental
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St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail:diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 05910**
Exposure Time(mins)	**40579**
Sample ID	**GB7**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	865.96	10.67	72.56
2,4-Dimethyl-1-heptene	642.20	7.91	39.88
Decane	341.90	4.21	23.93
Dodecane	315.96	3.89	26.47
Toluene	274.39	3.38	12.44
Heptane, 4-methyl-	271.41	3.34	17.12
Cyclohexanone	236.80	2.92	11.44
1-Pentene, 2-methyl-	231.37	2.85	9.58
Styrene	217.35	2.68	11.14
Tridecane	216.56	2.67	19.64
Decane, 3,6-dimethyl-	210.90	2.60	17.67
Undecane	148.81	1.83	11.44
Pentane	138.48	1.71	4.91
2,2,4,4-Tetramethyloctane	129.06	1.59	10.81
Decane, 4-methyl-	118.79	1.46	9.13
Pentane, 2-methyl-	115.87	1.43	4.91
Heptane, 2,4-dimethyl-	105.12	1.30	6.63
Octane, 4-methyl-	102.27	1.26	6.45
Limonene	102.20	1.26	6.85
Octane	90.10	1.11	5.06
Decane, 2,6,6-trimethyl-	88.40	1.09	8.02
2-Propanol, 2-methyl-	86.68	1.07	3.16
5-Undecene, 3-methyl-	85.24	1.05	7.06
2-Undecene, 4-methyl-	84.97	1.05	7.04
Nonane, 2,6-dimethyl-	84.28	1.04	6.48
m/p-Xylene	82.45	1.02	4.31
2-Propanol, 1-methoxy-	79.17	0.98	3.51
Nonane, 4-methyl-	78.26	0.96	5.48
Caprolactam	77.83	0.96	4.33
Hexane	77.72	0.96	3.29
Benzene, (1-methylethyl)-	56.60	0.70	3.35
Tetradecane	53.71	0.66	5.24
Benzene	51.61	0.64	1.98

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 00031**
Exposure Time(mins)	**40257**
Sample ID	**GB8**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	1117	14	94
2,4-Dimethyl-1-heptene	531.12	6.60	33.25
Decane	261.54	3.25	18.45
Dodecane	233.82	2.90	19.75
Heptane, 4-methyl-	220.88	2.74	14.05
Toluene	214.92	2.67	9.82
1-Pentene, 2-methyl-	204.75	2.54	8.54
Tridecane	197.36	2.45	18.04
Cyclohexanone	192.23	2.39	9.36
Styrene	178.56	2.22	9.23
2,2,4,4-Tetramethyloctane	157.78	1.96	13.33
Caprolactam	144.96	1.80	8.14
Pentane	116.34	1.45	4.16
Undecane	107.46	1.33	8.33
Decane, 2,6,6-trimethyl-	106.01	1.32	9.69
2-Propanol, 2-methyl-	105.14	1.31	3.87
Decane, 4-methyl-	95.00	1.18	7.36
Heptane, 2,4-dimethyl-	90.88	1.13	5.78
Pentane, 2-methyl-	89.04	1.11	3.80
Octane, 4-methyl-	84.38	1.05	5.37
Octane	80.72	1.00	4.57
2-Propanol, 1-methoxy-	69.92	0.87	3.13
Limonene	68.86	0.86	4.65
2-Undecene, 4-methyl-	66.72	0.83	5.57
Tetradecane	66.16	0.82	6.51
m/p-Xylene	65.62	0.81	3.46
Hexane	65.60	0.81	2.80
Nonane, 2,6-dimethyl-	63.89	0.79	4.95
5-Undecene, 3-methyl-	61.21	0.76	5.11
Phenol, 2,4-bis(1,1-dimethylethyl)-	45.46	0.56	4.65
Benzene	42.54	0.53	1.65
Propane, 2-ethoxy-2-methyl-	39.66	0.49	2.01
Oxetane, 2,2-dimethyl-	37.99	0.47	1.62

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 06107**
Exposure Time(mins)	**40257**
Sample ID	**GB8**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	988.98	12.28	83.53
2,4-Dimethyl-1-heptene	503.06	6.25	31.49
Decane	268.81	3.34	18.96
Dodecane	233.55	2.90	19.73
Toluene	212.01	2.63	9.69
Heptane, 4-methyl-	208.87	2.59	11.83
1-Pentene, 2-methyl-	207.72	2.58	8.67
Cyclohexanone	171.23	2.13	8.34
Tridecane	167.51	2.08	15.31
Styrene	161.07	2.00	8.32
2,2,4,4-Tetramethyloctane	139.74	1.74	11.80
Caprolactam	135.26	1.68	7.59
Pentane	123.03	1.53	4.40
2-Propanol, 2-methyl-	114.31	1.42	4.20
Undecane	113.27	1.41	8.78
Nonane, 4-methyl-	101.07	1.26	7.13
Pentane, 2-methyl-	98.68	1.23	4.22
Decane, 4-methyl-	96.65	1.20	7.49
Heptane, 2,4-dimethyl-	85.49	1.06	5.44
Octane, 4-methyl-	77.94	0.97	4.96
Limonene	74.24	0.92	5.02
Octane	72.65	0.90	4.11
2-Propanol, 1-methoxy-	70.62	0.88	3.16
2-Undecene, 4-methyl-	66.44	0.83	5.55
Nonane, 2,6-dimethyl-	66.30	0.82	5.14
m/p-Xylene	63.73	0.79	3.36
5-Undecene, 3-methyl-	63.15	0.78	5.27
Hexane	60.19	0.75	2.57
Benzene, 1-ethyl-3-methyl-	48.59	0.60	2.90
Benzene	43.90	0.55	1.70
Tetradecane	40.24	0.50	3.96
Oxetane, 2,2-dimethyl-	39.45	0.49	1.69
Propane, 2-ethoxy-2-methyl-	37.58	0.47	1.90

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Tube Number	**GRA 06449**
Exposure Time(mins)	**40257**
Sample ID	**GB8**

Top 33 VOC'S

Compounds	**ng on tube**	**ppb in air***	**ugm-3***
Heptane, 2,2,4,6,6-pentamethyl-	936.50	11.63	79.09
2,4-Dimethyl-1-heptene	560.84	6.97	35.11
Decane	316.30	3.93	22.31
Dodecane	276.38	3.43	23.34
Heptane, 4-methyl-	234.65	2.91	14.92
Toluene	234.26	2.91	10.71
1-Pentene, 2-methyl-	223.10	2.77	9.31
Tridecane	203.39	2.53	18.59
Decane, 3,6-dimethyl-	199.58	2.48	16.86
Cyclohexanone	195.53	2.43	9.52
Styrene	182.03	2.26	9.41
2,2,4,4-Tetramethyloctane	135.70	1.69	11.46
Pentane	133.18	1.65	4.76
Undecane	129.07	1.60	10.00
2-Propanol, 2-methyl-	126.62	1.57	4.65
Decane, 4-methyl-	110.16	1.37	8.54
Pentane, 2-methyl-	98.28	1.22	4.20
Heptane, 2,4-dimethyl-	92.19	1.15	5.86
Octane, 4-methyl-	89.09	1.11	5.67
Octane	79.83	0.99	4.52
Nonane, 4-methyl-	78.61	0.98	5.55
Limonene	76.75	0.95	5.19
Nonane, 2,6-dimethyl-	75.69	0.94	5.87
m/p-Xylene	69.02	0.86	3.63
Hexane	68.04	0.85	2.91
2-Propanol, 1-methoxy-	55.83	0.69	2.50
Tetradecane	55.45	0.69	5.45
Caprolactam	54.19	0.67	3.04
Benzene	46.07	0.57	1.79
Propane, 2-ethoxy-2-methyl-	43.17	0.54	2.19
1-Hexanol, 2-ethyl-	39.82	0.49	2.57
Cyclopentane, methyl-	33.40	0.41	1.39
Pentane, 3-methyl-	32.52	0.40	1.39

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

Where <LOD = below limit of detection.
Limit of Detections:
Benzene 3.9 ng
Toluene 2.7ng
Ethylbenzene 1.1 ng
p-Xylene 2.8ng
o-Xylene 1.0 ng

Comment:Tubes received with caps off.
Results are not Blank corrected.
Results greater than 1000ng are outside of our UKAS accredited calibration range.
Exposure Times on the diffusion sheet were incorrect.
Semi-quantitative results for ng on tube are calculated using toluene standards.

		Date of Analysis	22.02.12
Analysts Name	Mariella Angelova	Date of Amended Report	15.03.12

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L. Gates, Laboratory Supervisor

gradko environmental
(A division of Gradko International Ltd.)

St. Martins House, 77 Wales Street Winchester, Hampshire SO23 0RH
tel.: 01962 860331 fax: 01962 841339 e-mail: diffusion@gradko.co.uk

UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

REPORT NUMBER	**F6191R**
CUSTOMER	**Golder Associates** **Attenborough House** **Browns Lane Business Park** **Stanton-on-the-wolds** **Nottinghamshire NG12 5BL**
GRADKO LAB REFERENCE	**PE6G2441-2447**
DATE SAMPLES RECEIVED	**29.10.12**
DESPATCH REF.NUMBER	**SOR007959**
BOOKING IN REF.	**F6191**

IDENTIFICATION AND ESTIMATION (SEMI-QUANTITATIVE ANALYSIS) OF TOP 20 VOC ON TENAX DIFFUSION TUBES BY GC/MS

Analysis has been carried out in accordance with in-house method GLM 13

Tube Number	**GRA 011897****
Sample ID	**GB4**
Sample Location	**Farm Triplicate**
Exposure Time (mins)	**60480**

TOP 20 VOC	ng on tube	ppb in air*	μgm^{-3}*
2,4-Dimethyl-1-heptene +	1202	10	50
Toluene	961.67	7.95	29.26
Ethylbenzene	915.36	7.57	32.09
2-Propanol, 2-methyl +	782.30	6.47	19.14
m/p-Xylene	727.93	6.02	25.52
Decane	640.68	5.30	30.08
Heptane, 4-methyl +	622.45	5.15	23.47
n-Butyl ether +	554.18	4.58	23.82
Dodecane	526.62	4.35	29.60
1-Pentene, 2-methyl +	521.80	4.31	14.49
o-Xylene	471.58	3.90	16.53
Hexane	425.48	3.52	12.10
Cyclohexane, methyl-	414.17	3.42	13.42
Cyclohexane	305.92	2.53	8.50
Cyclopentane, methyl +	356.36	2.95	9.90
Octane	340.18	2.81	12.82
Heptane	330.18	2.73	10.92
Pentane, 2-methyl +	313.07	2.59	8.90
Decane, 4-methyl +	217.41	1.80	11.22

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LABORATORY ANALYSIS REPORT

1-Butanol	181.31	1.50	4.44

Tube Number	**GRA 04979****
Sample ID	**GB4**
Sample Location	**Farm Triplicate**
Exposure Time (mins)	**60480**

TOP 20 VOC	ng on tube	ppb in air*	µgm^{-3}*
Ethylbenzene	1345	11	47
2,4-Dimethyl-1-heptene +	1146	9	48
m/p-Xylene	1087	9	38
Toluene	974.62	8.06	29.65
n-Butyl ether +	744.19	6.15	31.99
2-Propanol, 2-methyl +	729.63	6.03	17.85
o-Xylene	663.67	5.49	23.26
Decane	634.86	5.25	29.81
Heptane, 4-methyl +	600.66	4.97	22.64
Dodecane	580.42	4.80	32.63
1-Pentene, 2-methyl +	465.18	3.85	12.92
Cyclohexane, methyl-	462.74	3.83	15.00
Hexane	428.27	3.54	12.18
Cyclohexane	319.46	2.64	8.87
Cyclopentane, methyl +	409.93	3.39	11.39
Octane	366.38	3.03	13.81
Heptane	355.27	2.94	11.75
1-Butanol	317.70	2.63	7.77
Pentane, 2-methyl +	317.00	2.62	9.02
Decane, 4-methyl +	233.73	1.93	12.06

Tube Number	**GRA 011972****
Sample ID	**GB4**
Sample Location	**Farm Triplicate**
Exposure Time (mins)	**60480**

TOP 20 VOC	ng on tube	ppb in air*	µgm^{-3}*
2,4-Dimethyl-1-heptene +	1185	10	49
Toluene	1008	8	31
Ethylbenzene	758.82	6.27	26.60
m/p-Xylene	600.74	4.97	21.06
Heptane, 4-methyl +	592.90	4.90	22.35

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UKAS TESTING 2187

LABORATORY ANALYSIS REPORT

n-Butyl ether +	579.99	4.79	24.93
2-Propanol, 2-methyl +	569.21	4.71	13.93
Decane	540.90	4.47	25.40
1-Pentene, 2-methyl +	474.98	3.93	13.19
Hexane	425.37	3.52	12.10
Dodecane	408.09	3.37	22.94
Cyclohexane, methyl-	396.84	3.28	12.86
Cyclopentane, methyl +	387.66	3.20	10.77
Cyclohexane	477.61	3.95	13.27
Octane	351.63	2.91	13.26
Heptane	326.50	2.70	10.80
Pentane, 2-methyl +	303.53	2.51	8.63
o-Xylene	276.79	2.29	9.70
1-Butanol	249.76	2.06	6.11
Decane, 4-methyl +	221.16	1.83	11.41

Tube Number	**GRA 011948****
Sample ID	**GB1**
Sample Location	**CASENHE**
Exposure Time (mins)	**59040**

TOP 20 VOC	**ng on tube**	**ppb in air***	**μgm^{-3}***
Ethylbenzene	1399	12	50
2,4-Dimethyl-1-heptene +	1136	10	48
m/p-Xylene	1105	9	40
Toluene	966.61	8.19	30.12
o-Xylene	681.40	5.77	24.47
Heptane, 4-methyl +	584.54	4.95	22.57
n-Butyl ether +	556.58	4.71	24.51
2-Propanol, 2-methyl +	544.41	4.61	13.65
Decane	531.54	4.50	25.57
1-Pentene, 2-methyl +	471.97	4.00	13.43
Dodecane	448.90	3.80	25.85
Hexane	417.31	3.53	12.16
Cyclohexane, methyl-	391.47	3.32	13.00
Octane	370.28	3.14	14.30
Cyclopentane, methyl +	369.69	3.13	10.52
Heptane	337.00	2.85	11.42
Pentane, 2-methyl +	311.36	2.64	9.07

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Cyclohexane	290.67	2.46	8.27
1-Butanol	212.87	1.80	5.34
Decane, 4-methyl +	197.25	1.67	10.42

Tube Number	**GRA 07538****
Sample ID	**GB2**
Sample Location	**SALIQ/ Box cut**
Exposure Time (mins)	**60480**

TOP 20 VOC	**ng on tube**	**ppb in air***	**µgm^{-3}***
Ethylbenzene	1324	11	46
m/p-Xylene	1073	9	38
2,4-Dimethyl-1-heptene +	1018	8	42
Toluene	880.69	7.28	26.79
2-Propanol, 2-methyl +	698.99	5.78	17.10
o-Xylene	644.43	5.33	22.59
n-Butyl ether +	571.21	4.72	24.56
Decane	554.20	4.58	26.02
Heptane, 4-methyl +	514.85	4.26	19.41
Dodecane	500.78	4.14	28.15
1-Pentene, 2-methyl +	428.56	3.54	11.90
Cyclohexane, methyl-	390.33	3.23	12.65
Hexane	382.21	3.16	10.87
1-Hexanol, 2-ethyl +	381.80	3.16	16.41
Octane	322.22	2.66	12.15
Heptane	297.51	2.46	9.84
Cyclopentane, methyl +	286.67	2.37	7.96
1-Butanol	281.84	2.33	6.90
Pentane, 2-methyl +	274.44	2.27	7.80
Cyclohexane	273.69	2.26	7.60

Tube Number	**GRA 011803****
Sample ID	**GB3**
Sample Location	**SARA LOBA**
Exposure Time (mins)	**60480**

TOP 20 VOC	**ng on tube**	**ppb in air***	**µgm^{-3}***
Ethylbenzene	1451	12	51
m/p-Xylene	1166	10	41
Toluene	827.53	6.84	25.18

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LABORATORY ANALYSIS REPORT

2,4-Dimethyl-1-heptene +	793.08	6.56	33.04
o-Xylene	700.41	5.79	24.55
2-Propanol, 2-methyl +	535.69	4.43	13.11
n-Butyl ether +	433.35	3.58	18.63
Decane	405.64	3.35	19.05
Heptane, 4-methyl +	388.41	3.21	14.64
1-Pentene, 2-methyl +	354.82	2.93	9.86
Dodecane	346.41	2.86	19.47
Hexane	345.51	2.86	9.83
Cyclohexane, methyl-	338.44	2.80	10.97
Cyclopentane, methyl +	334.37	2.76	9.29
Heptane	263.81	2.18	8.72
Octane	260.31	2.15	9.81
Pentane, 2-methyl +	257.29	2.13	7.32
Cyclohexane	254.88	2.11	7.08
1-Butanol	181.12	1.50	4.43
Decane, 4-methyl +	161.41	1.33	8.33

Tube Number **GRA 08941**
Sample Location **Travel Blank**

TOP 20 VOC	**ng on tube**
Pentadecane	<5
Tridecane	<5
Benzene	<5

3 Compounds Detected

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LABORATORY ANALYSIS REPORT

UPTAKE RATES
Semi Quantitative 2.00ng.ppm-1.min-1

Comments:
**The samples were received with there diffusion caps on. The results maybe compromised.
Sample GB5 was missing on arrival.
Results are not blank corrected.
Results greater than 1000ng are outside our UKAS accredited calibration range.
+These compounds are not covered by our UKAS accredited flexible scope.
Semi-quantitative results for ng on tube are calculated using toluene standards.**

		Date of Analysis	14.11.12
Analysts Name	G. Aikman	Date of Report	16.11.12

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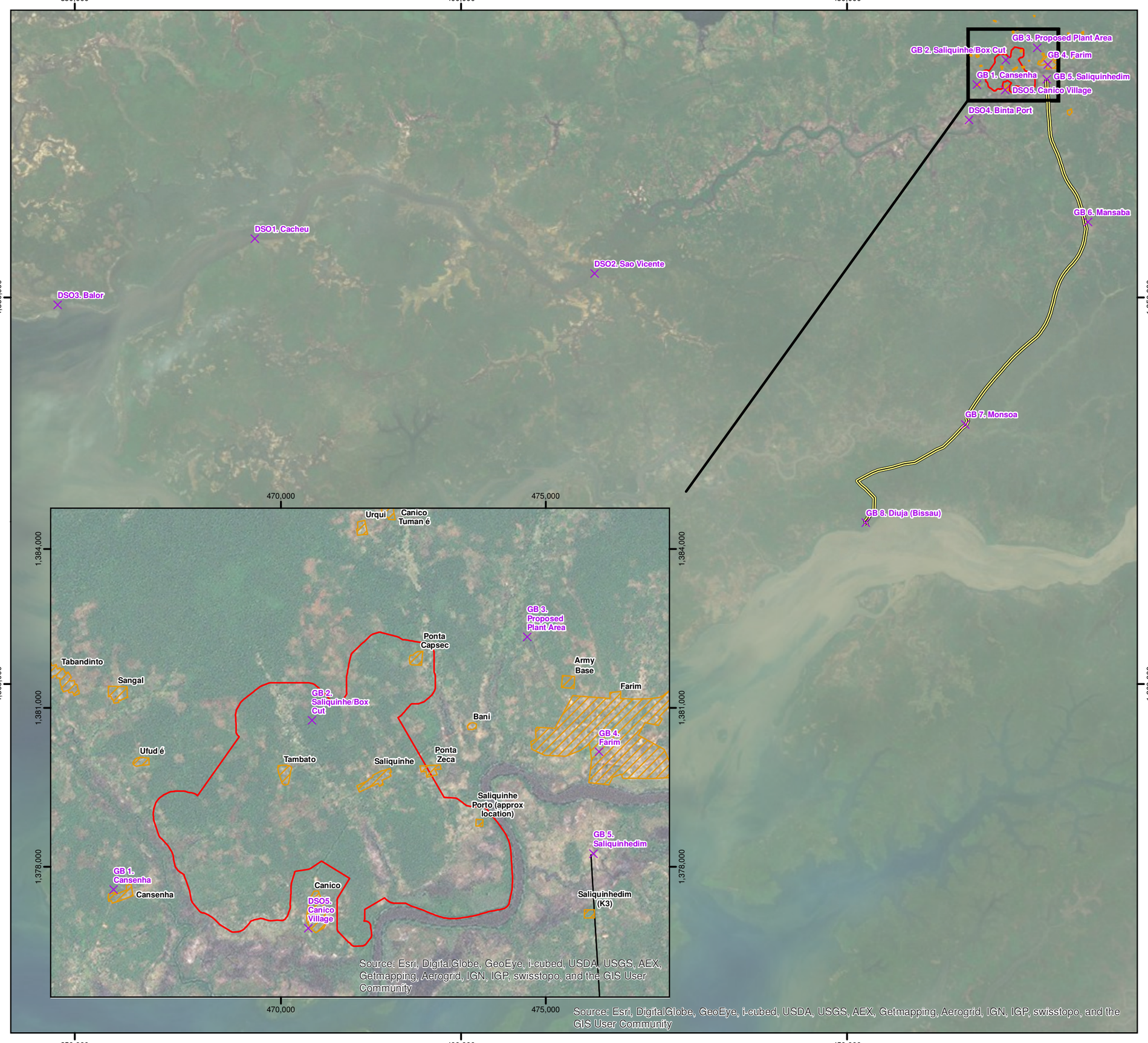
APPENDIX A5

Baseline Monitoring Location Plan

January 2014
Report No. 13514950200.550/B.0



Legend

- Air Quality Sampling Location
- Populated Settlement
- Site Boundary
- Road

REFERENCES

Coordinate System: Bissau UTM Zone 28N.
Data sourced from client

10 5 0 10 KILOMETRES

N

SCALE 1:480,000 1 CENTIMETER = 4.8 KILOMETRES
WHEN PRODUCED AT SIZE A3

PROJECT

GB MINERALS IMPACT ASSESSMENT

TITLE

AIR QUALITY SAMPLING LOCATIONS

Golder Associates
Bourne End, UK

PROJECT No.	13514950201		FILE No.	
DESIGN	TS	xx/xx/xxxx	SCALE AS SHOWN	REV 0
GIS	RE	20/11/2013	DRAWING 1	
CHECK	DB	20/11/2013		
REVIEW	XX	20/11/2013		

Z:\GIS_WORKSPACE_WORLD\GUINEA-BISSAU\Farim\Mapping\Air_Quality\13514950200-Base-map-20131120.mxd | 20/11/2013 11:27:56 | rwevans

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

April-19-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10270-APR12**
Reference: Whole Rock Analysis

Copy: #1

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Final Report

Sample ID	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	Cr2O3 %	V2O5 %	LOI %	Sum %
5: BH 08 00-12.45	74.6	7.92	11.5	0.06	< 0.01	0.03	0.05	0.75	0.03	0.03	0.04	0.04	5.14	100.2
6: BH 08 12.45-24.45	51.4	14.2	18.9	1.06	0.76	0.05	1.15	0.72	0.71	0.16	0.04	0.02	11.3	100.4
7: BH 08 24.45-27.45	55.9	22.6	4.56	0.84	0.31	0.05	1.01	1.13	0.17	0.02	0.04	0.03	12.2	98.9
8: BH 08 27.45-34.95	62.4	19.3	5.30	0.57	0.18	0.05	0.75	1.06	0.16	< 0.01	0.03	0.02	10.4	100.2
9: BH 08 34.95-54	62.2	14.9	9.62	0.57	0.23	0.05	0.87	1.06	0.16	0.05	0.03	0.02	10.1	100.0
10: BH 10 00-6.45	71.2	16.0	4.19	0.09	0.01	0.05	0.11	1.20	0.03	0.01	0.04	0.02	7.76	100.7
11: BH 10 6.45-15.45	56.6	22.0	8.60	0.36	0.04	0.05	0.65	1.12	0.16	0.01	0.02	0.03	10.7	100.4
12: BH 10 15.45-18.45	65.5	14.0	10.0	0.32	0.09	0.09	0.57	0.76	0.41	0.06	0.04	0.01	8.52	100.4
13: BH 10 18.45-30.45	70.1	12.0	9.31	0.23	0.06	0.05	0.43	0.89	0.18	0.02	0.02	0.02	6.91	100.2
14: BH 10 30.45-49.7	67.9	13.2	3.69	0.41	1.27	0.09	0.58	0.74	2.55	0.06	0.06	0.02	8.95	99.5
15: BH 10 30.45-49.7 Dup	76.2	9.21	3.27	0.33	0.82	0.07	0.45	0.64	1.57	0.06	0.07	0.02	7.02	99.8
16: BH 20 0.3-4.6	59.5	21.1	3.44	0.40	0.07	0.25	0.36	1.67	0.07	0.01	0.02	0.02	13.2	100.1
17: BH 20 10-00-18-00	94.8	1.55	1.76	0.03	0.04	0.04	0.03	0.22	0.02	0.01	0.07	< 0.01	1.31	99.9
18: BH 20 18.00-22.00	70.1	13.2	7.19	0.41	0.10	0.08	0.43	0.90	0.07	0.02	0.04	0.02	7.74	100.2
19: BH 20 29.00-32.00	85.0	6.69	3.14	0.18	0.07	0.07	0.17	0.56	0.08	0.02	0.04	< 0.01	3.71	99.8
20: BH 20 35.00-40.00	81.9	2.04	2.42	0.08	6.27	0.09	0.05	0.23	4.37	0.03	0.05	< 0.01	2.39	100.0
21: BH 23 0.33-3.0	56.2	16.6	12.4	0.36	0.22	0.28	0.20	1.36	0.09	0.03	0.02	0.03	12.2	100.0
22: BH 23 3.0-16.5	59.2	18.5	9.92	0.30	0.10	0.16	0.36	1.29	0.12	0.01	0.03	0.03	10.2	100.3
23: BH 23 3.0-16.5 Dup	62.4	19.0	6.62	0.37	0.10	0.16	0.51	1.24	0.07	0.01	0.03	0.03	9.46	100.0

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Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : **CA10270-APR12**

Sample ID	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	MnO %	Cr2O3 %	V2O5 %	LOI %	Sum %
24: BH 23 21.00-24.1	76.3	12.9	2.51	0.28	0.10	0.07	0.51	0.96	0.06	< 0.01	0.04	0.02	6.32	100.1
25: BH 23 24.1-28.5	90.9	4.25	1.84	0.13	0.03	0.09	0.19	0.55	0.03	< 0.01	0.09	< 0.01	2.40	100.5
26: BH 23 28.5-33.00	59.0	10.9	12.0	0.64	0.46	0.10	0.59	0.82	0.10	0.18	0.03	0.01	14.2	99.1

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

OnLine LIMS

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

April-25-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10271-APR12**

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: BH 08 00-12.45	6: BH 08 12.45-24.45	7: BH 08 24.45-27.45	8: BH 08 27.45-34.95	9: BH 08 34.95-54	10: BH 10 00-6.45	11: BH 10 6.45-15.45	12: BH 10 15.45-18.45	13: BH 10 18.45-30.45	14: BH 10 30.45-49.7
Cyanide (total) [%]	25-Apr-12	08:40	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.003	< 0.001	0.001
Mercury [µg/g]	16-Apr-12	16:14	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Silver [µg/g]	17-Apr-12	15:43	0.23	0.28	0.36	0.46	0.39	0.28	0.32	0.28	0.30	0.35
Aluminum [µg/g]	17-Apr-12	16:49	38000	69000	110000	87000	73000	78000	97000	67000	58000	63000
Arsenic [µg/g]	17-Apr-12	15:43	18	26	6.5	13	33	5.5	16	15	34	9.9
Barium [µg/g]	17-Apr-12	15:43	38	150	170	150	130	37	150	170	130	130
Beryllium [µg/g]	17-Apr-12	15:43	0.41	1.9	1.3	1.1	1.3	0.44	1.1	2.5	1.0	4.0
Bismuth [µg/g]	17-Apr-12	15:43	0.15	0.18	0.27	0.48	0.23	0.16	0.25	0.16	0.19	0.30
Calcium [µg/g]	17-Apr-12	16:49	150	5200	2100	1200	1600	110	330	690	550	8600
Cadmium [µg/g]	17-Apr-12	15:43	0.17	0.28	0.20	0.25	0.23	0.18	0.16	0.18	0.15	0.28
Cobalt [µg/g]	17-Apr-12	15:43	5.1	29	7.1	4.8	14	4.3	4.0	12	4.8	12
Chromium [µg/g]	17-Apr-12	15:43	310	210	190	220	220	180	180	230	210	350
Copper [µg/g]	17-Apr-12	15:43	16	12	13	11	12	13	11	11	10	13
Iron [µg/g]	17-Apr-12	16:49	77000	120000	30000	35000	66000	29000	55000	68000	64000	25000
Potassium [µg/g]	17-Apr-12	16:49	470	11000	9500	6700	8100	1000	5700	5200	3900	5400
Lithium [µg/g]	17-Apr-12	15:43	6	25	44	36	49	12	12	15	17	47
Magnesium [µg/g]	17-Apr-12	16:49	280	5900	4500	3000	3000	530	1800	1800	1200	2100
Manganese [µg/g]	17-Apr-12	15:44	200	1000	120	77	330	120	80	420	150	330
Molybdenum [µg/g]	17-Apr-12	15:44	3.2	2.3	2.3	1.8	4.0	1.4	2.3	4.6	2.2	1.3
Nickel [µg/g]	17-Apr-12	15:44	13	48	25	19	22	23	18	27	14	21

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : **CA10271-APR12**

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: BH 08 00-12.45	6: BH 08 12.45-24.45	7: BH 08 24.45-27.45	8: BH 08 27.45-34.95	9: BH 08 34.95-54	10: BH 10 00-6.45	11: BH 10 6.45-15.45	12: BH 10 15.45-18.45	13: BH 10 18.45-30.45	14: BH 10 30.45-49.7
Lead [µg/g]	17-Apr-12	15:44	15	15	22	19	16	13	20	14	14	12
Antimony [µg/g]	17-Apr-12	15:44	0.9	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
Selenium [µg/g]	17-Apr-12	15:44	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	1.0	< 0.7	< 0.7
Tin [µg/g]	17-Apr-12	15:44	1.7	1.7	2.7	2.4	1.8	2.5	2.1	2.0	1.7	1.6
Strontium [µg/g]	17-Apr-12	15:44	14	150	140	120	98	23	120	330	100	1300
Titanium [µg/g]	17-Apr-12	16:49	4000	4000	6100	5400	5500	5800	5800	4000	4600	3900
Thallium [µg/g]	17-Apr-12	15:44	0.08	0.17	0.28	0.22	0.24	0.10	0.20	0.15	0.14	0.14
Uranium [µg/g]	17-Apr-12	15:44	2.7	5.3	2.6	2.2	2.2	1.9	2.8	5.2	2.9	29
Vanadium [µg/g]	17-Apr-12	15:44	190	110	92	95	100	74	140	77	110	82
Yttrium [µg/g]	17-Apr-12	15:44	7.2	38	17	14	30	14	28	35	14	87
Zinc [µg/g]	17-Apr-12	15:44	8.7	180	62	41	51	16	39	82	37	70

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

April-25-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10271-APR12**

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	15: BH 10 30.45-49.7 Dup	16: BH 20 0.3-4.6	17: BH 20 10-00-18-00	18: BH 20 18.00-22.00	19: BH 20 29.00-32.00	20: BH 20 35.00-40.00	21: BH 23 0.33-3.0	22: BH 23 3.0-16.5	23: BH 23 3.0-16.5 Dup	24: BH 23 21.00-24.1	25: BH 23 24.1-28.5	26: BH 23 28.5-33.00
Cyanide (total) [%]	< 0.001	< 0.001	< 0.001	0.002	0.001	< 0.001	< 0.001	0.002	< 0.001	0.001	0.003	0.002
Mercury [µg/g]	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Silver [µg/g]	0.27	0.40	0.07	0.28	0.59	0.55	0.32	0.37	0.38	0.30	0.20	0.31
Aluminum [µg/g]	43000	100000	7000	64000	32000	10000	81000	88000	90000	61000	20000	53000
Arsenic [µg/g]	8.7	5.6	0.6	12	1.5	3.1	8.7	15	11	11	4.9	9.3
Barium [µg/g]	83	110	18	97	63	33	77	120	130	120	55	110
Beryllium [µg/g]	1.9	1.1	0.16	1.2	0.90	0.82	0.90	0.93	0.82	0.75	0.32	1.8
Bismuth [µg/g]	0.11	0.22	< 0.09	0.16	< 0.09	< 0.09	0.19	0.22	0.22	0.17	< 0.09	< 0.09
Calcium [µg/g]	5500	510	420	780	580	43000	1600	780	360	750	300	3300
Cadmium [µg/g]	0.22	0.23	0.10	0.19	0.13	0.69	0.19	0.21	0.18	0.16	0.13	0.43
Cobalt [µg/g]	9.9	6.8	2.5	9.2	9.7	3.9	4.9	5.0	4.2	2.8	2.2	17
Chromium [µg/g]	400	170	460	250	300	340	170	180	190	230	600	290
Copper [µg/g]	12	15	6.1	9.9	9.4	8.2	16	13	11	8.5	9.2	9.1
Iron [µg/g]	21000	23000	12000	49000	22000	16000	83000	69000	45000	17000	13000	81000
Potassium [µg/g]	3900	3400	310	3900	1500	460	1900	3400	4600	4600	1800	5500
Lithium [µg/g]	37	79	6	37	37	10	23	21	20	17	12	47
Magnesium [µg/g]	1700	2100	200	2300	920	340	2000	1600	2000	1500	800	3400
Manganese [µg/g]	340	77	140	150	140	130	160	81	70	73	82	1200
Molybdenum [µg/g]	1.3	1.6	1.4	1.6	5.0	1.4	3.1	2.6	3.2	1.2	13	2.3
Nickel [µg/g]	17	29	8.9	20	14	13	20	21	17	12	12	27

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Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : **CA10271-APR12**

Analysis	15: BH 10 30.45-49.7 Dup	16: BH 20 0.3-4.6	17: BH 20 10-00-18-00	18: BH 20 18.00-22.00	19: BH 20 29.00-32.00	20: BH 20 35.00-40.00	21: BH 23 0.33-3.0	22: BH 23 3.0-16.5	23: BH 23 3.0-16.5 Dup	24: BH 23 21.00-24.1	25: BH 23 24.1-28.5	26: BH 23 28.5-33.00
Lead [µg/g]	9.2	23	3.1	15	10	4.2	20	21	20	14	6.5	14
Antimony [µg/g]	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
Selenium [µg/g]	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	0.8	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
Tin [µg/g]	1.2	3.4	< 0.5	2.2	1.0	< 0.5	2.7	2.9	2.6	1.7	1.1	1.9
Strontium [µg/g]	520	72	12	74	110	150	45	100	85	85	36	110
Titanium [µg/g]	3300	7700	1200	4700	2900	1200	6400	6400	6200	4800	2800	4100
Thallium [µg/g]	0.12	0.25	< 0.02	0.16	0.11	0.07	0.18	0.20	0.20	0.17	0.05	0.18
Uranium [µg/g]	9.3	3.1	0.66	3.0	1.4	14	4.7	3.2	2.4	1.8	0.89	2.6
Vanadium [µg/g]	57	79	9	83	28	28	130	130	140	71	33	61
Yttrium [µg/g]	48	14	6.5	20	7.4	39	16	14	13	11	5.5	31
Zinc [µg/g]	86	25	4.6	44	40	26	20	24	25	23	12	69

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

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Semi-Quantitative X-Ray Diffraction

Report Prepared for:	*Environmental -Analytical*
Project Number/ LIMS No.	*MI4515-APR12*
Reporting Date:	*May 16, 2012*

Instrument:	BRUKER AXS D8 Advance Diffractometer
Test Conditions:	Co radiation, 40 kV, 35 mA Regular Scanning: Step: 0.02°, Step time:0.2s, 2θ range: 3-70°
Interpretations :	PDF2/PDF4 powder diffraction databases issued by the International Center for Diffraction Data (ICDD). DiffracPlus Eva software.
Detection Limit :	0.5-2%. Strongly dependent on crystallinity.

Contents:

1) Method Summary
2) Summary of Mineral Asemblages
3) Semi-Quantitative XRD Results
4) Chemical Balance(s)
5) XRD Pattern(s)

Bernie C. Yeung, B. Sc.
Mineralogist

Kimberly Lentini
Technician, XRD

Huyun Zhou, Ph.D., P.Geo.
Senior Mineralogist

Method Summary

Mineral Identification and Interpretation:

Mineral identification and interpretation involve matching the diffraction pattern of a test sample material to patterns of single-phase reference materials. The reference patterns are compiled by the Joint Committee on Powder Diffraction Standards - International Center for Diffraction Data (JCPDS-ICDD) and released on software as a database of Powder Diffraction Files (PDF).

Interpretations do not reflect the presence of non-crystalline and/or amorphous compounds. Mineral proportions are based on relative peak heights and may be strongly influenced by crystallinity, structural group or preferred orientations. Interpretations and relative proportions should be accompanied by supporting petrographic and geochemical data (Whole Rock Analysis, Inductively Coupled Plasma - Optical Emission Spectroscopy, etc.).

Semi-Quantitative Analysis:

The Semi-Quantitative analysis (RIR method) is performed based on each mineral's relative peak heights and of their respective I/Icor values, which are available from the PDF database. Mineral abundances for the bulk sample (in weight %) are generated by Bruker-EVA Software. These data are reconciled with a bulk chemistry (e.g. whole rock analysis including SiO_2, Al_2O_3, Na_2O, K_2O, CaO, MgO, Fe_2O_3, Cr_2O_3, MnO, TiO_2, P_2O_5, V_2O_5 or other chemical data). A chemical balance table shows the difference between the assay results and elemental concentrations determined by XRD.

Summary of Semi-Quantitative X-ray Diffraction Results

Crystalline Mineral Assemblage (relative proportions based on peak height)

Sample	Major (>30% Wt)	Moderate (10% -30% Wt)	Minor (2% -10% Wt)	Trace (<2% Wt)
(1) BH 08 00-12.45	quartz	kaolinite	goethite, sillimanite, hematite	*anatase
(2) BH 08 12.45-24.45	quartz	goethite, kaolinite, mica	halloysite, hematite, sillimanite, chlorite	*apatite, *anatase, *calcite, *palygorskite
(3) BH 08 24.45-27.45	kaolinite, quartz	halloysite	mica, goethite, potassium-feldspar, chlorite	*anatase, *magnetite, *palygorskite
(4) BH 08 27.45-34.95	quartz	kaolinite	halloysite, mica, goethite	*chlorite, *potassium-feldspar, *anatase, *magnetite
(5) BH 08 34.95-54	quartz	kaolinite	halloysite, goethite, mica, siderite, pyrite	*chlorite, *potassium-feldspar, *anatase, *magnetite
(6) BH 10 00-6.45	quartz	kaolinite, halloysite	goethite	*potassium-feldspar, *pyrite, *anatase, *magnetite
(7) BH 10 6.45-15.45	kaolinite, quartz	-	halloysite, goethite, mica	*anatase, *chlorite, *magnetite, *palygorskite
(8) BH 10 15.45-18.45	quartz	kaolinite	halloysite, goethite, potassium-feldspar	*pyrite, *anatase, *magnetite
(9) BH 10 18.45-30.45	quartz	kaolinite	halloysite, goethite, potassium-feldspar	*pyrite, *magnetite, *anatase
(10) BH 10 30.45-49.7	quartz	kaolinite	halloysite, crandallite, potassium-feldspar	*goethite, *pyrite, *anatase, *magnetite
(11) BH 10 30.45-49.7-Dup	quartz	kaolinite	halloysite, crandallite *potassium-feldspar	*pyrite, *goethite, *anatase, *magnetite
(12) BH 20 0.3-4.6	kaolinite, quartz	halloysite	goethite	*potassium-feldspar, *anatase, *chlorite, *magnetite
(13) BH 20 10-00-18-00	quartz	-	kaolinite	*hematite, *siderite

Crystalline Mineral Assemblage (relative proportions based on peak height)

Sample	Major (>30% Wt)	Moderate (10% -30% Wt)	Minor (2% -10% Wt)	Trace (<2% Wt)
(14) BH 20 18.00-22.00	quartz	kaolinite, halloysite	goethite, potassium-feldspar	*magnetite, *anatase, *pyrite
(15) BH 20 29.00-32.00	quartz	kaolinite	halloysite	*goethite, *hematite, *potassium-feldspar, *anatase
(16) BH 20 35.00-40.00	quartz	apatite	kaolinite	*goethite
(17) BH 23 0.33-3.0	quartz	kaolinite	siderite, halloysite. goethite	*anatase, *magnetite, *chlorite, *rutile, *potassium-feldspar
(18) BH 23 3.0-16.5	quartz, kaolinite	-	halloysite, goethite, siderite, mica	*anatase, *magnetite, *chlorite
(19) BH 23 3.0-16.5 Dup	kaolinite, quartz	-	halloysite, goethite, mica	*anatase, *potassium-feldspar, *magnetite, *chlorite
(20) BH 23 21.00-24.1	quartz	kaolinite	halloysite, goethite	*mica, *potassium-feldspar, *anatase, *chlorite, *magnetite
(21) BH 23 24.1-28.5	quartz	-	kaolinite, halloysite	*goethite, *potassium-feldspar, *anatase, *magnetite
(22) BH 23 28.5-33.00	quartz	kaolinite, siderite	halloysite, pyrite, mica, goethite	*potassium-feldspar, *anatase, *chlorite, *magnetite, *palygorskite

** tentative identification due to low concentrations, diffraction line overlap or poor crystallinity*

Mineral	Composition
Anatase	TiO2
Apatite	Ca5(PO4)3(F,Cl,OH)
Calcite	CaCO3
Chlorite	(Fe,(Mg,Mn)5,Al)(Si3Al)O10(OH)8
Crandallite	CaAl3(PO4)2(OH)5·(H2O)
Goethite	αFeO·OH
Halloysite	Al2Si2O5(OH)4 and Al2Si2O5(OH)4*2H2O
Hematite	Fe2O3
Kaolinite	Al2Si2O5(OH)4
Magnetite	Fe3O4
Mica	K(Mg,Fe)Al2Si3AlO10(OH)2
Palygorskite	(Mg,Al)2Si4O10(OH)*4H2O
Potassium-Feldspar	KAlSi3O8
Pyrite	FeS2
Quartz	SiO2
Rutile	TiO_2
Siderite	FeCO3
Sillimanite	Al2SiO5

Semi-Quantitative X-ray Diffraction Results

Mineral	BH 08 00-12.45 (wt %)	BH 08 12.45-24.45 (wt %)	BH 08 12.45-27.45 (wt %)	BH 08 27.45-34.95 (wt %)	BH 08 34.95-54 (wt %)	BH 10 00-6.45 (wt %)
Quartz	69.6	40.0	33.6	42.7	47.7	52.0
Kaolinite	12.9	13.0	38.8	35.4	24.3	28.7
Halloysite	-	7.4	10.8	8.5	8.7	10.2
Muscovite	-	10.9	5.1	3.9	4.0	-
Goethite	9.0	15.4	3.9	4.4	4.5	2.9
Orthoclase	-	-	2.9	1.4	1.5	1.9
Crandallite	-	-	-	-	-	-
Anatase	1.0	0.8	1.4	1.3	1.3	1.5
Pyrite	-	-	-	-	2.1	1.9
Clinochlore	-	2.9	2.3	1.8	1.8	-
Hematite	3.6	4.1	-	-	-	-
Sillimanite	4.0	3.1	-	-	-	-
Magnetite	-	-	0.9	0.7	0.7	0.8
Siderite	-	-	-	-	3.5	-
Palygorskite	-	0.1	0.4	-	-	-
Calcite	-	0.6	-	-	-	-
Fluorapatite	-	1.8	-	-	-	-
TOTAL	100.1	100.1	100.1	100.1	100.1	99.9

Semi-Quantitative X-ray Diffraction Results

Mineral	BH 10 6.45-15.45 (wt %)	BH 10 15.45-18.45 (wt %)	BH 10 18.45-30.45 (wt %)	BH 10 30.45-49.7 (wt %)	BH 10 30.45-49.7 Dup (wt %)	BH 20 0.3-4.6 (wt %)
Quartz	32.6	53.2	57.8	59.7	68.9	37.6
Kaolinite	42.3	25.1	20.4	13.2	10.1	43.9
Halloysite	9.4	8.9	8.9	9.8	7.6	10.5
Goethite	6.3	7.3	6.6	1.5	1.5	2.4
Muscovite	5.6	-	-	-	-	-
Orthoclase	-	2.0	2.4	2.3	2.6	1.8
Crandallite	-	-	-	9.5	6.1	-
Anatase	1.8	1.1	0.9	1.2	0.7	1.8
Pyrite	-	1.6	1.9	1.7	1.7	-
Clinochlore	0.9	-	-	-	-	1.1
Sillimanite	-	-	-	-	-	-
Magnetite	0.9	0.9	1.0	0.7	0.5	0.9
Siderite	-	-	-	0.5	0.4	-
Palygorskite	0.2	-	-	-	-	-
Calcite	-	-	-	-	-	-
TOTAL	100.0	100.1	99.9	100.1	100.1	100.0

Semi-Quantitative X-ray Diffraction Results

Mineral	BH 20 10-00-18-00 (wt %)	BH 20 18.00-22.00 (wt %)	BH 20 29.00-32.00 (wt %)	BH 20 35.00-40.00 (wt %)	BH 23 0.33-3.0 (wt %)	BH 23 3.0-16.5 (wt %)
Quartz	93.9	54.4	79.2	80.4	41.7	41.1
Kaolinite	3.2	24.7	11.0	5.8	32.5	35.6
Halloysite	-	10.7	4.8	-	7.2	7.9
Goethite	-	4.8	1.8	1.8	4.9	5.3
Muscovite	-	-	-	-	-	3.2
Orthoclase	-	2.9	1.0	-	1.1	-
Crandallite	-	-	-	-	-	-
Anatase	-	0.9	0.5	-	1.1	1.4
Pyrite	-	0.3	-	-	-	-
Clinochlore	-	-	-	-	0.6	0.7
Hematite	1.7	-	1.7	-	-	-
Sillimanite	-	-	-	-	-	-
Magnetite	-	1.3	-	-	0.7	0.8
Siderite	1.3	-	-	-	9.6	4.0
Palygorskite	-	-	-	-	-	-
Calcite	-	-	-	-	-	-
Rutile					0.5	
Fluorapatite	-	-	-	12.0	-	-
TOTAL	100.1	100.0	100.0	100.0	99.9	100.0

The Qualitative XRD method (METH # 8-8-1) used by SGS Minerals Services, P.O. Box 4300, 185 Concession Street, Lakefield, Ontario, Canada K0L 2H0.
Tel: (705) 652-2000 Fax: (705) 652-6365 Mini-method available upon request.

Semi-Quantitative X-ray Diffraction Results

Mineral	BH 23 3.0-16.5 Dup (wt %)	BH 23 21.00-24.1 (wt %)	BH 23 24.1-28.5 (wt %)	BH 23 28.5-33.00 (wt %)
Quartz	38.1	62.4	86.5	51.2
Kaolinite	40.9	21.5	6.7	20.0
Halloysite	9.1	8.1	3.5	4.8
Goethite	4.7	2.0	1.2	2.2
Muscovite	2.9	1.9	-	2.5
Orthoclase	1.0	1.5	1.2	1.3
Crandallite	-	-	-	-
Anatase	1.6	1.0	0.6	0.9
Pyrite	-	-	-	3.5
Clinochlore	0.7	0.9	-	0.9
Sillimanite	-	-	-	-
Magnetite	0.9	0.7	0.4	0.9
Siderite	-	-	-	11.0
Palygorskite	-	-	-	0.7
Calcite	-	-	-	-
TOTAL	99.9	100.0	100.1	99.9

Chemical Balance

BH 08 00-12.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	74.6	77.1	-2.49	Both
Fe2O3	11.5	11.6	-0.14	Both
Al2O3	7.92	7.59	0.33	Both
TiO2	0.75	0.97	-0.22	Both
MgO	0.06	-	0.06	XRF
K2O	0.05	-	0.05	XRF
V2O5	0.04	-	0.04	XRF
Cr2O3	0.04	-	0.04	XRF
MnO	0.03	-	0.03	XRF
P2O5	0.03	-	0.03	XRF
Na2O	0.03	-	0.03	XRF
H2O	-	2.71	2.71	SQD

BH 08 12.45-24.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	51.4	56.6	-5.22	Both
Fe2O3	18.9	17.9	1.00	Both
Al2O3	14.2	14.7	-0.51	Both
K2O	1.15	1.29	-0.14	Both
MgO	1.06	1.06	0.00	Both
CaO	0.76	1.34	-0.58	Both
TiO2	0.72	0.79	-0.07	Both
P2O5	0.71	0.73	-0.02	Both
MnO	0.16	-	0.16	XRF
Na2O	0.05	-	0.05	XRF
Cr2O3	0.04	-	0.04	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	5.30	5.30	SQD
CO2	-	0.25	0.25	SQD
Fluorine	-	0.06	0.06	SQD

BH 08 12.45-27.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	55.9	61.8	-5.93	Both
Al2O3	22.6	22.5	0.06	Both
Fe2O3	4.56	5.52	-0.96	Both
TiO2	1.13	1.37	-0.24	Both
K2O	1.01	1.10	-0.09	Both
MgO	0.84	0.89	-0.05	Both
CaO	0.31	-	0.31	XRF
P2O5	0.17	-	0.17	XRF
Na2O	0.05	-	0.05	XRF
Cr2O3	0.04	-	0.04	XRF
V2O5	0.03	-	0.03	XRF
MnO	0.02	-	0.02	XRF
H2O	-	7.70	7.70	SQD

BH 08 27.45-34.95

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	62.4	66.4	-3.96	Both
Al2O3	19.3	19.4	-0.12	Both
Fe2O3	5.30	5.92	-0.62	Both
TiO2	1.06	1.28	-0.23	Both
K2O	0.75	0.71	0.04	Both
MgO	0.57	0.65	-0.08	Both
CaO	0.18	-	0.18	XRF
P2O5	0.16	-	0.16	XRF
Na2O	0.05	-	0.05	XRF
Cr2O3	0.03	-	0.03	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	6.73	6.73	SQD

1. Values measured by chemical assay.

2. Values calculated based on mineral/compound formulas and quantites identified by semi-quantitative XRD.

Chemical Balance

BH 08 34.95-54

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	62.2	66.4	-4.24	Both
Al2O3	14.9	15.1	-0.25	Both
Fe2O3	9.62	9.81	-0.19	Both
TiO2	1.06	1.32	-0.26	Both
K2O	0.87	0.73	0.14	Both
MgO	0.57	0.65	-0.08	Both
CaO	0.23	-	0.23	XRF
P2O5	0.16	-	0.16	XRF
MnO	0.05	-	0.05	XRF
Na2O	0.05	-	0.05	XRF
Cr2O3	0.03	-	0.03	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	5.21	5.21	SQD
CO2	-	1.32	1.32	SQD
SO3	-	2.76	2.76	SQD

BH 10 00-6.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	71.2	71.4	-0.18	Both
Al2O3	16.0	15.7	0.27	Both
Fe2O3	4.19	5.54	-1.35	Both
TiO2	1.20	1.55	-0.35	Both
K2O	0.11	0.32	-0.21	Both
MgO	0.09	-	0.09	XRF
Na2O	0.05	-	0.05	XRF
Cr2O3	0.04	-	0.04	XRF
P2O5	0.03	-	0.03	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	5.57	5.57	SQD
SO3	-	2.50	2.50	SQD

BH 10 6.45-15.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	56.6	59.6	-3.01	Both
Al2O3	22.0	22.7	-0.75	Both
Fe2O3	8.60	8.50	0.10	Both
TiO2	1.12	1.77	-0.66	Both
K2O	0.65	0.66	-0.01	Both
MgO	0.36	0.34	0.02	Both
P2O5	0.16	-	0.16	XRF
Na2O	0.05	-	0.05	XRF
CaO	0.04	-	0.04	XRF
V2O5	0.03	-	0.03	XRF
Cr2O3	0.02	-	0.02	XRF
H2O	-	7.91	7.91	SQD

BH 10 15.45-18.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	65.5	70.3	-4.81	Both
Al2O3	14.0	13.8	0.20	Both
Fe2O3	10.0	10.6	-0.60	Both
TiO2	0.76	1.11	-0.35	Both
K2O	0.57	0.33	0.24	Both
P2O5	0.41	-	0.41	XRF
MgO	0.32	-	0.32	XRF
Na2O	0.09	-	0.09	XRF
CaO	0.09	-	0.09	XRF
MnO	0.06	-	0.06	XRF
Cr2O3	0.04	-	0.04	XRF
H2O	-	5.07	5.07	SQD
SO3	-	2.08	2.08	SQD

1. Values measured by chemical assay.

2. Values calculated based on mineral/compound formulas and quantites identified by semi-quantitative XRD.

Chemical Balance

BH 10 18.45-30.45

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	70.1	73.0	-2.89	Both
Al2O3	12.0	12.0	-0.05	Both
Fe2O3	9.31	10.2	-0.91	Both
TiO2	0.89	0.93	-0.04	Both
K2O	0.43	0.41	0.02	Both
MgO	0.23	-	0.23	XRF
P2O5	0.18	-	0.18	XRF
CaO	0.06	-	0.06	XRF
Na2O	0.05	-	0.05	XRF
MnO	0.02	-	0.02	XRF
V2O5	0.02	-	0.02	XRF
Cr2O3	0.02	-	0.02	XRF
H2O	-	4.40	4.40	SQD
SO3	-	2.50	2.50	SQD

BH 10 30.45-49.7

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	67.9	71.9	-4.02	Both
Al2O3	13.2	13.0	0.20	Both
Fe2O3	3.69	3.88	-0.19	Both
P2O5	2.55	3.25	-0.70	Both
CaO	1.27	1.29	-0.02	Both
TiO2	0.74	1.23	-0.49	Both
K2O	0.58	0.39	0.20	Both
MgO	0.41	-	0.41	XRF
Na2O	0.09	-	0.09	XRF
MnO	0.06	-	0.06	XRF
Cr2O3	0.06	-	0.06	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	4.72	4.72	SQD
CO2	-	0.17	0.17	SQD
SO3	-	2.24	2.24	SQD

BH 10 30.45-49.7 Dup

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	76.2	78.8	-2.65	Both
Al2O3	9.21	9.72	-0.51	Both
Fe2O3	3.27	3.64	-0.37	Both
P2O5	1.57	2.10	-0.53	Both
CaO	0.82	0.83	-0.01	Both
TiO2	0.64	0.65	-0.01	Both
K2O	0.45	0.45	0.00	Both
MgO	0.33	-	0.33	XRF
Na2O	0.07	-	0.07	XRF
Cr2O3	0.07	-	0.07	XRF
MnO	0.06	-	0.06	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	3.46	3.46	SQD
CO2	-	0.13	0.13	SQD
SO3	-	2.23	2.23	SQD

BH 20 0.3-4.6

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	59.5	64.5	-4.96	Both
Al2O3	21.1	22.0	-0.92	Both
Fe2O3	3.44	3.76	-0.32	Both
TiO2	1.67	1.81	-0.14	Both
MgO	0.40	0.41	-0.01	Both
K2O	0.36	0.30	0.06	Both
Na2O	0.25	-	0.25	XRF
P2O5	0.07	-	0.07	XRF
CaO	0.07	-	0.07	XRF
V2O5	0.02	-	0.02	XRF
Cr2O3	0.02	-	0.02	XRF
H2O	-	7.85	-7.85	SQD

1. Values measured by chemical assay.

2. Values calculated based on mineral/compound formulas and quantites identified by semi-quantitative XRD.

Chemical Balance

BH 20 10-00-18-00

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	94.8	95.3	-0.54	Both
Fe2O3	1.76	2.57	-0.81	Both
Al2O3	1.55	1.26	0.30	Both
TiO2	0.22	-	0.22	XRF
Cr2O3	0.07	-	0.07	XRF
Na2O	0.04	-	0.04	XRF
CaO	0.04	-	0.04	XRF
K2O	0.03	-	0.03	XRF
MgO	0.03	-	0.03	XRF
H2O	-	0.44	-0.44	SQD
CO2	-	0.48	0.48	SQD

BH 20 18.00-22.00

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	70.1	72.8	-2.72	Both
Al2O3	13.2	14.5	-1.33	Both
Fe2O3	7.19	7.17	0.02	Both
TiO2	0.90	0.92	-0.02	Both
K2O	0.43	0.50	-0.07	Both
MgO	0.41	-	0.41	XRF
CaO	0.10	-	0.10	XRF
Na2O	0.08	-	0.08	XRF
P2O5	0.07	-	0.07	XRF
Cr2O3	0.04	-	0.04	XRF
MnO	0.02	-	0.02	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	5.16	5.16	SQD
SO3	-	0.37	0.37	SQD

BH 20 29.00-32.00

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	85.0	87.2	-2.20	Both
Al2O3	6.69	6.42	0.27	Both
Fe2O3	3.14	3.86	-0.72	Both
TiO2	0.56	0.50	0.06	Both
MgO	0.18	-	0.18	XRF
K2O	0.17	0.17	0.00	Both
P2O5	0.08	-	0.08	XRF
Na2O	0.07	-	0.07	XRF
CaO	0.07	-	0.07	XRF
Cr2O3	0.04	-	0.04	XRF
MnO	0.02	-	0.02	XRF
H2O	-	2.29	2.29	SQD

BH 20 35.00-40.00

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	81.9	83.1	-1.22	Both
CaO	6.27	6.65	-0.38	Both
P2O5	4.37	5.05	-0.68	Both
Fe2O3	2.42	2.18	0.24	Both
Al2O3	2.04	2.29	-0.25	Both
TiO2	0.23	-	0.23	XRF
Na2O	0.09	-	0.09	XRF
MgO	0.08	-	0.08	XRF
K2O	0.05	-	0.05	XRF
Cr2O3	0.05	-	0.05	XRF
MnO	0.03	-	0.03	XRF
H2O	-	0.89	0.89	SQD
Fluorine	-	0.45	0.45	SQD

1. Values measured by chemical assay.

2. Values calculated based on mineral/compound formulas and quantites identified by semi-quantitative XRD.

Chemical Balance

BH 23 0.33-3.0

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	56.2	61.1	-4.94	Both
Al2O3	16.6	16.0	0.59	Both
Fe2O3	12.4	13.2	-0.77	Both
TiO2	1.36	1.60	-0.24	Both
MgO	0.36	0.23	0.13	Both
Na2O	0.28	-	0.28	XRF
CaO	0.22	-	0.22	XRF
K2O	0.20	0.20	0.01	Both
P2O5	0.09	-	0.09	XRF
MnO	0.03	-	0.03	XRF
V2O5	0.03	-	0.03	XRF
Cr2O3	0.02	-	0.02	XRF
H2O	-	5.84	5.84	SQD
CO2	-	3.66	3.66	SQD

BH 23 3.0-16.5

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	59.2	63.0	-3.79	Both
Al2O3	18.5	18.6	-0.05	Both
Fe2O3	9.92	9.94	-0.02	Both
TiO2	1.29	1.40	-0.11	Both
K2O	0.36	0.38	-0.02	Both
MgO	0.30	0.24	0.06	Both
Na2O	0.16	-	0.16	XRF
P2O5	0.12	-	0.12	XRF
CaO	0.10	-	0.10	XRF
V2O5	0.03	-	0.03	XRF
Cr2O3	0.03	-	0.03	XRF
H2O	-	6.55	6.55	SQD
CO2	-	1.52	1.52	SQD

BH 23 3.0-16.5 Dup

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	62.4	63.6	-1.19	Both
Al2O3	19.0	21.2	-2.20	Both
Fe2O3	6.62	6.59	0.03	Both
TiO2	1.24	1.60	-0.36	Both
K2O	0.51	0.52	-0.01	Both
MgO	0.37	0.25	0.12	Both
Na2O	0.16	-	0.16	XRF
CaO	0.10	-	0.10	XRF
P2O5	0.07	-	0.07	XRF
V2O5	0.03	-	0.03	XRF
Cr2O3	0.03	-	0.03	XRF
H2O	-	7.42	7.42	SQD

BH 23 21.00-24.1

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	76.3	78.3	-1.97	Both
Al2O3	12.9	12.8	0.05	Both
Fe2O3	2.51	3.10	-0.59	Both
TiO2	0.96	1.05	-0.09	Both
K2O	0.51	0.49	0.02	Both
MgO	0.28	0.32	-0.04	Both
CaO	0.10	-	0.10	XRF
Na2O	0.07	-	0.07	XRF
P2O5	0.06	-	0.06	XRF
Cr2O3	0.04	-	0.04	XRF
V2O5	0.02	-	0.02	XRF
H2O	-	4.41	4.41	SQD

1. Values measured by chemical assay.

2. Values calculated based on mineral/compound formulas and quantites identified by semi-quantitative XRD.

Chemical Balance

BH 23 24.1-28.5

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	90.9	92.0	-1.09	Both
Al2O3	4.25	4.25	0.00	Both
Fe2O3	1.84	1.81	0.03	Both
TiO2	0.55	0.58	-0.03	Both
K2O	0.19	0.20	-0.01	Both
MgO	0.13	-	0.13	XRF
Na2O	0.09	-	0.09	XRF
Cr2O3	0.09	-	0.09	XRF
P2O5	0.03	-	0.03	XRF
CaO	0.03	-	0.03	XRF
H2O	-	1.48	-1.48	SQD

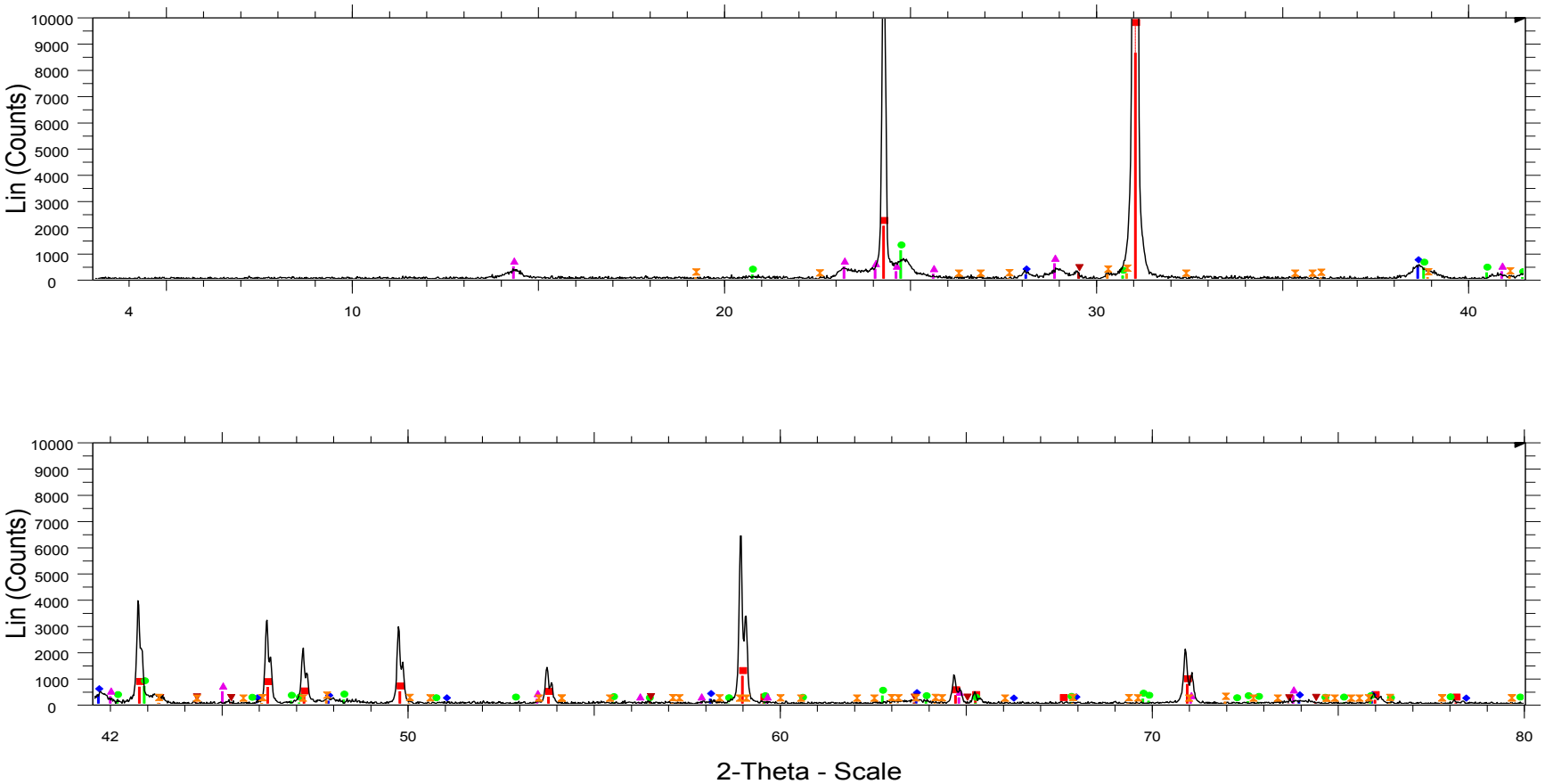
BH 23 28.5-33.00

Name	Assay[1]	SQD[2]	Delta	Status
SiO2	59.0	65.4	-6.45	Both
Fe2O3	12.0	13.5	-1.53	Both
Al2O3	10.9	11.2	-0.32	Both
TiO2	0.82	0.89	-0.07	Both
MgO	0.64	0.42	0.22	Both
K2O	0.59	0.51	0.08	Both
CaO	0.46	-	0.46	XRF
MnO	0.18	-	0.18	XRF
P2O5	0.10	-	0.10	XRF
Na2O	0.10	-	0.10	XRF
Cr2O3	0.03	-	0.03	XRF
H2O	-	3.94	3.94	SQD
CO2	-	4.19	4.19	SQD
SO3	-	4.71	4.71	SQD

1. Values measured by chemical assay.

2. Values calculated based on mineral/compound formulas and quantites identified by semi-quantitative XRD.

BH 08 00-12-45

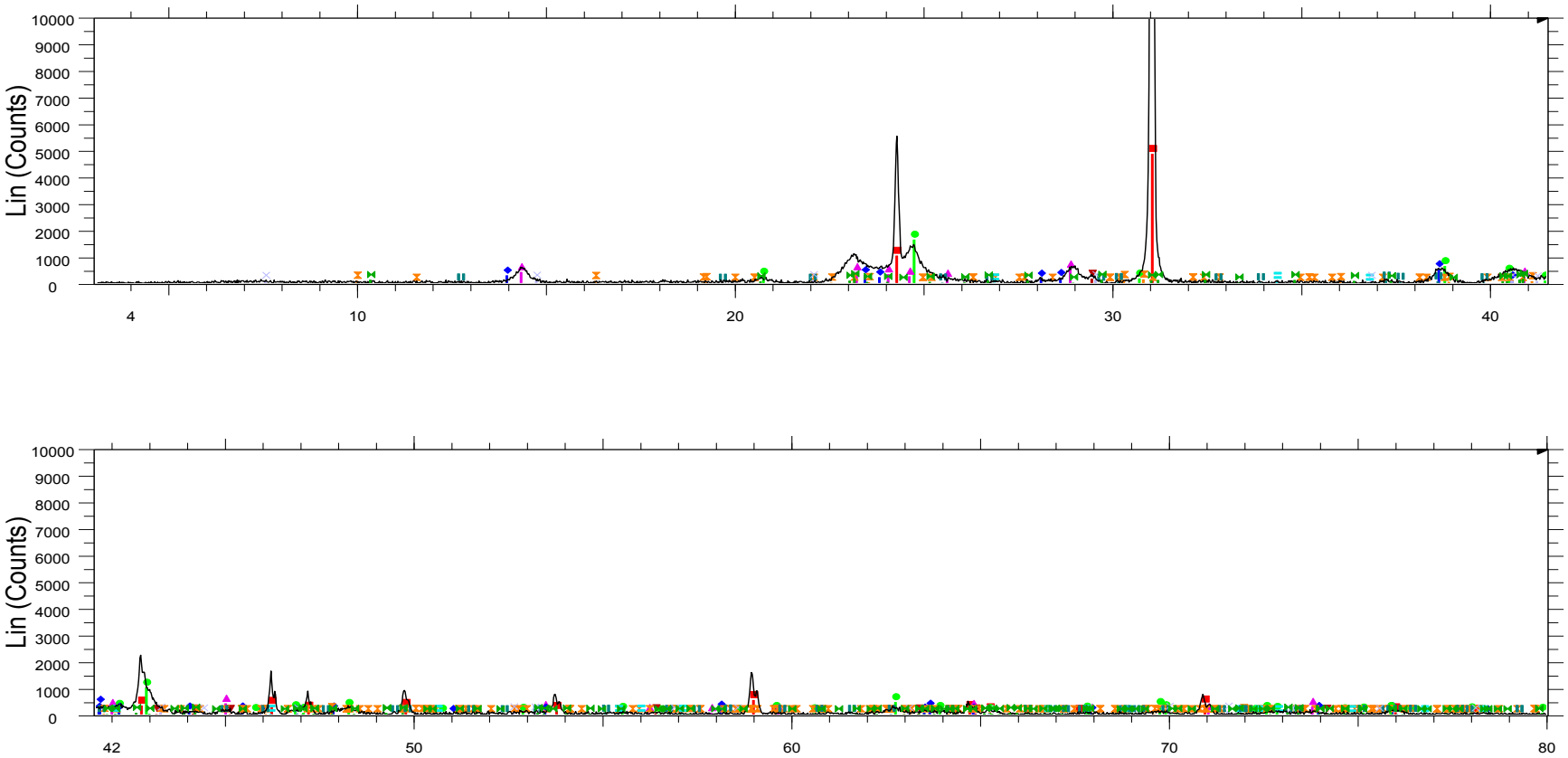


BH 08 00-12-45 - File: Apr4515-1 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 80.024 ° - Step: 0.019 ° - Step time: 60. s - Temp.: 25 °C (Room) - Time Started: 19 s - 2-Theta: 3.019
Operations: Displacement -0.042 | Displacement -0.021 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO_2
- 01-072-0469 (C) - Hematite - Fe_2O_3
- 01-081-0464 (C) - Goethite, syn - $FeO(OH)$
- 00-001-0527 (D) - Kaolinite - $Al_2Si_2O_5(OH)_4$
- 01-084-1286 (C) - Anatase, syn - TiO_2
- 01-083-1563 (C) - Sillimanite - Al_2SiO_5

Environmental -Analytical
MI4515-APR12
05/16/2012

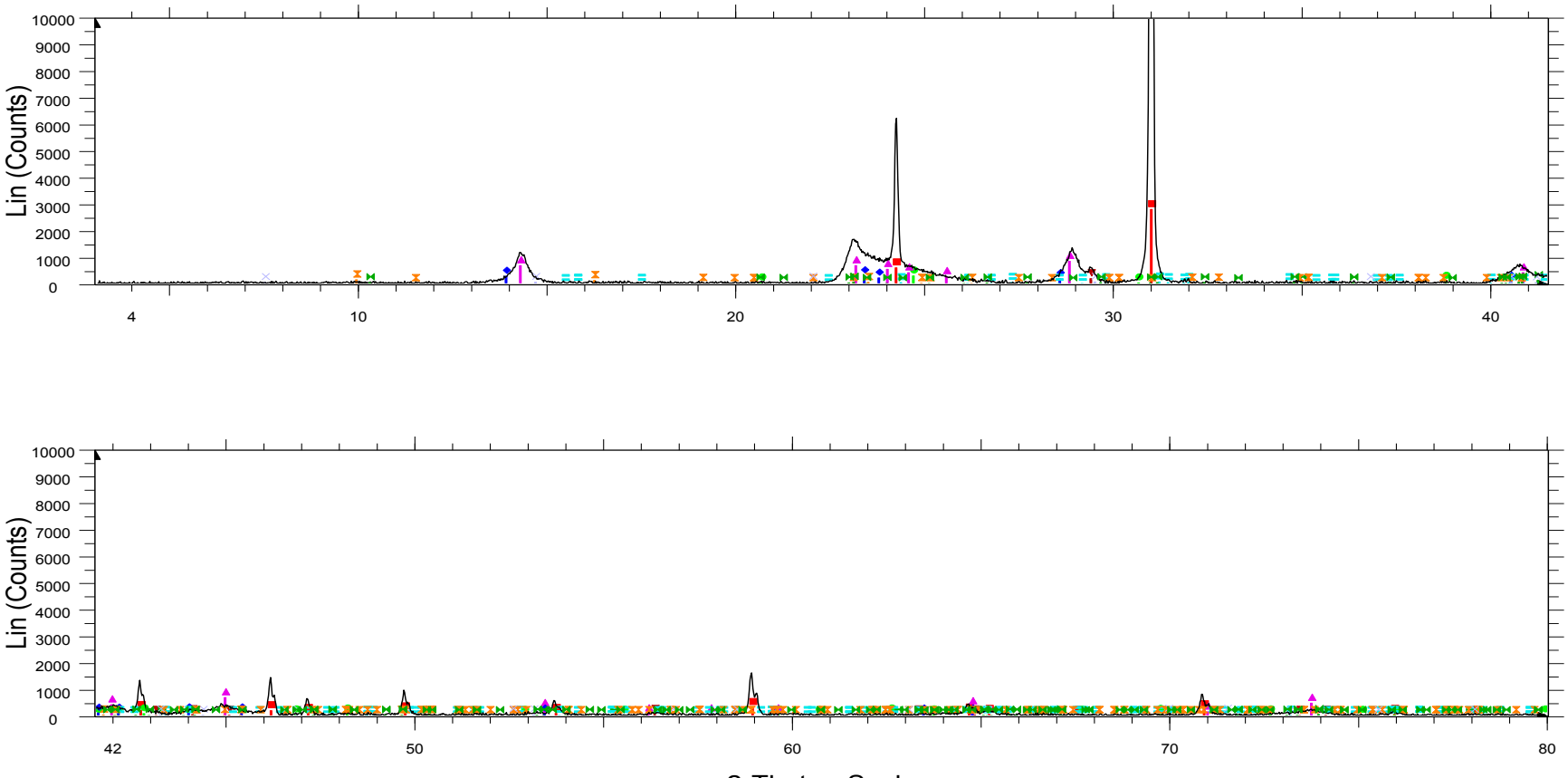
BH 08 12-45-24.45



BH 08 12-45-24.45 - File: Apr4515-2 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 8
Operations: Displacement -0.042 | Displacement -0.031 | Background 1.000,1.000 | Import

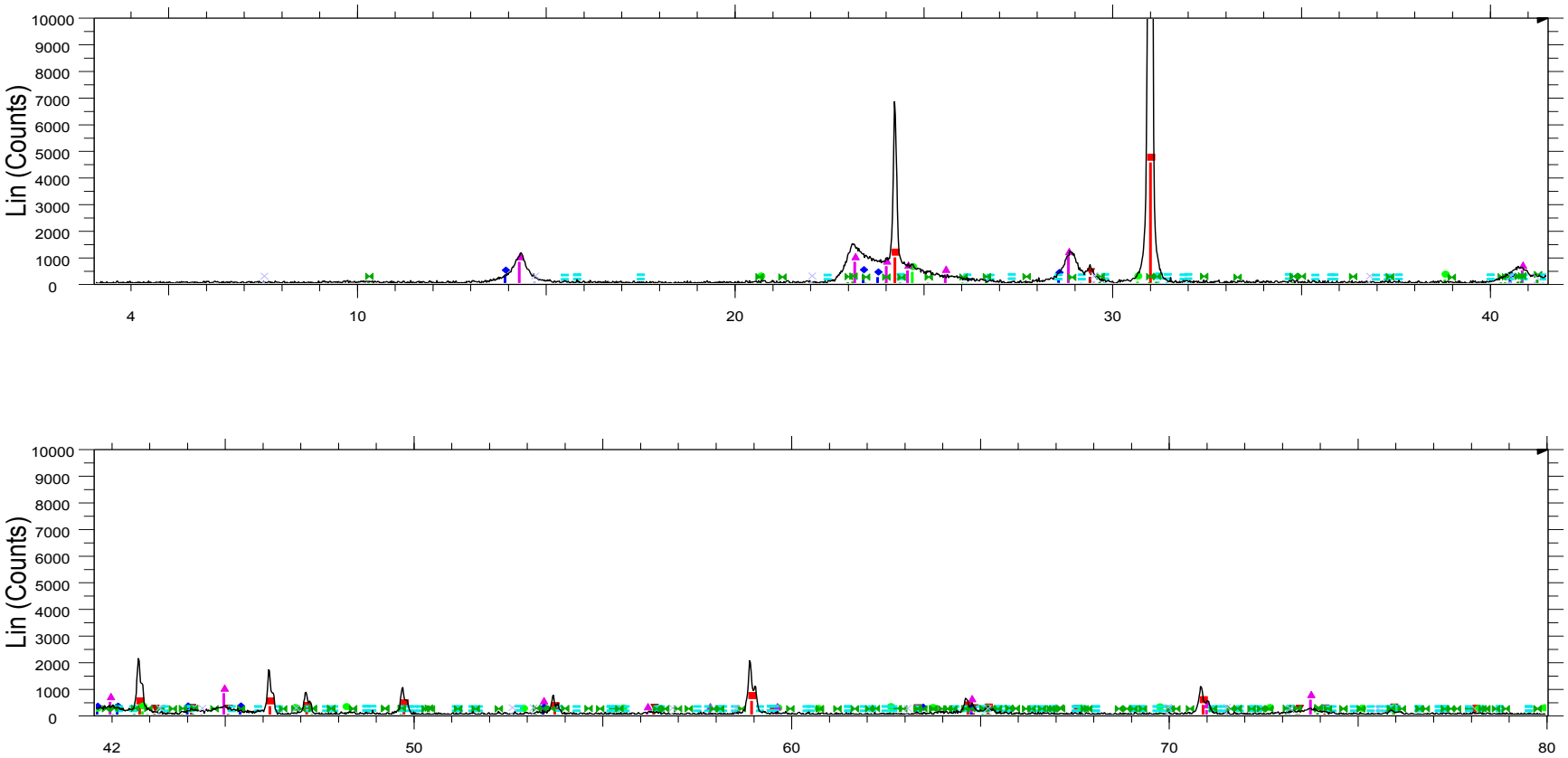
- 01-079-1910 (C) - Quartz - SiO2
- 01-072-0469 (C) - Hematite - Fe2O3
- 01-081-0464 (C) - Goethite, syn - FeO(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 01-083-1563 (C) - Sillimanite - Al2SiO5
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-082-1872 (C) - Palygorskite - (Mg0.669Al0.331)4(Si4O10)2(OH)2(H2O)8
- 01-072-1652 (C) - Calcite - CaCO3
- 01-083-0556 (C) - Fluorapatite - Ca5.061(P2.87O11.46)F0.89
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8

BH 08 12-45-27.45



BH 08 12-45-27.45 - File: Apr4515-3 Riet.raw - Type: 2Th/Th locked - Start: 3.024 ° - End:
01-079-1910 (C) - Quartz - SiO2
00-017-0536 (D) - Goethite - Fe+3O(OH)
00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
01-071-1167 (C) - Anatase - TiO2
00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
01-086-1358 (C) - Magnetite - Fe2.929O4
01-075-1592 (C) - Orthoclase - KAlSi3O8
01-082-1872 (C) - Palygorskite - (Mg0.669Al0.331)4(Si4O10)2(OH)2(H2O)8
00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2

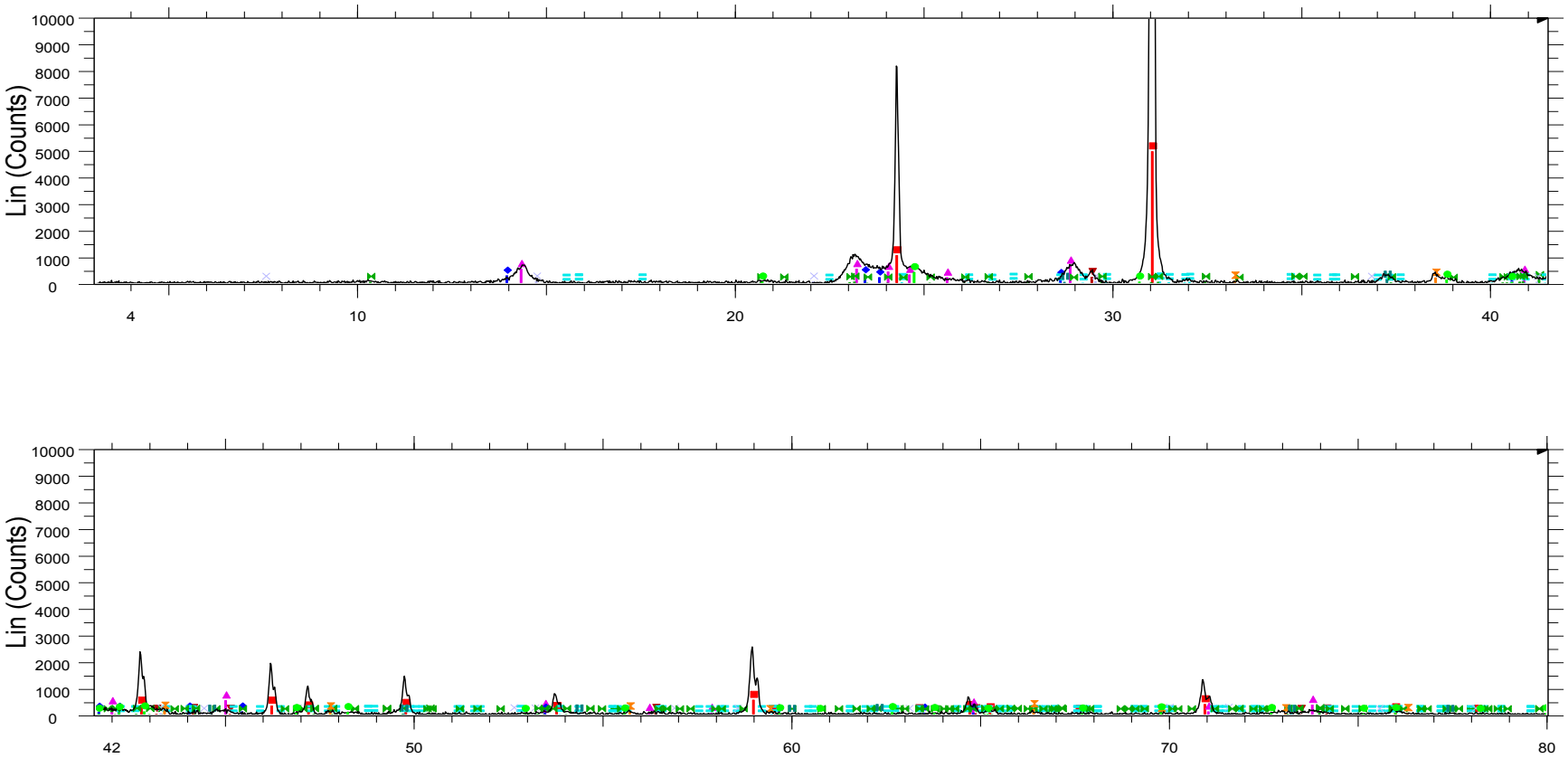
BH 08 27-45-34.95



BH 08 27-45-34.95 - File: Apr4515-4 Riet.raw - Type: 2Th/Th locked - Start: 3.024 ° - End: 8
Operations: Displacement -0.052 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2 - I/Ic PDF 3.1 - S-Q 42.7 %
- 00-017-0536 (D) - Goethite - Fe+3O(OH) - I/Ic PDF 1. - I/Ic User 2.7 - S-Q 4.4 %
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4 - I/Ic PDF 1. - I/Ic User 0.8 - S-Q 35.4 %
- 01-071-1167 (C) - Anatase - TiO2 - I/Ic PDF 4.9 - S-Q 1.3 %
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4 - I/Ic PDF 1. - S-Q 8.5 %
- 01-086-1358 (C) - Magnetite - Fe2.929O4 - I/Ic PDF 4.8 - S-Q 0.7 %
- 01-075-1592 (C) - Orthoclase - KAlSi3O8 - I/Ic PDF 0.8 - S-Q 1.4 %
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8 - I/Ic PDF 1. - S-Q 1.8 %
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2 - I/Ic PDF 0.4 - S-Q 3.9 %

BH 08 34-95-54



BH 08 34-95-54 - File: Apr4515-5 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 80.0
Operations: Displacement -0.042 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2
- 01-071-2219 (C) - Pyrite - FeS2
- 00-003-0746 (D) - Siderite - FeCO3

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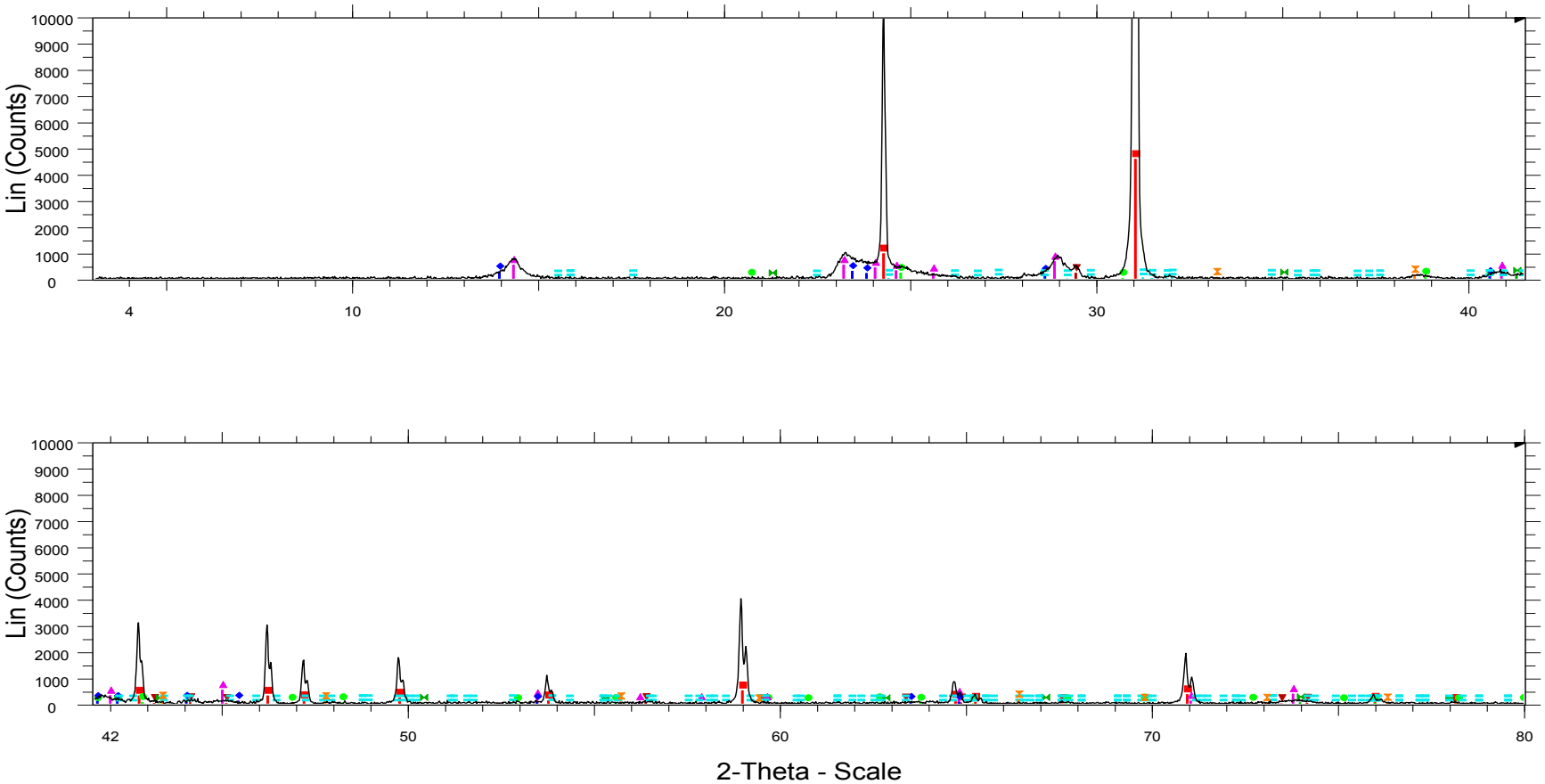
BH 10 00-6-45

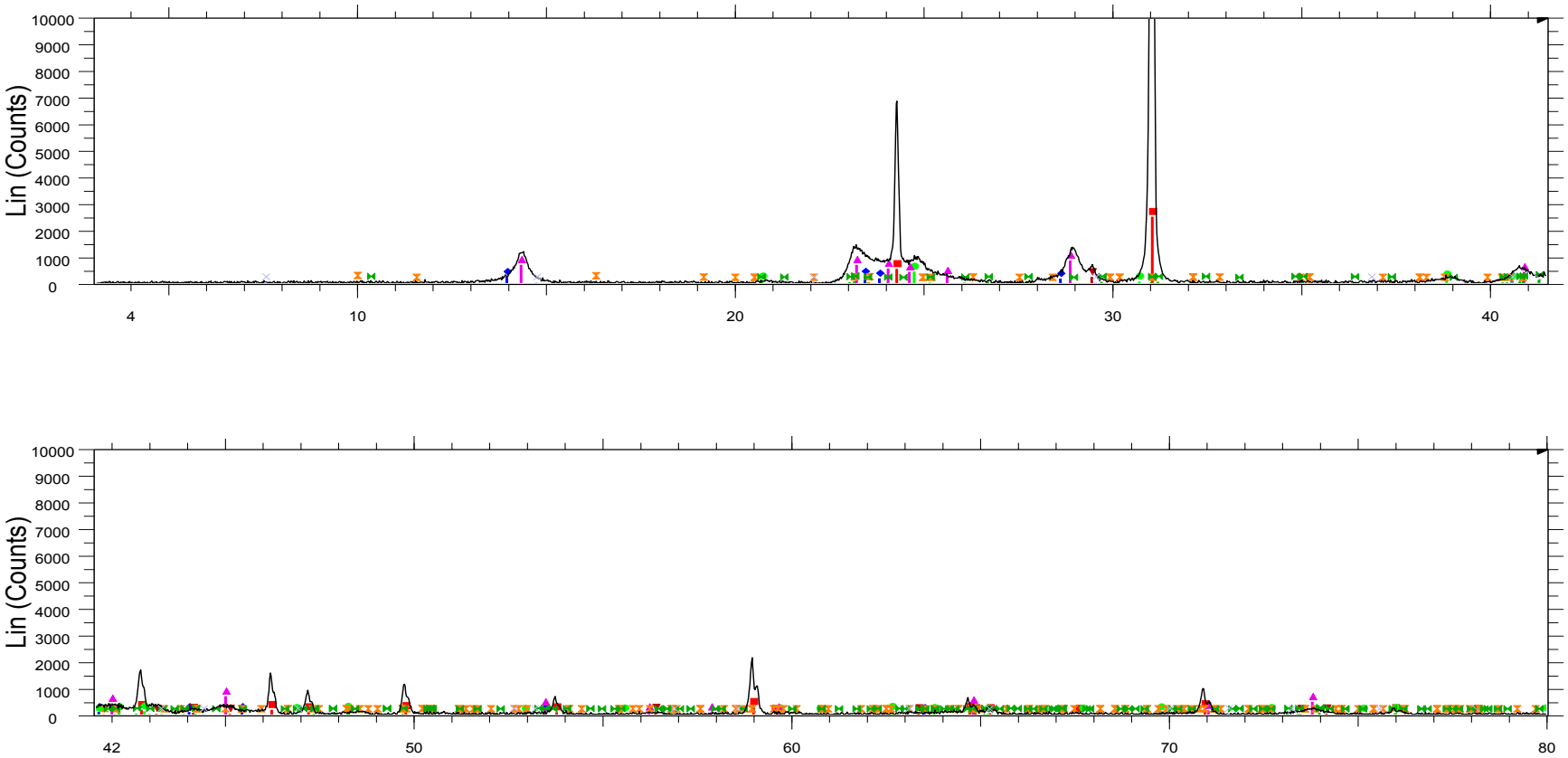


BH 10 00-6-45 - File: Apr4515-6 Riet.raw - Type: 2Th/Th locked - Start: 3.014 ° - End: 80.02
Operations: Displacement -0.031 | Displacement -0.042 | Displacement -0.021 | Backgroun

01-079-1910 (C) - Quartz - SiO2
00-017-0536 (D) - Goethite - Fe+3O(OH)
00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
01-071-1167 (C) - Anatase - TiO2
00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
01-086-1358 (C) - Magnetite - Fe2.929O4
01-075-1592 (C) - Orthoclase - KAlSi3O8
01-071-2219 (C) - Pyrite - FeS2

The Qualitative XRD method (METH # 8-8-1) used by SGS Minerals Services, P.O. Box 4300, 185 Concession Street, Lakefield, Ontario, Canada K0L 2H0.
Tel: (705) 652-2000 Fax: (705) 652-6365 Mini-method available upon request.

BH 10 6-45-15.45



BH 10 6-45-15.45 - File: Apr4515-7 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 80
Operations: Displacement -0.042 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 01-082-1872 (C) - Palygorskite - (Mg0.669Al0.331)4(Si4O10)2(OH)2(H2O)8
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8

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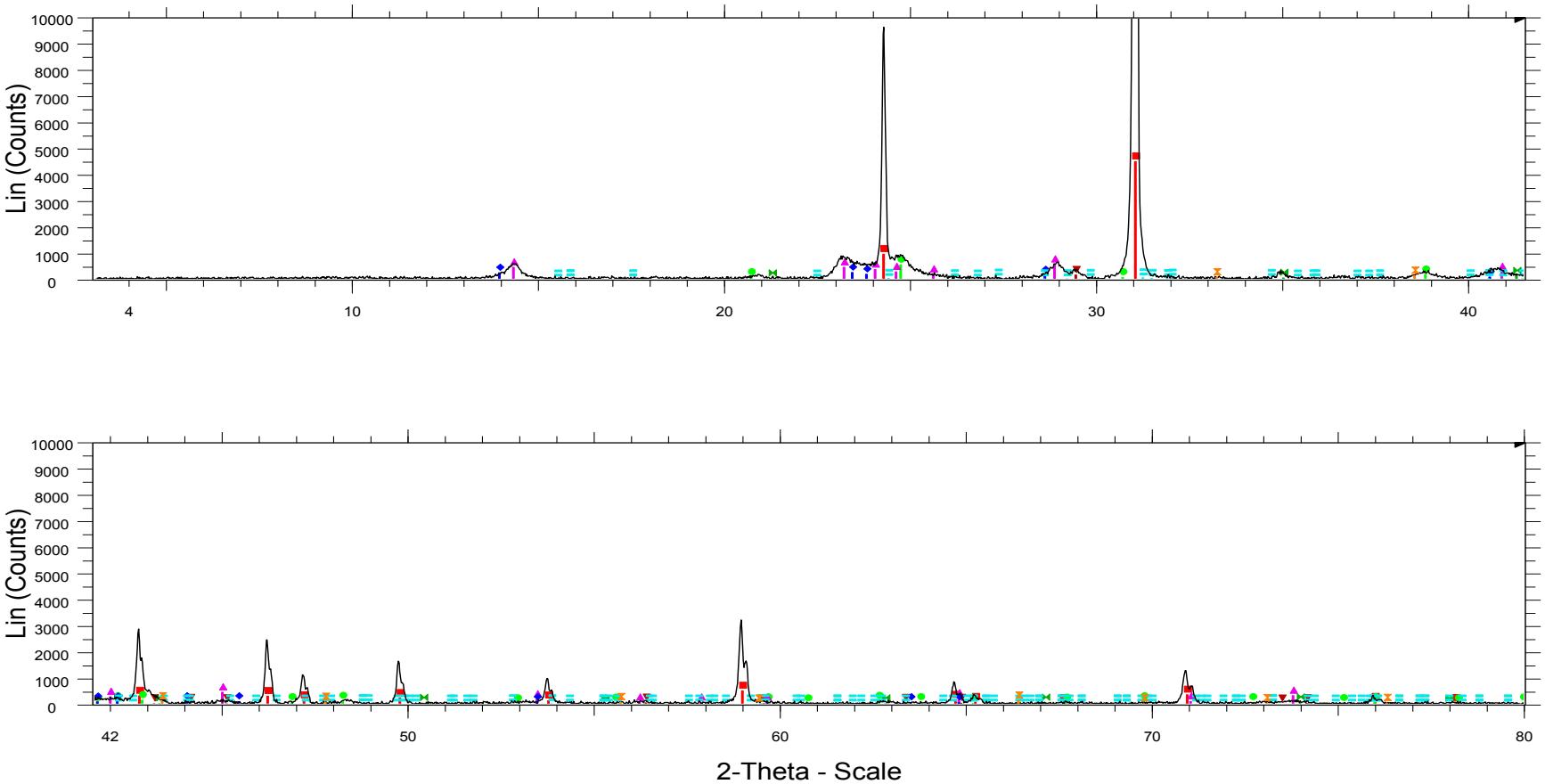
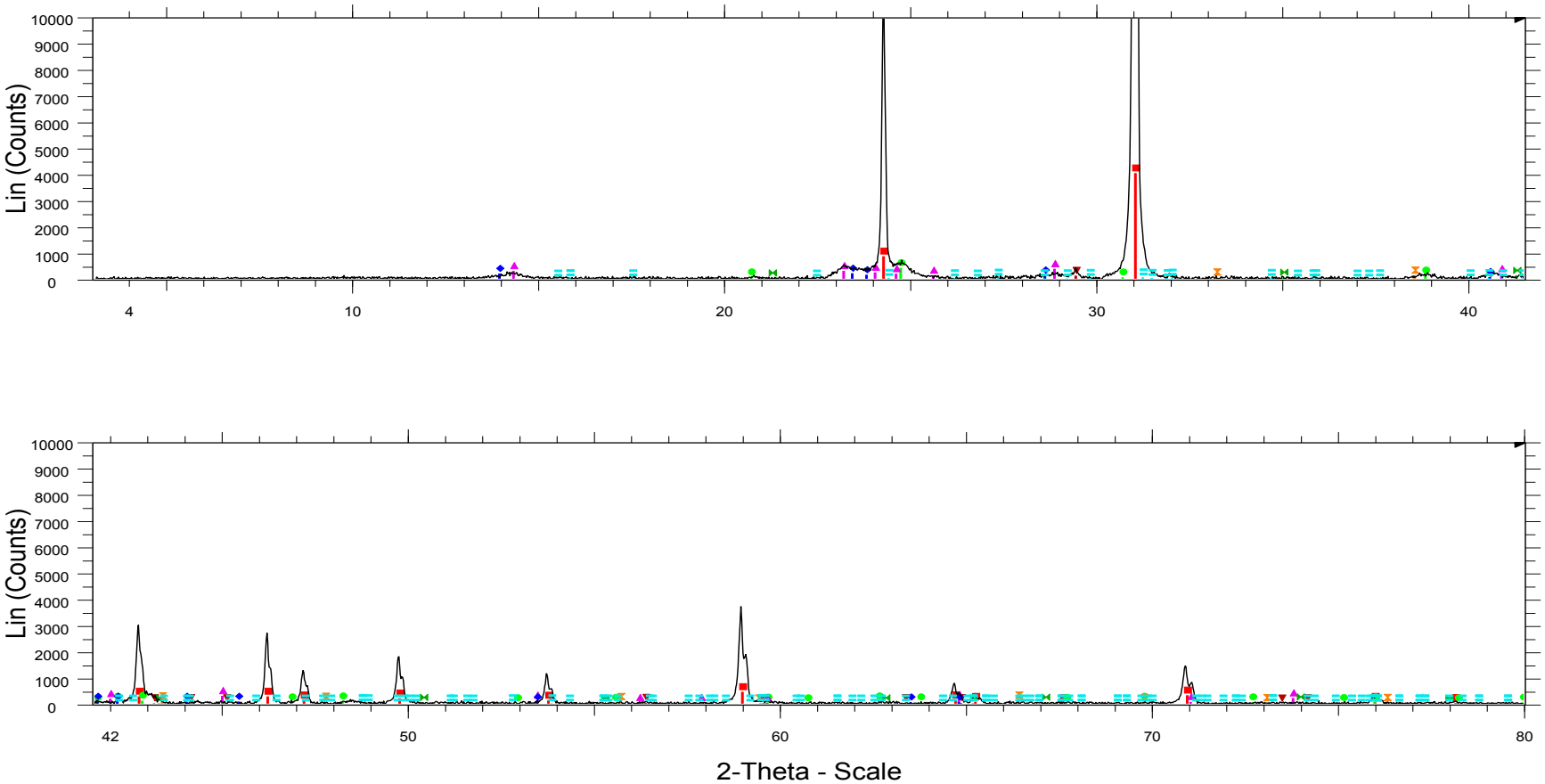
BH 10 15.45-18.45



BH 10 15.45-18.45 - File: Apr4515-8 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 8
Operations: Displacement -0.042 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 01-071-2219 (C) - Pyrite - FeS2

BH 10 18.45-30.45



BH 10 18.45-30.45 - File: Apr4515-9 Riet.raw - Type: 2Th/Th locked - Start: 3.014 ° - End: 8
Operations: Displacement -0.031 | Background 1.000,1.000 | Import

01-079-1910 (C) - Quartz - SiO2
00-017-0536 (D) - Goethite - Fe+3O(OH)
00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
01-071-1167 (C) - Anatase - TiO2
00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
01-086-1358 (C) - Magnetite - Fe2.929O4
01-075-1592 (C) - Orthoclase - KAlSi3O8
01-071-2219 (C) - Pyrite - FeS2

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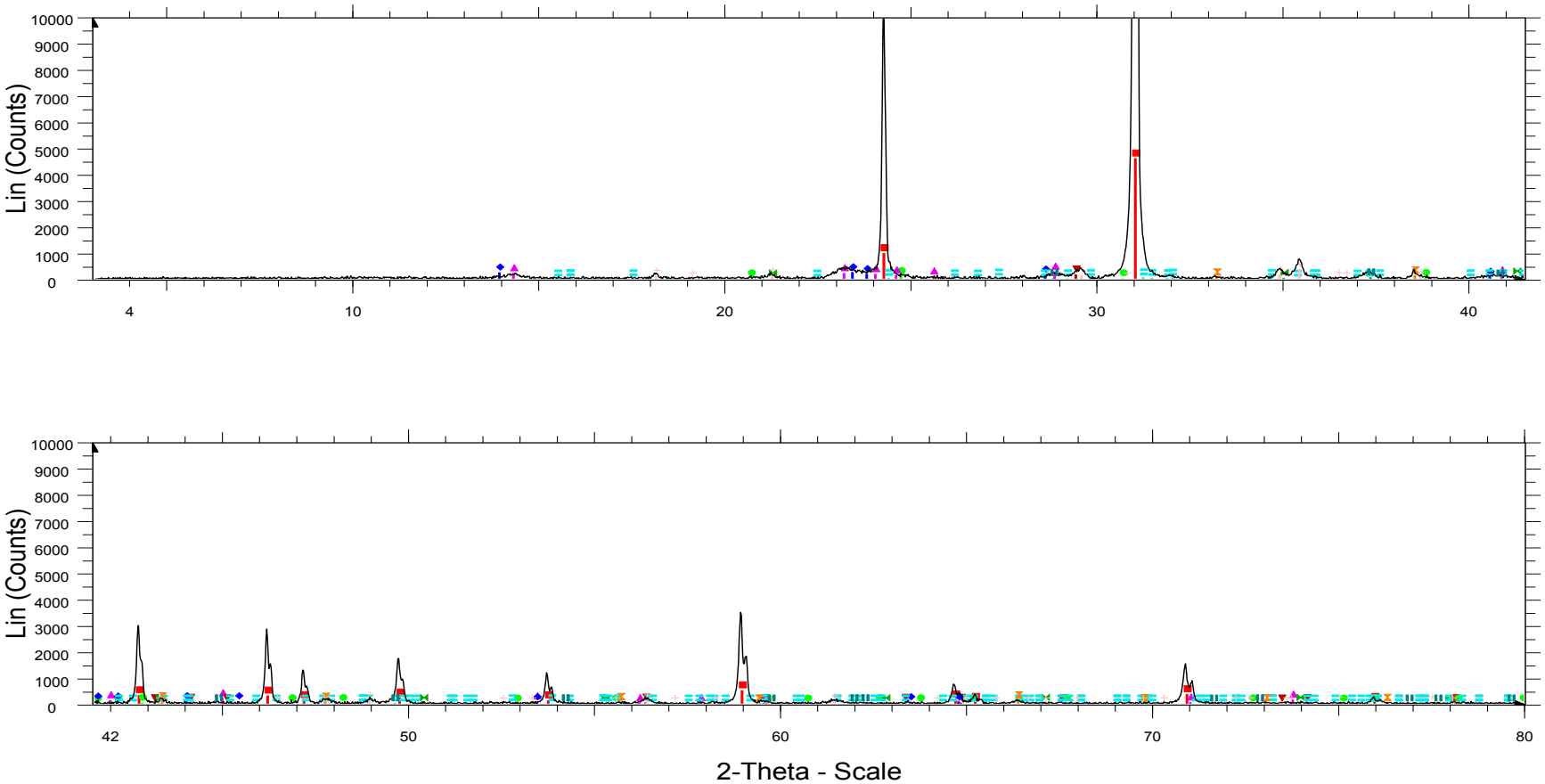
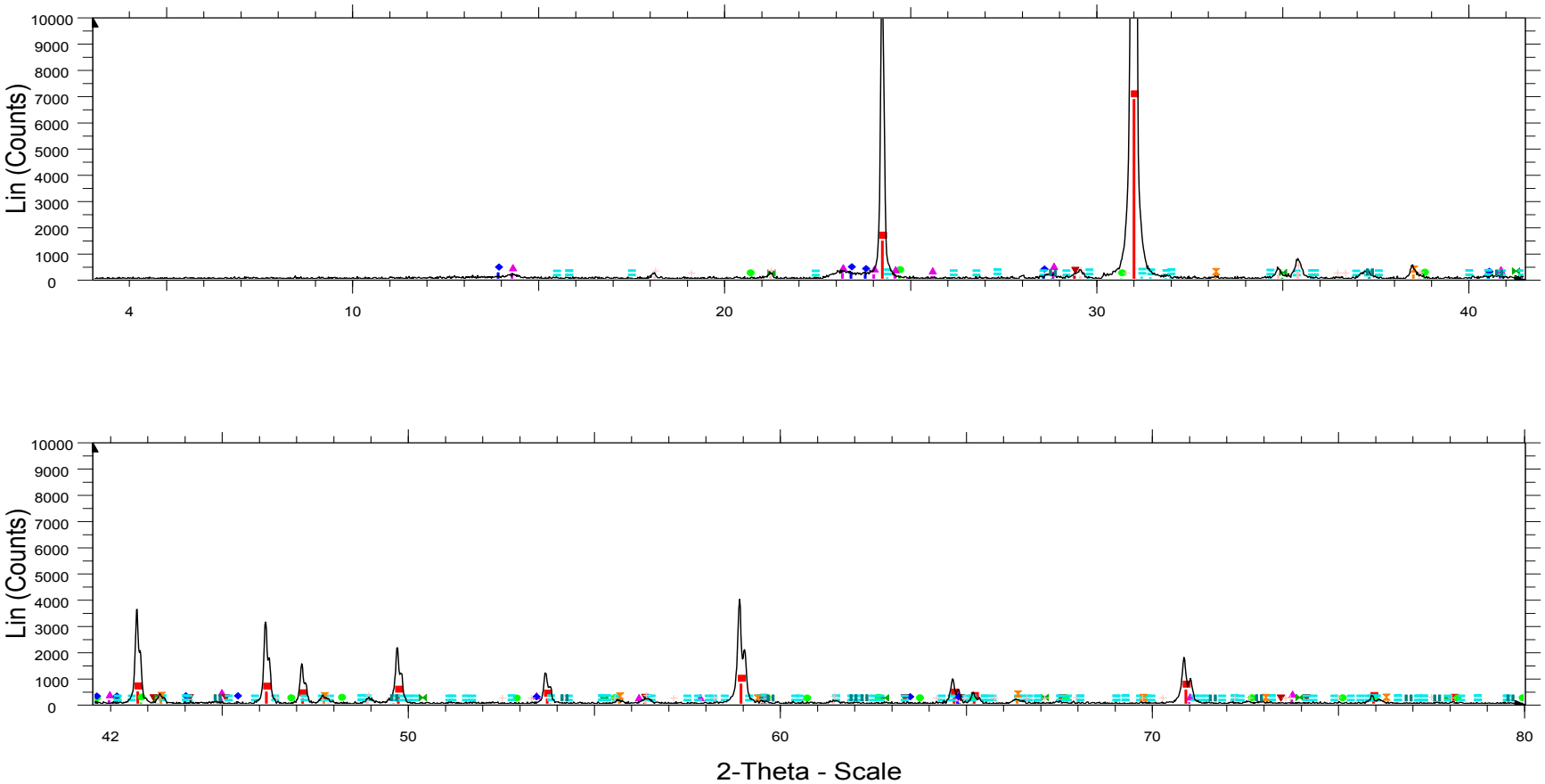
BH 10 30.45-49.7



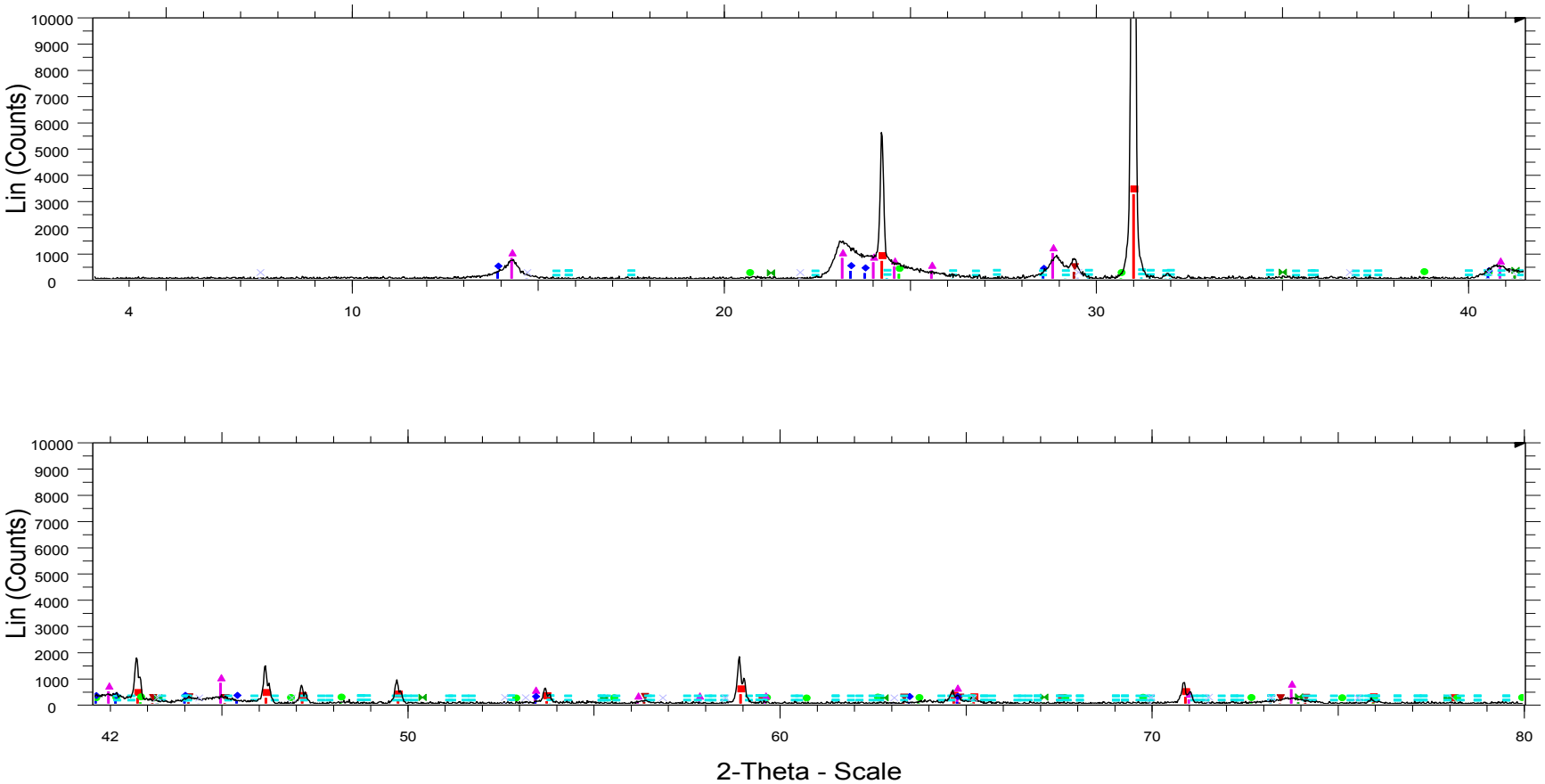
BH 10 30.45-49.7 - File: Apr4515-10 Riet.raw - Type: 2Th/Th locked - Start: 3.010 ° - End: 8
01-079-1910 (C) - Quartz - SiO2
00-017-0536 (D) - Goethite - Fe+3O(OH)
00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
01-071-1167 (C) - Anatase - TiO2
00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
01-086-1358 (C) - Magnetite - Fe2.929O4
01-075-1592 (C) - Orthoclase - KAlSi3O8
01-071-2219 (C) - Pyrite - FeS2
01-070-2069 (C) - Crandallite - CaAl3(OH)6(PO3(O0.5(OH)0.5))2
01-083-1764 (C) - Siderite - Fe(CO3)

BH 10 30.45-49.7 Dup



BH 10 30.45-49.7 Dup - File: Apr4515-11 dup Riet.raw - Type: 2Th/Th locked - Start: 3.014
01-079-1910 (C) - Quartz - SiO2
00-017-0536 (D) - Goethite - Fe+3O(OH)
00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
01-071-1167 (C) - Anatase - TiO2
00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
01-086-1358 (C) - Magnetite - Fe2.929O4
01-075-1592 (C) - Orthoclase - KAlSi3O8
01-071-2219 (C) - Pyrite - FeS2
01-070-2069 (C) - Crandallite - CaAl3(OH)6(PO3(O0.5(OH)0.5))2
01-083-1764 (C) - Siderite - Fe(CO3)

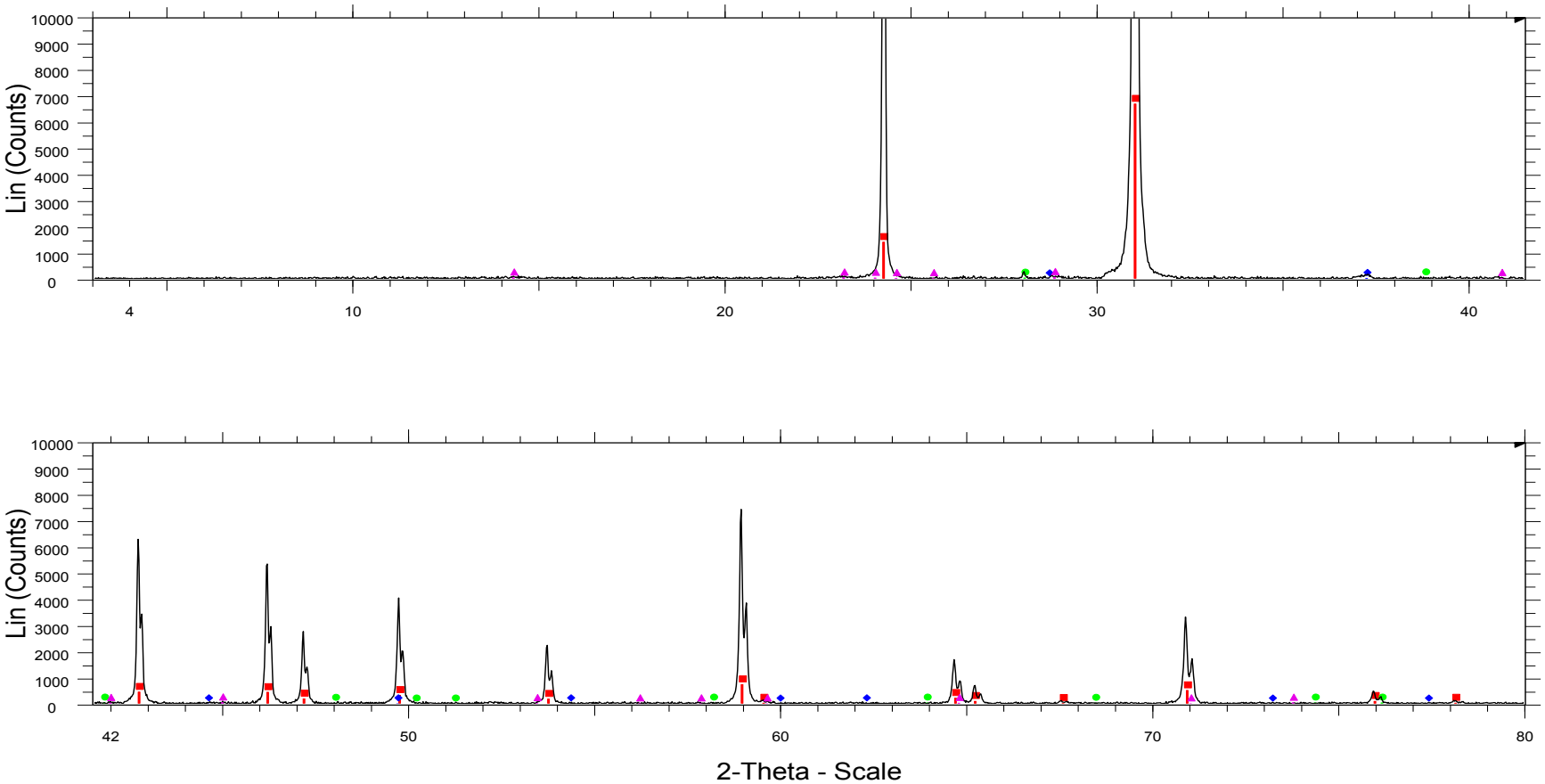
BH 20 0.3-4.6



BH 20 0.3-4.6 - File: Apr4515-12 Riet.raw - Type: 2Th/Th locked - Start: 3.024 ° - End: 80.0
Operations: Displacement -0.052 | Displacement -0.042 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8

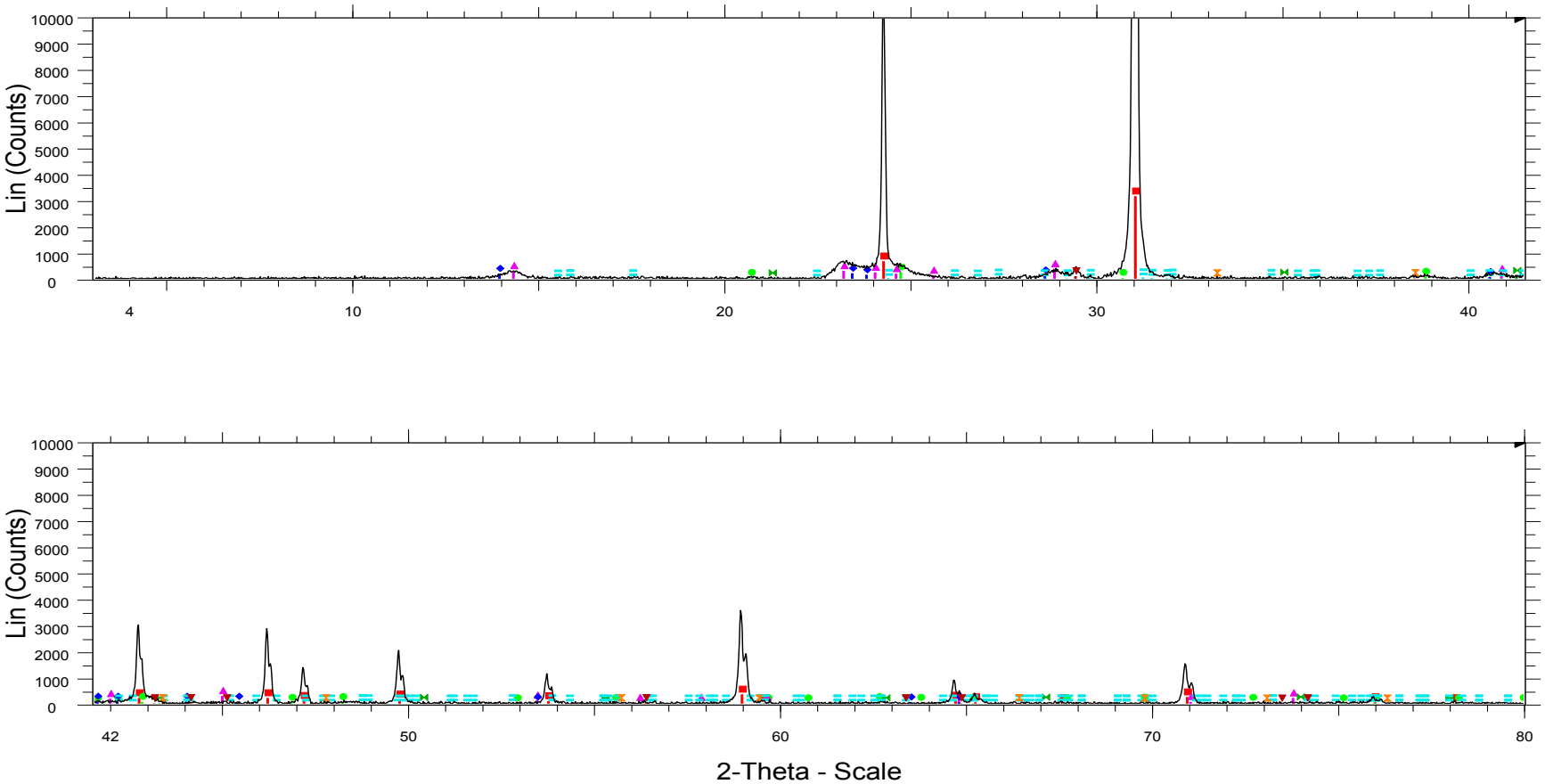
BH 20 10-00-18-00



BH 20 10-00-18-00 - File: Apr4515-13 Riet.raw - Type: 2Th/Th locked - Start: 3.005 ° - End: 80.013 ° - Step: 0.019 ° - Step time: 60. s - Temp.: 25 °C (Room) - Time Started: 17 s - 2-Theta: 3.
Operations: Displacement -0.010 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO_2
- 00-001-0527 (D) - Kaolinite - $Al_2Si_2O_5(OH)_4$
- 00-003-0746 (D) - Siderite - $FeCO_3$
- 00-002-0915 (D) - Hematite, syn - Fe_2O_3

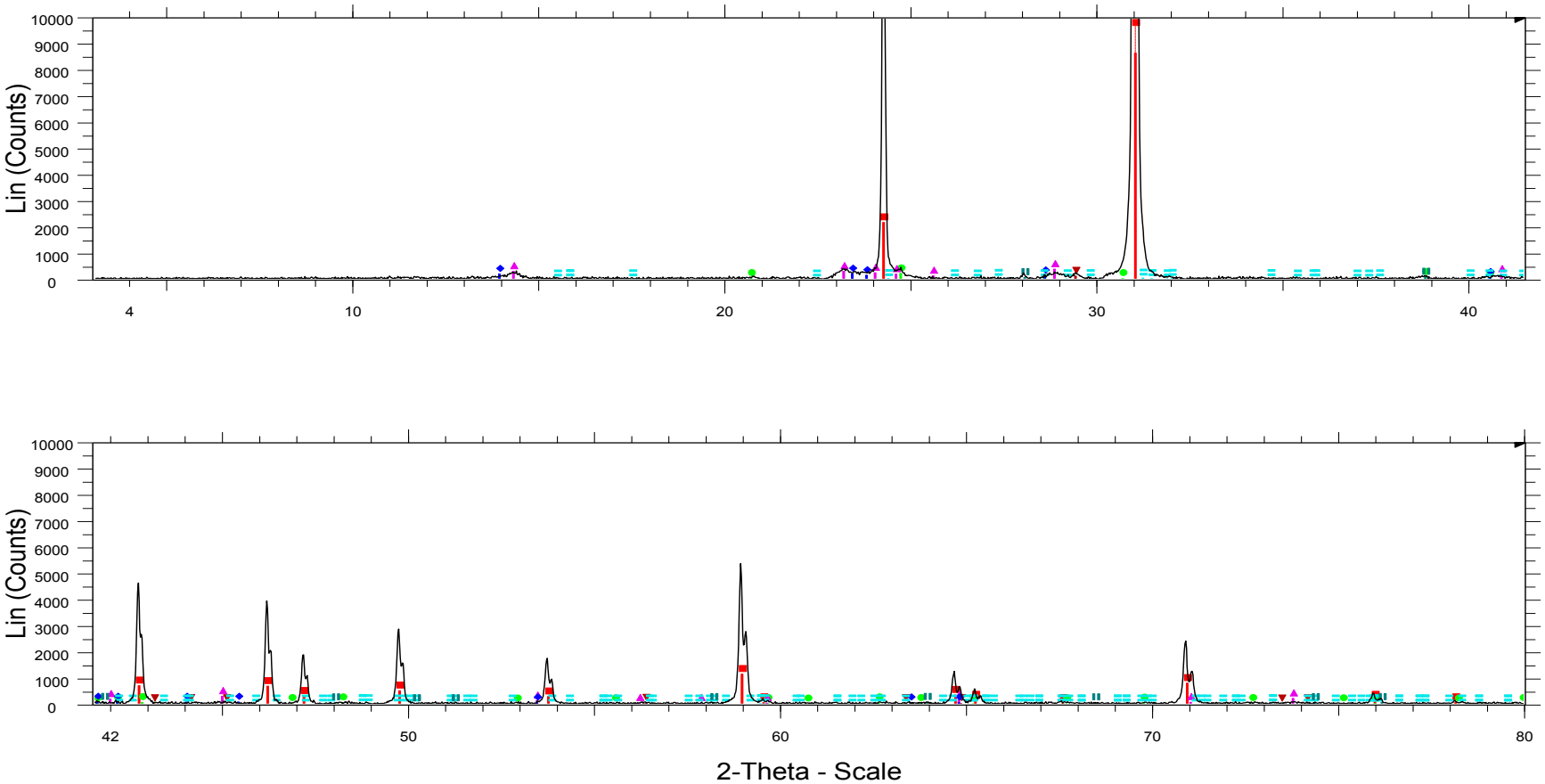
BH 20 18.00-22.00



BH 20 18.00-22.00 - File: Apr4515-14 Riet.raw - Type: 2Th/Th locked - Start: 3.010 ° - End:
Operations: Displacement -0.021 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 01-071-2219 (C) - Pyrite - FeS2

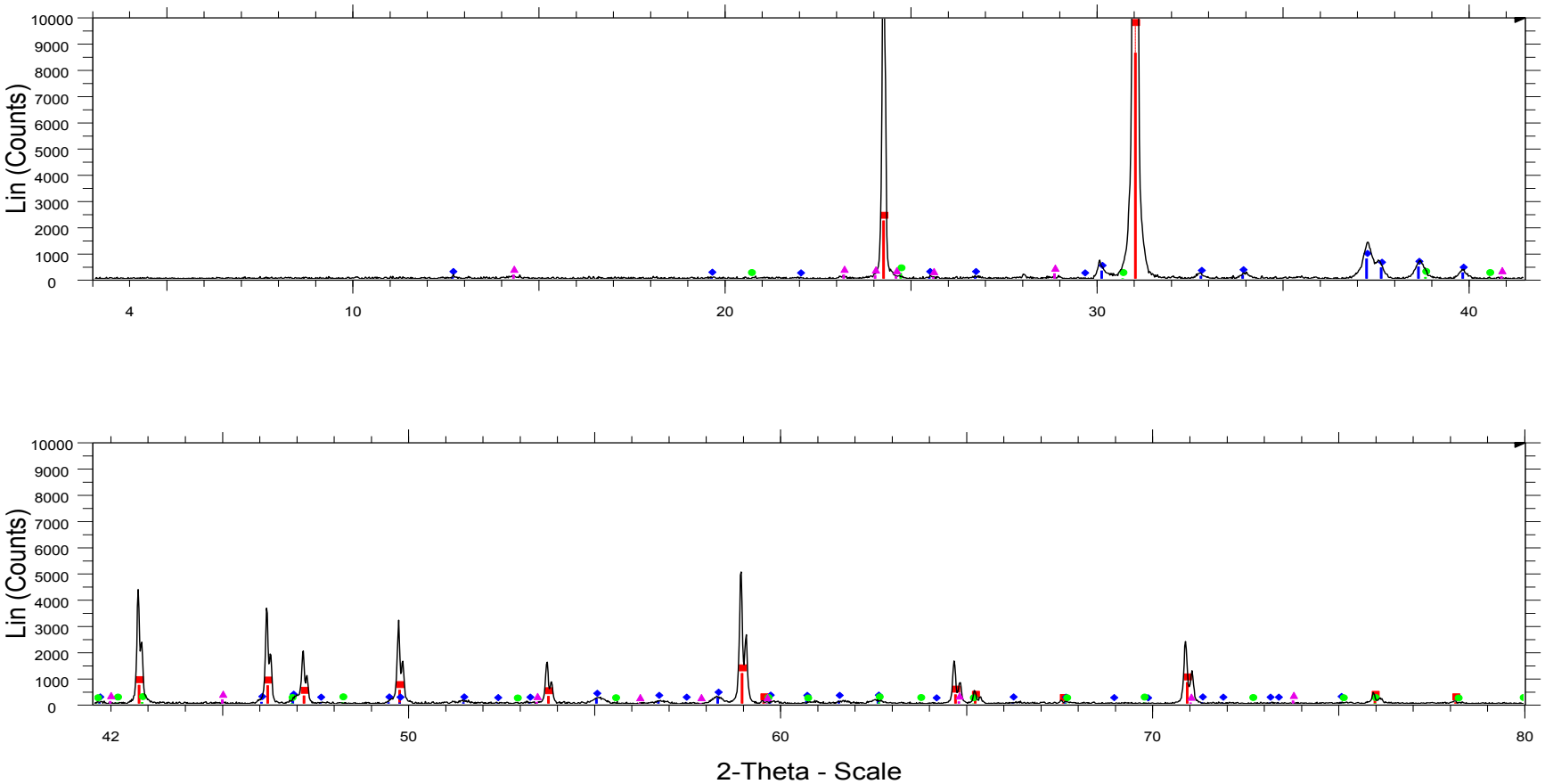
BH 20 29.00-32.00



BH 20 29.00-32.00 - File: Apr4515-15 Riet.raw - Type: 2Th/Th locked - Start: 3.009 ° - End:
Operations: Displacement -0.020 | Displacement -0.010 | Displacement -0.031 | Backgroun

- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 00-002-0915 (D) - Hematite, syn - Fe2O3

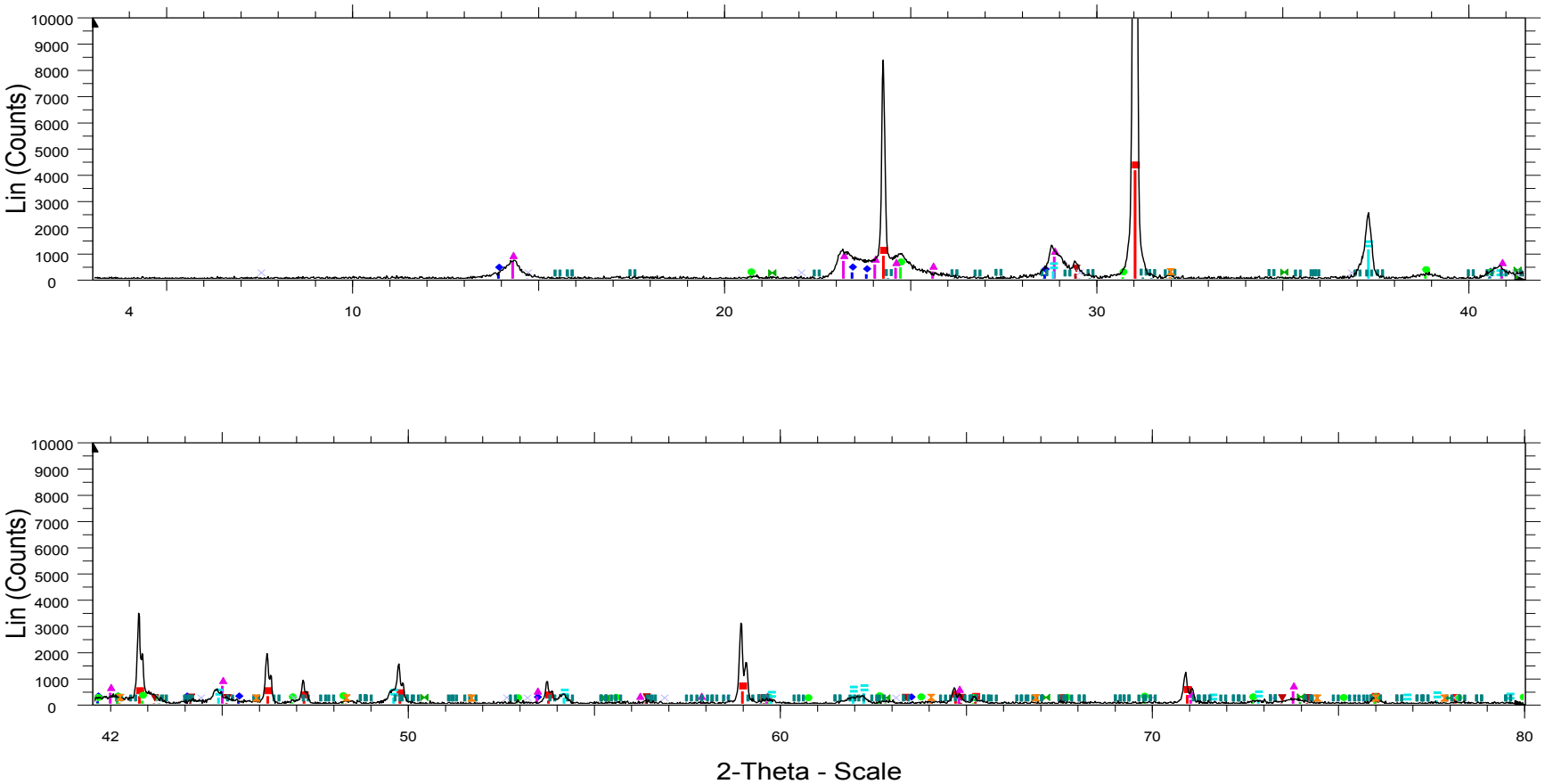
BH 20 35.00-40.00



BH 20 35.00-40.00 - File: Apr4515-16 Riet.raw - Type: 2Th/Th locked - Start: 3.005 ° - End: 80.013 ° - Step: 0.019 ° - Step time: 60. s - Temp.: 25 °C (Room) - Time Started: 17 s - 2-Theta: 3.
Operations: Displacement -0.011 | Background 1.000,1.000 | Import

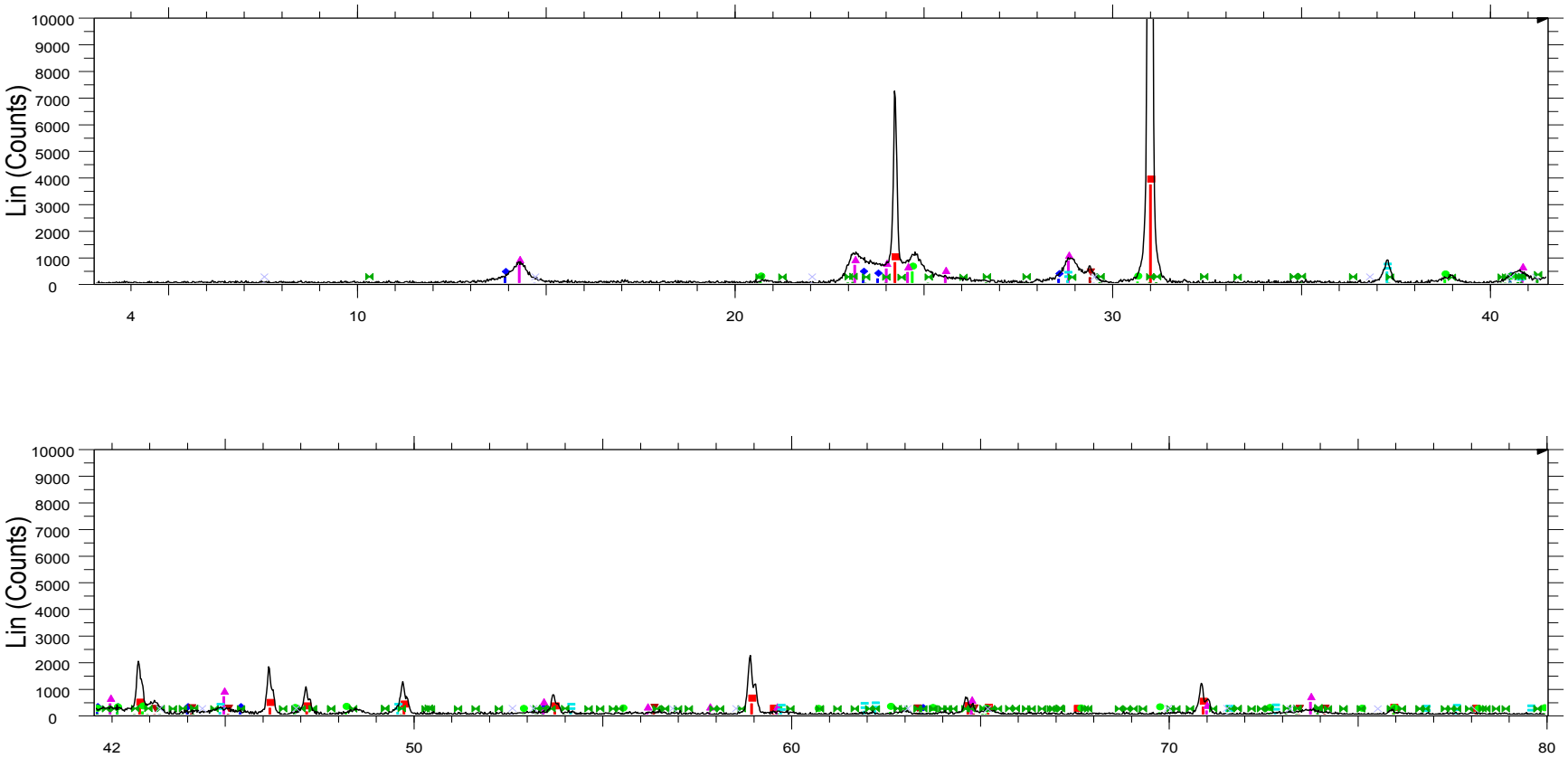
- 01-079-1910 (C) - Quartz - SiO2
- 00-015-0876 (*) - Fluorapatite, syn - Ca5(PO4)3F
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4

BH 23 0.33-3.0



BH 23 0.33-3.0 - File: Apr4515-17 Riet.raw - Type: 2Th/Th locked - Start: 3.014 ° - End: 80.
01-079-1910 (C) - Quartz - SiO2
00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
00-017-0536 (D) - Goethite - Fe+3O(OH)
00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
01-071-1167 (C) - Anatase - TiO2
01-086-1358 (C) - Magnetite - Fe2.929O4
00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
00-029-0696 (*) - Siderite - FeCO3
01-075-1592 (C) - Orthoclase - KAlSi3O8
01-087-0920 (C) - Rutile, syn - TiO2

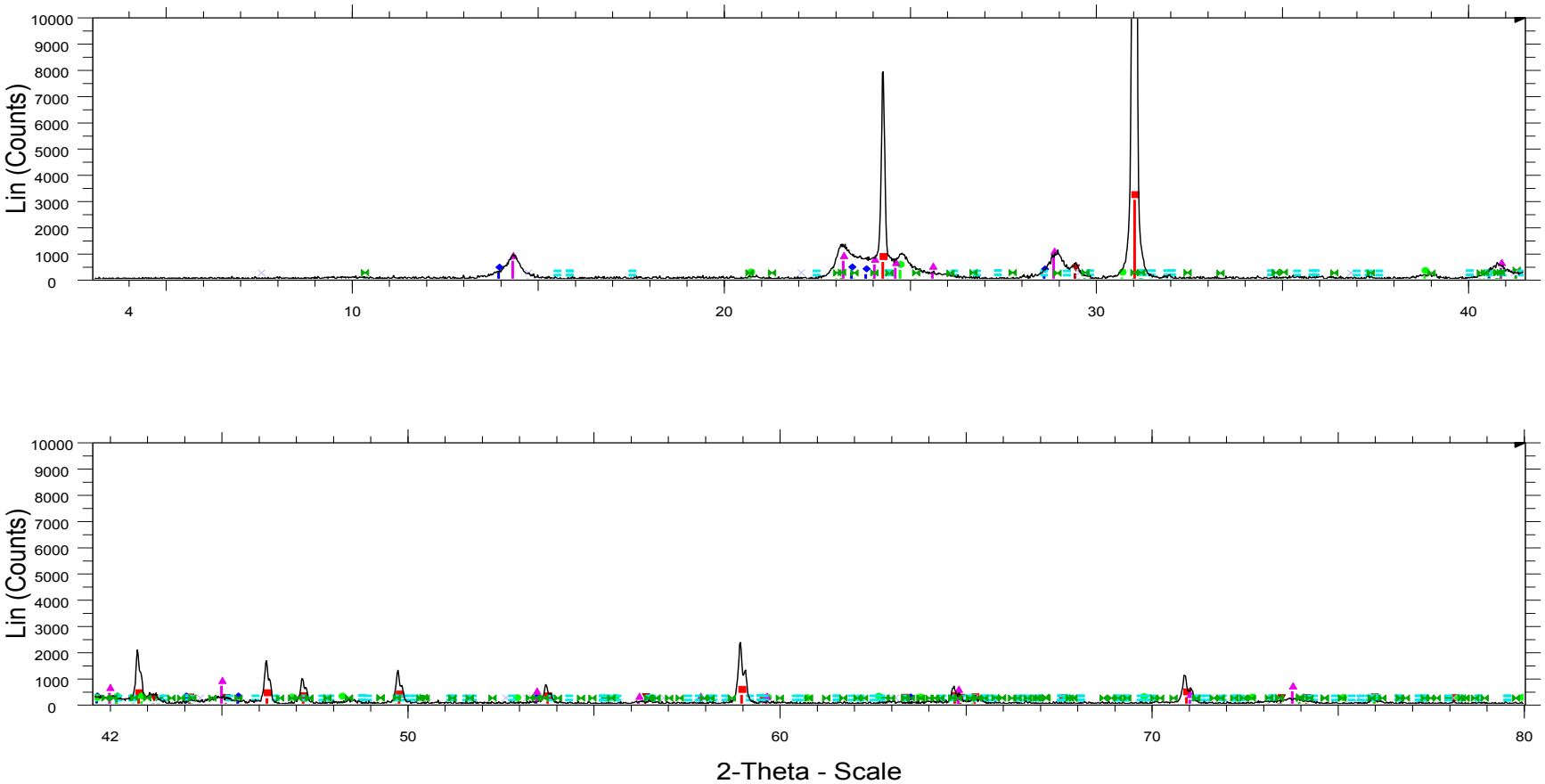
BH 23 3.0-16.5



BH 23 3.0-16.5 - File: Apr4515-18 Riet.raw - Type: 2Th/Th locked - Start: 3.024 ° - End: 80.
Operations: Displacement -0.052 | Displacement -0.031 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
- 00-029-0696 (*) - Siderite - FeCO3
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2

BH 23 3.0-16.5 Dup



BH 23 3.0-16.5 Dup - File: Apr4515-19 Riet.raw - Type: 2Th/Th locked - Start: 3.024 ° - End
Operations: Displacement -0.052 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2
- 01-075-1592 (C) - Orthoclase - KAlSi3O8

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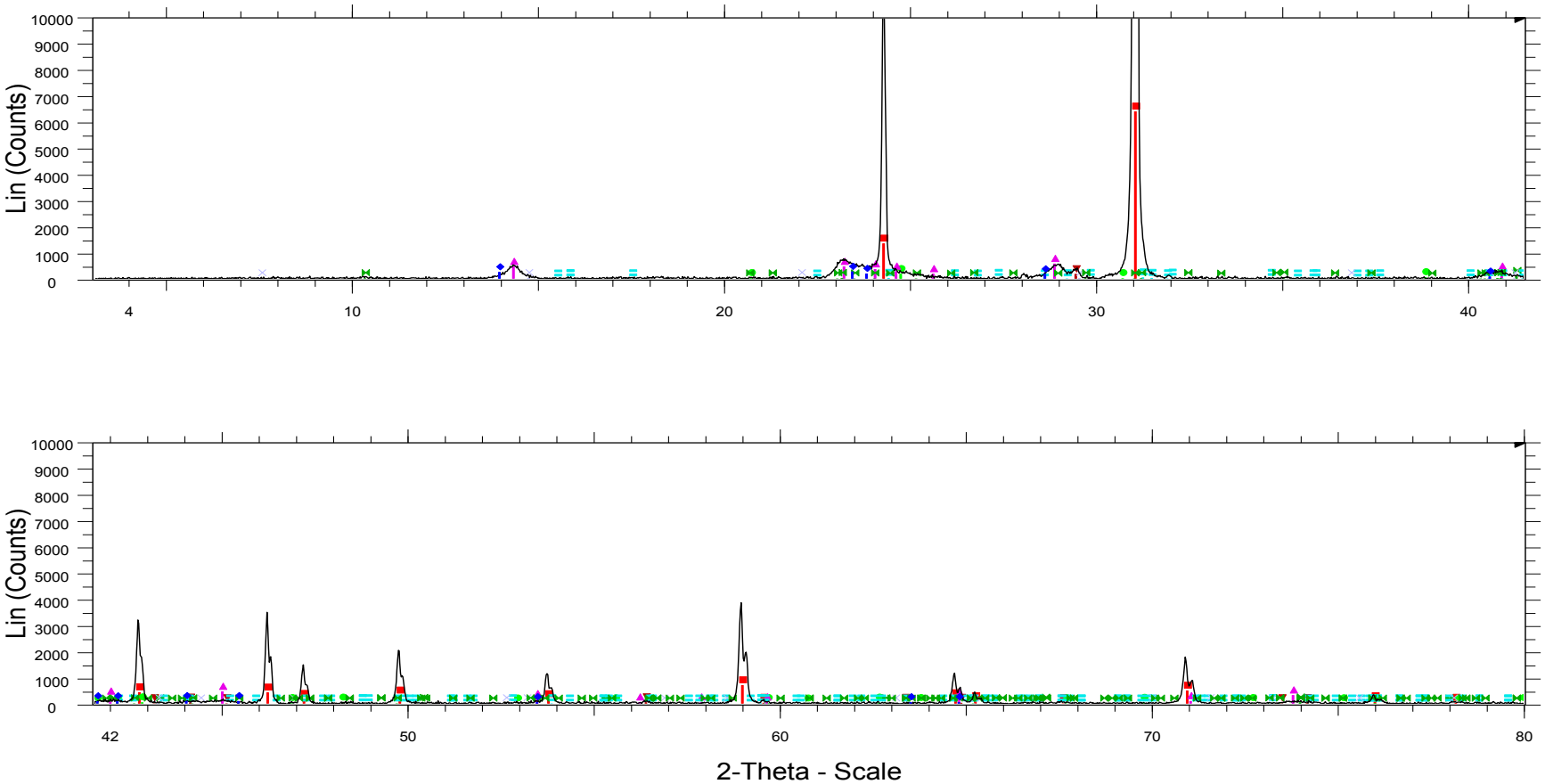
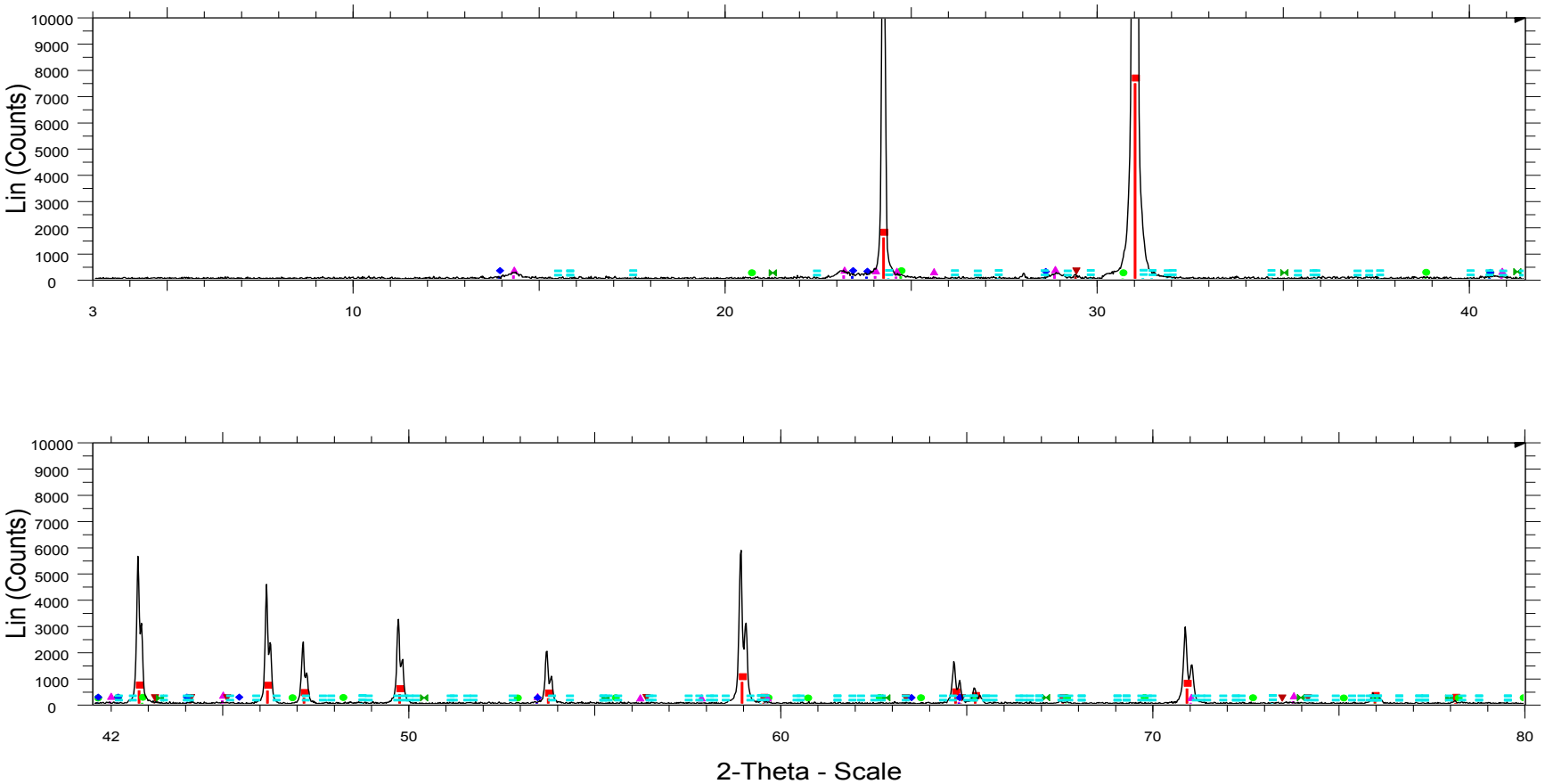
BH 23 21.00-24.1



BH 23 21.00-24.1 - File: Apr4515-20 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 8
Operations: Displacement -0.042 | Background 1.000,1.000 | Import

- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2

BH 23 24.1-28.5



BH 23 24.1-28.5 - File: Apr4515-21 Riet.raw - Type: 2Th/Th locked - Start: 3.000 ° - End: 80
Operations: Displacement 0.000 | Displacement -0.021 | Background 1.000,1.000 | Import

- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 01-079-1910 (C) - Quartz - SiO2
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 01-086-1358 (C) - Magnetite - Fe2.929O4

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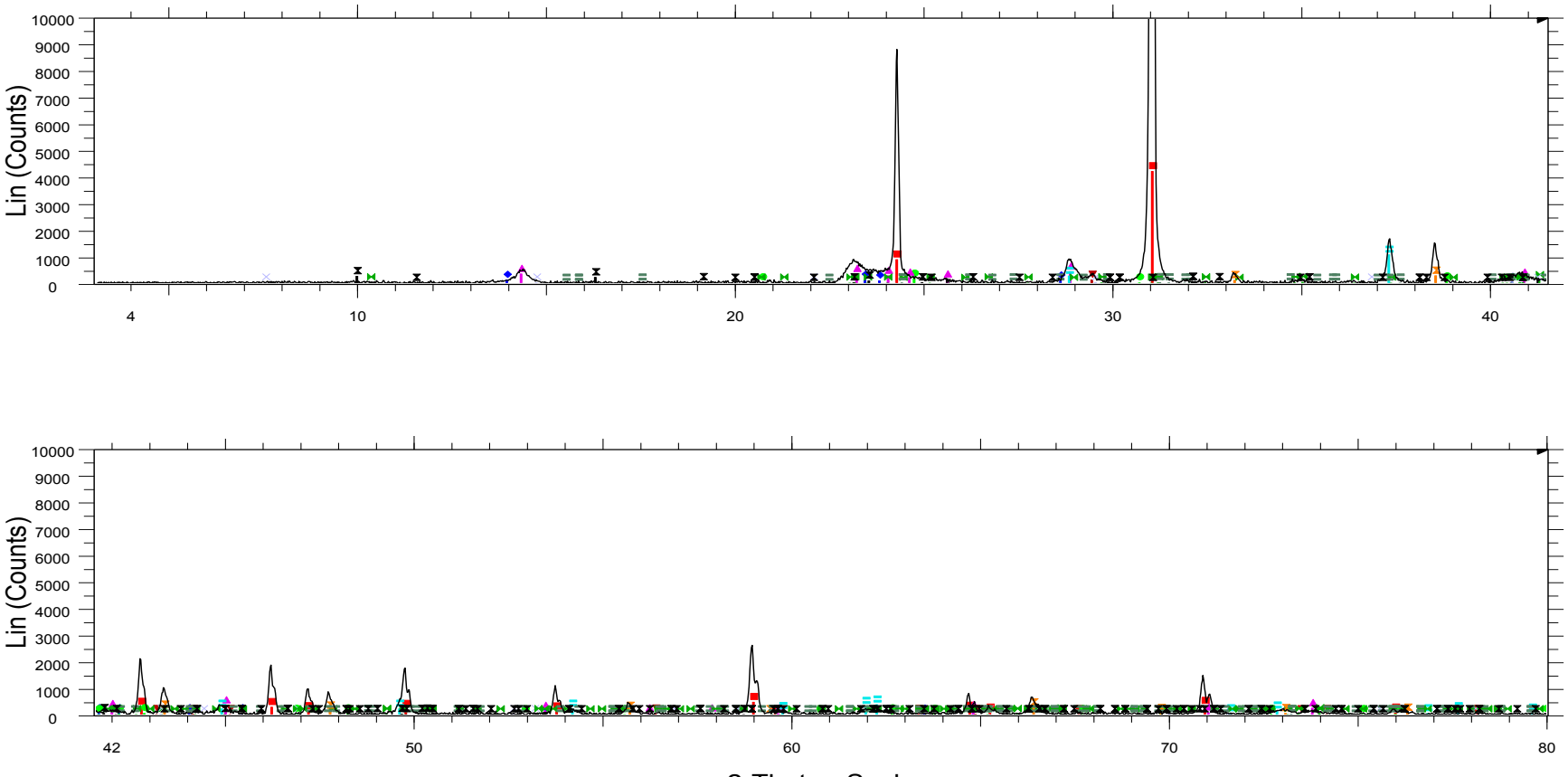
BH 23 28.5-33.00



BH 23 28.5-33.00 - File: Apr4515-22 Riet.raw - Type: 2Th/Th locked - Start: 3.019 ° - End: 8
Operations: Displacement -0.042 | Background 1.000,1.000 | Displacement 0.000 | Displac

- 01-079-1910 (C) - Quartz - SiO2
- 00-013-0375 (D) - Halloysite - Al2Si2O5(OH)4
- 00-017-0536 (D) - Goethite - Fe+3O(OH)
- 00-001-0527 (D) - Kaolinite - Al2Si2O5(OH)4
- 01-071-1167 (C) - Anatase - TiO2
- 01-086-1358 (C) - Magnetite - Fe2.929O4
- 00-002-0389 (D) - Clinochlore - Mg5Al(Si3Al)O10(OH)8
- 00-029-0696 (*) - Siderite - FeCO3
- 01-084-1302 (C) - Muscovite - KAl3Si3O10(OH)2
- 01-071-2219 (C) - Pyrite - FeS2
- 01-075-1592 (C) - Orthoclase - KAlSi3O8
- 01-082-1872 (C) - Palygorskite - (Mg0.669Al0.331)4(Si4O10)2(OH)2(H2O)8

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Modified ABA (Price 1997)

April-19-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10268-APR12**

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: BH 08 00-12.45	6: BH 08 12.45-24.45	7: BH 08 24.45-27.45	8: BH 08 27.45-34.95	9: BH 08 34.95-54	10: BH 10 00-6.45	11: BH 10 6.45-15.45	12: BH 10 15.45-18.45	13: BH 10 18.45-30.45	14: BH 10 30.45-49.7
Paste pH [units]	19-Apr-12	07:55	5.97	6.10	6.25	6.34	5.69	5.54	5.72	5.97	6.00	5.80
Fizz Rate [---]	19-Apr-12	07:55	1	1	1	1	1	1	1	1	1	1
Sample weight [g]	19-Apr-12	07:55	1.98	1.96	197	2.01	2.00	2.00	1.96	1.99	2.05	1.96
HCl added [mL]	19-Apr-12	07:55	20.00	20.00	26.00	27.00	33.10	25.30	34.50	37.70	34.60	37.30
HCl [Normality]	19-Apr-12	07:55	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
NaOH [Normality]	19-Apr-12	07:55	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
NaOH to [pH=8.3 mL]	19-Apr-12	07:55	20.00	19.59	26.73	27.35	32.59	25.69	34.92	37.93	34.25	36.65
Final pH [units]	19-Apr-12	07:55	1.34	1.55	1.67	1.78	1.88	1.59	1.72	1.78	1.91	1.85
NP [t CaCO3/1000 t]	19-Apr-12	07:55	0.0	1.0	0.0	-0.9	1.3	-1.0	-1.1	-0.6	0.9	1.7
AP [t CaCO3/1000 t]	19-Apr-12	07:55	0.62	1.25	0.62	0.62	15.3	0.62	0.94	0.62	0.62	19.8
Net NP [t CaCO3/1000 t]	19-Apr-12	07:55	-0.62	-0.25	-0.62	-1.52	-14.0	-1.62	-2.04	-1.22	0.28	-18.1
NP/AP [ratio]	19-Apr-12	07:55	0.00	0.80	0.00	-1.45	0.08	-1.61	-1.17	-0.97	1.45	0.09
Sulphur (total) [%]	11-Apr-12	14:17	0.042	0.050	0.041	0.028	0.581	0.020	0.035	0.120	0.028	0.773
Acid Leachable SO4-S [%]	13-Apr-12	08:41	< 0.01	< 0.01	< 0.01	< 0.01	0.18	< 0.01	< 0.01	< 0.01	< 0.01	0.18
Sulphide [%]	19-Apr-12	07:51	0.02	0.04	0.02	0.02	0.49	0.02	0.03	0.02	0.02	0.63
Carbon (total) [%]	11-Apr-12	14:16	0.096	0.062	0.095	0.098	0.694	0.134	0.060	0.063	0.052	0.798
Carbonate [%]	11-Apr-12	14:18	0.029	0.038	0.013	0.009	0.017	0.024	0.008	0.021	0.014	0.127

OnLine LIMS

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Modified ABA (Price 1997)

LR Report : **CA10268-APR12**

*NP (Neutralization Potential)

$$= \frac{50 \times (N \text{ of HCL} \times \text{Total HCL added} - N\ NaOH \times NaOH \text{ added})}{\text{Weight of Sample}}$$

*AP (Acid Potential) = % Sulphide Sulphur x 31.25
*Net NP (Net Neutralization Potential) = NP-AP
NP/AP Ratio = NP/AP
*Results expressed as tonnes CaCO3 equivalent/1000 tonnes of material
Samples with a % Sulphide value of <0.01 will be calculated using a 0.01 value.

Sulphur analysis performed following BC ARD Guidelines (Price 1997)

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

OnLine LIMS

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Modified ABA (Price 1997)

April-19-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10268-APR12**

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	15: BH 10 30.45-49.7 Dup	16: BH 20 0.3-4.6	17: BH 20 10-00-18-00	18: BH 20 18.00-22.00	19: BH 20 29.00-32.00	20: BH 20 35.00-40.00	21: BH 23 0.33-3.0	22: BH 23 3.0-16.5	23: BH 23 3.0-16.5 Dup	24: BH 23 21.00-24.1	25: BH 23 24.1-28.5	26: BH 23 28.5-33.00
Paste pH [units]	5.21	4.57	5.77	6.18	6.46	7.57	5.21	5.47	5.66	6.44	6.36	5.39
Fizz Rate [---]	1	1	1	1	1	1	1	1	1	1	1	1
Sample weight [g]	1.96	1.97	2.04	2.02	1.98	2.01	2.00	1.97	2.00	2.01	2.01	1.97
HCl added [mL]	31.70	20.00	20.00	26.50	20.00	46.50	26.70	25.50	32.90	26.30	20.00	58.70
HCl [Normality]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
NaOH [Normality]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
NaOH to [pH=8.3 mL]	31.80	21.81	19.19	26.82	19.65	34.66	26.18	25.87	33.33	26.46	19.28	54.22
Final pH [units]	1.61	1.55	1.27	1.66	1.22	1.81	1.65	1.95	1.59	1.58	1.58	1.68
NP [t CaCO3/1000 t]	-0.3	-4.6	2.0	-0.8	0.9	29.5	1.3	-0.9	-1.1	-0.4	1.8	11.4
AP [t CaCO3/1000 t]	12.9	1.25	0.31	1.25	0.31	3.69	2.50	3.34	0.94	0.31	0.31	72.8
Net NP [t CaCO3/1000 t]	-13.2	-5.85	1.69	-2.05	0.59	25.8	-1.20	-4.24	-2.04	-0.71	1.49	-61.4
NP/AP [ratio]	-0.02	-3.68	6.45	-0.64	2.90	8.0	0.52	-0.27	-1.17	-1.29	5.81	0.16
Sulphur (total) [%]	0.636	0.078	0.046	0.058	0.021	0.210	0.137	0.126	0.039	0.028	0.010	2.63
Acid Leachable SO4-S [%]	0.23	0.03	0.05	0.02	< 0.01	0.12	0.06	0.03	< 0.01	< 0.01	< 0.01	0.36
Sulphide [%]	0.41	0.04	< 0.01	0.04	< 0.01	0.12	0.08	0.11	0.03	0.01	< 0.01	2.33
Carbon (total) [%]	0.919	0.292	0.127	0.101	0.051	0.232	1.38	0.362	0.115	0.066	0.076	2.80
Carbonate [%]	0.105	0.023	0.025	0.020	0.022	0.370	0.049	0.026	0.018	0.018	0.039	0.034

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Modified ABA (Price 1997)

LR Report : **CA10268-APR12**

*NP (Neutralization Potential)

$$= \frac{50 \times (N \text{ of HCL} \times \text{Total HCL added} - N\ NaOH \times NaOH \text{ added})}{\text{Weight of Sample}}$$

*AP (Acid Potential) = % Sulphide Sulphur x 31.25
*Net NP (Net Neutralization Potential) = NP-AP
NP/AP Ratio = NP/AP
*Results expressed as tonnes CaCO3 equivalent/1000 tonnes of material
Samples with a % Sulphide value of <0.01 will be calculated using a 0.01 value.

Sulphur analysis performed following BC ARD Guidelines (Price 1997)

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

OnLine LIMS

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

April-19-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Date Rec. : 02 April 2012
LR Report: **CA10269-APR12**

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Copy: #1

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample weight g	Vol H2O2 mL	Final pH units	NaOH Normality	Vol NaOH to PH 4.5 mL	Vol NaOH to PH 7.0 mL	NAG (pH 4.5) kg H2SO4/tonne	NAG (pH 7.0) kg H2SO4/tonne
3: Analysis Approval Date	16-Apr-12	16-Apr-12	16-Apr-12	16-Apr-12	16-Apr-12	16-Apr-12	16-Apr-12	16-Apr-12
4: Analysis Approval Time	10:02	10:02	10:02	10:02	10:02	10:02	10:02	10:02
5: BH 08 00-12.45	1.47	150	5.78	0.10	0.00	0.45	0.0	1.5
6: BH 08 12.45-24.45	1.45	150	6.71	0.10	0.00	0.10	0.0	0.3
7: BH 08 24.45-27.45	1.46	150	6.62	0.10	0.00	0.16	0.0	0.5
8: BH 08 27.45-34.95	1.47	150	6.47	0.10	0.00	0.24	0.0	0.8
9: BH 08 34.95-54	1.47	150	3.93	0.10	0.52	3.30	1.7	11
10: BH 10 00-6.45	1.50	150	5.59	0.10	0.00	0.90	0.0	2.9
11: BH 10 6.45-15.45	1.47	150	6.02	0.10	0.00	0.50	0.0	1.7
12: BH 10 15.45-18.45	1.47	150	6.39	0.10	0.00	0.21	0.0	0.7
13: BH 10 18.45-30.45	1.48	150	6.36	0.10	0.00	0.39	0.0	1.3
14: BH 10 30.45-49.7	1.51	150	3.96	0.10	0.78	4.01	2.5	13
15: BH 10 30.45-49.7 Dup	1.51	150	4.05	0.10	0.48	3.48	1.6	11
16: BH 20 0.3-4.6	1.52	150	5.23	0.10	0.00	1.20	0.0	3.9
17: BH 20 10-00-18-00	1.48	150	5.87	0.10	0.00	0.60	0.0	2.0
18: BH 20 18.00-22.00	1.48	150	6.31	0.10	0.00	0.18	0.0	0.6
19: BH 20 29.00-32.00	1.55	150	6.01	0.10	0.00	0.78	0.0	2.5
20: BH 20 35.00-40.00	1.49	150	6.71	0.10	0.00	0.05	0.0	0.2
21: BH 23 0.33-3.0	1.53	150	7.08	0.10	0.00	0.00	0.0	0.0
22: BH 23 3.0-16.5	1.47	150	5.29	0.10	0.00	0.50	0.0	1.7
23: BH 23 3.0-16.5 Dup	1.45	150	6.06	0.10	0.00	0.38	0.0	1.3

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

NAG Test

LR Report : **CA10269-APR12**

Sample ID	Sample weight g	Vol H2O2 mL	Final pH units	NaOH Normality	Vol NaOH to PH 4.5 mL	Vol NaOH to PH 7.0 mL	NAG (pH 4.5) kg H2SO4/tonne	NAG (pH 7.0) kg H2SO4/tonne
24: BH 23 21.00-24.1	1.48	150	6.38	0.10	0.00	0.36	0.0	1.2
25: BH 23 24.1-28.5	1.48	150	6.29	0.10	0.00	0.71	0.0	2.4
26: BH 23 28.5-33.00	1.46	150	2.64	0.10	8.78	18.69	30	63

NAG = (49 x Vol. of base x N of base)/sample weight
kg H2SO4/tonne

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

OnLine LIMS

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Short-Term Leach (4:1 0.45µ, 18hr)

June-01-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10272-APR12**

Copy: #2

CERTIFICATE OF ANALYSIS

Final Report-revised

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: BH 08 00-12.45	6: BH 08 12.45-24.45	7: BH 08 24.45-27.45	8: BH 08 27.45-34.95	9: BH 08 34.95-54	10: BH 10 00-6.45	11: BH 10 6.45-15.45	12: BH 10 15.45-18.45	13: BH 10 18.45-30.45	14: BH 10 30.45-49.7
Sample Date & Time			Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a
Sample weight [g]	19-Apr-12	19:16	200	200	200	200	200	200	200	200	200	200
Volume D.I. Water [mL]	19-Apr-12	19:16	800	800	800	800	800	800	800	800	800	800
Initial pH [units]	19-Apr-12	19:16	4.91	5.47	5.68	5.25	4.08	4.88	4.57	4.52	4.80	4.19
Final pH [units]	19-Apr-12	19:16	5.54	5.27	5.63	5.32	4.29	5.09	4.90	4.90	5.22	4.41
pH [units]	24-Apr-12	11:09	7.06	8.05	7.84	9.01	7.74	7.10	7.78	7.03	7.22	6.86
Alkalinity [mg/L as CaCO3]	24-Apr-12	11:09	11	53	50	70	48	11	26	11	15	14
Conductivity [µS/cm]	24-Apr-12	11:09	71	155	158	214	741	89	112	205	137	837
Fluoride [mg/L]	23-Apr-12	08:41	0.08	1.37	1.41	1.05	0.60	0.07	0.20	0.12	0.19	0.24
Phosphorus (total reactive) [mg/L]	26-Apr-12	12:56	0.60	0.49	0.44	0.22	< 0.03	< 0.03	< 0.03	< 0.03	0.04	< 0.03
Ammonia+Ammonium (N) [mg/L]	25-Apr-12	09:18	< 0.1	< 0.1	0.1	< 0.1	0.7	< 0.1	< 0.1	< 0.1	0.1	1.2
Cyanide (total) [mg/L]	25-Apr-12	08:25	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chloride [mg/L]	26-Apr-12	15:26	12	11	14	19	14	18	16	53	29	36
Sulphate [mg/L]	26-Apr-12	15:26	0.7	3.2	3.1	5.3	290	0.6	1.5	0.8	2.3	340
Nitrite (as N) [mg/L]	24-Apr-12	12:07	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Nitrate (as N) [mg/L]	24-Apr-12	12:07	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.10	< 0.05
Mercury [mg/L]	24-Apr-12	13:30	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Calcium [mg/L]	25-May-12	11:19	0.56	0.68	0.74	0.57	69.9	0.42	0.61	1.48	1.10	91.0
Magnesium [mg/L]	25-May-12	11:19	0.212	0.372	0.395	0.206	17.8	0.159	0.214	0.846	0.367	18.9
Potassium [mg/L]	25-May-12	11:19	0.394	1.17	1.11	0.853	15.7	0.209	0.824	1.96	1.36	13.4
Sodium [mg/L]	25-May-12	11:19	11.1	30.9	31.7	44.6	44.2	15.1	19.7	32.9	21.5	40.5
Silver [mg/L]	26-Apr-12	18:34	< 0.00001	< 0.00001	0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Aluminum [mg/L]	24-Apr-12	16:26	0.03	3.54	5.09	3.43	< 0.01	0.03	1.10	0.07	0.15	< 0.01
Arsenic [mg/L]	26-Apr-12	18:34	< 0.0002	0.0043	0.0073	0.0043	0.0022	0.0003	0.0003	0.0004	0.0005	0.0019

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Short-Term Leach (4:1 0.45µ, 18hr)

LR Report : **CA10272-APR12**

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: BH 08 00-12.45	6: BH 08 12.45-24.45	7: BH 08 24.45-27.45	8: BH 08 27.45-34.95	9: BH 08 34.95-54	10: BH 10 00-6.45	11: BH 10 6.45-15.45	12: BH 10 15.45-18.45	13: BH 10 18.45-30.45	14: BH 10 30.45-49.7
Barium [mg/L]	26-Apr-12	18:34	0.00106	0.00284	0.00342	0.00052	0.0485	0.00201	0.00222	0.0123	0.00159	0.0241
Boron [mg/L]	26-Apr-12	18:34	0.0383	0.431	0.458	0.342	0.511	0.0423	0.176	0.0817	0.125	0.238
Beryllium [mg/L]	26-Apr-12	18:34	< 0.00002	0.00004	0.00005	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00002	< 0.00002	0.00255
Bismuth [mg/L]	26-Apr-12	18:34	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Cadmium [mg/L]	26-Apr-12	18:34	< 0.000003	< 0.000003	< 0.000003	< 0.000003	< 0.000003	< 0.000003	< 0.000003	< 0.000003	< 0.000003	0.001120
Cobalt [mg/L]	26-Apr-12	18:34	0.000105	0.000258	0.000224	0.000044	0.309	0.00011	0.000678	0.00166	0.000301	0.320
Chromium [mg/L]	26-Apr-12	18:35	< 0.0005	0.0109	0.0044	0.0014	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Copper [mg/L]	26-Apr-12	18:35	< 0.0005	< 0.0005	0.0010	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0020	0.0019	0.0007
Iron [mg/L]	24-Apr-12	16:26	0.014	1.59	1.18	0.670	< 0.003	0.008	0.238	0.020	0.033	3.33
Lithium [mg/L]	25-May-12	15:23	< 0.001	0.004	0.005	0.004	0.044	< 0.001	0.002	0.002	0.002	0.021
Molybdenum [mg/L]	25-May-12	15:23	< 0.00001	0.00006	0.00042	0.00026	0.00006	< 0.00001	< 0.00001	< 0.00001	0.00002	0.00006
Manganese [mg/L]	26-Apr-12	18:35	0.00687	0.00274	0.00204	0.00035	4.37	0.00447	0.00998	0.04640	0.00536	6.40
Nickel [mg/L]	26-Apr-12	18:35	0.0002	0.0010	0.0010	0.0001	0.229	0.0015	0.0006	0.0018	0.0003	0.354
Phosphorus [mg/L]	24-Apr-12	16:26	< 0.009	0.502	0.440	0.169	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009
Lead [mg/L]	26-Apr-12	18:35	< 0.00002	0.00019	0.00049	0.00005	< 0.00002	< 0.00002	0.00002	< 0.00002	< 0.00002	< 0.00002
Antimony [mg/L]	26-Apr-12	18:35	< 0.0002	0.0003	0.0003	0.0003	< 0.0002	0.0002	< 0.0002	< 0.0002	0.0002	< 0.0002
Silicon [mg/L]	24-Apr-12	16:26	2.43	17.9	18.0	13.7	7.81	1.93	6.86	4.13	5.33	5.81
Selenium [mg/L]	26-Apr-12	18:35	< 0.001	< 0.001	< 0.001	< 0.001	0.008	< 0.001	< 0.001	< 0.001	< 0.001	0.008
Tin [mg/L]	26-Apr-12	18:35	< 0.00001	0.00004	0.00005	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Strontium [mg/L]	24-Apr-12	16:26	0.0021	0.0054	0.0077	0.0048	0.119	0.0015	0.0033	0.0105	0.0029	0.155
Titanium [mg/L]	26-Apr-12	18:35	0.0017	0.0226	0.0548	0.0039	0.0004	0.0019	0.0027	0.0008	0.0009	0.0002
Thallium [mg/L]	26-Apr-12	18:35	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00005	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00007
Uranium [mg/L]	26-Apr-12	18:35	0.000005	0.000162	0.000226	0.000085	0.000021	0.000008	0.000016	0.000015	0.000010	0.000035
Vanadium [mg/L]	25-May-12	15:23	0.00013	0.00304	0.0118	0.00357	0.00029	0.00021	0.00037	0.00039	0.00045	0.00019
Zinc [mg/L]	26-Apr-12	18:35	< 0.001	0.007	0.007	< 0.001	0.022	0.003	< 0.001	0.017	< 0.001	0.741

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

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Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Short-Term Leach (4:1 0.45µ, 18hr)

June-01-12

GB Minerals AG - c/o GBM Minerals Engineering Consultants Ltd
Attn : Jacques Du Toit, Casey Jarman

Regal House, 70 London Road
Twickenham, Middlesex
TW1 3QS, England

Phone: +44 (0) 20 8607 9666
Fax:+44 (0) 20 8607 9777

Date Rec. : 02 April 2012
LR Report: **CA10272-APR12**

Copy: #2

CERTIFICATE OF ANALYSIS

Final Report-revised

Analysis	15: BH 10 30.45-49.7 Dup	16: BH 20 0.3-4.6	17: BH 20 10-00-18-00	18: BH 20 18.00-22.00	19: BH 20 29.00-32.00	20: BH 20 35.00-40.00	21: BH 23 0.33-3.0	22: BH 23 3.0-16.5	23: BH 23 3.0-16.5 Dup	24: BH 23 21.00-24.1	25: BH 23 24.1-28.5	26: BH 23 28.5-33.00
Sample Date & Time	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a	Date: n/a
Sample weight [g]	200	200	200	200	200	200	200	200	200	200	200	200
Volume D.I. Water [mL]	800	800	800	800	800	800	800	800	800	800	800	800
Initial pH [units]	3.51	4.14	4.30	5.05	7.11	6.17	5.15	4.69	4.48	6.27	6.92	4.03
Final pH [units]	3.99	4.03	4.83	5.26	7.38	6.71	5.17	4.80	4.83	6.97	7.50	4.15
pH [units]	6.26	8.53	6.74	9.32	7.30	7.39	7.45	7.48	9.25	9.33	7.61	6.41
Alkalinity [mg/L as CaCO3]	4	37	7	86	29	23	34	25	42	50	32	9
Conductivity [µS/cm]	1100	1350	473	590	241	609	2010	901	417	302	402	1880
Fluoride [mg/L]	0.50	0.27	0.08	1.15	2.20	0.55	0.22	0.21	0.36	0.84	1.17	1.20
Phosphorus (total reactive) [mg/L]	0.03	< 0.03	< 0.03	0.04	0.38	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.05
Ammonia+Ammonium (N) [mg/L]	0.9	0.1	< 0.1	< 0.1	0.2	< 0.1	0.4	0.4	0.2	0.1	< 0.1	2.0
Cyanide (total) [mg/L]	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chloride [mg/L]	42	300	48	66	35	78	500	230	92	48	90	31
Sulphate [mg/L]	500	150	120	84	16	130	190	57	12	16	10	1000
Nitrite (as N) [mg/L]	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Nitrate (as N) [mg/L]	< 0.05	0.46	< 0.05	< 0.05	0.20	< 0.05	< 0.05	< 0.05	< 0.05	0.07	0.09	< 0.05
Mercury [mg/L]	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Calcium [mg/L]	117	7.30	25.5	3.55	1.99	37.6	24.2	8.31	1.51	3.61	2.16	288
Magnesium [mg/L]	28.1	7.47	12.3	1.84	1.29	10.3	30.3	10.3	0.747	1.22	1.54	50.4
Potassium [mg/L]	16.5	3.23	3.38	3.02	1.96	4.75	13.6	8.09	2.24	1.86	4.25	21.1
Sodium [mg/L]	40.5	242	36.5	107	41.1	61.8	303	137	77.0	51.7	70.3	59.4
Silver [mg/L]	0.00001	< 0.00001	< 0.00001	< 0.00001	0.00054	0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Aluminum [mg/L]	0.14	3.05	< 0.01	3.77	4.61	0.03	0.01	0.03	1.57	0.54	4.70	0.15
Arsenic [mg/L]	0.0035	0.0012	0.0005	0.0013	0.0019	0.0008	0.0028	0.0018	0.0014	0.0007	0.0031	0.0023

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SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Short-Term Leach (4:1 0.45µ, 18hr)

LR Report : **CA10272-APR12**

Analysis	15: BH 10 30.45-49.7 Dup	16: BH 20 0.3-4.6	17: BH 20 10-00-18-00	18: BH 20 18.00-22.00	19: BH 20 29.00-32.00	20: BH 20 35.00-40.00	21: BH 23 0.33-3.0	22: BH 23 3.0-16.5	23: BH 23 3.0-16.5 Dup	24: BH 23 21.00-24.1	25: BH 23 24.1-28.5	26: BH 23 28.5-33.00
Barium [mg/L]	0.0353	0.00973	0.0206	0.00218	0.0181	0.00708	0.0188	0.0178	0.00164	0.00221	0.00159	0.0371
Boron [mg/L]	0.278	0.482	0.0472	0.353	0.538	0.0498	0.229	0.205	0.279	0.158	0.159	0.479
Beryllium [mg/L]	0.00935	0.00008	0.00012	0.00005	0.00061	< 0.00002	< 0.00002	0.00003	< 0.00002	< 0.00002	< 0.00002	0.0103
Bismuth [mg/L]	< 0.00001	< 0.00001	< 0.00001	< 0.00001	0.00003	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Cadmium [mg/L]	0.003294	< 0.000003	0.000299	< 0.000003	0.000416	0.000050	< 0.000003	< 0.000003	< 0.000003	< 0.000003	< 0.000003	0.009525
Cobalt [mg/L]	0.503	0.00261	0.0221	0.000709	0.00403	0.00270	0.00295	0.00217	0.000088	0.000060	0.000110	1.10
Chromium [mg/L]	0.0032	0.0013	0.0006	0.0022	0.0275	< 0.0005	< 0.0005	< 0.0005	0.0007	0.0009	0.0006	0.0025
Copper [mg/L]	0.0009	0.0007	0.0006	0.0006	0.0062	0.0006	0.0009	0.0005	0.0007	< 0.0005	0.0017	0.0013
Iron [mg/L]	21.7	0.499	1.29	0.839	0.929	0.004	0.006	0.013	0.279	0.085	1.14	36.0
Lithium [mg/L]	0.023	0.088	0.010	0.007	0.029	0.006	0.002	0.002	0.003	0.001	< 0.001	0.036
Molybdenum [mg/L]	0.00009	0.00002	< 0.00001	0.00006	0.00129	0.00062	0.00004	0.00002	0.00002	0.00015	0.00227	0.00018
Manganese [mg/L]	11.3	0.0513	5.40	0.0195	0.166	0.127	0.241	0.04373	0.00175	0.00191	0.00061	9.77
Nickel [mg/L]	0.493	0.0060	0.0341	0.0011	0.0066	0.0064	0.0070	0.0039	0.0002	0.0001	0.0017	0.717
Phosphorus [mg/L]	< 0.009	< 0.009	< 0.009	0.011	0.088	0.011	< 0.009	< 0.009	< 0.009	< 0.009	0.010	< 0.009
Lead [mg/L]	0.00008	0.00025	0.00004	0.00020	0.00486	< 0.00002	< 0.00002	< 0.00002	0.00005	0.00002	0.00013	0.00003
Antimony [mg/L]	< 0.0002	0.0003	< 0.0002	0.0003	0.0009	0.0002	0.0003	0.0002	< 0.0002	0.0002	0.0004	< 0.0002
Silicon [mg/L]	7.81	20.0	2.61	15.1	17.2	2.98	4.91	7.63	9.71	4.36	11.8	13.0
Selenium [mg/L]	0.008	0.002	< 0.001	0.002	< 0.001	0.005	0.006	0.002	< 0.001	< 0.001	< 0.001	0.013
Tin [mg/L]	0.00001	0.00003	< 0.00001	0.00004	0.00042	< 0.00001	0.00003	0.00002	0.00002	< 0.00001	0.00002	< 0.00001
Strontium [mg/L]	0.154	0.0384	0.0903	0.0118	0.0246	0.216	0.138	0.0674	0.0064	0.0088	0.0122	0.531
Titanium [mg/L]	0.0003	0.0070	0.0002	0.0150	0.441	0.0008	0.0009	0.0017	0.0034	0.0021	0.0029	0.0005
Thallium [mg/L]	0.00014	0.00002	0.00008	< 0.00002	0.00009	0.00010	0.00007	0.00004	< 0.00002	< 0.00002	< 0.00002	0.00009
Uranium [mg/L]	0.000138	0.000044	0.000087	0.000128	0.000529	0.000042	0.000028	0.000024	0.000030	0.000014	0.000068	0.000154
Vanadium [mg/L]	0.00011	0.00130	0.00021	0.00155	0.0126	0.00064	0.00167	0.00096	0.00086	0.00150	0.00242	0.00015
Zinc [mg/L]	5.96	0.008	0.588	0.006	0.029	< 0.001	0.003	0.001	0.002	< 0.001	0.002	1.82

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

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Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

Sample No.	Borehole	Depth mbgl	Al2O3_%	CaO_%	Cr2O3_%	Fe2O3_%	K2O_%	MgO_%	MnO_%	P2O5_%	SiO2_%	TiO2_%	LOI_%	F_%	C_%
FASO 001	SA 0	63.45	1.32	47.50	0.06	4.15	0.04	0.30	0.06	33.37	4.17	0.04	7.09	2.99	0.93
FASO 002	SA 0	65.60	2.23	40.45	0.03	4.66	0.16	2.19	0.16	14.64	7.96	0.09	18.55	1.46	5.17
FASO 003	SA 2	47.52	3.32	44.02	0.05	5.15	0.02	0.17	0.09	33.01	6.97	0.05	6.69	2.66	0.92
FASO 004	SA 2	49.00	2.48	43.36	0.03	6.10	0.08	0.25	0.14	31.37	8.29	0.12	6.26	2.73	0.97
FASO 005	SA 2	49.80	4.99	35.20	0.03	6.13	0.27	0.99	0.07	24.49	15.65	0.23	10.05	2.19	0.89
FASO 006	SA 3b	50.11	11.66	17.30	0.05	9.85	0.05	0.23	0.19	14.01	35.59	0.42	10.50	1.14	1.38
FASO 007	SA 3b	50.28	3.22	42.26	0.05	4.76	0.05	0.27	0.04	30.19	9.91	0.14	7.41	2.53	0.70
FASO 008	SA 3b	51.46	4.31	25.72	0.07	17.44	0.26	1.21	0.26	15.73	14.51	0.20	18.55	1.60	1.98
FASO 009	SA 3b	51.72	1.42	50.24	0.01	1.44	0.07	0.72	0.04	2.25	5.14	0.06	36.80	0.25	10.45
FASO 010	SB 3	46.10	5.78	37.14	0.05	2.70	0.05	0.28	0.02	27.00	18.93	0.17	7.15	2.30	0.56
FASO 011	SB 3	47.50	2.74	13.03	0.04	39.40	0.18	1.47	0.71	6.15	9.67	0.13	24.80	0.62	7.23
FASO 012	SB 3		1.80	48.43	0.01	0.82	0.04	0.90	0.01	1.87	6.51	0.08	38.10	0.22	10.30
FASO 013	SC 1	50.92	7.59	36.62	0.05	3.17	0.07	0.19	0.05	28.79	14.41	0.10	7.76	2.22	0.66
FASO 014	SC 1	52.65	0.96	48.43	0.05	2.54	0.01	0.14	0.02	35.52	7.08	0.02	3.74	3.08	0.53
FASO 015	SC 1	54.40	1.48	46.52	0.05	2.93	0.05	0.28	0.02	33.38	8.09	0.07	5.40	2.84	0.60
FASO 016	SC 1		0.32	54.36	0.01	1.07	0.02	0.38	0.05	4.30	1.62	0.01	36.00	0.44	10.50
FASO 017	SC 3b	33.10	3.61	40.39	0.04	3.18	0.08	0.19	0.06	29.04	14.80	0.16	6.70	2.46	0.54
FASO 018	SC 3b	34.50	1.57	47.98	0.05	2.67	0.03	0.24	0.03	34.76	4.70	0.05	6.38	3.18	0.50
FASO 019	SC 3b	35.55	2.06	46.55	0.05	2.06	0.07	0.33	0.02	33.89	7.47	0.08	5.62	3.12	0.61
FASO 020	FASO 020/12		1.79	48.96	0.02	0.84	0.04	0.91	0.01	2.32	6.51	0.08	37.40	0.22	10.25
FASO 021	SC 4b		8.73	1.38	0.01	1.71	0.12	0.15	0.01	2.20	79.00	0.60	5.83	0.14	0.15
FASO 022	SC 4b	30.16	12.67	5.69	0.08	1.74	0.04	0.13	0.04	9.88	60.36	0.51	8.02	0.52	0.32
FASO 023	SC 4b	30.96	7.34	27.30	0.04	2.69	0.07	0.15	0.04	21.24	32.62	0.19	6.81	1.82	0.46
FASO 024	SC 4b	32.10	3.35	40.04	0.04	2.18	0.03	0.16	0.03	28.70	18.03	0.12	5.39	2.62	0.60
FASO 025	SD 0b is b		1.48	43.98	0.05	6.08	0.05	0.41	0.14	28.70	7.00	0.05	8.05	2.50	2.36
FASO 026	SD 3		2.73	29.46	0.04	16.30	0.10	0.46	0.35	20.77	16.57	0.16	12.60	1.84	2.46
FASO 027	SD 3	41.20	1.63	47.03	0.06	5.67	0.03	0.25	0.08	34.01	4.34	0.06	5.17	3.03	0.76
FASO 028	SD 3	42.35	1.84	43.78	0.05	4.85	0.06	0.32	0.06	31.66	8.41	0.09	7.12	2.70	0.87
FASO 029	SD 3	43.50	2.06	21.38	0.04	26.67	0.10	1.04	0.57	13.91	15.07	0.15	17.15	1.37	3.80
FASO 030	SD 3		5.58	22.82	0.06	16.75	0.39	1.79	0.31	14.02	19.37	0.26	17.75	1.51	1.97
FASO 031	A1	41.00	1.82	42.23	0.05	4.62	0.05	0.26	0.04	28.77	12.92	0.08	7.23	2.43	1.19
FASO 032	A1	42.00	1.28	40.47	0.04	4.11	0.07	0.40	0.04	17.92	15.23	0.09	12.15	1.60	3.83
FASO 033	A1		0.44	52.42	0.01	1.37	0.03	0.49	0.03	5.91	2.97	0.02	33.30	0.62	9.56
FASO 034	A2	39.90	6.58	27.17	0.05	4.28	0.06	0.19	0.08	21.69	30.51	0.21	7.81	1.84	0.59
FASO 035	A2	41.50	2.90	36.06	0.05	2.57	0.07	0.19	0.04	25.71	24.58	0.16	5.66	2.44	0.55
FASO 036	A2	42.80	1.45	41.78	0.05	6.22	0.05	0.27	0.04	29.70	7.70	0.06	11.05	2.65	0.71
FASO 037	A2		1.00	45.99	0.02	3.02	0.04	0.53	0.05	6.14	9.29	0.05	30.00	0.64	8.57
FASO 038	A3	39.25	11.06	23.55	0.08	3.88	0.05	0.16	0.09	20.93	30.29	0.32	9.03	1.71	0.64
FASO 039	A3	40.40	1.97	45.31	0.06	2.33	0.02	0.15	0.03	33.24	10.45	0.08	4.55	2.86	0.54
FASO 040	A3	41.70	1.18	47.85	0.06	3.02	0.02	0.14	0.03	35.07	6.04	0.03	4.64	3.03	0.53
FASO 041	A3	42.50	0.97	45.06	0.05	5.37	0.02	0.14	0.03	32.97	6.04	0.03	7.40	3.08	0.55
FASO 042	A3	43.00	1.92	41.40	0.06	4.16	0.11	0.45	0.03	26.73	11.18	0.10	7.95	2.74	1.33
FASO 043	A3	43.55	1.43	43.56	0.06	5.41	0.08	0.50	0.11	26.23	8.70	0.05	8.83	2.55	2.26
FASO 044	A3		1.16	50.36	0.01	0.80	0.04	0.74	0.02	1.54	4.67	0.06	38.60	0.18	10.65
FASO 045	FASO 045/14		1.01	47.98	0.05	2.55	0.02	0.14	0.02	35.16	7.50	0.03	4.11	2.77	0.55
FASO 046	A4	38.85	1.99	44.70	0.06	3.20	0.03	0.16	0.04	32.51	10.32	0.07	5.02	2.72	0.53
FASO 047	A4	40.50	0.69	49.50	0.06	2.10	0.01	0.14	0.02	35.94	5.82	0.01	3.74	3.22	0.52
FASO 048	A4	41.20	0.89	47.42	0.06	5.16	0.03	0.24	0.12	33.93	6.17	0.03	5.39	3.15	0.97
FASO 049	A4	42.50	1.40	46.06	0.06	2.51	0.06	0.43	0.03	28.20	8.69	0.05	7.89	2.94	2.00
FASO 050	A4		0.74	52.14	0.03	1.35	0.03	0.54	0.03	7.90	4.33	0.04	31.10	0.83	8.67
FASO 051	A5	40.00	3.91	33.97	0.05	5.33	0.15	0.29	0.06	24.11	22.57	0.22	7.61	2.17	0.61
FASO 052	A5	41.80	1.12	42.94	0.04	5.89	0.03	0.22	0.12	30.68	10.69	0.05	6.20	2.65	1.00
FASO 053	A5	43.00	1.71	38.00	0.04	5.62	0.06	0.31	0.11	26.24	18.68	0.07	7.05	2.52	1.11
FASO 054	A6	39.30	1.81	40.85	0.06	8.43	0.05	0.35	0.15	29.17	8.75	0.09	8.56	2.54	1.28
FASO 055	A6	40.40	1.31	43.61	0.06	7.04	0.05	0.37	0.16	30.86	7.11	0.06	7.35	2.81	1.33
FASO 056	A6	41.90	2.77	33.13	0.05	10.13	0.11	0.64	0.19	21.26	16.87	0.16	10.80	2.10	2.33
FASO 057	A6		0.77	50.18	0.02	2.72	0.03	0.50	0.08	7.37	5.05	0.04	31.30	0.74	9.19
FASO 058	A6		0.98	50.78	0.02	1.12	0.03	0.57	0.03	9.97	5.22	0.04	29.60	1.05	8.00
FASO 059	A7	39.45	10.98	32.81	0.06	2.43	0.02	0.26	0.02	28.01	13.96	0.03	10.70	2.10	0.51
FASO 060	A7	41.80	1.28	47.76	0.06	3.50	0.02	0.16	0.03	34.01	7.11	0.01	5.81	3.04	0.63
FASO 061	A7	43.00	1.23	44.14	0.05	6.88	0.05	0.32	0.13	29.93	7.84	0.04	7.52	2.80	1.60
FASO 062	A7		0.57	49.40	0.02	2.99	0.02	0.56	0.07	7.44	3.56	0.02	31.40	0.75	8.62
FASO 063	A7		0.80	51.48	0.01	0.67	0.03	0.68	0.03	1.04	3.65	0.04	39.70	0.13	11.25
FASO 064	A8	38.40	7.78	36.42	0.05	3.57	0.02	0.15	0.06	30.12	11.98	0.07	9.23	2.44	0.55
FASO 065	A8	40.40	2.25	44.52	0.05	4.63	0.02	0.19	0.10	32.59	7.53	0.03	6.68	2.81	0.75
FASO 066	A8	41.90	2.03	40.27	0.05	8.33	0.06	0.24	0.15	28.40	10.67	0.09	8.40	2.47	1.12
FASO 067	FASO 68/12		1.98	48.06	0.02	0.89	0.05	0.88	0.02	2.80	6.56	0.08	37.00	0.31	9.97
FASO 068	A9	39.50	11.69	31.42	0.05	3.80	0.03	0.18	0.04	27.72	13.11	0.07	11.55	2.25	0.55
FASO 069	A9	41.10	2.07	46.48	0.06	3.12	0.02	0.16	0.03	33.92	7.41	0.02	5.78	3.06	0.56
FASO 070	A9	42.40	1.68	43.20	0.06	5.92	0.06	0.33	0.08	30.56	7.18	0.05	8.76	2.77	1.00
FASO 071	A10	39.80	6.86	37.80	0.06	3.50	0.04	0.18	0.06	30.01	12.81	0.08	8.24	2.65	0.60
FASO 072	A10	42.10	1.60	35.05	0.06	16.08	0.09	0.65	0.31	23.33	8.78	0.05	12.20	2.19	2.20
FASO 073	A11	40.50	14.60	18.10	0.06	3.87	0.09	0.22	0.04	17.04	34.37	0.36	10.75	1.29	0.50
FASO 074	A11	42.00	1.15	48.07	0.06	2.63	0.02	0.15	0.02	35.44	5.93	0.02	4.72	3.00	0.54
FASO 075	A11	43.40	1.32	33.79	0.05	18.60	0.08	0.64	0.38	21.90	7.86	0.05	13.35	2.04	2.43
FASO 076	A12	41.95	16.83	16.54	0.10	2.91	0.04	0.20	0.02	19.57	29.48	0.25	13.15	1.32	0.56
FASO 077	A12	43.22	2.39	40.71	0.05	4.05	0.05	0.17	0.07	29.85	15.97	0.09	6.08	2.47	0.56
FASO 078	A12	44.02	1.17	46.38	0.06	4.00	0.03	0.19	0.06	34.17	6.66	0.04	5.42	3.07	0.67
FASO 079	B1	39.30	3.14	41.48	0.05	4.77	0.02	0.16	0.10	30.79	11.01	0.07	6.79	2.64	0.73
FASO 080	B1	41.00	2.85	39.78	0.06	5.73	0.14	0.23	0.05	28.28	14.86	0.19	7.58	2.64	0.77
FASO 081	B1	43.00	1.41	44.11	0.06	5.43	0.06	0.45	0.06	30.74	8.61	0.05	7.12	2.90	1.30
FASO 082	B1		1.34	49.11	0.01	0.60	0.07	0.85	0.01	0.82	5.60	0.07	39.50	0.12	10.85
FASO 083	B2	41.35	5.00	28.40	0.07	12.31	0.02	0.17	0.22	21.94	18.47	0.09	12.35	1.89	1.10

Sample No.	Ag_ppm	Al_%	As_ppm	Ba_ppm	Be_ppm	Bi_ppm	Ca_%	Cd_ppm	Co_ppm	Cr_ppm	Cu_ppm	Fe_%	Ga_ppm	K_%	La_ppm	Mg_%	Mn_ppm	Mo_ppm
FASO 001	<0.5	0.75	13	30	1.1	5	31.00	6.10	10	381	24	2.79	<10	0.04	130	0.12	403	3
FASO 002	<0.5	1.22	19	30	0.8	2	25.60	4.70	6	219	15	3.07	<10	0.14	60	1.23	1045	4
FASO 003	<0.5	1.77	5	50	11.5	<2	28.90	6.00	15	278	9	3.39	<10	0.01	120	0.04	650	2
FASO 004	<0.5	1.37	9	40	6	5	28.80	4.20	15	220	15	4.07	<10	0.07	100	0.08	946	<1
FASO 005	<0.5	2.76	13	30	2.4	<2	22.90	6.40	19	219	30	4.22	<10	0.22	60	0.52	501	1
FASO 006	<0.5	6.27	<5	100	8.9	6	11.95	2.20	11	282	12	6.73	<10	0.04	110	0.07	1265	<1
FASO 007	<0.5	1.78	9	40	3.4	2	28.10	6.20	19	347	20	3.22	<10	0.04	130	0.1	272	<1
FASO 008	<0.5	2.38	11	30	1.7	11	17.95	5.90	64	366	24	12.20	<10	0.22	70	0.66	1860	3
FASO 009	<0.5	0.85	12	10	<0.5	<2	34.00	1.80	5	68	4	1.04	<10	0.08	20	0.38	264	<1
FASO 010	<0.5	3.08	18	40	3.9	2	24.10	4.80	9	359	22	1.83	<10	0.04	130	0.1	155	<1
FASO 011	<0.5	1.52	7	20	1.5	25	9.29	3.20	35	168	12	28.50	<10	0.15	30	0.84	5220	<1
FASO 012	<0.5	1.04	14	10	<0.5	<2	33.50	1.60	2	78	4	0.62	<10	0.12	20	0.49	101	<1
FASO 013	<0.5	4.02	10	60	5.9	2	23.20	8.40	6	327	9	2.14	<10	0.06	120	0.05	325	<1
FASO 014	<0.5	0.54	12	30	1.7	<2	31.80	5.90	2	346	8	1.71	<10	0.01	150	0.02	163	<1
FASO 015	<0.5	0.82	14	30	1.5	<2	30.50	8.90	5	335	23	1.97	<10	0.04	120	0.1	156	<1
FASO 016	<0.5	0.20	<5	10	<0.5	<2	35.20	1.40	1	77	5	0.75	<10	0.02	20	0.17	324	<1
FASO 017	<0.5	1.99	18	40	3	2	25.70	6.80	19	262	21	2.16	<10	0.07	100	0.05	465	3
FASO 018	<0.5	0.89	17	20	1.6	<2	31.90	6.90	14	294	17	1.87	<10	0.03	120	0.08	188	2
FASO 019	<0.5	1.13	7	20	1.4	<2	30.90	6.10	12	345	16	1.40	<10	0.06	130	0.13	151	2
FASO 020	<0.5	1.07	5	10	<0.5	<2	34.20	1.80	2	88	6	0.63	<10	0.12	20	0.5	101	<1
FASO 021	<0.5	4.37	9	190	2.2	<2	1.11	0.60	11	120	3	1.29	<10	0.11	80	0.04	79	<1
FASO 022	<0.5	3.88	15	170	7.3	<2	3.89	0.80	9	526	4	1.17	<10	0.03	160	0.01	281	<1
FASO 023	<0.5	3.99	13	60	4.9	<2	18.80	5.60	33	292	12	1.89	<10	0.06	120	0.03	301	<1
FASO 024	<0.5	1.79	10	40	2.4	<2	24.90	5.70	18	247	9	1.47	<10	0.03	100	0.03	258	<1
FASO 025	<0.5	0.85	5	30	1.3	3	30.60	12.20	17	331	46	4.31	<10	0.05	100	0.19	1050	1
FASO 026	<0.5	1.49	7	40	2.7	10	18.95	3.50	8	246	8	11.20	<10	0.09	80	0.21	2480	<1
FASO 027	<0.5	0.94	8	20	1.3	3	31.90	4.40	7	405	40	2.83	<10	0.03	120	0.09	563	<1
FASO 028	<0.5	1.02	17	30	1.2	<2	29.00	8.10	13	318	23	3.28	<10	0.06	120	0.12	397	1
FASO 029	<0.5	1.17	6	30	1.1	16	15.10	3.70	8	216	15	18.50	<10	0.09	70	0.57	4100	1
FASO 030	<0.5	3.12	6	30	1.3	11	16.05	6.30	13	346	28	11.85	<10	0.35	70	1.02	2200	1
FASO 031	<0.5	1.00	13	50	2.5	<2	25.60	5.30	32	316	21	3.05	<10	0.04	120	0.09	268	1
FASO 032	<0.5	0.71	16	30	1	<2	27.00	5.10	10	235	19	2.78	<10	0.06	80	0.18	246	1
FASO 033	<0.5	0.26	10	10	<0.5	<2	34.30	2.50	1	84	6	0.95	<10	0.02	30	0.25	174	<1
FASO 034	<0.5	3.72	8	70	5	3	18.65	11.10	7	335	29	3.08	<10	0.05	160	0.05	596	<1
FASO 035	<0.5	1.59	13	50	2.3	<2	23.10	7.40	5	313	23	1.78	<10	0.06	120	0.05	287	<1
FASO 036	<0.5	0.82	11	30	1.2	5	25.40	6.40	14	356	23	4.22	<10	0.04	140	0.1	316	<1
FASO 037	<0.5	0.58	15	20	0.6	3	31.20	2.20	5	73	11	2.07	<10	0.04	30	0.26	370	<1
FASO 038	<0.5	5.95	10	130	13.1	2	16.20	8.90	1	541	31	2.69	<10	0.04	170	0.03	645	<1
FASO 039	<0.5	1.08	11	40	3.2	<2	29.70	8.60	9	360	27	1.57	<10	0.02	140	0.02	214	<1
FASO 040	<0.5	0.65	16	40	2.3	<2	30.80	7.80	9	384	23	1.98	<10	0.01	150	0.02	225	<1
FASO 041	<0.5	0.53	7	40	2.4	2	29.50	5.30	25	322	31	3.53	<10	0.02	130	0.03	237	2
FASO 042	<0.5	1.07	9	40	1.2	<2	28.10	10.50	24	388	25	2.82	<10	0.10	130	0.2	183	1
FASO 043	<0.5	0.78	16	30	1	<2	28.90	9.30	19	384	30	3.63	<10	0.08	120	0.23	737	<1
FASO 044	<0.5	0.68	15	10	<0.5	<2	33.70	1.70	<1	55	5	0.57	<10	0.08	10	0.38	146	<1
FASO 045	<0.5	0.55	<5	30	1.6	<2	30.70	5.80	1	336	8	1.69	<10	0.02	140	0.02	165	<1
FASO 046	<0.5	1.10	7	40	3.4	<2	29.10	9.40	4	352	17	2.14	<10	0.08	140	0.03	269	<1
FASO 047	<0.5	0.40	11	30	1.6	<2	32.30	6.60	<1	396	12	1.45	<10	0.01	160	0.02	155	<1
FASO 048	<0.5	0.51	<5	30	1.8	<2	30.50	6.50	5	312	20	3.39	<10	0.03	130	0.08	816	1
FASO 049	<0.5	0.79	9	30	1	2	30.00	7.50	14	373	22	1.66	<10	0.07	120	0.19	223	1
FASO 050	<0.5	0.44	10	10	<0.5	<2	33.50	2.60	4	113	8	0.92	<10	0.04	40	0.27	237	<1
FASO 051	<0.5	2.10	16	60	3.4	4	21.10	5.10	5	304	17	3.52	<10	0.13	130	0.11	419	<1
FASO 052	<0.5	0.64	<5	40	2.1	<2	28.30	5.20	5	278	19	3.93	<10	0.03	130	0.07	854	<1
FASO 053	<0.5	0.94	11	40	2.3	<2	23.10	5.70	8	247	16	3.67	<10	0.05	110	0.12	788	<1
FASO 054	<0.5	0.98	12	40	2.3	5	24.40	4.70	3	316	26	5.54	<10	0.04	130	0.14	994	<1
FASO 055	<0.5	0.74	8	40	1.5	4	26.90	7.10	11	348	20	4.65	<10	0.04	130	0.15	1105	<1
FASO 056	<0.5	1.57	13	40	2	2	21.10	5.80	20	302	20	6.92	<10	0.11	110	0.32	1355	<1
FASO 057	<0.5	0.45	<5	20	0.6	<2	32.70	2.80	5	99	5	1.85	<10	0.03	40	0.24	517	<1
FASO 058	<0.5	0.58	8	20	0.5	<2	34.10	3.30	2	139	8	0.79	<10	0.08	40	0.29	195	<1
FASO 059	<0.5	6.06	14	100	7.6	<2	21.20	8.50	7	383	29	1.74	<10	0.01	120	0.08	158	1
FASO 060	<0.5	0.73	9	30	1.9	5	30.70	7.60	2	357	55	2.27	<10	0.01	140	0.03	218	<1
FASO 061	<0.5	0.71	14	40	1.7	3	28.70	7.10	47	315	28	4.77	<10	0.04	100	0.13	928	1
FASO 062	<0.5	0.34	10	10	<0.5	3	33.30	2.50	2	92	7	2.03	<10	0.03	30	0.28	497	<1
FASO 063	<0.5	0.48	13	10	<0.5	<2	34.60	1.30	2	40	3	0.49	<10	0.06	10	0.35	189	<1
FASO 064	<0.5	4.14	<5	90	7.7	2	22.90	9.80	8	326	23	2.35	<10	0.01	120	0.02	363	<1
FASO 065	<0.5	1.25	11	40	2.8	<2	29.40	9.50	12	346	21	3.13	<10	0.02	130	0.05	698	<1
FASO 066	<0.5	1.12	17	40	1.4	4	25.30	5.30	6	316	19	5.68	<10	0.05	130	0.08	1075	<1
FASO 067	<0.5	1.18	6	10	0.6	<2	33.50	2.20	4	85	5	0.65	<10	0.12	20	0.47	107	<1
FASO 068	<0.5	6.20	5	70	6.8	2	19.65	15.10	18	342	36	2.47	<10	0.02	150	0.04	257	<1
FASO 069	<0.5	1.11	6	30	1.6	2	29.20	7.00	5	388	25	2.08	<10	0.01	160	0.03	194	<1
FASO 070	<0.5	0.94	8	30	1.4	3	26.20	8.40	10	384	25	3.88	<10	0.06	130	0.13	523	1
FASO 071	<0.5	3.68	6	80	5.8	2	23.60	5.00	6	337	16	2.31	<10	0.02	140	0.04	384	<1
FASO 072	<0.5	0.89	7	30	1.1	3	21.60	6.50	17	321	41	10.95	<10	0.07	110	0.31	2180	<1
FASO 073	<0.5	6.49	10	220	7.8	5	12.25	3.50	7	370	10	2.59	<10	0.07	100	0.05	275	<1
FASO 074	<0.5	0.63	14	30	2.3	<2	31.10	7.50	9	353	37	1.76	<10	0.01	150	0.03	171	1
FASO 075	<0.5	0.75	<5	20	1.1	<2	20.20	6.20	3	302	23	11.85	<10	0.07	100	0.31	2600	2
FASO 076	<0.5	6.15	9	190	18.7	6	10.65	3.70	4	622	14	1.86	<10	0.02	120	0.03	178	1
FASO 077	<0.5	1.26	11	50	3.8	3	24.60	8.30	4	296	13	2.60	<10	0.03	130	0.04	468	1
FASO 078	<0.5	0.65	11	30	2.7	<2	29.80	7.50	3	341	32	2.60	<10	0.02	140	0.05	436	<1
FASO 079	<0.5	1.68	12	50	4.6	3	25.80	8.60	4	341	26	3.24	<10	0.02	120	0.03	757	<1
FASO 080	<0.5	1.46	17	40	1.7	3	24.00	5.90	8	302	15	3.63	<10	0.11	130	0.07	333	1
FASO 081	<0.5	0.75	13	30	1.1	<2	27.90	11.00	31	359	138	3.52	<10	0.05	130	0.2	398	<1
FASO 082	<0.5	0.77	7	10	<0.5	<2	33.50	1.40	<1	56	4	0.43	<10	0.08	10	0.44	87	<1
FASO 083	<0.5	2.61	11	50	5.6	4	17.80	9.70	13	417	35	7.79	<10	0.01	160	0.04	1385	<1

Sample No.	Na_%	Ni_ppm	P_ppm	Pb_ppm	S_%	Sb_ppm	Sc_ppm	Sr_ppm	Th_ppm	Ti_%	Tl_ppm	U_ppm	V_ppm	W_ppm	Zn_ppm
FASO 001	0.13	114	>10000	5	3.00	<5	6	421	20	0.03	<10	110	259	<10	226
FASO 002	0.20	114	>10000	3	3.49	<5	4	552	20	0.06	<10	120	196	<10	129
FASO 003	0.07	16	>10000	3	1.66	<5	4	1540	20	0.03	<10	70	162	<10	200
FASO 004	0.06	21	>10000	5	1.64	<5	6	318	20	0.06	10	80	183	<10	130
FASO 005	0.04	94	>10000	3	1.99	<5	7	176	<20	0.09	<10	40	207	<10	318
FASO 006	0.04	17	>10000	8	1.45	5	9	2330	<20	0.24	<10	70	100	<10	92
FASO 007	0.07	46	>10000	5	2.95	<5	7	470	20	0.06	<10	100	400	<10	373
FASO 008	0.10	230	>10000	3	6.70	<5	6	278	<20	0.12	<10	110	971	<10	814
FASO 009	0.04	26	>10000	2	0.60	<5	2	620	20	0.04	<10	10	40	<10	46
FASO 010	0.07	55	>10000	4	1.42	<5	7	794	20	0.04	10	100	404	<10	166
FASO 011	0.05	157	>10000	<2	0.51	<5	4	161	<20	0.08	10	20	144	<10	175
FASO 012	0.05	17	8710	2	<0.01	<5	2	874	20	0.05	10	20	36	<10	38
FASO 013	0.06	18	>10000	5	1.55	<5	5	1420	20	0.05	<10	70	145	<10	212
FASO 014	0.07	17	>10000	4	1.80	<5	4	397	30	0.02	<10	90	201	<10	195
FASO 015	0.06	99	>10000	4	2.02	5	5	262	20	0.04	10	120	475	10	279
FASO 016	0.04	17	>10000	2	0.80	<5	1	224	20	0.01	<10	20	56	<10	37
FASO 017	0.06	68	>10000	2	1.48	6	5	549	20	0.03	<10	80	235	<10	445
FASO 018	0.07	75	>10000	5	2.05	<5	6	263	20	0.03	10	110	266	<10	289
FASO 019	0.08	77	>10000	4	1.22	<5	7	328	20	0.05	10	110	257	<10	273
FASO 020	0.05	20	>10000	3	<0.01	<5	2	886	20	0.05	<10	20	38	<10	44
FASO 021	0.03	24	>10000	7	0.84	<5	12	1830	20	0.32	<10	<10	62	<10	87
FASO 022	0.02	10	>10000	11	0.71	<5	9	5470	30	0.22	<10	80	184	<10	114
FASO 023	0.06	39	>10000	4	1.10	<5	9	2070	20	0.06	<10	70	157	<10	384
FASO 024	0.07	25	>10000	4	1.01	<5	5	1160	20	0.03	<10	80	144	<10	351
FASO 025	0.11	179	>10000	2	1.66	<5	4	376	20	0.04	<10	120	517	<10	291
FASO 026	0.06	11	>10000	4	2.68	5	5	753	20	0.09	<10	40	140	<10	143
FASO 027	0.08	20	>10000	4	2.20	<5	5	304	20	0.04	10	130	380	<10	199
FASO 028	0.07	99	>10000	4	2.51	<5	6	305	20	0.06	<10	80	301	10	261
FASO 029	0.06	96	>10000	4	4.29	<5	5	213	<20	0.08	<10	50	193	10	115
FASO 030	0.12	165	>10000	7	4.37	<5	8	319	<20	0.16	<10	100	279	<10	198
FASO 031	0.14	150	>10000	3	3.08	9	4	1200	20	0.05	<10	70	225	<10	519
FASO 032	0.15	126	>10000	<2	2.70	<5	4	526	20	0.05	<10	60	169	<10	147
FASO 033	0.07	20	>10000	2	1.10	<5	1	356	<20	0.01	<10	30	55	<10	45
FASO 034	0.05	16	>10000	10	2.00	<5	9	2270	20	0.07	10	60	203	10	267
FASO 035	0.07	14	>10000	4	1.40	<5	5	882	20	0.03	<10	40	216	<10	376
FASO 036	0.15	192	>10000	4	4.27	<5	5	607	20	0.04	<10	70	213	<10	233
FASO 037	0.08	31	>10000	6	1.20	<5	2	591	<20	0.03	<10	30	61	<10	80
FASO 038	0.05	12	>10000	11	1.36	<5	12	4290	30	0.16	10	110	386	<10	189
FASO 039	0.06	18	>10000	5	1.60	5	5	700	30	0.04	<10	70	282	<10	362
FASO 040	0.08	33	>10000	5	2.19	<5	4	685	30	0.02	<10	60	163	<10	371
FASO 041	0.08	177	>10000	2	4.13	<5	4	417	30	0.03	10	60	258	<10	212
FASO 042	0.20	136	>10000	5	3.00	<5	6	572	30	0.06	10	90	280	<10	209
FASO 043	0.17	118	>10000	2	2.19	<5	6	507	20	0.04	<10	110	261	<10	316
FASO 044	0.04	22	7250	3	<0.01	<5	1	745	<20	0.04	10	20	33	<10	41
FASO 045	0.08	18	>10000	4	1.81	<5	4	390	30	0.02	<10	80	197	<10	192
FASO 046	0.06	10	>10000	7	2.06	<5	5	581	20	0.04	<10	70	205	<10	290
FASO 047	0.07	8	>10000	4	1.60	<5	5	378	30	0.02	<10	70	203	<10	281
FASO 048	0.09	59	>10000	4	1.89	<5	4	381	20	0.03	<10	60	269	<10	176
FASO 049	0.19	146	>10000	5	1.66	<5	5	563	20	0.04	<10	100	274	<10	172
FASO 050	0.09	32	>10000	2	1.00	<5	2	478	<20	0.03	<10	40	88	<10	65
FASO 051	0.07	22	>10000	6	2.26	<5	7	714	20	0.06	<10	50	195	<10	250
FASO 052	0.12	73	>10000	5	2.46	<5	5	527	20	0.03	<10	70	206	<10	195
FASO 053	0.18	92	>10000	5	2.55	<5	5	816	20	0.04	<10	80	184	<10	154
FASO 054	0.09	39	>10000	3	3.15	<5	5	515	20	0.05	10	50	377	<10	279
FASO 055	0.15	103	>10000	5	2.51	<5	5	469	20	0.04	10	80	350	<10	284
FASO 056	0.17	143	>10000	3	2.42	<5	7	738	20	0.09	10	80	251	<10	175
FASO 057	0.07	33	>10000	2	0.80	5	2	339	<20	0.03	<10	30	79	<10	73
FASO 058	0.18	47	>10000	<2	0.70	<5	2	544	20	0.03	<10	60	114	<10	80
FASO 059	0.06	26	>10000	4	1.92	<5	5	5050	20	0.03	<10	60	284	<10	212
FASO 060	0.10	34	>10000	<2	2.61	<5	4	456	20	0.02	<10	60	253	<10	183
FASO 061	0.16	530	>10000	5	2.10	<5	4	509	20	0.03	<10	80	248	<10	306
FASO 062	0.09	44	>10000	2	1.00	<5	2	432	<20	0.02	<10	40	81	<10	40
FASO 063	0.03	20	4870	2	<0.01	<5	1	572	<20	0.03	<10	20	29	<10	27
FASO 064	0.05	17	>10000	6	2.40	<5	8	2700	20	0.04	<10	70	273	<10	270
FASO 065	0.08	56	>10000	5	2.06	<5	4	894	20	0.02	10	70	196	10	278
FASO 066	0.11	41	>10000	5	3.43	<5	5	494	20	0.06	<10	60	184	10	240
FASO 067	0.05	18	>10000	3	0.19	<5	2	971	20	0.05	<10	20	45	<10	49
FASO 068	0.04	29	>10000	<2	2.77	<5	7	3060	20	0.05	10	60	315	<10	449
FASO 069	0.08	26	>10000	3	2.38	5	5	759	20	0.02	<10	60	281	10	337
FASO 070	0.18	136	>10000	6	3.70	<5	5	558	20	0.04	<10	90	247	<10	166
FASO 071	0.06	23	>10000	2270	1.78	8	7	2190	20	0.05	<10	70	300	<10	168
FASO 072	0.17	188	>10000	6	3.72	<5	5	486	20	0.04	<10	80	298	<10	193
FASO 073	0.06	17	>10000	10	1.62	<5	13	4360	30	0.17	<10	70	177	<10	190
FASO 074	0.07	65	>10000	6	1.86	<5	4	359	30	0.02	<10	60	232	<10	338
FASO 075	0.14	135	>10000	4	4.64	5	5	434	20	0.04	<10	70	239	<10	181
FASO 076	0.05	8	>10000	7	1.69	<5	8	7070	20	0.11	<10	130	146	<10	160
FASO 077	0.05	16	>10000	4	1.84	<5	5	767	20	0.04	<10	70	153	<10	167
FASO 078	0.07	40	>10000	4	2.05	<5	5	361	30	0.03	10	70	315	<10	232
FASO 079	0.05	16	>10000	3	2.48	<5	5	992	20	0.05	<10	70	142	<10	187
FASO 080	0.06	54	>10000	6	2.50	<5	5	314	20	0.07	<10	40	176	<10	244
FASO 081	0.15	196	>10000	5	1.09	<5	5	437	20	0.04	<10	90	331	<10	182
FASO 082	0.04	18	3960	2	<0.01	<5	1	896	<20	0.04	<10	10	28	<10	42
FASO 083	0.04	25	>10000	7	5.93	<5	7	2120	20	0.06	<10	80	155	<10	171

Sample No.	Borehole	Depth mbgl	Al2O3_%	CaO_%	Cr2O3_%	Fe2O3_%	K2O_%	MgO_%	MnO_%	P2O5_%	SiO2_%	TiO2_%	LOI_%	F_%	C_%
FASO 084	B2	43.20	0.97	41.63	0.05	10.56	0.04	0.42	0.17	29.91	5.87	0.03	8.25	2.58	1.70
FASO 085	B3	41.10	5.11	35.31	0.07	3.38	0.05	0.19	0.04	26.61	20.38	0.13	7.63	2.29	0.57
FASO 086	B3	42.50	0.92	45.92	0.05	5.38	0.02	0.19	0.06	33.37	4.94	0.02	7.23	2.83	0.68
FASO 087	B3	43.80	1.27	32.58	0.05	19.97	0.07	0.75	0.33	21.20	7.77	0.05	13.00	2.04	3.36
FASO 088	B4	39.15	3.12	43.31	0.06	3.19	0.03	0.15	0.03	32.22	11.10	0.05	6.18	2.87	0.55
FASO 089	B4	40.50	1.37	47.56	0.06	3.26	0.01	0.15	0.04	34.92	6.33	0.02	5.05	3.16	0.55
FASO 090	B4	42.00	0.83	47.53	0.06	3.74	0.02	0.19	0.04	34.30	6.02	0.03	5.39	3.27	0.63
FASO 091	B4	43.50	1.24	39.86	0.05	10.52	0.08	0.56	0.20	23.61	8.73	0.05	9.14	2.34	2.58
FASO 092	Test		1.00	47.85	0.05	2.59	0.02	0.14	0.02	35.14	7.28	0.02	4.03	3.47	0.52
FASO 093	B5	39.20	4.59	42.67	0.05	2.35	0.02	0.15	0.03	32.34	10.38	0.06	6.75	3.07	0.56
FASO 094	B5	40.80	0.83	48.43	0.06	2.91	0.01	0.16	0.03	34.97	5.52	0.02	5.00	3.33	0.54
FASO 095	B5	42.10	1.14	44.20	0.05	5.33	0.06	0.35	0.07	27.15	7.59	0.05	7.38	2.72	1.98
FASO 096	B6	39.35	3.65	41.16	0.05	3.18	0.03	0.16	0.03	30.30	13.21	0.10	6.78	2.93	0.51
FASO 097	B6	41.15	1.21	44.53	0.05	5.85	0.04	0.28	0.09	31.51	7.24	0.04	7.15	2.96	1.07
FASO 098	B6		0.58	51.89	0.02	1.48	0.02	0.49	0.06	7.84	3.17	0.02	32.60	0.87	8.96
FASO 099	B7	39.80	1.22	42.92	0.05	5.23	0.03	0.20	0.04	30.83	9.60	0.05	8.01	2.91	0.62
FASO 100	B7	41.60	1.26	39.11	0.05	12.18	0.08	0.56	0.26	23.28	7.98	0.05	9.59	2.32	2.88
FASO 101	B8	40.00	6.35	20.53	0.04	2.84	0.05	0.16	0.03	15.68	45.83	0.30	8.03	1.51	0.56
FASO 102	B8	42.00	1.14	44.19	0.06	5.44	0.03	0.22	0.08	31.03	7.61	0.04	8.05	2.86	1.11
FASO 103	test		1.83	48.86	0.01	0.83	0.03	0.93	0.01	1.83	6.65	0.08	38.90	0.25	10.25
FASO 104	SB 2	56.60	8.39	24.80	0.03	4.84	0.13	0.16	0.04	20.93	29.88	0.23	8.52		0.70
FASO 105	SB 2	58.15	2.26	28.20	0.03	3.80	0.05	0.12	0.03	20.20	39.36	0.19	4.50		0.47
FASO 106	SB 2	59.60	1.82	41.53	0.04	6.90	0.08	0.42	0.15	28.76	10.45	0.09	6.85		1.43
FASO 107	SB -2	50.12	24.84	11.20	0.06	1.98	0.08	0.15	<0.01	20.05	22.63	0.11	16.35		0.85
FASO 108	SB-2	50.88	2.37	45.58	0.04	2.23	0.03	0.14	0.04	33.43	9.11	0.03	5.60		0.72
FASO 109	SB-2	51.95	1.51	37.37	0.05	12.14	0.07	0.35	0.34	26.46	8.99	0.07	9.39		2.09
FASO 110	SB-2	53.04	2.06	29.31	0.03	23.37	0.11	0.44	0.73	11.08	8.34	0.11	20.70		6.16
FASO 111	SB-2	53.70	0.59	52.40	0.01	1.35	0.03	0.51	0.03	5.61	2.35	0.03	35.20		9.75
FASO 112	SB 1	58.40	1.82	43.38	0.05	6.76	0.04	0.19	0.06	30.13	7.90	0.07	7.88		0.83
FASO 113	SM-2	37.10	1.10	40.32	0.02	9.20	0.05	0.58	0.16	12.82	8.86	0.08	20.10		5.98
FASO 114	SM-2	38.10	0.46	51.03	0.01	1.87	0.03	0.46	0.04	6.67	3.07	0.03	32.20		9.01
FASO 115	SM-2	39.10	0.40	51.95	<0.01	0.93	0.02	0.44	0.03	3.92	3.10	0.02	36.70		10.05
FASO 116	SM-3	33.05	7.12	23.60	0.06	5.82	0.24	0.45	0.05	16.57	34.10	0.47	8.50		0.62
FASO 117	SM-3	33.65	1.66	44.97	0.05	5.10	0.05	0.35	0.08	29.57	5.58	0.07	7.42		1.47
FASO 118	SM-3	35.00	1.02	46.65	0.02	5.95	0.06	0.41	0.02	6.30	4.14	0.05	26.70		8.14
FASO 120	SK-1	52.15	5.49	38.59	0.04	3.91	0.12	0.26	0.03	26.78	13.24	0.20	9.39		1.01
FASO 121	duplicate		5.19	39.40	0.04	3.70	0.10	0.26	0.03	27.86	12.20	0.17	8.96		1.04
FASO 122	SK-1	53.60	1.81	37.45	0.04	12.44	0.07	0.43	0.16	22.15	6.29	0.07	9.97		2.89
FASO 123	SK-1	55.10	0.50	47.76	0.02	5.14	0.03	0.42	0.08	7.00	2.16	0.02	29.30		8.60
FASO 124	SC-2	53.67	0.51	48.72	0.01	0.49	0.03	0.45	0.01	8.64	10.13	0.02	29.10		7.86
FASO 125	SC-3	60.52	1.19	46.50	0.02	1.54	0.07	0.71	0.01	14.73	8.85	0.05	22.10		5.85
FASO 126	SK 1b	48.00	1.94	46.45	0.04	3.28	0.07	0.19	0.07	32.04	8.72	0.11	5.06		0.78
FASO 127	SK 1b	49.30	4.87	25.80	0.04	11.73	0.37	1.17	0.26	15.00	22.33	0.23	12.80		1.83
FASO 128	SK 0	54.18	4.43	42.79	0.04	2.70	0.03	0.18	0.03	31.39	9.83	0.07	6.55		0.69
FASO 129	SK 0	55.18	2.12	43.51	0.04	2.53	0.03	0.15	0.05	30.37	14.66	0.12	4.52		0.75
FASO 130	SK 0	56.29	1.13	46.44	0.05	4.42	0.03	0.22	0.03	33.26	4.22	0.05	5.88		0.88
FASO 131	SK 0	57.77	1.70	33.52	0.04	9.75	0.08	0.32	0.05	23.17	16.01	0.13	10.60		0.79
FASO 132	SC 0	65.00	3.25	40.81	0.04	4.27	0.07	0.16	0.04	29.68	12.63	0.13	6.75		0.79
FASO 133	SC 0	66.42	1.81	43.01	0.06	4.43	0.07	0.34	0.02	29.90	8.50	0.09	6.73		1.05
FASO 134	SC 0	67.46	0.72	40.77	0.02	4.42	0.04	6.58	0.36	7.65	3.54	0.03	32.30		8.93
FASO 135	SC-1	66.63	4.39	28.94	0.03	4.72	0.09	0.21	0.05	20.96	31.06	0.20	7.55		1.04
FASO 136	SB-3	55.23	1.90	45.27	0.02	1.49	0.09	0.75	0.02	29.17	8.45	0.11	9.64		1.50
FASO 137	SN-2	32.29	3.95	7.15	0.02	40.98	0.31	2.02	0.81	2.96	12.89	0.15	25.90		6.81
FASO 138	SB-3	55.58	0.68	50.13	0.02	0.68	0.05	0.72	0.03	10.40	6.13	0.06	29.20		7.77
FASO 139	MW 4	46.74	19.55	19.78	0.12	1.73	0.06	0.13	0.01	24.56	18.81	0.17	12.55		0.68
FASO 140	MW 4	47.80	2.56	45.45	0.04	2.97	0.04	0.23	0.03	32.92	7.06	0.07	6.23		0.72
FASO 142	SN 8	33.58	1.08	49.82	0.01	1.23	0.03	0.83	0.02	0.73	4.38	0.05	40.00		10.60
FASO 143	SN-3	35.32	6.32	35.73	0.05	3.85	0.03	0.17	0.02	26.35	17.17	0.12	8.12		0.64
FASO 144	SN-3	36.27	1.43	31.59	0.04	20.38	0.07	0.47	0.17	20.69	5.00	0.05	14.35		2.20
FASO 145	SL 8	39.10	0.88	37.42	0.05	13.45	0.03	0.89	0.11	25.01	7.05	0.05	11.70		2.90
FASO 146	SL 8b	38.24	1.29	42.81	0.05	7.32	0.02	0.32	0.07	29.75	8.78	0.06	6.13		1.45
FASO 147	SL 8b	39.95	1.17	34.54	0.05	17.11	0.04	0.73	0.17	23.85	6.97	0.05	11.80		3.24
FASO 149	SI 3	49.22	0.68	36.21	0.04	14.89	0.06	0.52	0.47	23.66	7.18	0.02	9.96		2.69
FASO 150	SI 3	50.75	0.66	39.30	0.05	9.71	0.05	0.31	0.41	26.12	10.47	0.04	7.16		2.03
FASO 151	SH 2	57.50	14.82	4.20	0.08	2.84	0.10	0.14	0.01	9.95	54.73	1.16	9.75		0.37
FASO 152	SH 2	60.69	0.62	43.13	0.06	6.88	0.05	0.38	0.12	28.48	8.98	0.02	7.21		1.80
FASO 153	SH 2	62.14	0.55	48.55	0.04	2.19	0.01	0.42	0.04	15.44	5.86	0.02	20.80		6.01
FASO 155	CEX 4 bis	25.65	11.89	3.69	0.07	4.63	0.17	0.24	0.08	8.16	58.66	0.67	9.68		0.69
FASO 156	CEX 4 bis	26.13	26.43	7.47	0.06	3.04	0.14	0.33	0.01	16.02	25.70	0.41	17.70		0.53
FASO 157	CEX 4 bis	26.69	11.54	27.64	0.03	3.13	0.10	0.76	0.02	22.32	19.10	0.18	13.10		0.48
FASO 158	CEX 4 bis	27.69	3.27	33.41	0.03	10.11	0.12	0.74	0.20	22.80	17.07	0.20	10.30		1.87
FASO 159	CEX 4 bis	28.78	4.69	21.95	0.03	8.43	0.19	2.61	0.12	12.55	31.32	0.33	16.20		2.34
FASO 160	duplicate		4.68	22.02	0.04	8.45	0.20	2.62	0.12	12.54	31.42	0.32	16.20		2.34

Sample No.	Ag_ppm	Al_%	As_ppm	Ba_ppm	Be_ppm	Bi_ppm	Ca_%	Cd_ppm	Co_ppm	Cr_ppm	Cu_ppm	Fe_%	Ga_ppm	K_%	La_ppm	Mg_%	Mn_ppm	Mo_ppm
FASO 084	<0.5	0.53	<5	30	1.6	5	24.80	6.00	13	322	22	6.90	<10	0.03	120	0.18	1160	<1
FASO 085	<0.5	2.71	12	60	7.3	<2	22.10	8.90	11	456	21	2.29	<10	0.04	180	0.05	291	1
FASO 086	<0.5	0.52	5	30	2.3	<2	29.80	5.60	6	333	19	3.58	<10	0.01	140	0.05	409	<1
FASO 087	<0.5	0.71	<5	20	1.2	<2	19.50	6.00	13	285	21	12.65	<10	0.06	90	0.37	2280	1
FASO 088	<0.5	1.67	16	60	5.3	<2	27.90	8.50	2	350	16	2.13	<10	0.02	120	0.03	234	1
FASO 089	<0.5	0.74	11	40	2.9	<2	29.70	5.80	1	359	21	2.08	<10	0.01	140	0.02	260	<1
FASO 090	<0.5	0.44	7	30	1.3	<2	29.20	7.00	4	343	17	2.36	<10	0.02	140	0.05	242	<1
FASO 091	<0.5	0.66	8	20	0.9	4	23.30	9.50	12	291	28	6.63	<10	0.07	100	0.25	1310	<1
FASO 092	<0.5	0.54	8	30	1.6	<2	30.10	5.50	1	322	8	1.69	<10	0.01	140	0.02	165	<1
FASO 093	<0.5	2.42	10	60	5.7	4	25.30	9.20	2	293	21	1.55	<10	0.01	120	0.02	213	<1
FASO 094	<0.5	0.46	14	30	2	<2	30.60	6.20	2	384	31	1.89	<10	<0.01	150	0.03	178	<1
FASO 095	<0.5	0.62	15	30	1.5	3	26.40	7.90	18	304	30	3.38	<10	0.04	110	0.14	465	1
FASO 096	<0.5	1.91	11	60	6.9	<2	24.60	8.10	5	309	20	2.07	<10	0.02	110	0.04	195	<1
FASO 097	<0.5	0.66	10	30	1.6	6	26.10	6.30	3	338	20	3.80	<10	0.03	130	0.1	625	<1
FASO 098	<0.5	0.33	5	10	<0.5	<2	32.50	3.10	2	113	8	0.98	<10	0.03	40	0.22	364	<1
FASO 099	<0.5	0.65	20	30	2.2	2	25.10	5.90	35	298	14	3.35	<10	0.02	120	0.06	266	1
FASO 100	<0.5	0.65	10	20	0.8	3	22.60	5.70	17	298	24	7.58	<10	0.06	110	0.26	1675	1
FASO 101	<0.5	3.19	15	100	5.8	<2	13.15	5.80	18	203	12	1.85	<10	0.04	80	0.03	190	<1
FASO 102	<0.5	0.61	14	40	1.5	<2	25.10	5.90	24	311	14	3.42	<10	0.02	130	0.07	506	<1
FASO 103	<0.5	1.00	8	10	<0.5	<2	31.50	1.60	1	79	4	0.57	<10	0.11	20	0.47	91	<1
FASO 104	3.4	4.61	23	100	9.8	2	17.40	5.20	19	226	12	3.41	<10	0.11	80	0.06	296	6
FASO 105	1.3	1.32	8	40	2.3	<2	20.40	2.80	16	222	11	2.71	<10	0.04	80	0.03	256	6
FASO 106	1.3	1.08	7	30	1.8	<2	28.60	5.70	19	312	31	4.74	<10	0.07	100	0.2	1130	5
FASO 107	8.8	9.95	<5	410	26.2	<2	7.69	12.60	11	448	40	1.29	<10	0.05	100	0.05	64	4
FASO 108	1.7	1.45	11	60	5.1	<2	31.40	11.20	31	323	31	1.56	<10	0.02	100	0.04	279	6
FASO 109	0.8	0.88	14	20	1.4	<2	25.70	6.40	29	328	52	7.83	<10	0.06	100	0.16	2370	5
FASO 110	0.9	1.22	12	30	1.1	3	21.00	2.40	4	190	23	15.70	<10	0.10	60	0.22	5320	4
FASO 111	0.8	0.35	<5	10	<0.5	<2	35.90	1.60	2	97	7	0.93	<10	0.03	30	0.26	263	3
FASO 112	0.9	1.04	15	30	2	<2	28.70	4.70	11	340	25	4.42	<10	0.03	100	0.07	446	4
FASO 113	1	0.64	14	30	1.2	<2	27.30	3.10	8	169	10	5.96	<10	0.04	40	0.29	1100	3
FASO 114	1	0.27	10	10	0.6	<2	35.00	1.40	1	88	9	1.28	<10	0.03	30	0.23	290	4
FASO 115	0.8	0.24	7	10	<0.5	<2	34.60	1.20	1	54	6	0.64	<10	0.03	20	0.22	241	3
FASO 116	0.8	3.86	13	60	1.9	<2	16.30	10.90	9	387	29	3.95	10	0.19	110	0.21	385	4
FASO 117	1.2	0.92	8	40	2	<2	28.50	6.00	22	317	20	3.21	<10	0.04	100	0.15	524	4
FASO 118	0.8	0.58	9	20	0.5	<2	31.20	2.00	6	104	8	3.71	<10	0.05	30	0.19	172	3
						<2												
FASO 120	2.3	2.97	14	60	3.6	<2	24.90	6.30	15	248	18	2.51	<10	0.09	80	0.11	213	6
FASO 121	2.2	2.78	15	60	3.5	<2	24.90	6.30	16	244	18	2.33	<10	0.07	80	0.1	206	5
FASO 122	1.3	0.98	9	40	1.4	<2	24.20	3.70	5	271	17	7.76	<10	0.06	80	0.19	1080	4
FASO 123	1.1	0.30	8	10	0.5	<2	32.00	1.80	<1	105	7	3.33	<10	0.02	30	0.2	595	4
FASO 124	0.9	0.28	<5	10	0.6	<2	31.10	2.80	1	114	7	0.33	<10	0.03	30	0.21	67	3
FASO 125	1.6	0.67	5	40	0.8	<2	30.70	4.20	1	138	16	1.03	<10	0.07	30	0.35	118	5
FASO 126	0.9	1.03	8	40	1.6	<2	29.00	4.70	41	249	14	2.03	<10	0.05	80	0.06	453	8
FASO 127	1.1	2.50	10	60	1.1	<2	16.50	2.30	30	261	22	7.11	<10	0.28	60	0.56	1730	8
FASO 128	2.9	2.38	<5	80	5.8	<2	27.10	3.80	2	252	12	1.67	<10	0.02	90	0.05	187	6
FASO 129	1.2	1.12	6	40	2.2	<2	27.20	4.80	3	267	17	1.56	<10	0.02	90	0.04	324	7
FASO 130	0.9	0.62	9	30	1.3	<2	29.70	5.40	12	346	20	2.72	<10	0.02	110	0.08	209	4
FASO 131	1.1	0.94	12	30	1.1	<2	22.50	5.90	7	286	24	6.32	<10	0.06	80	0.13	366	6
FASO 132	1.4	1.81	6	50	3.8	<2	26.80	4.40	12	260	20	2.81	<10	0.05	90	0.05	268	5
FASO 133	1.1	0.97	6	30	1.5	<2	27.00	24.60	49	356	60	2.76	<10	0.05	110	0.14	154	5
FASO 134	0.9	0.39	<5	10	0.6	<2	25.60	2.20	3	128	6	2.67	<10	0.03	40	3.55	2430	4
FASO 135	2.3	2.25	12	80	3.1	<2	18.20	6.40	6	213	13	2.85	<10	0.06	70	0.08	307	5
FASO 136	2	1.06	8	60	1.5	<2	28.50	3.90	2	180	17	0.97	<10	0.07	40	0.36	181	4
FASO 137	<0.5	2.07	10	30	10.6	2	4.74	0.60	14	149	11	25.30	<10	0.24	30	1.06	5490	1
FASO 138	<0.5	0.39	<5	90	0.5	<2	32.70	4.40	3	138	13	0.47	<10	0.04	40	0.35	210	1
FASO 139	0.7	7.32	<5	220	13.4	<2	12.15	6.50	11	744	60	1.10	<10	0.03	190	0.03	111	2
FASO 140	<0.5	1.43	10	50	3	<2	29.50	14.30	32	263	28	1.94	<10	0.03	100	0.08	205	2
FASO 142	<0.5	0.61	<5	10	<0.5	<2	32.80	1.20	2	55	5	0.81	<10	0.05	10	0.41	185	<1
FASO 143	<0.5	3.35	9	70	6.7	<2	23.50	5.10	12	318	17	2.50	<10	0.02	110	0.06	125	2
FASO 144	<0.5	0.81	14	150	2.5	<2	21.30	4.40	49	247	17	12.85	<10	0.06	80	0.21	1175	2
FASO 145	0.6	0.50	<5	110	1.8	<2	24.60	8.00	12	287	26	8.43	<10	0.03	100	0.44	721	<1
FASO 146	30.8	0.70	10	70	2.5	<2	27.60	26.50	11	311	25	4.59	<10	0.02	100	0.13	458	2
FASO 147	3	0.68	6	20	1.9	<2	23.50	8.30	17	291	37	11.00	<10	0.04	90	0.36	1155	1
FASO 149	<0.5	0.38	6	30	2.2	<2	24.20	9.10	3	285	28	9.30	<10	0.05	80	0.23	3220	1
FASO 150	<0.5	0.37	5	30	1.1	<2	26.50	9.50	2	320	22	6.28	<10	0.04	90	0.12	2870	<1
FASO 151	0.5	6.94	8	150	5.3	3	2.89		3	530	3	1.88	10	0.08	120	0.04	72	2
FASO 152	<0.5	0.35	7	30	1.5	<2	28.70	12.80	4	368	30	4.42	<10	0.04	100	0.16	835	<1
FASO 153	<0.5	0.32	8	20	0.9	<2	32.10	7.10	2	208	16	1.45	<10	0.04	60	0.19	300	<1
FASO 155	<0.5	5.74	18	130	5.7	<2	2.52	0.60	16	448	8	3.08	10	0.13	240	0.09	561	3
FASO 156	<0.5	10.05	10	120	11.3	<2	4.88	8.00	24	422	12	1.87	<10	0.10	100	0.14	117	3
FASO 157	<0.5	6.10	12	50	6.1	<2	18.30	14.60	40	206	12	2.05	<10	0.08	90	0.38	118	2
FASO 158	<0.5	1.82	8	20	1.2	<2	22.50	8.80	10	194	10	6.58	<10	0.10	90	0.36	1360	<1
FASO 159	<0.5	2.57	5	30	1	<2	14.90	4.10	11	251	10	5.69	<10	0.16	50	1.41	887	<1
FASO 160	<0.5	2.62	7	30	1.1	<2	15.10	4.10	12	256	10	5.71	<10	0.17	50	1.44	885	<1

Sample No.	Na_%	Ni_ppm	P_ppm	Pb_ppm	S_%	Sb_ppm	Sc_ppm	Sr_ppm	Th_ppm	Ti_%	Tl_ppm	U_ppm	V_ppm	W_ppm	Zn_ppm
FASO 084	0.09	130	>10000	5	2.15	5	4	370	20	0.02	<10	60	265	<10	183
FASO 085	0.07	23	>10000	7	2.16	<5	8	1850	30	0.05	10	70	270	<10	293
FASO 086	0.08	81	>10000	2	3.28	<5	4	477	20	0.02	<10	50	206	<10	178
FASO 087	0.14	115	>10000	3	2.03	7	5	517	20	0.03	<10	70	254	<10	180
FASO 088	0.07	9	>10000	3	1.88	<5	4	1650	20	0.03	<10	70	236	<10	235
FASO 089	0.08	12	>10000	4	2.26	<5	4	1050	20	0.02	<10	70	367	<10	157
FASO 090	0.08	58	>10000	3	2.23	<5	4	348	20	0.02	<10	60	320	<10	208
FASO 091	0.14	118	>10000	3	2.42	<5	4	420	<20	0.03	<10	80	232	<10	181
FASO 092	0.07	15	>10000	2	1.88	<5	4	384	20	0.02	<10	80	193	<10	189
FASO 093	0.06	15	>10000	3	1.69	<5	5	1410	20	0.04	<10	70	263	<10	213
FASO 094	0.08	15	>10000	4	2.25	5	4	554	20	0.02	10	60	331	<10	351
FASO 095	0.18	178	>10000	4	3.31	<5	4	593	20	0.03	<10	80	240	<10	219
FASO 096	0.06	20	>10000	5	2.30	<5	5	1410	20	0.04	10	60	381	<10	258
FASO 097	0.12	42	>10000	5	2.42	<5	4	466	20	0.03	<10	60	413	<10	361
FASO 098	0.09	28	>10000	<2	0.70	<5	2	369	<20	0.02	<10	40	90	<10	37
FASO 099	0.08	352	>10000	3	3.60	12	4	394	20	0.04	<10	50	625	10	237
FASO 100	0.10	187	>10000	3	3.37	7	4	344	20	0.03	10	60	225	<10	108
FASO 101	0.05	52	>10000	5	1.89	9	6	1850	<20	0.14	<10	30	439	<10	262
FASO 102	0.10	139	>10000	4	3.44	<5	4	371	20	0.03	<10	60	455	<10	285
FASO 103	0.05	15	8110	2	0.12	<5	2	838	<20	0.05	<10	10	33	<10	39
FASO 104	0.06	48	>10000	6	2.52	<5	5	2550	20	0.11	<10	50	132	<10	235
FASO 105	0.05	70	>10000	2	2.34	<5	4	577	20	0.07	<10	50	135	10	220
FASO 106	0.08	134	>10000	5	1.64	5	6	368	20	0.05	<10	120	398	<10	331
FASO 107	0.05	32	>10000	3	1.61	<5	8	6560	30	0.06	<10	200	380	<10	468
FASO 108	0.07	88	>10000	3	1.67	<5	3	923	20	0.02	<10	100	260	<10	498
FASO 109	0.09	223	>10000	7	3.09	<5	5	313	20	0.05	<10	160	341	<10	217
FASO 110	0.08	60	>10000	5	1.49	<5	4	365	<20	0.07	<10	60	137	<10	122
FASO 111	0.07	19	>10000	3	0.41	<5	2	381	20	0.02	<10	40	58	<10	39
FASO 112	0.08	78	>10000	3	4.80	<5	5	474	20	0.05	<10	100	402	<10	134
FASO 113	0.15	84	>10000	2	2.47	<5	3	514	<20	0.04	<10	50	163	<10	79
FASO 114	0.12	22	>10000	<2	1.58	<5	2	483	20	0.02	<10	30	40	<10	25
FASO 115	0.07	13	>10000	<2	0.73	<5	1	359	<20	0.02	<10	30	37	<10	18
FASO 116	0.07	23	>10000	10	2.98	<5	10	359	20	0.25	<10	190	289	<10	274
FASO 117	0.19	153	>10000	5	2.72	6	6	603	20	0.04	<10	110	567	<10	540
FASO 118	0.10	77	>10000	2	4.35	<5	2	369	20	0.03	<10	30	218	<10	77
FASO 120	0.15	62	>10000	4	2.34	<5	5	1265	20	0.06	<10	90	288	<10	254
FASO 121	0.15	61	>10000	3	2.18	<5	5	1265	20	0.06	<10	90	287	<10	243
FASO 122	0.21	76	>10000	4	3.65	<5	5	641	20	0.04	<10	70	201	<10	108
FASO 123	0.11	19	>10000	3	3.21	<5	2	395	<20	0.01	<10	40	89	<10	33
FASO 124	0.11	21	>10000	4	0.30	<5	1	421	<20	0.02	<10	70	106	<10	47
FASO 125	0.23	66	>10000	<2	1.03	<5	2	704	20	0.04	<10	90	124	<10	91
FASO 126	0.08	107	>10000	<2	1.76	<5	5	320	20	0.05	<10	90	237	<10	444
FASO 127	0.12	139	>10000	6	5.20	5	6	387	20	0.12	<10	70	253	<10	296
FASO 128	0.07	10	>10000	2	1.69	<5	3	2070	30	0.03	<10	80	223	<10	69
FASO 129	0.09	10	>10000	5	1.22	<5	4	491	20	0.06	<10	90	287	10	145
FASO 130	0.09	160	>10000	3	3.13	<5	6	338	20	0.03	<10	100	237	<10	108
FASO 131	0.12	137	>10000	8	7.79	<5	5	396	20	0.07	<10	120	254	<10	135
FASO 132	0.09	35	>10000	5	2.92	<5	5	813	20	0.06	<10	90	196	<10	388
FASO 133	0.15	319	>10000	4	3.27	6	5	465	20	0.05	<10	120	461	<10	488
FASO 134	0.08	32	>10000	4	1.16	<5	2	307	<20	0.02	<10	30	72	<10	46
FASO 135	0.06	26	>10000	4	2.49	<5	5	1640	20	0.07	<10	80	187	<10	158
FASO 136	0.37	67	>10000	3	0.87	<5	5	1115	20	0.04	<10	60	110	<10	191
FASO 137	0.08	38	>10000	13	1.64	<5	5	244	<20	0.08	<10	10	52	<10	208
FASO 138	0.15	53	>10000	3	0.41	<5	2	515	20	0.02	<10	50	83	<10	92
FASO 139	0.06	14	>10000	11	1.06	<5	12	7260	40	0.08	<10	80	627	<10	225
FASO 140	0.07	75	>10000	4	2.00	<5	6	840	20	0.03	<10	100	478	<10	492
FASO 142	0.04	17	3610	<2	0.54	<5	2	468	<20	0.03	<10	10	25	<10	52
FASO 143	0.07	41	>10000	4	2.81	<5	7	1365	20	0.05	<10	90	430	<10	169
FASO 144	0.17	179	>10000	2	8.36	<5	4	500	<20	0.03	<10	50	362	<10	130
FASO 145	0.15	65	>10000	2	0.64	<5	4	433	20	0.03	<10	90	225	<10	173
FASO 146	0.08	50	>10000	4	1.31	<5	3	396	20	0.04	<10	70	174	20	313
FASO 147	0.09	67	>10000	3	0.92	<5	4	304	<20	0.04	<10	110	269	70	361
FASO 149	0.25	68	>10000	4	3.78	<5	2	693	20	0.02	<10	80	208	<10	155
FASO 150	0.22	31	>10000	3	2.63	7	2	643	20	0.02	<10	50	173	<10	155
FASO 151	0.05	5	>10000	17	1.99	<5	18	5840	30	0.59	<10		197	<10	27
FASO 152	0.20	55	>10000	2	1.64	<5	3	606	20	0.02	<10	80	271	<10	198
FASO 153	0.18	30	>10000	<2	1.55	<5	2	603	20	0.02	<10	30	100	<10	93
FASO 155	0.04	14	>10000	17	1.36	<5	25	4760	40	0.33	<10		75	<10	87
FASO 156	0.08	66	>10000	10	2.08	<5	19	6530	20	0.20	<10	30	175	<10	257
FASO 157	0.08	103	>10000	5	1.72	<5	10	2920	20	0.10	<10	30	182	<10	667
FASO 158	0.07	51	>10000	5	0.72	<5	5	366	20	0.10	<10	30	60	<10	410
FASO 159	0.12	80	>10000	4	0.49	<5	6	361	<20	0.17	<10	10	94	<10	199
FASO 160	0.12	82	>10000	4	0.48	<5	6	368	<20	0.18	<10	10	97	<10	207

APPENDIX C1

Hydrocensus Data

Number	Date	Hour	Area	Location	North (lat)	West (long)	Easting (UTM co-ord)	North (UTM co-ord)	Elevation	Topography	Geology	General informations	Accessibility	Owner	BoreHole Depth (m)	Diameter (m)	Water level (m)	Height (m)	Yield	pH	EC (µs/cm)	Age of BH
PC01	05/02/2012	09:35	Porte Chugue	Dugal	N11 59.416	W15 26.545	451836.7568	1325515.974	41 m	Flat	Light brown CLAY	Inside village of Dugal, behind Houses		Community	16.20	0.50	14.89	0.60	Dry in April/May	6.50	122	2000
PC02	05/02/2012	09:50	Porte Chugue	Dugal	N11 58.883	W15 26.472	451967.6395	1324533.434	33 m	Slope to West	Red brown CLAY with Pebbles	Outside village, 20m far from houses		Private	15.00	0.50	11.10	0.80	Never dry	6.70	63	2008
PC03	05/02/2012	10:20	Porte Chugue	Dugal	N11 58.651	W15 25.701	453365.9483	1324103.652	30 m	Flat	Light red brown CLAY with Pebbles	Isolated house		Private	16.45	0.50	14.79	0.60	Dry in April/May	6.62	121	2007
PC04	**05/02/2012**	**10:40**	**Porte Chugue**	**Chungue**	**N11 58.422**	**W15 25.611**	453528.6022	1323681.349	**26 m**	**Flat**	**Light grey CLAY**	**Well with pump, 25m far from school**		**Private**	**23.02**	**0.66**	**16.62**	**0.70**	**Never dry**	**6.60**	**179**	**2011**
PC05	**05/02/2012**	**11:10**	**Porte Chugue**	**Chungue**	**N11 58.393**	**W15 24.901**	454816.8444	1323625.938	**16 m**	**Flat**	**White CLAY with red pebbles (Laterite)**	**100m far from village**		**Community**	**7.86**	**0.50**	**6.55**	**0.62**	**Dry in April/May**	**6.51**	**223**	**2010**
PC06	05/02/2012	11:30	Porte Chugue	Chungue	N11 58.408	W15 24.993	454649.9484	1323653.835	15 m	Flat		Well with pump, 150m far from village		Community	?	?	?	?	Dry in April/May	6.55	215	1996
PC07	05/02/2012	11:45	Porte Chugue	Chungue	N11 58.015	W15 24.649	455273.0726	1322928.598	11 m	Flat	Red brown CLAY	100m far from village		Community	5.10	0.90	3.89	0.30	Never dry	6.70	70	2010
PC08	05/02/2012	12:00	Porte Chugue	Chungue	N11 58.359	W15 25.646	453464.9136	1323565.338	31 m	Flat	Light brown CLAY	150m far from PC04, called E69		Community	?	?	?	?	Never dry	6.69	140	1997
PC09	05/02/2012	12:20	Porte Chugue	Chungue	N11 58.307	W15 25.714	453341.3756	1323469.692	27 m	Flat	White to grey CLAY	Middle of the village		Community	15.45	1.40	12.78	0.70	Never dry	6.55	74	2007
PC10	05/02/2012	14:50	Porte Chugue	Chungue	N11 57.537	W15 25.955	452901.8469	1322051.256	27 m	Flat	White to grey CLAY	Middle of the village		Community	17.34	1.00	16.90	0.70	Never dry	6.60	333	2011
PC11	05/02/2012	15:00	Porte Chugue	Chungue	N11 57.204	W15 26.241	452381.8892	1321438.349	30 m	Flat	Grey CLAY	Middle of the village		Community	12.30	1.20	9.30	0.70	Dry in April/May	6.62	74	2007
PC12	05/02/2012	15:30	Porte Chugue	Chungue	N11 56.458	W15 26.056	452715.4472	1320062.936	14 m	Flat	Laterite, and clayey MUD	Beach, sea water sample, just for checking		Community	-	-	-	-	-	6.60	36.35 mS/cm	-
PC13	**05/02/2012**	**16:00**	**Porte Chugue**	**Chungue**	**N11 56.955**	**W15 26.239**	452384.7931	1320979.434	**21 m**	**Flat**	**Light brown CLAY**	**Middle of village CHUNGUE**		**Community**	**10.05**	**1.00**	**8.80**	**0.70**	**Never dry**	**7.20**	**439**	**2010**
W01	01/02/2012	08:20	Farim	Farim	N12 29.348	W15 13.308	475899.4059	1380652.085	8 m	Flat	Light brown CLAY	Middle of Farim	Easy access	Community	9.00	1.20	DRY	0.67	DRY	-	-	-
W02	01/02/2012	08:25	Farim	Farim	N12 29.376	W15 13.387	475756.3808	1380703.81	9 m	Flat	Light brown CLAY	Middle of Farim	Easy access	Community	8.00	1.20	DRY	0.70	DRY	-	-	-
W03	01/02/2012	08:40	Farim	Farim	N12 29.385	W15 13.389	475752.7728	1380720.401	6 m	Flat	Light brown CLAY	Middle of Farim, 15m from road to Salinquinhe	Easy access	Private	9.54	2.00	8.90	0.45	Never dry	5.37	420	1982
W04	01/02/2012	09:20	Farim	Nema	N12 29.335	W15 13.463	475618.6816	1380628.362	12 m	Flat	Light brown CLAY	8m from road to Salinquinhe	Easy access	Private	13.00	0.45	9.94	0.63	Never dry	6.35	200	1974
W04	11/09/2013	13:37	Farim	Nema	N12 29.335	W15 13.463	475618.6816	1380628.362	12 m	Flat	Light brown CLAY	8m from road to Salinquinhe	Easy access	Private	13.00	0.45	9.76	0.63	Never dry	6.35	200	1974
W05	01/02/2012	09:40	Farim	Nema	N12 29.313	W15 13.626	475323.4545	1380588.066	16 m	Flat	Light brown CLAY	10m from road to Salinquinhe	Easy access	Private	13.15	0.50	10.34	0.40	Never dry	5.60	172	1999
W06	01/02/2012	09:45	Farim	Nema	N12 29.292	W15 13.762	475077.1252	1380549.574	15 m	Flat	Light brown CLAY	15m from road to Salinquinhe, Well with pump	Easy access	Community	-	-	-	-	Never dry	5.34	126	2011
W07	01/02/2012	09:50	Farim	Nema	N12 29.289	W15 14.041	474571.8509	1380544.487	15 m	Flat	Light brown CLAY	6m from road to Salinquinhe	Easy access	Private	15.10	0.50	11.38	0.48	Never dry	5.63	114	-
W08	01/02/2012	10:00	Farim	Salinquinhe	N12 28.810	W15 15.545	471847.2389	1379664.201	17 m	Flat	Light brown CLAY	20m from main street of Salinquinhe	Easy access	Community	14.76	0.50	11.17	0.35	Never dry	5.07	393	-
W08	02/09/2013	14:54	Farim	Salinquinhe	N12 28.810	W15 15.545	471847.2389	1379664.201	17 m	Flat	Light brown CLAY	20m from main street of Salinquinhe	Easy access	Community	14.76	0.50	10.18	0.35	Never dry	5.07	393	-
W09	01/02/2012	10:20	Farim	Canico	N12 27.611	W15 16.197	470664.1787	1377455.563	14 m	Flat	Red brown CLAY	Middle of village	Easy access	Community	13.40	1.70	11.20	0.60	Never dry	5.71	85	2007
W10	01/02/2012	10:50	Farim	Cansenhe	N12 27.604	W15 18.164	467101.5274	1377446.503	9 m	Flat	Black grey CLAY	Middle of village, 30m from road	Easy access	Community	7.80	1.20	5.50	0.00	Never dry	4.70	1360	-
W10	10/09/2013	15:30	Farim	Cansenhe	N12 27.604	W15 18.164	467101.5274	1377446.503	9 m	Flat	Black grey CLAY	Middle of village, 30m from road	Easy access	Community	7.80	1.20	5.10	0.00	Never dry	4.70	1360	-
W11	**01/02/2012**	**11:00**	**Farim**	**Cansenhe**	**N12 27.586**	**W15 18.274**	466902.2566	1377413.556	**13 m**	**Flat**	**Black grey CLAY**	**Middle of village, 30m from road (other side)**	**Easy access**	**Community**	**13.50**	**1.00**	**8.32**	**0.83**	**Unknow**	**6.59**	**225**	**2011**
W11	**19/09/2012**	**14:00**	**Farim**	**Cansenhe**	**N12 27.586**	**W15 18.274**	466902.2566	1377413.556	**13 m**	**Flat**	**Black grey CLAY**	**Middle of village, 30m from road (other side)**	**Easy access**	**Community**	**13.50**	**1.00**	**4.60**	**0.83**	**Unknow**	**6.57**	**380**	**2011**
W11	10/09/2013	15:23	Farim	Cansenhe	N12 27.586	W15 18.274	466902.2566	1377413.556	13 m	Flat	Black grey CLAY	Middle of village, 30m from road (other side)	Easy access	Community	13.50	1.00	7.60	0.83	Unknow	6.59	225	2011
W12	01/02/2012	11:15	Farim	Cansenhe	N12 27.560	W15 18.289	466875.0335	1377365.668	17 m	Flat	Black grey CLAY	Entrance of village	Easy access	Community	16.70	1.30	13.70	0.60	Unknow	7.02	489	2011
W12	10/09/2013	15:20	Farim	Cansenhe	N12 27.560	W15 18.289	466875.0335	1377365.668	17 m	Flat	Black grey CLAY	Entrance of village	Easy access	Community	16.70	1.30	7.72	0.60	Unknow	7.02	489	2011
W13	01/02/2012	11:30	Farim	Caurdim	N12 27.144	W15 18.502	466488.3553	1376599.404	14 m	Flat	Brown CLAY with gravels	Middle of village	Easy access	Community	14.78	1.00	12.17	0.63	Never dry	7.21	58	2008
W14	01/02/2012	11:35	Farim	Caurdim	N12 27.137	W15 18.471	466544.4894	1376586.437	18 m	Flat	Brown CLAY with gravels	Middle of village, in front of the school (named ChristLove)	Easy access	Community	15.00	0.80	12.47	à.74	Never dry	7.23	130	2005
W15	01/02/2012	12:10	Farim	Tambato	N12 28.801	W15 16.517	470086.8697	1379649.387	22 m	Flat	Light brown CLAY	Middle of village, named AMA-KUWAIT	Easy access	Community	18.90	1.30	15.75	0.70	Never dry	7.40	102	2007
W15	02/09/2013	14:24	Farim	Tambato	N12 28.801	W15 16.517	470086.8697	1379649.387	22 m	Flat	Light brown CLAY	Middle of village, named AMA-KUWAIT	Easy access	Community	18.90	1.30	14.36	0.70	Never dry	7.40	102	2007
W16	01/02/2012	12:20	Farim	Tambato	N12 28.913	W15 16.555	470018.2641	1379655.881	27 m	Flat	Light brown CLAY	Middle of village	Easy access	Community	18.00	0.60	15.60	0.30	Never dry	7.32	105	-
W16	02/09/2013	14:30	Farim	Tambato	N12 28.913	W15 16.555	470018.2641	1379655.881	27 m	Flat	Light brown CLAY	Middle of village	Easy access	Community	18.00	0.60	14.38	0.30	Never dry	7.32	105	-
W17	01/02/2012	12:40	Farim	Utudé	N12 28.960	W15 18.042	467325.3271	1379945.433	18 m	Flat	Brown CLAY	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.30	452	-
W18	01/02/2012	12:55	Farim	Utudé	N12 28.953	W15 18.152	467126.097	1379932.758	17 m	Flat	Boulders and Clay	Middle of village	Easy access	Community	15.70	0.50	9.29	0.40	Never dry	7.32	67	-
W18	11/09/2013	10:54	Farim	Utudé	N12 28.953	W15 18.152	467126.097	1379932.758	17 m	Flat	Boulders and Clay	Middle of village	Easy access	Community	15.70	0.50	8.77	0.40	Never dry	7.32	67	-
W19	**01/02/2012**	**13:20**	**Farim**	**Sanjalo**	**N12 29.720**	**W15 18.249**	466952.0478	1381346.584	**18 m**	**Flat**	**Grey to brown CLAY, with pebbles**	**Middle of village**	**Easy access**	**Community**	**10.05**	**0.60**	**8.36**	**0.20**	**Unknow**	**7.25**	**123**	**2011**
W19	11/09/2013	11:25	Farim	Sanjalo	N12 29.720	W15 18.249	466952.0478	1381346.584	18 m	Flat	Grey to brown CLAY, with pebbles	Middle of village	Easy access	Community	10.05	0.60	6.28	0.20	Unknow	7.25	123	2011
W20	**01/02/2012**	**15:35**	**Farim**	**Canico Tumané**	**N12 31.555**	**W15 15.495**	471942.7286	1384723.29	**31 m**	**Small Hill**	**Brown CLAY, cobbles**	**50m on the left on road, next of football playground**	**Easy access**	**Community**	**22.80**	**1.30**	**16.50**	**0.60**	**Never dry**	**7.23**	**160**	**2011**
W20	03/09/2013	16:53	Farim	Canico Tumané	N12 31.555	W15 15.495	471942.7286	1384723.29	31 m	Small Hill	Brown CLAY, cobbles	50m on the left on road, next of football playground	Easy access	Community	22.80	1.30	15.93	0.60	Never dry	7.23	160	2011
W21	01/02/2012	16:00	Farim	Sitchan Sidi	N12 31.384	W15 15.742	471495.1623	1384408.568	38 m	Flat	Clay and pebbles	Middle of village	Easy access	Community	24.00	1.30	21.50	0.60	Never dry	7.29	127	-
W21	03/09/2013	16:40	Farim	Sitchan Sidi	N12 31.384	W15 15.742	471495.1623	1384408.568	38 m	Flat	Clay and pebbles	Middle of village	Easy access	Community	24.00	1.30	18.99	0.60	Never dry	7.29	127	-
W22	01/02/2012	16:15	Farim	Canico Tumané	N12 31.550	W15 15.442	472038.6889	1384713.981	29 m	Flat	Brown CLAY, cobbles	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.35	153	-
W23	01/02/2012	16:45	Farim	Berendinto	N12 33.893	W15 16.193	470683.2392	1389033.626	32 m	Flat	Grey to black CLAY	Middle of village	Easy access	Community	10.45	1.00	5.24	0.50	Never dry	7.55	100	-
W24	01/02/2012	17:30	Farim	Sare Yoba	N12 30.884	W15 14.296	474112.6916	1383484.562	24 m	Flat	Brown CLAY, with pebbles	20m from road to Sare Yoba	Easy access	Private	8.50	0.50	DRY	0.50	DRY	-	-	-
W25	01/02/2012	17:40	Farim	Sare Yoba	N12 30.866	W15 14.230	474232.1758	1383451.28	19 m	Flat	CLAY and pebbles	Outside the village	Easy access	Community	14.50	0.50	11.53	0.70	Never dry	7.39	82	-
W25	03/09/2013	17:16	Farim	Sare Yoba	N12 30.866	W15 14.230	474232.1758	1383451.28	19 m	Flat	CLAY and pebbles	Outside the village	Easy access	Community	14.50	0.50	8.33	0.70	Never dry	7.39	82	-
W26	02/02/2012	08:45	Farim	Farim	N12 28.949	W15 13.091	476291.7861	1379916.384	6 m	Flat	White grey CLAY	Middle of Farim	Easy access	Private	10.90	0.80	5.70	0.50	Dry in April/May	7.02	505	-
W27	02/02/2012	09:55	Farim	Nema	N12 29.444	W15 13.475	475597.12	1380829.272	16 m	Flat	CLAY and cobbles	Middle of Village	Easy access	Private	14.60	0.50	11.65	0.5à	Never dry	7.15	238	-
W28	02/02/2012	10:00	Farim	Bamcoulé	N12 29.513	W15 13.548	475465.0266	1380956.555	26 m	Flat	Brown CLAY	10m of the road, outside village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.12	78	-
W29	**02/02/2012**	**10:15**	**Farim**	**Sare Yoba**	**N12 30.796**	**W15 14.226**	474239.3	1383322.26	**17 m**	**Flat**	**Brown CLAY**	**Middle of village**	**Easy access**	**Community**	**14.00**	**1.10**	**8.80**	**0.70**	**Never dry**	**7.12**	**126**	**-**
W30	02/02/2012	10:25	Farim	Sare Yoba	N12 31.019	W15 14.104	474460.5897	1383733.063	24 m	Flat	Grey CLAY with Pebbles	Outside, 5min walking from village	Easy access	Community	15.10	0.50	5.80	0.30	Dry in April/May	7.05	95	-
W31	02/02/2012	10:45	Farim	Camadé	N12 32.049	W15 13.948	474744.7451	1385631.156	25 m	Flat	White CLAY with pebbles, claystone	Middle of village	Easy access	Community	10.00	0.50	9.10	0.50	Dry in the afternoon	6.94	106	-
W32	02/02/2012	11:10	Farim	Camadé	N12 29.622	W15 13.528	475501.417	1381157.416	21 m	Flat	White CLAY with pebbles, claystone	Middle of village (in front of W32), well with pump	Easy access	Community	-	-	-	-	Never dry	6.88	68	-
W33	02/02/2012	11:15	Farim	Bancoulé	N12 29.631	W15 13.513	475528.5956	1381173.98	22 m	Flat	Brown CLAY and pebbles	Middle of Bancoulé	Easy access	Community	16.90	0.50	14.60	0.39	Dry in April/May	6.86	116	-
W34	02/02/2012	11:25	Farim	Bancoulé	N12 29.605	W15 13.381	475767.6021	1381125.859	21 m	Flat	Brown CLAY and pebbles	Middle of Bancoulé, used only for fresh water by population	Easy access	Community	16.50	1.40	15.60	0.78	Dry in April/May	6.79	124	-
W35	02/02/2012	12:00	Farim	Bisari	N12 31.698	W15 13.472	475606.0791	1384983.499	19 m	Flat	Brown CLAY and pebbles	Middle of village, for washing only	Easy access	Community	7.90	2.00	6.60	0.00	Dry in April/May	6.90	165	-
W36	02/02/2012	12:10	Farim	Sintcham	N12 29.624	W15 13.169	476151.5555	1381160.556	25 m	Flat	Brown red CLAY	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.03	63	-
W37	02/02/2012	12:30	Farim	Sintcham	N12 29.503	W15 13.103	476270.8951	1380937.449	18 m	Flat	Brown red CLAY	Middle of village	Easy access	Community	11.10	0.80	9.70	0.30	Dry in April/May	6.90	78	-
W38	02/02/2012	12:45	Farim	Morcunda	N12 29.217	W15 13.049	476367.3094	1380426.183	9 m	Flat	Grey CLAY	Outside the village	Easy access	Community	7.50	0.90	5.10	0.40	Dry in April/May	6.80	104	-
W39	02/02/2012	12:50	Farim	Morcunda	N12 29.095	W15 13.058	476350.8251	1380201.342	14 m	Flat	Grey to brown CLAY, with pebbles	Middle of village	Easy access	Community	7.50	0.80	6.90	0.55	Dry in April/May	6.76	404	-
W40	02/02/2012	13:10	Farim	Sancalanco	N12 31.248	W15 11.764	478698.1726	1384151.665	22 m	Flat	Grey CLAY	Middle of village	Easy access	Community	10.50	1.30	9.20	0.80	Dry in April/May	6.85	201	-
W41	**02/02/2012**	**13:30**	**Farim**	**Sare Donia**	**N12 31.317**	**W15 10.761**	476368.2551	1380410.257	**26 m**	**Flat**	**Dark grey CLAY with cobbles**	**Middle of village**	**Easy access**	**Community**	**17.00**	**1.50**	**13.10**	**0.77**	**Never dry**	**7.02**	**137**	**1998**
W42	02/02/2012	13:35	Farim	Sare Donia	N12 31.294	W15 10.741	480514.4609	1384277.545	26 m	Flat	Dark grey CLAY with cobbles	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	6.94	93	-
W43	02/02/2012	13:45	Farim	Madina	N12 30.549	W15 11.617	480550.6474	1384235.131	34 m	Flat	Grey to brown CLAY, with pebbles	Middle of village, 15m from the road	Easy access	Community	20.10	0.60	16.50	0.66	Never dry	6.90	198	1998
W44	02/02/2012	14:00	Farim	Bantaja	N12 29.742	W15 12.418	478963.4125	1382863.18	27 m	Flat	Grey to red brown CLAY, laterite pebbles	Middle of village	Easy access	Community	21.34	0.50	18.40	0.40	Dry in April/May	7.02	55	2006
W45	02/02/2012	14:05	Farim	Bantaja	N12 29.720	W15 12.462	477432.0435	1381336.456	36 m	Flat	Red brown CLAY with pebbles	Middle of village	Easy access	Community	21.05	0.60	18.10	0.70	Dry in April/May	6.67	87	1993
W46	02/02/2012	14:10	Farim	Bantandjan	N12 29.712	W15 12.458	477439.2758	1381321.706	31 m	Flat	Red brown CLAY with pebbles	Middle of village, well with pump, 10m next to W45	Easy access	Community	-	-	-	-	Never dry	6.67	62	-
W47	02/02/2012	14:15	Farim	Bantandjan	N12 29.598	W15 12.553	477267.0695	1381111.734	30 m	Flat	Brown CLAY	Middle of village	Easy access	Community	17.05	0.50	15.50	0.40	Never dry	7.01	64	2006
W48	02/02/2012	14:20	Farim	Bantandjan	N12 29.500	W15 12.733	476940.9513	1380931.375	28 m	Flat	Grey brown CLAY and pebbles	Middle of village, next to mosque, named 15A	Easy access	Community	12.30	1.20	10.20	0.70	Never dry	6.82	157	2008
W49	02/02/2012	14:25	Farim	Bantandjan	N12 29.516	W15 12.743	476922.8653	1380960.878	24 m	Flat	Grey to brown CLAY, with pebbles	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	6.97	100	2008
W50	02/02/2012	14:50	Farim	Farim	N12 29.119	W15 13.001	476455.0358	1380229.568	19 m	Flat	Grey to brown CLAY, with pebbles	Middle of village, L.Camara's house	Easy access	Private	12.15	0.90	7.20	0.20	Never dry	6.87	364	1974
W51	02/02/2012	15:30	Farim	Farim	N12 28.913	W15 13.030	476402.2051	1379849.943	19 m	Flat	White grey CLAY	Inside Farim, well with pump	Easy access	Community	-	-	-	-	-	6.73	191	2011
W52	**02/02/2012**	**15:40**	**Farim**	**Farim**	**N12 28.941**	**W15 12.972**	476507.2877	1379901.463	**10 m**	**Flat**	**White grey CLAY with cobbles**	**Inside Farim, in front of football playground**	**Easy access**	**Private**	**8.10**	**0.70**	**4.90**	**0.40**	**Dry in April/May**	**6.80**	**462**	**-**
W52	**19/09/2012**	**15:20**	**Farim**	**Farim**	**N12 28.941**	**W15 12.972**	476507.2877	1379901.463	**11 m**	**Flat**	**White grey CLAY**	**Inside Farim, close to football playground**	**Easy access**	**Private**	**8.10**	**0.70**	**2.45**	**0.40**	**Dry in May**	4.06	360	**-**
W53	02/02/2012	15:45	Farim	Farim	N12 28.966	W15 12.865	476701.1063	1379947.382	16 m	Flat	White grey CLAY with cobbles	Bangalades, 10m next to street	Easy access	Private	8.32	0.50	5.40	0.30	Dry in April/May	6.90	188	2010
W54	02/02/2012	15:55	Farim	Farim	N12 28.982	W15 12.655	477081.4475	1379976.565	18 m	Flat	White grey CLAY with cobbles	Bangalades, after football playground	Easy access	Private	10.00	0.40	7.10	0.65	Dry in April/May	7.02	64	-
W55	02/02/2012	16:10	Farim	Fafaco	N12 29.544	W15 11.504	479166.6971	1381010.772	25 m	Flat	White grey CLAY with cobbles	Edge of the road	Easy access	Community	-	-	-	-	Never dry	7.02	205	-
W56	02/02/2012	16:15	Farim	Fafaco	N12 29.562	W15 11.456	479253.6475	1381043.884	31 m	Flat	White grey CLAY with cobbles	Middle of village	Easy access	Community	20.15	1.60	17.85	0.80	Dry in April/May	6.92	66	1975
W58	02/02/2012	16:30	Farim	Old Farim	N12 29.172	W15 11.902	478445.4184	1380325.69	15 m	Flat	Black grey CLAY	Outside the village	Easy access	Community	8.00	0.50	3.80	0.50	Never dry	7.09	198	1963
W59	03/02/2012	09:00	Farim	-	N12 32.769	W15 11.704	478808.89	1386954.862	41 m	Flat	Red brown CLAY	Middle of the bush, BH28 (high EC due to polymer in water)	Easy access	-	45.10	0.10	17.80	0.00	Unknow	6.99	4110	2012
W60	03/02/2012	10:40	Farim	Buro	N12 25.598	W15 15.229	472413.8786	1373743.788	20 m	Flat	Brown CLAY with cobbles	Middle of the village	Easy access	Community	17.90	0.70	14.60	0.70	Never dry	7.30	350	2005
W61	03/02/2012	10:45	Farim	Buro	N12 25.614	W15 15.205	472457.381	1373773.236	21 m	Flat	Brown CLAY with cobbles	Middle of the village	Easy access	Community	26.78	0.80	14.00	0.20	Never dry	7.19	211	2005
W62	03/02/2012	10:50	Farim	Buro	N12 25.642	W15 15.263	472352.3674	1373824.941	14 m	Flat	Brown CLAY with cobbles	Edge of Buro, well with pump	Easy access	Community	-	-	-	-	Never dry	7.05	119	-
W63	**03/02/2012**	**11:00**	**Farim**	**Irabato**	**N12 25.947**	**W15 14.431**	473859.9812	1374385.667	**10 m**	**Flat**	**Dark grey CLAY**	**Middle of village**	**Easy access**	**Community**	**8.34**	**0.60**	**5.20**	**0.00**	**Never dry**	**7.25**	**1252**	**-**
W64	03/02/2012	11:05	Farim	Irabato	N12 25.982	W15 14.409	473899.89	1374450.138	12 m	Flat	Dark grey CLAY	Middle of village	Easy access	Private	8.45	0.50	6.60	0.10	Never dry	7.01	2422	1987

Number	Date	Hour	Area	Location	North (lat)	West (long)	Easting (UTM co-ord)	North (UTM co-ord)	Elevation	Topography	Geology	General informations	Accessibility	Owner	BoreHole Depth (m)	Diameter (m)	Water level (m)	Height (m)	Yield	pH	EC (µs/cm)	Age of BH
W65	03/02/2012	11:10	Farim	Irabato	N12 26.015	W15 14.425	473870.9627	1374510.984	14 m	Flat	Dark grey CLAY	Edge of the village, in direction of North	Easy access	Community	10.10	0.80	7.50	0.20	Never dry	7.05	1578	-
W66	03/02/2012	11:20	Farim	Irabato	N12 26.024	W15 14.332	474039.4361	1374527.42	17 m	Flat	Brown CLAY with pebbles	Middle of village	Easy access	Private	12.89	0.70	9.80	0.20	Never dry	7.20	584	2007
W67	03/02/2012	11:30	Farim	Irabato	N12 26.045	W15 14.336	474032.2254	1374566.13	15 m	Flat	Brown CLAY with pebbles	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.15	461	-
W68	03/02/2012	11:45	Farim	Tungina	N12 26.311	W15 14.580	473590.6989	1375056.779	13 m	Flat	Grey CLAY	Middle of village	Easy access	Community	12.00	0.50	10.50	0.50	Never dry	7.07	133	2005
W69	03/02/2012	11:50	Farim	Tungina	N12 26.264	W15 14.592	473568.8815	1374970.176	13 m	Flat	Grey CLAY	Middle of village	Easy access	Community	10.35	1.10	8.30	0.30	Never dry	7.10	86	-
W70	**03/02/2012**	**12:15**	**Farim**	**Biribao**	**N12 25.728**	**W15 11.702**	478802.9599	1373977.998	**22 m**	**Flat**	**Grey CLAY, with red pebbles**	**Middle of village**	**Easy access**	**Community**	**12.10**	**0.50**	**9.60**	**0.30**	**Never dry**	**7.01**	**576**	**1991**
W71	03/02/2012	12:30	Farim	Biribao	N12 25.715	W15 11.599	478989.5176	1373953.902	27 m	Flat	Grey CLAY, with red pebbles	Middle of village	Easy access	Community	15.45	0.50	12.40	0.40	Never dry	7.01	630	1977
W72	03/02/2012	12:35	Farim	Biribao	N12 25.624	W15 11.520	479132.4981	1373786.082	31 m	Flat	Grey CLAY, with red pebbles	Middle of village	Easy access	Community	20.05	1.45	16.80	0.60	Never dry	7.00	98	2009
W73	03/02/2012	12:50	Farim	Nhambura	N12 26.949	W15 11.144	479815.2975	1376227.62	20 m	Flat	Brownish orange CLAY	Middle of village	Easy access	Community	12.55	1.10	10.30	0.50	Never dry	7.05	122	2006
W74	03/02/2012	13:00	Farim	Nhambura	N12 26.996	W15 11.092	479909.5436	1376314.177	20 m	Flat	Brownish orange CLAY	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.05	464	1996
W75	03/02/2012	13:25	Farim	Bafata Oio	N12 27.772	W15 12.142	478008.807	1377745.761	24 m	Flat	Grey CLAY	Behind a house	Easy access	Community	18.90	0.60	15.10	0.30	Dry in April/May	7.10	111	2000
W76	03/02/2012	13:40	Farim	Ponta Pinto	N12 27.722	W15 11.328	479483.0367	1377652.523	21 m	Flat	White Grey CLAY	Middle of village	Easy access	Private	14.15	0.50	13.20	0.50	Dry in April/May	7.02	61	2008
W77	03/02/2012	13:45	Farim	Ponta Pinto	N12 27.758	W15 11.282	479566.3979	1377718.813	19 m	Flat	White Grey CLAY	Far away from village, have to ask local people	Difficult access	Community	12.30	0.50	11.20	0.50	Dry in April/May	6.99	188	1992
W78	03/02/2012	14:10	Farim	Bafata	N12 27.905	W15 12.205	477894.8908	1377990.973	22 m	Flat	White Grey CLAY	Middle of village, well with pump	Easy access	Community	-	-	-	-	Never dry	7.03	100	
W79	03/02/2012	14:20	Farim	Bafata	N12 27.911	W15 12.185	477931.1226	1378002.003	19 m	Flat	White Grey CLAY	Middle of village	Easy access	Community	12.50	0.50	9.10	0.70	Dry in April/May	7.05	284	1978
W80	03/02/2012	14:25	Farim	Bafata	N12 27.861	W15 12.291	477739.0686	1377909.999	21 m	Flat	White Grey CLAY	Middle of village, well with pump	Easy access	Community		-	-	-	Never dry	7.03	326	1996
W81	**03/02/2012**	**14:30**	**Farim**	**Bafata**	**N12 27.757**	**W15 12.455**	477441.8879	1377718.553	**19 m**	**Flat**	**White Grey CLAY**	**Middle of village, used only for washing clothes**	**Easy access**	**Community**	**12.05**	**0.60**	**10.80**	**0.60**	**Never dry**	**6.94**	**106**	**2008**
W82	03/02/2012	14:45	Farim	Saliquenhendim	N12 26.907	W15 13.232	476033.3027	1376153.103	27 m	Flat	White Grey CLAY	20m from Farim-Bissau road	Easy access	Community	12.00	1.30	11.60	0.80	Dry in April/May	6.95	173	-
W83	03/02/2012	14:55	Farim	Saliquenhendim	N12 27.051	W15 13.237	476024.4666	1376418.508	22 m	Flat	White Grey CLAY	15m from Farim-Bissau road, well with pump	Easy access	Community	-	-	-	-	Never dry	6.83	183	-
W84	03/02/2012	15:00	Farim	Saliquenhendim	N12 27.168	W15 13.243	476013.7781	1376634.153	24 m	Flat	White Grey CLAY	20m from Farim-Bissau road	Easy access	Community	12.00	0.70	10.70	0.40	Dry in April/May	6.85	522	1986
W85	03/02/2012	15:10	Farim	Saliquenhendim	N12 27.249	W15 13.236	476026.5808	1376783.429	25 m	Flat	White Grey CLAY	20m from Farim-Bissau road, next to mosque	Easy access	Community	11.55	2.00	10.20	0.70	Dry in April/May	6.95	584	1994
W86	03/02/2012	15:15	Farim	Saliquenhendim	N12 27.338	W15 13.250	476001.3599	1376947.481	21 m	Flat	White Grey CLAY	10m from Farim - Bissau road, well with pump	Easy access	Community	-	-	-	-	Never dry	7.05	116	-
W87	03/02/2012	15:20	Farim	Saliquenhendim	N12 27.435	W15 13.233	476032.2991	1377126.23	13 m	Flat	White to grey CLAY	Middle of village, 20m of the road	Easy access	Private	10.10	0.50	6.40	0.10	Dry in April/May	7.05	546	1977
SAL1	02/09/2013	14:47	Farim	Salinquinhe	N12 27.435	W15 13.233	471622.5238	1379584.165	20 m	Flat	-	Old well, new headworks	-	-	-	-	10.88	-	-	-	-	-
SAL3	09/09/2013	12:40	Farim	Salinquinhe	N12 27.435	W15 13.233	471873.2077	1379458.296	24 m	Flat	-	200m south of Salinquinhe	-	-	-	0.55	10.79	0.21	-	-	-	-
SAL4	11/09/2013	13:17	Farim	Salinquinhe	N12 27.435	W15 13.233	471897.7759	1379690.388	12 m	Flat	-	New well	-	-	-	1.20	9.49	0.80	-	-	-	2013
SP1	02/09/2013	17:17	Farim	Salinquinhe Porto	N12 27.435	W15 13.233	472982.8064	1379321.989	20 m	Flat	-	-	-	-	-	-	4.70	-	-	-	-	-
SP2	06/09/2013	10:31	Farim	Salinquinhe Porto	N12 27.435	W15 13.233	473209.1964	1378537.625	8 m	Flat	-	Near to well P1 (pumping test well), next to garden	-	-	-	-	2.80	-	-	-	-	-

APPENDIX D1

CCME Freshwater Standards

Water Quality Guidelines for the Protection of Aquatic Life (General)

	Freshwater		Marine	
	Concentration (µg/L)	Concentration (µg/L)	Concentration (µg/L)	Concentration (µg/L)
Chemical Name	**Short Term**	**Long Term**	**Short Term**	**Long Term**
Ammonia (total)	No data	Table	No data	No data
Ammonia (unionized as N)	No data	16	No data	No data
Arsenic	No data	5	No data	12.5
Cadmium	No data	0.018	No data	0.12
Chloride	640,000	120,000	NRG	NRG
Chromium (total)	No data	No data	No data	No data
Copper	No data	2	No data	No data
Cyanide	No data	5 (as free CN)	No data	No data
Dissolved oxygen	No data	6000	No data	>8000
Iron	No data	300	No data	No data
Lead	No data	1	No data	No data
Nickel	No data	25	No data	No data
pH	No data	6.5 to 9.0	No data	7.0 to 8.7
Suspended sediments	No data	(Note 1)	No data	Narrative
Zinc	No data	30	No data	No data

Freshwater Guideline Notes:

1) Suspended sediments

Clear flow
Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d).

High flow
Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when background is ≥ 250 mg/L.

2) Copper
The CWQG is a minimum of 2 µg/L regardless of water hardness (Demayo and Taylor, 1981). If the water hardness is not known, the CWQG is 2 µg/L. The maximum CWQG is 4 µg/L, which occurs at a water hardness of 180 mg/L CaCO3 or greater.

Copper concentration = e0.8545[ln(hardness)]-1.465 * 0.2 µg/L

3) Cadmium
Cadmium concentration = $10^{0.86[\log10(hardness)]-3.2}$ µg/L

Note: Interim guideline Out of convenience, this guideline was presented as a single value using the equation and a hardness of 48.5 mg/L in earlier versions of CCME (1999). It is now presented as the equation.

Water Quality Guidelines for the Protection of Aquatic Life (General)

4) Dissolved Oxygen
Lowest acceptable dissolved oxygen concentration:

for warm water biota: early life stages = 6000 µg/L

for warm water biota: other life stages = 5500 µg/L

for cold water biota: early life stages = 9500 µg/L

for cold water biota: other life stages = 6500 µg/L

5) Lead
The CWQG is a minimum of 1 µg/L regardless of water hardness (CCREM, 1987: Table 3-10). If the water hardness is not known, the CWQG is 1 µg/L.

Lead concentration = e1.273[ln(hardness)]-4.705 µg/L

6) Nickel
The CWQG is a minimum of 25 µg/L regardless of water hardness (IJC 1976). If the water hardness is not known, the CWQG is 25 µg/L.

Nickel concetration = e0.76[ln(hardness)]+1.06 µg/L

Water Quality Guidelines for the Protection of Aquatic Life (PAH)

	Freshwater		Marine	
	Concentration (µg/L)	Concentration (µg/L)	Concentration (µg/L)	Concentration (µg/L)
Chemical Name	**Short Term**	**Long Term**	**Short Term**	**Long Term**
Acenaphthene	No data	5.8	No data	Insufficient data
Acenaphthylene	No data	No data	No data	No data
Benzo(a)anthracene	No data	0.018	No data	Insufficient data
Benzo(a)pyrene	No data	0.015	No data	Insufficient data
Chrysene	No data	Insufficient data	No data	Insufficient data
Fluoranthene	No data	0.04	No data	Insufficient data
Fluorene	No data	3	No data	Insufficient data
Naphthalene	No data	1.1	No data	1.4
Phenanthrene	No data	0.4	No data	Insufficient data
Pyrene	No data	0.025	No data	Insufficient data

APPENDIX D2

Compiled In-situ Sampling Results

January 2014
Report No. 13514950200.550/B.0

Site Number	Date	Time	Sample Depth (m)	pH	Temp (°C)	DO (mg/L)	DO (%)	Cond (µS/cm)	Total Dissolved Solids (ppm)	ORP
7	14/12/2011	11:57	0.3	7.02	23.12	8.2	96.5	2750	NR	NR
9	12/12/2011	13:03	0.3	7.04	22.34	9.01	111.1	2970	NR	NR
28	15/12/2011	12:01	0.3	6.78	23.87	2.61	30.4	3132	NR	NR
45	15/12/2011	18:11	0.4	6.99	24.73	1.22	14.7	2586	NR	NR
	15/12/2011	18:11	1.8	6.97	24.72	1.16	14.0	2588	NR	NR
44	15/12/2011	18:01	0.4	7.02	24.79	1.46	17.6	2578	NR	NR
	15/12/2011	18:01	1.8	6.99	24.79	1.40	17.0	2580	NR	NR
43	15/12/2011	17:49	0.4	7.01	24.79	1.39	16.8	2574	NR	NR
	15/12/2011	17:49	1.8	6.99	24.78	1.37	16.6	2577	NR	NR
42	15/12/2011	17:34	0.4	7.23	24.82	1.74	21.1	2571	NR	NR
	15/12/2011	17:34	1.8	7.09	24.79	1.64	19.8	2579	NR	NR
41	15/12/2011	17:20	0.4	7.01	24.82	1.6	19.40	2571	NR	NR
	15/12/2011	17:20	1.8	6.98	24.78	1.4	17.40	2573	NR	NR
40	15/12/2011	17:03	0.4	7.07	24.84	1.80	21.8	2570	NR	NR
	15/12/2011	17:03	1.8	7.01	24.89	1.60	19.5	2575	NR	NR
39	15/12/2011	16:55	0.4	7.10	24.92	1.99	24.4	2575	NR	NR
	15/12/2011	16:55	1.8	6.98	24.92	1.76	21.5	2579	NR	NR
38	15/12/2011	16:46	0.4	7.20	25.02	2.30	27.0	2584	NR	NR
	15/12/2011	16:46	1.8	7.04	25.02	1.86	22.9	2584	NR	NR
10	14/12/2011	16:03	Day 1	7.25	25.16	2.16	26.7	2577	NR	NR
	15/12/2011	NR	Day 2	7.43	25.39	8.51	103.2	2651	NR	NR
12	14/12/2011	16:13	Day 1	7.26	24.96	2.11	25.4	2590	NR	NR
	15/12/2011	NR	Day 2	7.26	25.28	8.04	98.1	2660	NR	NR
13	14/12/2011	16:20	Day 1	6.95	25.09	2.4	28.0	2623	NR	NR
	15/12/2011	NR	Day 2	7.28	25.68	7.34	90.4	2668	NR	NR
14	14/12/2011	16:28	0.4	7.24	25.36	7.7	94.0	2681	NR	NR
	14/12/2011	16:28	1.5	7.18	25.32	7.44	90.8	2689	NR	NR
15	14/12/2011	16:50	0.4	7.31	25.97	7.14	87.2	2713	NR	NR
	14/12/2011	16:50	1.5	7.23	25.34	7.05	86.1	2713	NR	NR
16	14/12/2011	16:51	0.4	7.13	25.51	6.94	84.9	2735	NR	NR
	14/12/2011	16:51	1.5	7.12	25.51	6.72	82.1	2757	NR	NR
17	14/12/2011	17:08	0.4	7.20	25.5	7.27	88.6	2785	NR	NR
	14/12/2011	17:08	1.5	7.14	25.45	6.82	83.1	2800	NR	NR
18	14/12/2011	17:22	0.4	7.22	25.46	7.5	93.3	2837	NR	NR
	14/12/2011	17:22	1.5	7.12	25.47	6.72	82.8	2853	NR	NR
19	14/12/2011	17:42	0.4	7.48	25.46	6.81	83.7	3095	NR	NR
	14/12/2011	17:42	1.5	7.20	25.44	6.75	83.0	3114	NR	NR
21	14/12/2011	18:21	0.4	7.05	25.52	6.6	81.4	3509	NR	NR
	14/12/2011	18:21	1.5	7.03	25.52	6.52	80.7	3512	NR	NR
22	14/12/2011	18:26	0.4	7.08	25.82	6.67	82.0	3504	NR	NR
	14/12/2011	18:26	1.5	7.03	25.51	6.55	80.7	3505	NR	NR
23	14/12/2011	17:22	0.4	7.00	25.49	6.33	78.2	3939	NR	NR
	14/12/2011	17:22	1.5	6.98	25.49	6.15	76.1	3956	NR	NR
24	14/12/2011	18:57	0.4	7.07	25.48	6.31	77.9	3929	NR	NR
	14/12/2011	18:57	1.5	7.01	25.49	6.06	74.0	3957	NR	NR
SW02	03/02/2012	11:15	NR	7.34	23.8	NR	NR	>3999	NR	NR
SW03	03/02/2012	12:10	NR	7.4	24.5	NR	NR	3769	NR	NR
SW04	04/02/2012	10:45	NR	7	21.0	NR	NR	>3999	NR	NR
SW01	01/02/2012	09:51	NR	7.36	23.4	NR	NR	>3999	NR	NR
SW05	04/02/2012	12:45	NR	7.45	25.6	NR	NR	3725	NR	NR
SW06	04/02/2012	13:30	NR	7.46	25.2	NR	NR	3615	NR	NR
SW02	19/09/2012	14:20	NR	6.54	28.2	2.46	NR	1075	537	163
SW08	19/09/2012	14:45	NR	6.51	30.3	4.65	NR	57	29	91.2
SW06	04/09/2013	09:30	NR	7.02	27.7	NR	NR	-3999	NR	NR
SW04	07/09/2013	17:22	NR	6.45	28,2	NR	NR	-3999	NR	NR
SW03	07/09/2013	17:42	NR	7.04	28.3	NR	NR	-3999	NR	NR
SW02	10/09/2013	16:45	NR	4.69	29.0	NR	NR	1798	NR	NR

APPENDIX D3

Laboratory Sampling Results Including Screening

January 2014
Report No. 13514950200.550/B.0

February 2012 Sampling Mission

Parameter	Units	CCME Freshwater WQ	RSA			LSA		
			SW06	SW05	SW01	SW02	SW03	SW04
			04/02/2012	04/02/2012	01/02/2012	03/02/2012	03/02/2012	04/02/2012
Alkalinity	mmole/l	-	6.8	6	6.4	7.2	6.6	8.6
Calcium	mg/l	-	40	36	48	16	16	48
Chloride	mg/l	120	**1278**	**1331.25**	**1817.6**	**1455.5**	**1242.5**	**1562**
Conductivity	µS/cm	-	4010	3450	5700	3970	3330	4570
Dissolved Oxygen	mg/l	5.5	5.7	6.6	5.8	6.5	6.1	5.8
Dissolved Iron	µg/l	-	20	50	40	30	10	30
Total Iron	µg/l	300	26	110	120	40	60	60
Magnesium	mg/l	-	43.2	26.4	48	48	38.4	48
Dissolved Manganese	µg/l	-	*<10*	30	130	130	50	200
pH	pH units	6.5 to 9.0	7.47	7.55	7.28	7.33	7.39	7.23
Sodium	mg/l	-	687	705	1050	841	688	788
Sulphate	mg/l	-	84	81	130	102	77	93
Temperature	°C	-	23.7	24	24.9	24	24	23.7
Total Dissolved Solids	ppm	-	2160	1850	3200	2140	1790	2460
Dissolved Zinc	mg/l	0.03	0.0024	0.0025	**0.047**	0.0032	0.0098	0.0027
Total Zinc	mg/l	0.03	*<0.005*	*<0.005*	**0.061**	*<0.005*	0.011	*<0.005*
Ammoniacal Nitrogen	mg/l	-	0.5	*<0.5*	*<0.5*	*<0.5*	0.5	*<0.5*
Phosphates	mg/l	-	*<0.5*	*<0.05*	*<0.5*	*<0.5*	*<0.5*	*<0.5*
Copper - Dissolved	mg/l	2	*<0.05*	*<0.001*	*<0.05*	*<0.001*	0.0013	*<0.05*
Copper - Total	mg/l	2	*<0.05*	*<0.005*	*<0.05*	*<0.005*	*<0.005*	*<0.05*
Potassium	mg/l	-	26.2	27.2	*<0.5*	33.4	26.3	29.3
PAH								
Fluoranthene	ug/l	0.04	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Fluorene	ug/l	3	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Benzo(a)anthracene	ug/l	0.018	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Benzo(ah)anthracene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Benzo(b)fluoranthene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Benzo(k)fluoranthene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Benzo(a)pyrene	ug/l	0.015	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Benzo(ghi)perylene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Indeno (1,2,3-cd) pyrene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Acenaphthylene	ug/l	-	*<0.1*	*<0.1*	NR	*<0.1*	*<0.1*	*<0.1*
Acenaphthene	ug/l	5.8	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Anthracene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Chrysene	ug/l	-	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Naphthalene	ug/l	1.1	*<0.1*	*<0.1*	NR	*<0.1*	*<0.1*	*<0.1*
Phenanthrene	ug/l	0.4	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Pyrene	ug/l	0.025	*<0.005*	*<0.005*	NR	*<0.005*	*<0.005*	*<0.005*
Arsenic - Dissolved	ug/l	5	*<0.5*	*<0.5*	*<0.5*	*<0.5*	*<0.5*	*<0.5*
Arsenic - Total	ug/l	5	*<5*	*<5*	*<5*	*<5*	*<5*	*<5*
Cadmium - Dissolved	ug/l	0.018	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
Cadmium - Total	ug/l	0.018	**<1**	**<1**	**<1**	**<1**	**<1**	**<1**
Chromium - Dissolved	ug/l	-	*<0.5*	*<0.5*	*<0.5*	*<0.5*	*<0.5*	*<0.5*
Chromium - Total	ug/l	-	*<5*	*<5*	*<5*	*<5*	*<5*	*<5*
Mercury - Dissolved	ug/l	-	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*
Mercury - Total	ug/l	-	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*
Nickel - Dissolved	ug/l	25	0.7	0.7	0.7	0.6	0.7	0.9
Nickel - Total	ug/l	25	*<5*	*<5*	*<5*	*<5*	*<5*	*<5*
Lead - Dissolved	ug/l	1	*<0.2*	*<0.2*	*<0.2*	*<0.2*	*<0.2*	*<0.2*
Lead - Total	ug/l	1	**<5**	**<5**	**<5**	**<5**	**<5**	**<5**
TPH	ug/l	-	*<100*	*<100*	*<100*	*<100*	*<100*	*<100*
Manganese - Dissolved (FRANCE)	ug/l	-	NR	NR	NR	NR	NR	NR

1	= CCME guideline for total metal, not dissolved
<0.01	= Less than analytical detection limit
5	= CCME Freshwater Guideline threshold exceeded
NR	= Result not reported

September 2012 Sampling Mission

Parameter	Units	CCME Freshwater WQ	RSA				LSA	
			SW6	SW5	SW7	SW1	SW2	SW8
			17/09/2012	17/09/2012	17/09/2012	17/09/2012	19/09/2012	19/09/2012
Dissolved Arsenic	ug/l	5	1	*<0.9*	*<0.9*	*<0.9*	*<0.9*	1
Dissolved Cadmium	ug/l	0.018	**0.06**	**0.08**	**0.08**	**0.05**	**0.12**	**0.04**
Dissolved Calcium	mg/l	-	19.5	18.9	19.6	21.3	25	4.8
Total Dissolved Chromium	ug/l	-	1.5	1.1	0.9	0.7	1.3	0.8
Dissolved Copper	ug/l	2	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*
Total Dissolved Iron	ug/l	-	732.6	726.2	584.9	473.1	923.5	577.7
Dissolved Lead	ug/l	1	**1.7**	0.8	1	0.9	**1.4**	**1.1**
Dissolved Magnesium	mg/l	-	10.5	10.7	12.5	16.4	25.7	1.6
Dissolved Manganese	ug/l	-	153.1	116.4	39.5	32.5	150.8	40.3
Dissolved Nickel	ug/l	25	2	1.8	1.8	1.8	4.3	0.3
Dissolved Potassium	mg/l	-	2.9	2.9	3.4	5.3	5.8	0.6
Dissolved Sodium	mg/l	-	84	88.3	100.9	133.3	202.5	3
Dissolved Zinc	ug/l	-	7.6	8	7.9	8.1	17.2	6.3
Total Iron	ug/l	300	**746.8**	**796.2**	**801.8**	**521.9**	**940.5**	**1055**
Total Zinc	ug/l	30	9.6	9	8.1	8.2	18.6	10
PAH MS								
Naphthalene	ug/l	1.1	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Acenaphthylene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Acenaphthene	ug/l	5.8	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Fluorene	ug/l	3	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Phenanthrene	ug/l	0.4	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Anthracene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Fluoranthene	ug/l	0.04	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Pyrene	ug/l	0.025	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Benzo(a)anthracene	ug/l	0.018	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Chrysene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Benzo(bk)fluoranthene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Benzo(a)pyrene	ug/l	0.015	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Indeno(123cd)pyrene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Dibenzo(ah)anthracene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Benzo(ghi)perylene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
PAH 16 Total	ug/l	-	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*
PAH Surrogate % Recovery	%	-	101	106	102	100	103	106
EPH (C8-C40)	ug/l	-	*<10*	*<10*	*<10*	*<10*	*<10*	*<10*
Sulphate	mg/l	-	10.13	10.46	13.13	19.27	30.04	3.54
Chloride	mg/l	120	**161.8**	**163.8**	**190.8**	**249.1**	**378**	3.9
Ortho Phosphate as PO4	mg/l	-	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*
Ammoniacal Nitrogen as N	mg/l	-	0.17	0.12	0.14	0.12	0.13	0.12
Total Alkalinity as CaCO3	mg/l	-	36	28	32	28	34	26
Dissolved Oxygen	mg/l	5.5	9	9	**5**	9	9	9
Electrical Conductivity @25C	uS/cm	-	647	656	746	935	1401	91
pH	pH units	6.5 to 9.0	7.6	6.67	6.68	6.66	7.46	6.75
Total Dissolved Solids	mg/l	-	402	372	448	536	828	118
Total Suspended Solids	mg/l	-	*<10*	27	*<10*	24	23	12

1	= CCME guideline for total metal, not dissolved
<0.01	= Less than analytical detection limit
5	= CCME Freshwater Guideline threshold exceeded

May 2013 Sampling Mission

Parameter	Units	CCME Freshwater WQ	LOD	RSA				LSA		
				SW6	SW5	SW7	SW1	SW02	SW03	SW04
				14/05/2013	14/05/2013	15/05/2013	16/05/2013	15/05/2013	15/05/2013	15/05/2013
Dissolved Arsenic	ug/l	5	<0.9	**5.2**	*<0.9*	*<0.9*	*<0.9*	*<0.9*	*<0.9*	*<0.9*
Dissolved Cadmium	ug/l	0.018	<0.03	**0.07**	*<0.03*	**0.3**	*<0.03*	*<0.03*	**0.1**	**0.05**
Dissolved Calcium	mg/l	-	<0.2	53.9	79	53.9	75	63.9	56.2	55.5
Total Dissolved Chromium	ug/l	-	<0.2	1.9	2.6	7.6	1.9	4.3	1.1	13.2
Dissolved Copper	ug/l	2	<3	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*
Total Dissolved Iron	ug/l	-	<4.7	8	194.3	45.1	6.8	107	7	73.4
Dissolved Lead	ug/l	1	<0.4	*<0.4*	*<0.4*	*<0.4*	*<0.4*	*<0.4*	*<0.4*	*<0.4*
Dissolved Magnesium	mg/l	-	<0.1	95.6	122.9	134.1	219.5	167.8	119.3	118.3
Dissolved Manganese	ug/l	-	<1.5	25.1	12.5	11.1	3.9	21.9	21.1	19
Dissolved Nickel	ug/l	25	<0.2	1.8	2	3.3	0.9	1.8	0.6	6.9
Dissolved Potassium	mg/l	-	<0.1	33.3	35.7	37.3	61.6	49	36.1	35.3
Dissolved Sodium	mg/l	-	<0.1	914.5	997.8	1138	1765	1426	973.9	944.6
Dissolved Zinc	ug/l	-	<1.5	5.1	*<1.5*	*<1.5*	*<1.5*	*<1.5*	*<1.5*	*<1.5*
Total Iron	ug/l	300	<4.7	**948.9**	196.2	105.1	287.1	115.4	298	146.3
Total Zinc	ug/l	30	<1.5	6.5	1.7	*<1.5*	*<1.5*	*<1.5*	*<1.5*	5.5
Dissolved Mercury	ug/l	-	<0.01	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Total Mercury	ug/l	-	<0.01	0.01	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
EPH (C8-C40)	ug/l	-	<10	*<10*	*<10*	NR	*<10*	*<10*	*<10*	*<10*
				0	0	0	0	0	0	0
Sulphate	mg/l	-	<0.05	154	133.77	219.05	370.24	267.51	172.77	167.07
Chloride	mg/l	120	<0.3	**1574.4**	**1624.4**	**1951.5**	**3145.2**	**2315.1**	**1729.7**	**1658**
Ortho Phosphate as PO4	mg/l	-	<0.03	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*
Ammoniacal Nitrogen as N	mg/l	-	<0.01	0.14	0.11	0.28	0.19	0.16	0.12	0.16
Total Alkalinity as CaCO3	mg/l	-	<1	62	62	62	68	68	62	64
Dissolved Oxygen	mg/l	5.5	<1	9	10	10	10	9	9	9
Electrical Conductivity @25C	uS/cm	-	<2	5368	4511	6308	9734	7617	5646	5686
pH	pH units	6.5 to 9.0	<0.01	7.03	7.46	7.39	7.36	7.32	7.18	7.18
Total Dissolved Solids	mg/l	-	<10	3439	2878	4622	6487	5073	3692	3689
Total Suspended Solids	mg/l	-	<10	102	35	24	45	16	34	31

1	= CCME guideline for total metal, not dissolved
<0.01	= Less than analytical detection limit
5	= CCME Freshwater Guideline threshold exceeded
NR	= Result not reported

September 2013 Sampling Mission

			RSA				LSA		
Parameter	**Units**	**CCME WQ**	**SW06**	**SW05**	**SW07**	**SW01**	**SW02**	**SW03**	**SW04**
			03/09/2013	02/09/2013	02/09/2013	02/09/2013	10/09/2013	07/09/2013	07/09/2013
Dissolved Arsenic	ug/l	5	1.5	*<0.9*	1.1	2.3	1	*<0.9*	*<0.9*
Dissolved Cadmium	ug/l	0.018	**0.24**	**0.12**	**0.03**	**0.26**	**0.12**	*<0.03*	**0.14**
Dissolved Calcium	mg/l	-	43.2	42.1	51.4	65	15.2	47.5	46.1
Total Dissolved Chromium	ug/l	-	*<0.2*	*<0.2*	2.2	*<0.2*	0.2	5.1	*<0.2*
Dissolved Copper	ug/l	2	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*	*<3*
Total Dissolved Iron	ug/l	300	10.9	10.9	**325.1**	10.1	56.2	37.2	*<4.7*
Dissolved Lead	ug/l	1	*<0.4*	*<0.4*	0.9	*<0.4*	0.9	*<0.4*	*<0.4*
Dissolved Magnesium	mg/l	-	75.2	73.8	141	206.2	28.8	94.3	88.9
Dissolved Manganese	ug/l	-	5.8	4.3	72.6	4.4	50.4	12.8	13.2
Dissolved Nickel	ug/l	25	0.9	0.9	1.6	0.3	0.3	2.4	0.7
Dissolved Potassium	mg/l	-	24.6	24.2	36	50.8	10.3	30.7	29.6
Dissolved Sodium	mg/l	-	821.3	861.3	1085	1588	302.9	934.7	868.2
Dissolved Zinc	ug/l	-	11.8	15.2	11.9	3.3	3.1	2.9	2.8
Total Iron	ug/l	300	**398.4**	**635.9**	**325.1**	**766.1**	**339.2**	256.1	**575**
Total Zinc	ug/l	30	11.8	15.2	11.9	3.3	8.5	2.9	2.8
PAH MS									
Naphthalene	ug/l	1.1	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Acenaphthylene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Acenaphthene	ug/l	5.8	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Fluorene	ug/l	3	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Phenanthrene	ug/l	0.4	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Anthracene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Fluoranthene	ug/l	0.04	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Pyrene	ug/l	0.025	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Benzo(a)anthracene	ug/l	0.018	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Chrysene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Benzo(bk)fluoranthene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Benzo(a)pyrene	ug/l	0.015	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Indeno(123cd)pyrene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Dibenzo(ah)anthracene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
Benzo(ghi)perylene	ug/l	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	NR
PAH 16 Total	ug/l	-	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	NR
PAH Surrogate % Recovery	%	-	70	74	81	91	91	70	NR
EPH (C8-C40)	ug/l	-	480	*<10*	*<10*	*<10*	*<10*	*<10*	NR
Sulphate	mg/l	-	0.56	106.43	179.81	44.27	302.02	142.09	125.89
Chloride	mg/l	120	1.7	**1315.9**	**1970.3**	**471.5**	**2939.4**	**1737.8**	**1558.9**
Ortho Phosphate as PO4	mg/l	-	1.7	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*
Ammoniacal Nitrogen as N	mg/l	-	0.95	0.68	0.28	0.32	0.22	0.33	0.16
Total Alkalinity as CaCO3	mg/l	-	82	82	76	46	68	70	76
Dissolved Oxygen	mg/l	5.5	10	10	11	10	10	10	11
Electrical Conductivity @25C	uS/cm	-	4710	53	6554	5116	187	5401	5128
pH	pH units	6.5 to 9.0	6.79	6.84	6.83	6.56	6.71	6.68	6.74
Total Dissolved Solids	mg/l	-	2693	2698	3674	874	5412	234	2941
Total Suspended Solids	mg/l	-	60	91	62	33	82	58	60

1	= CCME guideline for total metal, not dissolved
<0.01	= Less than analytical detection limit
5	= CCME Freshwater Guideline threshold exceeded
NR	= Result not reported

APPENDIX D4

QA of Laboratory Sampling

May 2013 Quality Assurance

Parameter	Units	LOD	SW1	SW10	% Difference
Dissolved Arsenic	ug/l	<0.9	*<0.9*	*<0.9*	0%
Dissolved Cadmium	ug/l	<0.03	*<0.03*	0.05	233%
Dissolved Calcium	mg/l	<0.2	75	81.9	9%
Total Dissolved Chromium	ug/l	<0.2	1.9	1.8	5%
Dissolved Copper	ug/l	<3	*<3*	*<3*	0%
Total Dissolved Iron	ug/l	<4.7	6.8	19.6	**188%**
Dissolved Lead	ug/l	<0.4	*<0.4*	*<0.4*	0%
Dissolved Magnesium	mg/l	<0.1	219.5	215.5	2%
Dissolved Manganese	ug/l	<1.5	3.9	3.7	5%
Dissolved Nickel	ug/l	<0.2	0.9	1.5	67%
Dissolved Potassium	mg/l	<0.1	61.6	66	7%
Dissolved Sodium	mg/l	<0.1	1765	1750	1%
Dissolved Zinc	ug/l	<1.5	*<1.5*	*<1.5*	0%
Total Iron	ug/l	<4.7	287.1	312.4	9%
Total Zinc	ug/l	<1.5	*<1.5*	*<1.5*	0%
Dissolved Mercury	ug/l	<0.01	*<0.01*	*<0.01*	0%
Total Mercury	ug/l	<0.01	*<0.01*	*<0.01*	0%
EPH (C8-C40)	ug/l	<10	*<10*	*<10*	0%
			0	0	
Sulphate	mg/l	<0.05	370.24	367.22	1%
Chloride	mg/l	<0.3	3145.2	3155.6	0%
Ortho Phosphate as PO4	mg/l	<0.03	*<0.03*	*<0.03*	0%
Ammoniacal Nitrogen as N	mg/l	<0.01	0.19	0.13	**32%**
Total Alkalinity as CaCO3	mg/l	<1	68	70	3%
Dissolved Oxygen	mg/l	<1	10	10	0%
Electrical Conductivity @25C	uS/cm	<2	9734	9743	0%
pH	pH units	<0.01	7.36	7.33	0%
Total Dissolved Solids	mg/l	<10	6487	6394	1%
Total Suspended Solids	mg/l	<10	45	49	9%

Notable Results:	**7%**
QC Grade:	**High**

September 2013 Quality Assurance

Parameter	Units	LOD	SW02	SW020	% Difference	SW04	SW040	% Difference
			10/09/2013	10/09/2013		07/09/2013	07/09/2013	
Dissolved Arsenic	ug/l	<0.9	1	*<0.9*	55%	*<0.9*	1.3	189%
Dissolved Cadmium	ug/l	<0.03	0.12	0.06	50%	0.14	*<0.03*	89%
Dissolved Calcium	mg/l	<0.2	15.2	14.9	2%	46.1	46.1	0%
Total Dissolved Chromium	ug/l	<0.2	0.2	*<0.2*	50%	*<0.2*	*<0.2*	0%
Dissolved Copper	ug/l	<3	*<3*	*<3*	0%	*<3*	*<3*	0%
Total Dissolved Iron	ug/l	<4.7	56.2	60.2	7%	*<4.7*	10.2	334%
Dissolved Lead	ug/l	<0.4	0.9	*<0.4*	78%	*<0.4*	*<0.4*	0%
Dissolved Magnesium	mg/l	<0.1	28.8	27.5	5%	88.9	86.1	3%
Dissolved Manganese	ug/l	<1.5	50.4	49.4	2%	13.2	13	2%
Dissolved Nickel	ug/l	<0.2	0.3	0.9	200%	0.7	0.6	14%
Dissolved Potassium	mg/l	<0.1	10.3	10	3%	29.6	28.6	3%
Dissolved Sodium	mg/l	<0.1	302.9	278.8	8%	868.2	884.9	2%
Dissolved Zinc	ug/l	<1.5	3.1	2.5	19%	2.8	3	7%
Total Iron	ug/l	<4.7	339.2	793.3	**134%**	575	341.8	**41%**
Total Zinc	ug/l	<1.5	8.5	2.5	71%	2.8	3	7%
PAH MS								
Naphthalene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Acenaphthylene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Acenaphthene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Fluorene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Phenanthrene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Anthracene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Fluoranthene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Pyrene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Benzo(a)anthracene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Chrysene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Benzo(bk)fluoranthene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Benzo(a)pyrene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Indeno(123cd)pyrene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Dibenzo(ah)anthracene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
Benzo(ghi)perylene	ug/l	<0.01	*<0.01*	*<0.01*	0%	NR	*<0.01*	NR
PAH 16 Total	ug/l	<0.1	*<0.1*	*<0.1*	0%	NR	*<0.1*	NR
PAH Surrogate % Recovery	%	<0	91	73	20%	NR	94	NR
EPH (C8-C40)	ug/l	<10	*<10*	*<10*	0%	-	*<10*	-
Sulphate	mg/l	<0.05	302.02	44.59	**85%**	125.89	92.52	**27%**
Chloride	mg/l	<0.3	2939.4	472.1	**84%**	1558.9	1494.3	4%
Ortho Phosphate as PO4	mg/l	<0.03	*<0.03*	*<0.03*	0%	*<0.03*	*<0.03*	0%
Ammoniacal Nitrogen as N	mg/l	<0.01	0.22	0.24	9%	0.16	0.49	**206%**
Total Alkalinity as CaCO3	mg/l	<1	68	48	**29%**	76	72	5%
Dissolved Oxygen	mg/l	<1	10	9	10%	11	10	9%
Electrical Conductivity @25C	uS/cm	<2	187	48	**74%**	5128	522	**90%**
pH	pH units	<0.01	6.71	6.59	2%	6.74	6.77	0%
Total Dissolved Solids	mg/l	<10	5412	888	**84%**	2941	2869	2%
Total Suspended Solids	mg/l	<10	82	*<10*	94%	60	65	8%

Notable Results:	**14%**	**Notable Results:**	**12%**
QC Grade:	**Moderate**	**QC Grade**	**Moderate**

APPENDIX E1

Plant Species Recorded

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
ACANTHACEAE	*Asystasia gangetica*		X		X		X
ACANTHACEAE	*Barleria oenotheroides*			X		X	
ACANTHACEAE	*Blepharis maderaspatensis*		X			X	
ACANTHACEAE	*Dicliptera verticillata*						
ACANTHACEAE	*Dyschoriste perrottettii*						
ACANTHACEAE	*Hygrophila auriculata*						
ACANTHACEAE	*Hygrophila barbata*						
ACANTHACEAE	*Hygrophila brevituba*						
ACANTHACEAE	*Hygrophila odora*						
ACANTHACEAE	*Hygrophila senegalensis*						
ACANTHACEAE	*Hypoestes cancellata*		X	X		X	
ACANTHACEAE	*Justicia kotschyi*						
ACANTHACEAE	*Justicia ladanoides*						
ACANTHACEAE	*Lepidagathis chevalieri*						
ACANTHACEAE	*Lepidagathis collina*						
ACANTHACEAE	*Lepidagathis fimbriata*						
ACANTHACEAE	*Lepidagathis sericea*					X	
ACANTHACEAE	*Monechma ciliatum*						
ACANTHACEAE	*Nelsonia canescens*		X	X		X	
ACANTHACEAE	*Phaulopsis falcisepala*				X	X	
ACANTHACEAE	*Phaulopsis imbricata*					X	
ACANTHACEAE	*Rungia eriostachya*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
ACANTHACEAE	*Rungia grandis*			X		X	
ACANTHACEAE	*Rungia guineensis*						
ACANTHACEAE	*Ruspolia hypocrateriformis*						
ACANTHACEAE	*Thunbergia erecta*		X			X	
AIZOACEAE	*Sesuvium portulacastrum*						
AIZOACEAE	*Trianthema portulacastrum*		X	X			
ALISMATACEAE	*Sagittaria guayanensis*						
AMARANTHACEAE	*Achyranthes aspera*						
AMARANTHACEAE	*Amaranthus cruentus*						
AMARANTHACEAE	*Amaranthus spinosus*						
AMARANTHACEAE	*Blutaparon vermiculare*		X		X	X	X
AMARANTHACEAE	*Celosia trigyna*		X	X	X	X	
AMARANTHACEAE	*Cyathula prostrata*		X	X			
AMARANTHACEAE	*Pandiaka angustifolia*						
AMARANTHACEAE	*Pandiaka involucrata*						
AMARANTHACEAE	*Pupalia lappacea*						
ANACARDIACEAE	*Anacardium occidentale*			X			
ANACARDIACEAE	*Heeria insignis*						
ANACARDIACEAE	*Lannea acida*			X		X	
ANACARDIACEAE	*Lannea nigritana*					X	
ANACARDIACEAE	*Lannea velutina*					X	
ANACARDIACEAE	*Mangifera indica*			X			

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
ANACARDIACEAE	*Ozoroa insignis*						
ANACARDIACEAE	*Pseudospondias microcarpa*						
ANACARDIACEAE	*Sclerocarya birrea*						
ANACARDIACEAE	*Sorindeia juglandifolia*			X	X	X	
ANACARDIACEAE	*Spondias mombin*		X	X	X	X	
ANCISTROCLADACEAE	*Ancistrocladus barteri*					X	
ANISOPHYLLEACEAE	*Anisophyllea laurina*						
ANNONACEAE	*Annona glauca*			X		X	
ANNONACEAE	*Annona senegalensis*			X		X	
ANNONACEAE	*Artabotrys velutinus*			X		X	
ANNONACEAE	*Hexalobus monopetalus*		X				
ANNONACEAE	*Monanthotaxis barteri*			X	X	X	
ANNONACEAE	*Monanthotaxis vogelii*		X				
ANNONACEAE	*Monodora tenuifolia*						
ANNONACEAE	*Uvaria chamae*			X		X	
ANNONACEAE	*Xylopia longipetala*		X	X		X	
APOCYNACEAE	*Adenium obesum*						
APOCYNACEAE	*Alafia benthamii*						
APOCYNACEAE	*Alafia scandens*					X	
APOCYNACEAE	*Anisopus efulensis*						
APOCYNACEAE	*Baissea leonensis*						
APOCYNACEAE	*Baissea multiflora*				X	X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
APOCYNACEAE	*Cryptolepis sanguinolenta*			X		X	
APOCYNACEAE	*Isonema smeathmannii*		X			X	
APOCYNACEAE	*Landolphia dulcis*		X		X	X	
APOCYNACEAE	*Landolphia heudelotii*					X	
APOCYNACEAE	*Oncinotis nitida*						
APOCYNACEAE	*Pleiocarpa pycnantha*						
APOCYNACEAE	*Rauvolfia vomitoria*		X	X		X	
APOCYNACEAE	*Saba senegalensis*		X		X	X	X
APOCYNACEAE	*Strophanthus hispidus*			X		X	
APOCYNACEAE	*Strophanthus sarmentosus*		X			X	X
APOCYNACEAE	*Tabernaemontana africana*					X	
APOCYNACEAE	*Voacanga africana*						
APOCYNACEAE	*Voacanga thouarsii*		X			X	
ARACEAE	*Cercestis afzelii*						
ARACEAE	*Cercestis afzelii*						
ARACEAE	*Pistia stratiotes*						
ARACEAE	*Pistia stratiotes*						
ARACEAE	*Stylochiton lancifolium*						
ARECACEAE	*Borassus aethiopum*						
ARECACEAE	*Borassus aethiopum*						
ARECACEAE	*Hyphaene thebaica*		X	X	X	X	X
ARECACEAE	*Phoenix reclinata*		X		X		X

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
ARECACEAE	*Elias guineensis*		X	X	X		
ARECACEAE	*Raphia palma-pinus*	DD	X			X	
ASCLEPIADACEAE	*Aspidoglossum connatum*						
ASCLEPIADACEAE	*Calotropis procera*			X		X	
ASCLEPIADACEAE	*Ceropegia nigra*					X	
ASCLEPIADACEAE	*Cynanchum longipes*						
ASCLEPIADACEAE	*Ectadiopsis oblongifolia*						
ASCLEPIADACEAE	*Gymnema sylvestre*		X			X	
ASCLEPIADACEAE	*Raphionacme brownii*		X		X		
ASCLEPIADACEAE	*Secamone afzelii*		X	X		X	
ASCLEPIADACEAE	*Tacazzea apiculata*						
ASPARAGACEAE	*Asparagus flagellaris*					X	
ASPARAGACEAE	*Chlorophytum blepharophyllum*						
ASPARAGACEAE	*Chlorophytum filipendulum*					X	
ASPARAGACEAE	*Chlorophytum immaculatum*						
ASPARAGACEAE	*Chlorophytum macrophyllum*			X			
ASPARAGACEAE	*Sansevieria senegambica*					X	
ASTERACEAE	*Acanthospermum hispidum*			X			
ASTERACEAE	*Adenostemma perrottetii*						
ASTERACEAE	*Ageratum conyzoides*						
ASTERACEAE	*Bidens borianiana*			X			
ASTERACEAE	*Bidens engleri*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
ASTERACEAE	*Bidens pilosa*			X			
ASTERACEAE	*Blumea axillaris*						
ASTERACEAE	*Blumea viscosa*						
ASTERACEAE	*Centaurea perrottetii*						
ASTERACEAE	*Elephantopus mollis*		X	X	X		
ASTERACEAE	*Ethulia conyzoides*						
ASTERACEAE	*Galinsoga quadriradiata*						
ASTERACEAE	*Galinsoga quadriradiata*						
ASTERACEAE	*Herderia truncata*						
ASTERACEAE	*Melanthera gambica*						
ASTERACEAE	*Microglossa pyrifolia*						
ASTERACEAE	*Mikania cordata*		X		X	X	
ASTERACEAE	*Pentanema indicum*						
ASTERACEAE	*Pentanema indicum*						
ASTERACEAE	*Pleiotaxis chlorolepis*			X			
ASTERACEAE	*Pleiotaxis newtonii*						
ASTERACEAE	*Porphyrostemma chevalieri*						
ASTERACEAE	*Sphaeranthus senegalensis*		X		X		
ASTERACEAE	*Vernonia adoensis*						
ASTERACEAE	*Vernonia ambigua*						
ASTERACEAE	*Vernonia galamensis*						
ASTERACEAE	*Vernonia galamensis*		X	X		X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
ASTERACEAE	*Vernonia nigritiana*					X	
ASTERACEAE	*Vernonia tenoreana*						
BEGONIACEAE	*Begonia rostrata*						
BIGNONIACEAE	*Markhamia tomentosa*					X	
BIGNONIACEAE	*Newbouldia laevis*					X	
BIGNONIACEAE	*Spathodea campanulata*						
BIGNONIACEAE	*Stereospermum acuminatissimum*						
BIGNONIACEAE	*Stereospermum kunthianum*					X	
BOMBACACEAE	*Adansonia digitata*			X		X	
BOMBACACEAE	*Bombax costatum*						
BOMBACACEAE	*Ceiba pentandra*						
BORAGINACEAE	*Coldenia procumbens*		X				
BORAGINACEAE	*Rotula aquatica*		X			X	
BRASSICACEAE	*Rorippa humifusa*						
BURSERACEAE	*Canarium schweinfurthii*		X			X	
CAMPANULACEAE	*Wahlenbergia lobelioides*						
CAMPANULACEAE	*Wahlenbergia perrottetii*						
CAPPARACEAE	*Cleome gynandra*						
CAPPARACEAE	*Cleome viscosa*						
CAPPARACEAE	*Maerua duchesnei*		X	X		X	
CAPPARACEAE	*Ritchiea capparoides*					X	
CAPPARACEAE	*Ritchiea duchesnei*			X		X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
CAPPARACEAE	*Ritchiea longipedicellata*						
CARYOPHYLLACEAE	*Polycarpaea eriantha*						
CARYOPHYLLACEAE	*Polycarpaea linearifolia*				X		X
CARYOPHYLLACEAE	*Polycarpaea tenuifolia*						
CARYOPHYLLACEAE	*Polycarpon prostratum*		X		X		X
CELASTRACEAE	*Apodostigma pallens*						
CELASTRACEAE	*Reissantia indica*		X		X	X	
CELASTRACEAE	*Salacia debilis*					X	
CELASTRACEAE	*Salacia senegalensis*		X		X		
CHRYSOBALANACEAE	*Chrysobalanus icaco*		X	X	X	X	X
CHRYSOBALANACEAE	*Neocarya macrophylla*				X		X
CHRYSOBALANACEAE	*Parinari curatellifolia*			X		X	
CHRYSOBALANACEAE	*Parinari excelsa*			X		X	
CLUSIACEAE	*Garcinia elliotii*						
CLUSIACEAE	*Psorospermum alternifolium*						
CLUSIACEAE	*Psorospermum glaberrimum*						
COMBRETACEAE	*Combretum adenogonium*					X	
COMBRETACEAE	*Combretum bipindense*						
COMBRETACEAE	*Combretum collinum*			X		X	
COMBRETACEAE	*Combretum conchipetalum*						
COMBRETACEAE	*Combretum glutinosum*						
COMBRETACEAE	*Combretum grandiflorum*			X		X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
COMBRETACEAE	*Combretum micranthum*					X	
COMBRETACEAE	*Combretum mucronatum*						
COMBRETACEAE	*Combretum nigricans*						
COMBRETACEAE	*Combretum nioroense*						
COMBRETACEAE	*Combretum paniculatum*			X		X	
COMBRETACEAE	*Combretum racemosum*					X	
COMBRETACEAE	*Combretum rochetianum*						
COMBRETACEAE	*Combretum tomentosum*						
COMBRETACEAE	*Conocarpus erectus*						
COMBRETACEAE	*Pteleopsis suberosa*						
COMBRETACEAE	*Terminalia albida*			X		X	
COMBRETACEAE	*Terminalia macroptera*			X		X	
COMBRETACEAE	*Terminalia scutifera*					X	
COMMELINACEAE	*Aneilema beniniense*						
COMMELINACEAE	*Aneilema beniniense*						
COMMELINACEAE	*Aneilema paludosum*						
COMMELINACEAE	*Commelina benghalensis*						
COMMELINACEAE	*Commelina capitata*			X		X	
COMMELINACEAE	*Commelina congesta*			X			
COMMELINACEAE	*Commelina lagosensis*						
COMMELINACEAE	*Commelina nigritana*						
COMMELINACEAE	*Cyanotis lanata*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
COMMELINACEAE	*Cyanotis longifolia*						
COMMELINACEAE	*Floscopa glomerata*						
COMMELINACEAE	*Floscopa axillaris*	DD					
COMMELINACEAE	*Palisota hirsuta*						
COMMELINACEAE	*Palisota hirsuta*						
CONNARACEAE	*Agelaea pentagyna*						
CONNARACEAE	*Cnestis corniculata*						
CONNARACEAE	*Cnestis ferruginea*						
CONNARACEAE	*Connarus africanus*			X		X	
CONNARACEAE	*Rourea coccinea*			X	X	X	
CONNARACEAE	*Rourea minor*						
CONNARACEAE	*Rourea thomsonii*						
CONVOLVULACEAE	*Aniseia martinicensis*						
CONVOLVULACEAE	*Bonamia thunbergiana*			X		X	
CONVOLVULACEAE	*Calycobolus heudelotii*						
CONVOLVULACEAE	*Cressa cretica*						
CONVOLVULACEAE	*Evolvulus alsinoides*						
CONVOLVULACEAE	*Ipomoea cairica*		X	X		X	
CONVOLVULACEAE	*Ipomoea eriocarpa*						
CONVOLVULACEAE	*Ipomoea imperati*						
CONVOLVULACEAE	*Ipomoea mauritiana*						
CONVOLVULACEAE	*Ipomoea obscura*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
CONVOLVULACEAE	*Lepistemon owariensis*						
CONVOLVULACEAE	*Lepistemon owariensis*						
CONVOLVULACEAE	*Merremia aegyptia*						
CONVOLVULACEAE	*Merremia aegyptica*						
CONVOLVULACEAE	*Merremia hederacea*						
CONVOLVULACEAE	*Merremia pinnata*						
CONVOLVULACEAE	*Stictocardia beraviensis*						
CONVOLVULACEAE	*Xenostegia tridentata*						
COSTACEAE	*Costus afer*						
COSTACEAE	*Costus afer*						
CUCURBITACEAE	*Cayaponia africana*						
CUCURBITACEAE	*Citrullus lanatus*						
CUCURBITACEAE	*Citrullus mucosospermus*						
CUCURBITACEAE	*Coccinia keayana*						
CUCURBITACEAE	*Cucumeropsis mannii*					X	
CUCURBITACEAE	*Cucurbita moschata*			X			
CUCURBITACEAE	*Cucurbita pepo*						
CUCURBITACEAE	*Luffa aegyptiaca*						
CUCURBITACEAE	*Melothria capillacea*						
CUCURBITACEAE	*Melothria deltoidea*						
CUCURBITACEAE	*Melothria maderaspatana*						
CUCURBITACEAE	*Melothria tridactyla*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
CUCURBITACEAE	*Mukia maderaspatana*						
CUCURBITACEAE	*Zehneria hallii*						
CUCURBITACEAE	*Zehneria thwaitesii*			X			
CYPERACEAE	*Cyperus amabilis*						
CYPERACEAE	*Cyperus amabilis*		X		X		
CYPERACEAE	*Cyperus crassipes*				X		X
CYPERACEAE	*Cyperus cyperoides*						X
CYPERACEAE	*Cyperus difformis*				X		
CYPERACEAE	*Cyperus dilatatus*		X		X	X	
CYPERACEAE	*Cyperus haspan*				X		
CYPERACEAE	*Cyperus ligularis*				X		X
CYPERACEAE	*Cyperus margaritaceus*		X		X		
CYPERACEAE	*Cyperus tenuiculmis*						
CYPERACEAE	*Eleocharis mutata*		X		X		
CYPERACEAE	*Fimbristylis dichotoma*					X	
CYPERACEAE	*Fimbristylis ferruginea*		X			X	
CYPERACEAE	*Fimbristylis schoenoides*				X		X
CYPERACEAE	*Fuirena ciliaris*						
CYPERACEAE	*Kyllinga squamulata*				X	X	
CYPERACEAE	*Pycreus acuticarinatus*						
CYPERACEAE	*Pycreus mundtii*		X				
CYPERACEAE	*Pycreus testui*				X	X	X

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
CYPERACEAE	*Rhynchospora candida*						
CYPERACEAE	*Schoenoplectus litoralis*		X		X		
CYPERACEAE	*Scleria catophylla*				X		X
CYPERACEAE	*Scleria depressa*				X		
DICHAPETALACEAE	*Dichapetalum heudelotii*						
DICHAPETALACEAE	*Dichapetalum toxicarium*						
DICRANALES	*Octoblepharum albidum*						
DILLENIACEAE	*Tetracera potatoria*			X			
DIOSCOREACEAE	*Dioscorea bulbifera*						
DIOSCOREACEAE	*Dioscorea bulbifera*						
DIOSCOREACEAE	*Dioscorea hirtiflora*						
DIOSCOREACEAE	*Dioscorea sagittifolia*						
DIOSCOREACEAE	*Dioscorea sagittifolia*						
DRYOPTERIDACEAE	*Bolbitis acrostichoides*						
EBENACEAE	*Diospyros ferrea*					X	X
EBENACEAE	*Diospyros sandwicensis*						
EBENACEAE	*Diospyros sandwicensis*						
ERIOCAULACEAE	*Mesanthemum prescottianum*						
ERIOCAULACEAE	*Mesanthemum prescottianum*						
ERIOCAULACEAE	*Mesanthemum radicans*						
ERIOCAULACEAE	*Mesanthemum radicans*						
EUPHORBIACEAE	*Acalypha fimbriata*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
EUPHORBIACEAE	*Alchornea cordifolia*						
EUPHORBIACEAE	*Anthostema senegalense*						
EUPHORBIACEAE	*Astraea lobata*						
EUPHORBIACEAE	*Astraea lobata*						
EUPHORBIACEAE	*Croton scarciesii*						
EUPHORBIACEAE	*Erythrococca anomala*						
EUPHORBIACEAE	*Euphorbia convolvuloides*						
EUPHORBIACEAE	*Euphorbia grandifolia*						
EUPHORBIACEAE	*Euphorbia hirta*			X			
EUPHORBIACEAE	*Euphorbia macrophylla*						
EUPHORBIACEAE	*Euphorbia prostrata*			X			
EUPHORBIACEAE	*Euphorbia trinervia*						
EUPHORBIACEAE	*Jatropha curcas*						
EUPHORBIACEAE	*Macaranga heterophylla*		X	X	X	X	
EUPHORBIACEAE	*Macaranga heudelotii*						
EUPHORBIACEAE	*Mareya micrantha*						
EUPHORBIACEAE	*Ricinodendron heudelotii*						
EUPHORBIACEAE	*Ricinus communis*			X			
FABACEAE	*Abrus canescens*		X			X	
FABACEAE	*Abrus fruticulosus*						
FABACEAE	*Abrus precatorius*					X	X
FABACEAE	*Abrus pulchellus*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Acacia kamerunensis*			X		X	
FABACEAE	*Acacia macrostachya*					X	
FABACEAE	*Acacia nilotica*						
FABACEAE	*Acacia pentagona*						
FABACEAE	*Aeschynomene afraspera*						
FABACEAE	*Aeschynomene aspera*						
FABACEAE	*Aeschynomene indica*						
FABACEAE	*Aeschynomene lateritia*						
FABACEAE	*Aeschynomene pulchella*					X	
FABACEAE	*Aeschynomene schimperi*		X		X		
FABACEAE	*Aeschynomene sensitiva*		X				
FABACEAE	*Aeschynomene tambacoundensis*						
FABACEAE	*Aeschynomene uniflora*						
FABACEAE	*Afzelia africana*	VU					
FABACEAE	*Aganope stuhlmannii*						
FABACEAE	*Albizia adianthifolia*			X		X	
FABACEAE	*Albizia altissima*						
FABACEAE	*Albizia ferruginea*	VU				X	
FABACEAE	*Albizia glaberrima glaberrima*			X		X	
FABACEAE	*Albizia rhombifolia*					X	
FABACEAE	*Albizia zygia*					X	
FABACEAE	*Alysicarpus ovalifolius*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Alysicarpus rugosus*						
FABACEAE	*Anthonotha crassifolia*						
FABACEAE	*Arachis hypogaea*						
FABACEAE	*Bauhinia reticulata*						
FABACEAE	*Bauhinia rufescens*			X		X	
FABACEAE	*Bauhinia thonningii*			X		X	
FABACEAE	*Bobgunnia madagascariensis*						
FABACEAE	*Bryaspis lupulina*						
FABACEAE	*Burkea africana*						
FABACEAE	*Caesalpinia benthamiana*						
FABACEAE	*Caesalpinia bonduc*						
FABACEAE	*Caesalpinia coriaria*						
FABACEAE	*Cajanus cajan*						
FABACEAE	*Cajanus scarabaeoides*						
FABACEAE	*Calopogonium mucunoides*						
FABACEAE	*Canavalia plagiosperma*						
FABACEAE	*Canavalia rosea*						
FABACEAE	*Cassia aldabrensis*						
FABACEAE	*Cassia sieberiana*			X	X	X	
FABACEAE	*Centrosema pubescens*						
FABACEAE	*Chamaecrista jaegeri*						
FABACEAE	*Chamaecrista mimosoides*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Chamaecrista nigricans*					X	
FABACEAE	*Clitoria falcata*						
FABACEAE	*Copaifera salikounda*						
FABACEAE	*Cordyla africana*						
FABACEAE	*Cordyla pinnata*						
FABACEAE	*Crotalaria calycina*			X		X	
FABACEAE	*Crotalaria comosa*						
FABACEAE	*Crotalaria ebenoides*						
FABACEAE	*Crotalaria glauca*					X	
FABACEAE	*Crotalaria glaucoides*			X			
FABACEAE	*Crotalaria goreensis*						
FABACEAE	*Crotalaria hyssopifolia*					X	
FABACEAE	*Crotalaria lathyroides*						
FABACEAE	*Crotalaria leprieurii*					X	
FABACEAE	*Crotalaria occidentalis*			X			
FABACEAE	*Crotalaria ochroleuca*						
FABACEAE	*Crotalaria ononoides*						
FABACEAE	*Crotalaria pallida*						
FABACEAE	*Crotalaria perrottetii*						
FABACEAE	*Crotalaria pseudotenuirama*						
FABACEAE	*Crotalaria retusa*						
FABACEAE	*Crudia senegalensis*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Cyclocarpa stellaris*						
FABACEAE	*Cynometra vogelii*						
FABACEAE	*Dalbergia bignonae*						
FABACEAE	*Dalbergia boehmii*		X	X		X	X
FABACEAE	*Dalbergia ecastaphyllum*						
FABACEAE	*Dalbergia hostilis*			X		X	
FABACEAE	*Dalbergia noldeae*						
FABACEAE	*Dalbergia rufa*						
FABACEAE	*Dalbergia saxatilis*					X	
FABACEAE	*Daniellia oliveri*						
FABACEAE	*Daniellia thurifera*						
FABACEAE	*Desmodium adscendens*						
FABACEAE	*Desmodium gangeticum*					X	
FABACEAE	*Desmodium hirtum*						
FABACEAE	*Desmodium laxiflorum*						
FABACEAE	*Desmodium linearifolium*			X			
FABACEAE	*Desmodium procumbens*					X	
FABACEAE	*Desmodium salicifolium*						
FABACEAE	*Desmodium setigerum*						
FABACEAE	*Desmodium tortuosum*			X			
FABACEAE	*Desmodium velutinum*						
FABACEAE	*Detarium microcarpum*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Detarium senegalense*						
FABACEAE	*Dialium guianense*			X			
FABACEAE	*Dialium guineense*						
FABACEAE	*Dichrostachys cinerea*		X	X	X	X	X
FABACEAE	*Dioclea reflexa*						
FABACEAE	*Dolichos schweinfurthii*						
FABACEAE	*Entada africana*						
FABACEAE	*Entada mannii*						
FABACEAE	*Entada rheedii*		X				
FABACEAE	*Entada rheedii*					X	
FABACEAE	*Entada wahlbergii*						
FABACEAE	*Eriosema afzelii*						
FABACEAE	*Eriosema glomeratum*						
FABACEAE	*Eriosema laurentii*		X				
FABACEAE	*Eriosema psoraleoides*						
FABACEAE	*Eriosema spicatum*						
FABACEAE	*Erythrina senegalensis*			X		X	
FABACEAE	*Erythrina sigmoidea*						
FABACEAE	*Erythrophleum africanum*						
FABACEAE	*Erythrophleum suaveolens*					X	
FABACEAE	*Erythrophleum suaveolens*						
FABACEAE	*Faidherbia albida*			X			

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Faidherbia albida*						
FABACEAE	*Flemingia faginea*						
FABACEAE	*Guibourtia copallifera*						
FABACEAE	*Guibourtia leonensis*			X		X	
FABACEAE	*Indigofera arrecta*						
FABACEAE	*Indigofera berhautiana*				X		
FABACEAE	*Indigofera capitata*						
FABACEAE	*Indigofera congesta*					X	
FABACEAE	*Indigofera congolensis*						
FABACEAE	*Indigofera dendroides*						
FABACEAE	*Indigofera elliotii*					X	
FABACEAE	*Indigofera heudelotii*			X			
FABACEAE	*Indigofera heudelotii heudelotii*						
FABACEAE	*Indigofera hirsuta*					X	
FABACEAE	*Indigofera leprieurii*						
FABACEAE	*Indigofera macrocalyx*						
FABACEAE	*Indigofera macrophylla*						
FABACEAE	*Indigofera nummulariifolia*			X			
FABACEAE	*Indigofera omissa*						
FABACEAE	*Indigofera paniculata*					X	
FABACEAE	*Indigofera pilosa*						
FABACEAE	*Indigofera pulchra*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Indigofera scarciesii*			X		X	
FABACEAE	*Indigofera secundiflora*						
FABACEAE	*Indigofera simplicifolia*						
FABACEAE	*Indigofera spicata*						
FABACEAE	*Indigofera stenophylla*					X	
FABACEAE	*Indigofera suffruticosa*						
FABACEAE	*Indigofera terminalis*						
FABACEAE	*Indigofera trita*			X		X	
FABACEAE	*Kotschya ochreata*						
FABACEAE	*Kotschya ochreata*					X	
FABACEAE	*Kotschya ochreata ochreata*			X			
FABACEAE	*Macrotyloma biflorum*						
FABACEAE	*Macrotyloma biflorum*					X	
FABACEAE	*Melliniella micrantha*						
FABACEAE	*Millettia barteri*						
FABACEAE	*Mimosa pigra*		X	X			
FABACEAE	*Mucuna pruriens*						
FABACEAE	*Nesphostylis holosericea*						
FABACEAE	*Ormocarpum sennoides*						
FABACEAE	*Ormocarpum verrucosum*						
FABACEAE	*Ostryocarpus riparius*						
FABACEAE	*Parkia biglobosa*			X		X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Pentaclethra macrophylla*						
FABACEAE	*Pericopsis laxiflora*						
FABACEAE	*Phaseolus vulgaris*						
FABACEAE	*Pisum sativum*						
FABACEAE	*Prosopis africana*			X		X	
FABACEAE	*Pseudarthria fagifolia*						
FABACEAE	*Psophocarpus monophyllus*						
FABACEAE	*Psophocarpus palustris*						
FABACEAE	*Pterocarpus erinaceus*						
FABACEAE	*Pterocarpus santalinoides*						
FABACEAE	*Rhynchosia buettneri*						
FABACEAE	*Rhynchosia pycnostachya*						
FABACEAE	*Rhynchosia viscosa*						
FABACEAE	*Rothia hirsuta*						
FABACEAE	*Samanea dinklagei*						
FABACEAE	*Samanea dinklagei*						
FABACEAE	*Senna alata*			X		X	
FABACEAE	*Senna insularis*			X			
FABACEAE	*Senna obtusifolia*						
FABACEAE	*Senna obtusifolia*						
FABACEAE	*Senna occidentalis*			X		X	
FABACEAE	*Senna podocarpa*			X			

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Sesbania bispinosa*			X			
FABACEAE	*Sesbania hepperi*						
FABACEAE	*Stylosanthes erecta*						
FABACEAE	*Stylosanthes fruticosa*						
FABACEAE	*Tamarindus indica*						
FABACEAE	*Tephrosia bracteolata*						
FABACEAE	*Tephrosia deflexa*		X				
FABACEAE	*Tephrosia elegans*						
FABACEAE	*Tephrosia flexuosa*					X	
FABACEAE	*Tephrosia linearis*						
FABACEAE	*Tephrosia lupinifolia*			X			
FABACEAE	*Tephrosia mossiensis*						
FABACEAE	*Tephrosia nana*						
FABACEAE	*Tephrosia pedicellata*				X		
FABACEAE	*Tephrosia purpurea*						
FABACEAE	*Teramnus labialis*		X				
FABACEAE	*Teramnus micans micans*						
FABACEAE	*Teramnus uncinatus*					X	
FABACEAE	*Vigna adenantha*			X			
FABACEAE	*Vigna adenantha*						
FABACEAE	*Vigna gracilis*			X			
FABACEAE	*Vigna heterophylla*					X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
FABACEAE	*Vigna heterophylla*						
FABACEAE	*Vigna laurentii*						
FABACEAE	*Vigna luteola*		X				
FABACEAE	*Vigna racemosa*			X		X	
FABACEAE	*Vigna radiata*						
FABACEAE	*Vigna reticulata*						
FABACEAE	*Vigna unguiculata*						
FABACEAE	*Vigna venulosa*				X	X	
FABACEAE	*Xeroderris stuhlmannii*		X	X			
FABACEAE	*Zornia glochidiata*						
FLACOURTIACEAE	*Byrsanthus brownii*						
FLACOURTIACEAE	*Dovyalis zenkeri*		X		X		
FLACOURTIACEAE	*Flacourtia indica*			X		X	
FLACOURTIACEAE	*Oncoba spinosa*		X			X	
FLACOURTIACEAE	*Scottellia leonensis*		X		X		
GENTIANACEAE	*Schultesia guyanensis*						
GENTIANACEAE	*Schultesia stenophylla*		X				
GENTIANACEAE	*Swertia welwitschii*						
HYPNALES	*Taxithelium stenosekos*						
ICACINACEAE	*Icacina senegalensis*				X	X	
IRVINGIACEAE	*Klainedoxa gabonensis*					X	
LAMIACEAE	*Hoslundia opposita*		X			X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
LAMIACEAE	*Hyptis spicigera*						
LAMIACEAE	*Hyptis suaveolens*						
LAMIACEAE	*Leonotis nepetifolia*						
LAMIACEAE	*Leucas martinicensis*						
LAMIACEAE	*Ocimum canum*						
LAMIACEAE	*Ocimum cuanzae*						
LAMIACEAE	*Platostoma africanum*						
LAURACEAE	*Cassytha filiformis*						
LENTIBULARIACEAE	*Utricularia stellaris*						
LINACEAE	*Hugonia planchoni*						
LOGANIACEAE	*Anthocleista djalonensis*						
LOGANIACEAE	*Anthocleista nobilis*						
LOGANIACEAE	*Mostuea hirsuta*						
LOGANIACEAE	*Strychnos afzelii*						
LOGANIACEAE	*Strychnos congolana*						
LOGANIACEAE	*Strychnos spinosa*			X	X	X	
LOGANIACEAE	*Strychnos splendens*					X	
LOGANIACEAE	*Usteria guineensis*						
LORANTHACEAE	*Agelanthus brunneus*						
LORANTHACEAE	*Agelanthus dodoneifolius*						
LORANTHACEAE	*Englerina parviflora*					X	
LORANTHACEAE	*Globimetula cupulata*					X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
LORANTHACEAE	*Phragmanthera leonensis*						
LORANTHACEAE	*Tapinanthus bangwensis*			X		X	
LORANTHACEAE	*Tapinanthus pentagonus*						
LYGODIACEAE	*Lygodium microphyllum*						
LYTHRACEAE	*Nesaea angustifolia*						
LYTHRACEAE	*Nesaea radicans*		X				
LYTHRACEAE	*Nesaea santoi*						
MALPIGHIACEAE	*Acridocarpus plagiopterus*				X	X	
MALPIGHIACEAE	*Acridocarpus smeathmannii*		X	X		X	
MALPIGHIACEAE	*Acridocarpus spectabilis*						
MALPIGHIACEAE	*Flabellaria paniculata*			X		X	
MALPIGHIACEAE	*Stigmaphyllon bannisterioides*						
MALVACEAE	*Gossypium barbosanum*						
MALVACEAE	*Hibiscus asper*						
MALVACEAE	*Hibiscus sterculiifolius*			X			
MALVACEAE	*Hibiscus surattensis*				X		
MALVACEAE	*Sida acuta*		X	X			
MALVACEAE	*Urena lobata*			X			
MALVACEAE	*Wissadula rostrata*						
MELASTOMATACEAE	*Dissotis senegambiensis*						
MELASTOMATACEAE	*Tristemma mauritianum*				X		
MELIACEAE	*Khaya anthotheca*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
MELIACEAE	*Khaya senegalensis*	VU					
MELIACEAE	*Trichilia prieureana*			X		X	
MELIACEAE	*Trichilia roka*						
MENISPERMACEAE	*Triclisia patens*						
MENYANTHACEAE	*Nymphoides indica*		X				
MOLLUGINACEAE	*Glinus lotoides*						
MOLLUGINACEAE	*Glinus oppositifolius*						
MORACEAE	*Chlorophora regia*						
MORACEAE	*Ficus dicranostyla*					X	
MORACEAE	*Ficus glumosa*					X	
MORACEAE	*Ficus lutea*			X		X	
MORACEAE	*Ficus ottoniifolia*				X	X	
MORACEAE	*Ficus ovata*			X		X	
MORACEAE	*Ficus sagittifolia*						
MORACEAE	*Ficus scott-elliotii*					X	
MORACEAE	*Milicia regia*	VU					
MORINGACEAE	*Moringa oleifera*						
MYRTACEAE	*Callistemon viminalis*						
MYRTACEAE	*Eugenia calophylloides*						
MYRTACEAE	*Syzygium guineense*					X	
NYCTAGINACEAE	*Boerhavia coccinea*						
NYCTAGINACEAE	*Boerhavia diffusa*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
NYCTAGINACEAE	*Boerhavia erecta*						
NYMPHAEACEAE	*Nymphaea lotus*		X				
NYMPHAEACEAE	*Nymphaea micrantha*		X				
OCHNACEAE	*Lophira alata*						
OCHNACEAE	*Lophira lanceolata*			X	X	X	
OCHNACEAE	*Sauvagesia erecta*						
OLACACEAE	*Ximenia americana*				X	X	
OLEACEAE	*Schrebera arborea*						
ONAGRACEAE	*Ludwigia hyssopifolia*						
ONAGRACEAE	*Ludwigia octovalvis*						
OPILIACEAE	*Opilia amentacea*						
ORCHIDACEAE	*Calyptrochilum christyanum*						
ORCHIDACEAE	*Calyptrochilum christyanum*						
ORCHIDACEAE	*Eulophia cucullata*						
ORCHIDACEAE	*Eulophia juncifolia*					X	
ORCHIDACEAE	*Eulophia rosea*				X	X	
ORCHIDACEAE	*Graphorkis lurida*						
ORCHIDACEAE	*Habenaria buettneriana*						
ORCHIDACEAE	*Habenaria zambesina*				X	X	
ORCHIDACEAE	*Platylepis glandulosa*						
OXALIDACEAE	*Biophytum petersianum*						
PANDANACEAE	*Pandanus guineabissauensis*				X		

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
PASSIFLORACEAE	*Adenia dinklagei*			X		X	
PASSIFLORACEAE	*Adenia lobata*					X	
PASSIFLORACEAE	*Paropsia laevigata*						
PASSIFLORACEAE	*Smeathmannia laevigata*						
PEDALIACEAE	*Sesamum orientale*						
PEDALIACEAE	*Sesamum orientale*						
PHYLLANTHACEAE	*Antidesma membranaceum*						
PHYLLANTHACEAE	*Bridelia micrantha*						
PHYLLANTHACEAE	*Hymenocardia acida*						
PHYLLANTHACEAE	*Hymenocardia heudelotii*						
PHYLLANTHACEAE	*Hymenocardia lyrata*						
PHYLLANTHACEAE	*Phyllanthus muellerianus*		X	X	X	X	
PHYLLANTHACEAE	*Phyllanthus niruroides*					X	
PHYLLANTHACEAE	*Phyllanthus odontadenius*						
PHYLLANTHACEAE	*Phyllanthus reticulatus*					X	
POACEAE	*Anadelphia leptocoma*		X	X	X		
POACEAE	*Anadelphia trepidaria*						
POACEAE	*Axonopus compressus*		X	X		X	
POACEAE	*Brachiaria villosa*		X	X	X	X	X
POACEAE	*Cenchrus biflorus*			X		X	
POACEAE	*Centotheca lappacea*		X		X		
POACEAE	*Digitaria ciliaris*			X		X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
POACEAE	*Digitaria exilis*			X			
POACEAE	*Digitaria horizontalis*			X			
POACEAE	*Digitaria nuda*			X			
POACEAE	*Digitaria patagiata*	DD		X			
POACEAE	*Echinochloa colona*		X		X	X	
POACEAE	*Echinochloa crus-galli*						
POACEAE	*Echinochloa crus-galli*		X				
POACEAE	*Echinochloa pyramidalis*						
POACEAE	*Echinochloa stagnina*					X	
POACEAE	*Eleusine indica*		X				
POACEAE	*Elymandra androphila*			X	X	X	
POACEAE	*Eragrostis ciliaris*						
POACEAE	*Eragrostis japonica*		X	X		X	
POACEAE	*Hackelochloa granularis*						
POACEAE	*Leersia hexandra*						
POACEAE	*Loudetia annua*						
POACEAE	*Oryza glaberrima*		X			X	
POACEAE	*Oryza longistaminata*		X			X	
POACEAE	*Oryza sativa*		X			X	
POACEAE	*Oxytenanthera abyssinica*						
POACEAE	*Panicum hymeniochilum*		X	X			
POACEAE	*Panicum laxum*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
POACEAE	*Panicum repens*				X	X	
POACEAE	*Panicum tenellum*						
POACEAE	*Paratheria prostrata*		X				
POACEAE	*Paspalum scrobiculatum*					X	
POACEAE	*Paspalum vaginatum*						
POACEAE	*Pennisetum hordeoides*						
POACEAE	*Pennisetum pedicellatum*		X				
POACEAE	*Pennisetum polystachion*					X	
POACEAE	*Perotis scabra*		X		X		
POACEAE	*Rhytachne triaristata*			X		X	
POACEAE	*Rottboellia cochinchinensis*		X	X	X		
POACEAE	*Sacciolepis cymbiandra*					X	
POACEAE	*Sacciolepis interrupta*						
POACEAE	*Sacciolepis micrococca*						
POACEAE	*Schizachyrium brevifolium*		X				
POACEAE	*Schizachyrium platyphyllum*				X		
POACEAE	*Setaria megaphylla*			X		X	
POACEAE	*Setaria pumila*		X				
POACEAE	*Sorghastrum incompletum*			X			
POACEAE	*Sorghum bicolor*			X		X	
POACEAE	*Sporobolus robustus*						
POACEAE	*Sporobolus virginicus*		X		X		

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
POACEAE	*Streptogyna crinita*						
POALES	*Acroceras zizanioides*		X				
PODOSTEMACEAE	*Ledermanniella adamesii*	DD					
POLYGALACEAE	*Atroxima afzeliana*						
POLYGALACEAE	*Carpolobia alba*						
POLYGALACEAE	*Polygala arenaria*					X	
POLYGALACEAE	*Polygala multiflora*						
POLYGALACEAE	*Securidaca longepedunculata*						
PONTEDERIACEAE	*Monochoria brevipetiolata*		X				
PORTULACACEAE	*Portulaca oleracea*						
PORTULACACEAE	*Portulaca quadrifida*						
RANUNCULACEAE	*Clematis hirsuta*						
RHAMNACEAE	*Ventilago africana*		X				
RHAMNACEAE	*Ziziphus mauritiana*			X	X	X	
RHIZOPHORACEAE	*Rhizophora mangle*				X		X
RHIZOPHORACEAE	*Rhizophora racemosa*			X			X
RUBIACEAE	*Argocoffeopsis subcordata*						
RUBIACEAE	*Bertiera spicata*		X			X	
RUBIACEAE	*Chassalia afzelii*						
RUBIACEAE	*Craterispermum laurinum*						
RUBIACEAE	*Crossopteryx febrifuga*						
RUBIACEAE	*Diodella serrulata*			X			X

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
RUBIACEAE	*Diodella serrulata*		X				
RUBIACEAE	*Euclinia longiflora*					X	
RUBIACEAE	*Gardenia nitida*						
RUBIACEAE	*Gardenia ternifolia*			X			
RUBIACEAE	*Ixora laxiflora*						
RUBIACEAE	*Kohautia grandiflora*						X
RUBIACEAE	*Macrosphyra longistyla*						
RUBIACEAE	*Mitracarpus hirtus*				X		
RUBIACEAE	*Mitracarpus hirtus*			X		X	X
RUBIACEAE	*Mitragyna inermis*						
RUBIACEAE	*Morelia senegalensis*					X	
RUBIACEAE	*Mussaenda elegans*						X
RUBIACEAE	*Oldenlandia corymbosa*		X		X		
RUBIACEAE	*Oldenlandia herbacea*			X			
RUBIACEAE	*Oxyanthus racemosus*						
RUBIACEAE	*Oxyanthus speciosus*					X	
RUBIACEAE	*Pauridiantha afzelii*				X	X	
RUBIACEAE	*Pauridiantha hirtella*		X	X			
RUBIACEAE	*Pavetta corymbosa*						
RUBIACEAE	*Pavetta oblongifolia*					X	
RUBIACEAE	*Pouchetia africana*		X				
RUBIACEAE	*Psychotria peduncularis*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
RUBIACEAE	*Rothmannia whitfieldii*			X			
RUBIACEAE	*Sabicea discolor*						
RUBIACEAE	*Sabicea venosa*				X	X	
RUBIACEAE	*Sarcocephalus latifolius*			X			
RUBIACEAE	*Spermacoce exilis*						
RUBIACEAE	*Spermacoce exilis*					X	
RUBIACEAE	*Spermacoce ruelliae*		X				
RUBIACEAE	*Tarenna nitidula*						
RUBIACEAE	*Tricalysia reticulata*					X	
RUBIACEAE	*Uncaria africana*						
RUBIACEAE	*Vangueriella discolor*			X			
RUTACEAE	*Afraegle paniculata*					X	
RUTACEAE	*Fagara leprieurii*						
RUTACEAE	*Fagara rubescens*		X				
RUTACEAE	*Zanthoxylum zanthoxyloides*						
SAPINDACEAE	*Allophylus africanus*						
SAPINDACEAE	*Aporrhiza lastoursvillensis*					X	
SAPINDACEAE	*Blighia sapida*						
SAPINDACEAE	*Blighia unijugata*			X			
SAPINDACEAE	*Cardiospermum halicacabum*						
SAPINDACEAE	*Dodonaea viscosa*			X			
SAPINDACEAE	*Eriocoelum kerstingii*		X				

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
SAPINDACEAE	*Lecaniodiscus cupanioides*					X	
SAPINDACEAE	*Lepisanthes senegalensis*						
SAPINDACEAE	*Paullinia pinnata*						
SAPINDACEAE	*Placodiscus riparius*					X	
SAPOTACEAE	*Pouteria alnifolia*						
SAPOTACEAE	*Synsepalum brevipes*			X			
SAPOTACEAE	*Vitellaria paradoxa*					X	
SCROPHULARIACEAE	*Alectra rigida paludosa*						
SCROPHULARIACEAE	*Bacopa crenata*		X				
SCROPHULARIACEAE	*Buchnera hispida*						
SCROPHULARIACEAE	*Craterostigma guineense*			X		X	
SCROPHULARIACEAE	*Crepidorhopalon gracilis*						
SCROPHULARIACEAE	*Lindernia crustacea*						
SCROPHULARIACEAE	*Lindernia senegalensis*			X		X	
SCROPHULARIACEAE	*Micrargeria barteri*						
SCROPHULARIACEAE	*Micrargeria filiformis*			X		X	
SCROPHULARIACEAE	*Rhamphicarpa fistulosa*						
SCROPHULARIACEAE	*Scoparia dulcis*						
SCROPHULARIACEAE	*Striga hermonthica*						
SCROPHULARIACEAE	*Striga klingii*						
SCROPHULARIACEAE	*Striga macrantha*			X			
SIMAROUBACEAE	*Hannoa undulata*			X		X	

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
SIMAROUBACEAE	*Quassia undulata*						
SOLANACEAE	*Physalis angulata*		X				
SOLANACEAE	*Schwenckia americana*					X	
SOLANACEAE	*Solanum distichum*						
SOLANACEAE	*Solanum lycopersicum*					X	
SOLANACEAE	*Solanum terminale*						
STERCULIACEAE	*Cola cordifolia*						
STERCULIACEAE	*Cola laurifolia*						
STERCULIACEAE	*Waltheria indica*			X		X	
THYMELAEACEAE	*Dicranolepis disticha*						
THYMELAEACEAE	*Synaptolepis retusa*						
TILIACEAE	*Corchorus olitorius*						
ULMACEAE	*Trema orientalis*			X			
URTICACEAE	*Urera oblongifolia*					X	
VERBENACEAE	*Avicennia africana*						X
VERBENACEAE	*Avicennia germinans*						X
VERBENACEAE	*Clerodendrum capitatum*						
VERBENACEAE	*Clerodendrum sinuatum*						
VERBENACEAE	*Stachytarpheta angustifolia*					X	
VERBENACEAE	*Vitex doniana*		X				
VERBENACEAE	*Vitex ferruginea*						
VIOLACEAE	*Rinorea aylmeri*						

Family	Species	IUCN status	Rice paddies	Secondary forest	Floodplain	Natural forest	Mangrove
VIOLACEAE	*Rinorea microdon*					X	
VITACEAE	*Ampelocissus africana*						
VITACEAE	*Ampelocissus pentaphylla*						
VITACEAE	*Cissus aralioides*		X			X	
VITACEAE	*Cissus populnea*			X			
VITACEAE	*Cissus quadrangularis*					X	
VITACEAE	*Cissus rufescens*		X			X	
VITACEAE	*Cissus waterloti*						
VITACEAE	*Cyphostemma adenocaule*			X			
VITACEAE	*Cyphostemma rubrosetosa*						
XYRIDACEAE	*Xyris anceps*						
ZINGIBERACEAE	*Aframomum alboviolaceum*				X	X	
ZINGIBERACEAE	*Aframomum alboviolaceum*						
XYRIDACEAE	*Xyris anceps*						

APPENDIX E2

Non-chordate Species Recorded

Order	Family	Species	Common Name	IUCN Status
ACTINIARIA	HORMATHIIDAE	*Calliactis brevicornis*	Hermit Crab	Not Listed
DECAPODA	OCYPODIDAE	*Uca tangeri*	Fiddler Crab	Not Listed
ARACHNIDA	ARANEAE	*Echemus incinctus*		Not Listed
ARACHNIDA	ASTIGMATA	*Dentocarpus chaerephon*		Not Listed
INSECTA	COLEOPTERA	*Caelostomus punctifrons*		Not Listed
INSECTA	COLEOPTERA	*Stenus*	Stenus frigidus	Not Listed
INSECTA	COLEOPTERA	*Stenolophus unicolor*		Not Listed
INSECTA	COLEOPTERA	*Cybister immarginatus*		Not Listed
DIPLOPODA	STEMMIULIDA	*Diopsiulus latens*		Not Listed
DIPLOPODA	STEMMIULIDA	*Diopsiulus feae*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge perplicata*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge pervittata*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge trauni*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge guineae*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Ophistreptus penetrans*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Urotropis perpunctata*		Not Listed
GASTROPODA	NEOTAENIOGLOSSA	*Tympanotonus radula*	West African Mud Creeper (Snail)	Not Listed
GASTROPODA	NEOTAENIOGLOSSA	*Tympanotonus fuscatus*	Mud-flat Periwinkle	Not Listed
INSECTA	HEMIPTERA	*Platymeris biguttata*		Not Listed
INSECTA	COLEOPTERA	*Berosus undatus*		Not Listed
INSECTA	COLEOPTERA	*Helochares normatus*		Not Listed
INSECTA	COLEOPTERA	*Hydrocanthus texanus*		Not Listed
INSECTA	COLEOPTERA	*Ataenius insolitus*		Not Listed
INSECTA	COLEOPTERA	*Rhyssemus senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Rhyssemus archambaulti*		Not Listed
INSECTA	COLEOPTERA	*Ruteloryctes morio*		Not Listed
INSECTA	COLEOPTERA	*Pseudosyrichthus senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Heteroligus meles*		Not Listed
INSECTA	COLEOPTERA	*Diplognatha gagates*		Not Listed
INSECTA	COLEOPTERA	*Eudicella frontalis*		Not Listed
INSECTA	COLEOPTERA	*Tiniocellus spinipes*		Not Listed
INSECTA	COLEOPTERA	*Garreta nitens*		Not Listed
INSECTA	COLEOPTERA	*Pinacotarsus dohrni*		Not Listed
INSECTA	COLEOPTERA	*Gymnopleurus fulgidus*		Not Listed
INSECTA	COLEOPTERA	*Catharsius sesostris*		Not Listed
INSECTA	COLEOPTERA	*Catharsius guineensis*		Not Listed
INSECTA	COLEOPTERA	*Catharsius achates*		Not Listed
INSECTA	COLEOPTERA	*Heliocopris antenor*		Not Listed

Order	Family	Species	Common Name	IUCN Status
INSECTA	COLEOPTERA	*Anachalcos convexus*		Not Listed
INSECTA	COLEOPTERA	*Anachalcos aurescens*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus cupreus*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus thomsoni*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus bidens*		Not Listed
INSECTA	COLEOPTERA	*Pedaria ouangoensis*		Not Listed
INSECTA	COLEOPTERA	*Pedaria tuberculigera*		Not Listed
INSECTA	COLEOPTERA	*Pedaria criberrima*		Not Listed
INSECTA	COLEOPTERA	*Onitis cupreus*		Not Listed
INSECTA	COLEOPTERA	*Rhyzopertha dominica*		Not Listed
INSECTA	COLEOPTERA	*Mallodon downesii*		Not Listed
INSECTA	COLEOPTERA	*Hypothenemus areccae*		Not Listed
INSECTA	HYMENOPTERA	*Braunsapis foveata*		Not Listed
INSECTA	HYMENOPTERA	*Leptacis longiciliata*		Not Listed
INSECTA	HYMENOPTERA	*Platyscelio africanus*		Not Listed
INSECTA	HYMENOPTERA	*Trithemis kirbyi*		Not Listed
INSECTA	HYMENOPTERA	*Fusicornia bambeyi*		Not Listed
INSECTA	DIPTERA	*Physocephala gracilis*		Not Listed
INSECTA	DIPTERA	*Anopheles gambiae*		Not Listed
INSECTA	DIPTERA	*Anopheles melas*		Not Listed
INSECTA	DIPTERA	*Anopheles arabiensis*		Not Listed
INSECTA	ORTHOPTERA	*Catantopsilus hintzi*		Not Listed
INSECTA	ORTHOPTERA	*Parga bissauensis*		Not Listed
INSECTA	ORTHOPTERA	*Locusta migratoria*	Migrating Locust	Not Listed
INSECTA	COLEOPTERA	*Xyloperthella picea*		Not Listed
INSECTA	COLEOPTERA	*Sinoxylon ruficorne*		Not Listed
INSECTA	COLEOPTERA	*Enochrus natalensis*		Not Listed
INSECTA	COLEOPTERA	*Sternolophus solieri*		Not Listed
INSECTA	COLEOPTERA	*Stenus fuscipes*		Not Listed
INSECTA	COLEOPTERA	*Korynetes coxalis*		Not Listed
INSECTA	COLEOPTERA	*Gonocephalum assimile*		Not Listed
INSECTA	COLEOPTERA	*Gonocephalum prolixum*		Not Listed
INSECTA	COLEOPTERA	*Pachnephorus bistriatus*		Not Listed
INSECTA	COLEOPTERA	*Cybister vulneratus*		Not Listed
INSECTA	COLEOPTERA	*Cybister tripunctatus*		Not Listed
INSECTA	COLEOPTERA	*Mesomorphus darwini*		Not Listed
INSECTA	COLEOPTERA	*Gonocephalum insulanum*		Not Listed
INSECTA	COLEOPTERA	*Leichenum canaliculatum*		Not Listed

Order	Family	Species	Common Name	IUCN Status
INSECTA	COLEOPTERA	*Cordylomera torrida*		Not Listed
INSECTA	COLEOPTERA	*Berosus approximans*		Not Listed
INSECTA	COLEOPTERA	*Strandius obliquus*		Not Listed
INSECTA	COLEOPTERA	*Hydrochus variolatus*		Not Listed
INSECTA	COLEOPTERA	*Eretes sticticus*		Not Listed
INSECTA	COLEOPTERA	*Hyperaspis senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Tribolium castaneum*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus mosambicus*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus parumpunctatus*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus licas*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus fossor*		Not Listed
INSECTA	COLEOPTERA	*Phyllognathus burmeisteri*		Not Listed
INSECTA	COLEOPTERA	*Oryctes boas*		Not Listed
INSECTA	COLEOPTERA	*Sisyphus costatus*		Not Listed
INSECTA	COLEOPTERA	*Xyleborus ferrugineus*		Not Listed
INSECTA	COLEOPTERA	*Xyleborus affinis*		Not Listed
INSECTA	COLEOPTERA	*Hydaticus leander*		Not Listed
INSECTA	COLEOPTERA	*Myriochila melancholica*		Not Listed
INSECTA	COLEOPTERA	*Cybister vicinus*		Not Listed
INSECTA	COLEOPTERA	*Cybister marginicollis*		Not Listed
INSECTA	COLEOPTERA	*Hydaticus dorsiger*		Not Listed
INSECTA	COLEOPTERA	*Hydroglyphus flavoguttatus*		Not Listed
INSECTA	COLEOPTERA	*Hydroglyphus geminodes*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus acuminatus*		Not Listed
INSECTA	COLEOPTERA	*Sinoxylon senegalense*		Not Listed
INSECTA	COLEOPTERA	*Hister aequatorius*		Not Listed
INSECTA	COLEOPTERA	*Laccophilus persimilis*		Not Listed
INSECTA	COLEOPTERA	*Laccophilus propinquus*		Not Listed
INSECTA	COLEOPTERA	*Yola cuspis*		Not Listed
INSECTA	COLEOPTERA	*Yola nigrosignata*		Not Listed
INSECTA	COLEOPTERA	*Hydroglyphus koppi*		Not Listed
INSECTA	COLEOPTERA	*Copelatus carinatus*		Not Listed
INSECTA	COLEOPTERA	*Hydaticus severini*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus reticuliceps*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus perssoni*		Not Listed
INSECTA	COLEOPTERA	*Xylion inflaticauda*		Not Listed
INSECTA	COLEOPTERA	*Minthea obsita*		Not Listed

Order	Family	Species	Common Name	IUCN Status
INSECTA	HYMENOPTERA	*Anteon lankanum*		Not Listed
INSECTA	COLEOPTERA	*Eutochia pulla*		Not Listed
INSECTA	COLEOPTERA	*Berosus elongatulus*		Not Listed
INSECTA	COLEOPTERA	*Helochares normatus*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus thomsoni*		Not Listed
INSECTA	COLEOPTERA	*Mallodon downesii*		Not Listed
INSECTA	COLEOPTERA	*Cordylomera torrida*		Not Listed
INSECTA	COLEOPTERA	*Berosus approximans*		Not Listed
INSECTA	COLEOPTERA	*Phyllognathus burmeisteri*		Not Listed
INSECTA	COLEOPTERA	*Sisyphus costatus*		Not Listed

APPENDIX E3

Reptile Species in Guinea-Bissau

January 2014
Report No. 13514950200.550/B.0

APPENDIX E3
Reptile Species in Guinea-Bissau

Family	Species	Status	Recorded
TYPHLOPIDAE	*Afrotyphlops punctatus*		
AGAMIDAE	*Agama agama*		x
AGAMIDAE	*Agama weidholzi*		
COLUBRIDAE	*Amblyodipsas unicolor*		
COLUBRIDAE	*Atractaspis aterrima*		
ELAPIDAE	*Bitis arietans*		x
ELAPIDAE	*Bitis rhinoceros*		
COLUBRIDAE	*Boaedon fuliginosus*		
COLUBRIDAE	*Boaedon lineatus*		
ELAPIDAE	*Causus rhombeatus*		x
SCINCIDAE	*Chalcides armitagei*		
CHAMAELEONIDAE	*Chamaeleo senegalensis*		
CHELONIIDAE	*Chelonia mydas*		
CROCODYLIDAE	*Crocodylus niloticus*		x
CROCODYLIDAE	*Crocodylus cataphractus*	DD	
CROCODYLIDAE	*Osteolaemus tetraspis*	VU	
TRIONYCHIDAE	*Cyclanorbis senegalensis*		
AMPHISBAENIDAE	*Cynisca feae*		
AMPHISBAENIDAE	*Cynisca leonina*		
AMPHISBAENIDAE	*Cynisca oligopholis*		
COLUBRIDAE	*Dasypeltis confusa*		
COLUBRIDAE	*Dasypeltis fasciata*		x
COLUBRIDAE	*Dasypeltis gansi*		
COLUBRIDAE	*Dasypeltis scabra*		
ELAPIDAE	*Dendroaspis polylepis*		
ELAPIDAE	*Dendroaspis viridis*		
ELAPIDAE	*Elapsoidea semiannulata*		
COLUBRIDAE	*Gonionotophis grantii*		
COLUBRIDAE	*Gonionotophis stenophthalmus*		
COLUBRIDAE	*Grayia smithii*		
COLUBRIDAE	*Hapsidophrys lineatus*		
COLUBRIDAE	*Hapsidophrys smaragdina*		
GEKKONIDAE	*Hemidactylus angulatus*		
TESTUDINIDAE	*Kinixys belliana*		
LACERTIDAE	*Latastia ornata*		
COLUBRIDAE	*Lycophidion albomaculatum*		
COLUBRIDAE	*Lycophidion semicinctum*		
GEKKONIDAE	*Lygodactylus gutturalis*		

GEKKONIDAE	*Lygodactylus picturatus*		
CROCODYLIDAE	*Mecistops cataphractus*		
LEPTOTYPHLOPIDAE	*Myriopholis boueti*		
LEPTOTYPHLOPIDAE	*Myriopholis narirostris*		
ELAPIDAE	*Naja haje*		
ELAPIDAE	*Naja melanoleuca*		x
ELAPIDAE	*Naja nigricollis*		x
ELAPIDAE	*Naja senegalensis*		
CROCODYLIDAE	*Osteolaemus tetraspis*	VU	
COLUBRIDAE	*Philothamnus carinatus*		
COLUBRIDAE	*Philothamnus heterodermus*		
COLUBRIDAE	*Philothamnus irregularis*		x
PROSYMNIDAE	*Prosymna meleagris*		
COLUBRIDAE	*Psammophis elegans*		
COLUBRIDAE	*Psammophis lineatus*		x
COLUBRIDAE	*Psammophis phillipsi*		
COLUBRIDAE	*Psammophis praeornatus*		
COLUBRIDAE	*Psammophis sibilans*		
PYTHONIDAE	*Python regius*		
PYTHONIDAE	*Python sebae*		
COLUBRIDAE	*Rhamphiophis oxyrhynchus*		
LEPTOTYPHLOPIDAE	*Rhinoleptus koniagui*		
GEKKONIDAE	*Tarentola ephippiata*		
COLUBRIDAE	*Telescopus variegatus*		
COLUBRIDAE	*Thelotornis kirtlandii*		
COLUBRIDAE	*Toxicodryas blandingii*		
SCINCIDAE	*Trachylepis affinis*		
SCINCIDAE	*Trachylepis perrotetii*		
SCINCIDAE	*Trachylepis quinquetaeniata*		
VARANUS	*Varanus exanthematicus*		x
VARANUS	*Varanus ornatus*		x

APPENDIX E4

Amphibian Species in Guinea-Bissau

January 2014
Report No. 13514950200.550/B.0

APPENDIX E4
Amphibian Species in Guinea-Bissau

Family	Species	IUCN status	Recorded
ARTHROLEPTIDAE	*Arthroleptis poecilonotus*		
HYPEROLIIDAE	*Leptopelis spiritusnoctis*		
HYPEROLIIDAE	*Leptopelis viridis*		
BUFONIDAE	*Amietophrynus regularis*		x
DICROGLOSSIDAE	*Hoplobatrachus occipitalis*		
HEMISOTIDAE	*Hemisus guineensis*		
HEMISOTIDAE	*Hemisus marmoratus*		
HYPEROLIIDAE	*Afrixalus quadrivittatus*		
HYPEROLIIDAE	*Afrixalus vittiger*		
HYPEROLIIDAE	*Afrixalus weidholzi*		
HYPEROLIIDAE	*Hyperolius fusciventris*		
HYPEROLIIDAE	*Hyperolius lamottei*		
HYPEROLIIDAE	*Hyperolius occidentalis*		x
HYPEROLIIDAE	*Hyperolius spatzi*		
HYPEROLIIDAE	*Kassina cassinoides*		
HYPEROLIIDAE	*Kassina fusca*		
HYPEROLIIDAE	*Kassina senegalensis*		x
PHRYNOBATRACHIDAE	*Phrynobatrachus francisci*		
PHRYNOBATRACHIDAE	*Phrynobatrachus gutturosus*		
PHRYNOBATRACHIDAE	*Phrynobatrachus latifrons*		
PHRYNOBATRACHIDAE	*Phrynobatrachus natalensis*		x
PHRYNOBATRACHIDAE	*Phrynobatrachus tokba*		
PIPIDAE	*Pseudhymenochirus merlini*		
PIPIDAE	*Silurana tropicalis*		
PTYCHADENIDAE	*Ptychadena arnei*		
PTYCHADENIDAE	*Ptychadena bibroni*		
PTYCHADENIDAE	*Ptychadena mascareniensis*		
PTYCHADENIDAE	*Ptychadena oxyrhynchus*		
PTYCHADENIDAE	*Ptychadena tournieri*		
PTYCHADENIDAE	*Ptychadena trinodis*		
PYXICEPHALIDAE	*Tomopterna cryptotis*		
PYXICEPHALIDAE	*Pyxicephalus edulis*		
RANIDAE	*Hylarana galamensis*		
RANIDAE	*Ametia angolensis*		x

APPENDIX E5

Bird Species in Guinea-Bissau

January 2014
Report No. 13514950200.550/B.0

APPENDIX E5
Bird Species in Guinea-Bissau

Family	Species	Common name	IUCN status	Recorded
ACCIPITRIDAE	*Accipiter badius*	Shikra		
ACCIPITRIDAE	*Accipiter erythropus*	Red-thighed Sparrowhawk		
ACCIPITRIDAE	*Accipiter melanoleucus*	Black Goshawk		
ACCIPITRIDAE	*Accipiter toussenelii*	Red-chested Goshawk		
ACCIPITRIDAE	*Aquila rapax*	Tawny Eagle		
ACCIPITRIDAE	*Aquila spilogaster*	African Hawk-Eagle		
ACCIPITRIDAE	*Aviceda cuculoides*	African Cuckoo-Hawk		
ACCIPITRIDAE	*Butastur rufipennis*	Grasshopper Buzzard		
ACCIPITRIDAE	*Buteo auguralis*	Red-necked Buzzard		
ACCIPITRIDAE	*Circaetus beaudouini*	Beaudouin's Snake-Eagle	VU	
ACCIPITRIDAE	*Circaetus cinerascens*	Banded Snake-Eagle		X
ACCIPITRIDAE	*Circaetus cinereus*	Brown Snake-Eagle		
ACCIPITRIDAE	*Circus aeruginosus*	Eurasian Marsh-Harrier		
ACCIPITRIDAE	*Circus macrourus*	Pallid Harrier	NT	
ACCIPITRIDAE	*Elanus caeruleus*	Black-shouldered Kite		
ACCIPITRIDAE	*Gypohierax angolensis*	Palm-nut Vulture		X
ACCIPITRIDAE	*Gyps africanus*	White-backed Vulture	NT	
ACCIPITRIDAE	*Gyps rueppellii*	Rueppell's Griffon	NT	
ACCIPITRIDAE	*Haliaeetus vocifer*	African Fish-Eagle		X
ACCIPITRIDAE	*Hieraaetus pennatus*	Booted Eagle		
ACCIPITRIDAE	*Hieraaetus wahlbergi*	Wahlberg's Eagle		
ACCIPITRIDAE	*Kaupifalco monogrammicus*	Lizard Buzzard		
ACCIPITRIDAE	*Lophaetus occipitalis*	Long-crested Eagle		X
ACCIPITRIDAE	*Macheiramphus alcinus*	Bat Hawk		
ACCIPITRIDAE	*Melierax metabates*	Dark Chanting-Goshawk		X
ACCIPITRIDAE	*Micronisus gabar*	Gabar Goshawk		
ACCIPITRIDAE	*Milvus migrans*	Black Kite		X
ACCIPITRIDAE	*Necrosyrtes monachus*	Hooded Vulture	EN	X
ACCIPITRIDAE	*Neophron percnopterus*	Egyptian Vulture	EN	
ACCIPITRIDAE	*Pernis apivorus*	European Honey-buzzard		
ACCIPITRIDAE	*Polemaetus bellicosus*	Martial Eagle		
ACCIPITRIDAE	*Polyboroides typus*	African Harrier-Hawk		
ACCIPITRIDAE	*Stephanoaetus coronatus*	Crowned Hawk-Eagle		
ACCIPITRIDAE	*Terathopius ecaudatus*	Bateleur		
ACCIPITRIDAE	*Trigonoceps occipitalis*	White-headed Vulture	VU	
FRINGILLIDAE	*Serinus leucopygius*	White-rumped Seedeater		X
FRINGILLIDAE	*Serinus mozambicus*	Yellow-fronted Canary		
HELIORNITHIDAE	*Podica senegalensis*	African Finfoot		

Family	Species	Common name	IUCN status	Recorded
SULIDAE	*Morus bassanus*	Northern Gannet		
ACROCEPHALIDAE	*Acrocephalus schoenobaenus*	Sedge Warbler		X
ACROCEPHALIDAE	*Acrocephalus scirpaceus*	Eurasian Reed-Warbler		
ACROCEPHALIDAE	*Hippolais pallida*	Eastern Olivaceous Warbler		
ACROCEPHALIDAE	*Hippolais polyglotta*	Melodious Warbler		
ALAUDIDAE	*Galerida cristata*	Crested Lark		
ALAUDIDAE	*Galerida modesta*	Sun Lark		
ALAUDIDAE	*Mirafra rufocinnamomea*	Flappet Lark		
ALAUDIDAE	*Pinarocorys erythropygia*	Rufous-rumped Lark		
ALCEDINIDAE	*Alcedo quadribrachys*	Shining-blue Kingfisher		
ALCEDINIDAE	*Ceryle rudis*	Pied Kingfisher		
ALCEDINIDAE	*Corythornis cristatus*	Malachite Kingfisher		X
ALCEDINIDAE	*Halcyon chelicuti*	Striped Kingfisher		X
ALCEDINIDAE	*Halcyon leucocephala*	Gray-headed Kingfisher		
ALCEDINIDAE	*Halcyon malimbica*	Blue-breasted Kingfisher		
ALCEDINIDAE	*Halcyon senegalensis*	Woodland Kingfisher		X
ALCEDINIDAE	*Ispidina picta*	African Pygmy-Kingfisher		
ALCEDINIDAE	*Megaceryle maximus*	Giant Kingfisher		
ANATIDAE	*Alopochen aegyptiaca*	Egyptian Goose		
ANATIDAE	*Anas acuta*	Northern Pintail		
ANATIDAE	*Anas clypeata*	Northern Shoveler		
ANATIDAE	*Anas crecca*	Green-winged Teal		
ANATIDAE	*Anas penelope*	Eurasian Wigeon		
ANATIDAE	*Anas querquedula*	Garganey		
ANATIDAE	*Dendrocygna viduata*	White-faced Whistling-Duck		
ANATIDAE	*Nettapus auritus*	African Pygmy-Goose		
ANATIDAE	*Plectropterus gambensis*	Spur-winged Goose		
ANATIDAE	*Sarkidiornis melanotos*	Comb Duck		X
ANATIDAE	*Thalassornis leuconotus*	White-backed Duck		
ANHINGIDAE	*Anhinga rufa*	African Darter		X
APODIDAE	*Apus affinis*	Little Swift		
APODIDAE	*Apus apus*	Common Swift		
APODIDAE	*Apus caffer*	White-rumped Swift		
APODIDAE	*Apus pallidus*	Pallid Swift		
APODIDAE	*Cypsiurus parvus*	African Palm-Swift		
APODIDAE	*Telacanthura ussheri*	Mottled Spinetail		
ARDEIDAE	*Ardea alba*	Great Egret		X
ARDEIDAE	*Ardea cinerea*	Gray Heron		X

Family	Species	Common name	IUCN status	Recorded
ARDEIDAE	*Ardea goliath*	Goliath Heron		
ARDEIDAE	*Ardea melanocephala*	Black-headed Heron		
ARDEIDAE	*Ardea purpurea*	Purple Heron		
ARDEIDAE	*Ardeola ralloides*	Squacco Heron		
ARDEIDAE	*Bubulcus ibis*	Cattle Egret		X
ARDEIDAE	*Butorides striata*	Striated Heron		
ARDEIDAE	*Egretta ardesiaca*	Black Heron		
ARDEIDAE	*Egretta garzetta*	Little Egret		
ARDEIDAE	*Egretta gularis*	Western Reef-Heron		
ARDEIDAE	*Gorsachius leuconotus*	White-backed Night-Heron		X
ARDEIDAE	*Ixobrychus minutus*	Little Bittern		
ARDEIDAE	*Ixobrychus sturmii*	Dwarf Bittern		
ARDEIDAE	*Mesophoyx intermedia*	Intermediate Egret		X
ARDEIDAE	*Nycticorax nycticorax*	Black-crowned Night-Heron		
ARDEIDAE	*Tigriornis leucolopha*	White-crested Bittern		
BUCEROTIDAE	*Bucorvus abyssinicus*	Abyssinian Ground-Hornbill		
BUCEROTIDAE	*Ceratogymna elata*	Yellow-casqued Hornbill	NT	
BUCEROTIDAE	*Ceratogymna fistulator*	Piping Hornbill		
BUCEROTIDAE	*Tockus erythrorhynchus*	Northern Red-billed Hornbill		X
BUCEROTIDAE	*Tockus fasciatus*	African Pied Hornbill		
BUCEROTIDAE	*Tockus nasutus*	African Gray Hornbill		X
BUPHAGIDAE	*Buphagus africanus*	Yellow-billed Oxpecker		
BURHINIDAE	*Burhinus senegalensis*	Senegal Thick-knee		
CAMPEPHAGIDAE	*Campephaga phoenicea*	Red-shouldered Cuckoo-shrike		
CAMPEPHAGIDAE	*Coracina pectoralis*	White-breasted Cuckoo-shrike		
CAPRIMULGIDAE	*Caprimulgus climacurus*	Long-tailed Nightjar		
CAPRIMULGIDAE	*Caprimulgus europaeus*	Eurasian Nightjar		
CAPRIMULGIDAE	*Caprimulgus inornatus*	Plain Nightjar		
CAPRIMULGIDAE	*Caprimulgus nigriscapularis*	Black-shouldered Nightjar		
CAPRIMULGIDAE	*Caprimulgus pectoralis*	Fiery-necked Nightjar		X
CAPRIMULGIDAE	*Caprimulgus ruficollis*	Red-necked Nightjar		
CAPRIMULGIDAE	*Macrodipteryx longipennis*	Standard-winged Nightjar		
CAPRIMULGIDAE	*Macrodipteryx vexillarius*	Pennant-winged Nightjar		
CERTHIIDAE	*Salpornis spilonotus*	Spotted Creeper		
CHARADRIIDAE	*Charadrius alexandrinus*	Kentish Plover		
CHARADRIIDAE	*Charadrius dubius*	Little Ringed Plover		
CHARADRIIDAE	*Charadrius forbesi*	Forbes's Plover		
CHARADRIIDAE	*Charadrius hiaticula*	Common Ringed Plover		

Family	Species	Common name	IUCN status	Recorded
CHARADRIIDAE	*Charadrius pecuarius*	Kittlitz's Plover		X
CHARADRIIDAE	*Pluvialis squatarola*	Black-bellied Plover		
CHARADRIIDAE	*Vanellus albiceps*	White-headed Lapwing		
CHARADRIIDAE	*Vanellus lugubris*	Senegal Lapwing		
CHARADRIIDAE	*Vanellus senegallus*	Wattled Lapwing		
CHARADRIIDAE	*Vanellus spinosus*	Spur-winged Plover		
CHARADRIIDAE	*Vanellus tectus*	Black-headed Lapwing		
CICONIIDAE	*Ciconia ciconia*	White Stork		
CICONIIDAE	*Ciconia episcopus*	Woolly-necked Stork		
CICONIIDAE	*Ciconia nigra*	Black Stork		
CICONIIDAE	*Ephippiorhynchus senegalensis*	Saddle-billed Stork		
CICONIIDAE	*Leptoptilos crumeniferus*	Marabou Stork		
CICONIIDAE	*Mycteria ibis*	Yellow-billed Stork		
CISTICOLIDAE	*Camaroptera brachyura*	Green-backed Camaroptera		
CISTICOLIDAE	*Camaroptera chloronota*	Olive-green Camaroptera		
CISTICOLIDAE	*Cisticola brachypterus*	Siffling Cisticola		
CISTICOLIDAE	*Cisticola cantans*	Singing Cisticola		X
CISTICOLIDAE	*Cisticola dorsti*	Dorst's Cisticola		
CISTICOLIDAE	*Cisticola erythrops*	Red-faced Cisticola		
CISTICOLIDAE	*Cisticola eximius*	Black-necked Cisticola		
CISTICOLIDAE	*Cisticola galactotes*	Winding Cisticola		
CISTICOLIDAE	*Cisticola juncidis*	Zitting Cisticola		X
CISTICOLIDAE	*Cisticola lateralis*	Whistling Cisticola		
CISTICOLIDAE	*Cisticola natalensis*	Croaking Cisticola		X
CISTICOLIDAE	*Cisticola ruficeps*	Red-pate Cisticola		
CISTICOLIDAE	*Cisticola rufus*	Rufous Cisticola		
CISTICOLIDAE	*Eremomela pusilla*	Senegal Eremomela		
CISTICOLIDAE	*Hypergerus atriceps*	Oriole Warbler		
CISTICOLIDAE	*Prinia erythroptera*	Red-winged Prinia		
CISTICOLIDAE	*Prinia subflava*	Tawny-flanked Prinia		
COLIIDAE	*Urocolius macrourus*	Blue-naped Mousebird		
COLUMBIDAE	*Columba guinea*	Speckled Pigeon		
COLUMBIDAE	*Oena capensis*	Namaqua Dove		X
COLUMBIDAE	*Streptopelia decipiens*	Mourning Collared-Dove		
COLUMBIDAE	*Streptopelia hypopyrrha*	Adamawa Turtle-Dove		
COLUMBIDAE	*Streptopelia semitorquata*	Red-eyed Dove		
COLUMBIDAE	*Streptopelia senegalensis*	Laughing Dove		X
COLUMBIDAE	*Streptopelia turtur*	European Turtle-Dove		X

Family	Species	Common name	IUCN status	Recorded
COLUMBIDAE	*Streptopelia vinacea*	Vinaceous Dove		
COLUMBIDAE	*Treron calvus*	African Green-Pigeon		X
COLUMBIDAE	*Treron waalia*	Bruce's Green-Pigeon		
COLUMBIDAE	*Turtur abyssinicus*	Black-billed Wood-Dove		
COLUMBIDAE	*Turtur afer*	Blue-spotted Wood-Dove		
COLUMBIDAE	*Turtur tympanistria*	Tambourine Dove		
CORACIIDAE	*Coracias abyssinicus*	Abyssinian Roller		
CORACIIDAE	*Coracias cyanogaster*	Blue-bellied Roller		X
CORACIIDAE	*Coracias naevius*	Rufous-crowned Roller		X
CORACIIDAE	*Eurystomus glaucurus*	Broad-billed Roller		
CORACIIDAE	*Eurystomus gularis*	Blue-throated Roller		
CORVIDAE	*Corvus albus*	Pied Crow		
CUCULIDAE	*Centropus grillii*	Black Coucal		
CUCULIDAE	*Centropus leucogaster*	Black-throated Coucal		
CUCULIDAE	*Centropus monachus*	Blue-headed Coucal		
CUCULIDAE	*Centropus senegalensis*	Senegal Coucal		X
CUCULIDAE	*Ceuthmochares aereus*	Yellowbill		
CUCULIDAE	*Chrysococcyx caprius*	Dideric Cuckoo		X
CUCULIDAE	*Chrysococcyx cupreus*	African Emerald Cuckoo		
CUCULIDAE	*Chrysococcyx klaas*	Klaas's Cuckoo		
CUCULIDAE	*Clamator glandarius*	Great Spotted Cuckoo		
CUCULIDAE	*Clamator jacobinus*	Pied Cuckoo		
CUCULIDAE	*Clamator levaillantii*	Levaillant's Cuckoo		
CUCULIDAE	*Cuculus canorus*	Common Cuckoo		
CUCULIDAE	*Cuculus clamosus*	Black Cuckoo		X
CUCULIDAE	*Cuculus gularis*	African Cuckoo		
CUCULIDAE	*Cuculus solitarius*	Red-chested Cuckoo		
DICRURIDAE	*Dicrurus adsimilis*	Fork-tailed Drongo		X
DICRURIDAE	*Dicrurus ludwigii*	Square-tailed Drongo		
EMBERIZIDAE	*Emberiza affinis*	Brown-rumped Bunting		
EMBERIZIDAE	*Emberiza cabanisi*	Cabanis's Bunting		
EMBERIZIDAE	*Emberiza tahapisi*	Cinnamon-breasted Bunting		
ESTRILDIDAE	*Amadina fasciata*	Cut-throat		
ESTRILDIDAE	*Estrilda caerulescens*	Lavender Waxbill		
ESTRILDIDAE	*Estrilda melpoda*	Orange-cheeked Waxbill		X
ESTRILDIDAE	*Estrilda troglodytes*	Black-rumped Waxbill		
ESTRILDIDAE	*Euodice cantans*	African Silverbill		
ESTRILDIDAE	*Lagonosticta larvata*	Black-faced Firefinch		

Family	Species	Common name	IUCN status	Recorded
ESTRILDIDAE	*Lagonosticta rubricata*	African Firefinch		
ESTRILDIDAE	*Lagonosticta rufopicta*	Bar-breasted Firefinch		
ESTRILDIDAE	*Lagonosticta senegala*	Red-billed Firefinch		
ESTRILDIDAE	*Nesocharis capistrata*	Gray-headed Oliveback		
ESTRILDIDAE	*Nigrita bicolor*	Chestnut-breasted Negrofinch		
ESTRILDIDAE	*Ortygospiza atricollis*	Black-faced Quailfinch		
ESTRILDIDAE	*Pyrenestes sanguineus*	Crimson Seedcracker		
ESTRILDIDAE	*Pytilia melba*	Green-winged Pytilia		X
ESTRILDIDAE	*Pytilia phoenicoptera*	Red-winged Pytilia		
ESTRILDIDAE	*Spermestes bicolor*	Black-and-white Mannikin		
ESTRILDIDAE	*Spermestes cucullatus*	Bronze Mannikin		
ESTRILDIDAE	*Spermestes fringilloides*	Magpie Mannikin		
ESTRILDIDAE	*Spermophaga haematina*	Western Bluebill		
ESTRILDIDAE	*Sporaeginthus subflavus*	Zebra Waxbill		
ESTRILDIDAE	*Uraeginthus bengalus*	Red-cheeked Cordonbleu		
FALCONIDAE	*Falco alopex*	Fox Kestrel		
FALCONIDAE	*Falco ardosiaceus*	Gray Kestrel		
FALCONIDAE	*Falco biarmicus*	Lanner Falcon		
FALCONIDAE	*Falco chicquera*	Red-necked Falcon		
FALCONIDAE	*Falco cuvierii*	African Hobby		
FALCONIDAE	*Falco naumanni*	Lesser Kestrel	VU	
FALCONIDAE	*Falco peregrinus*	Peregrine Falcon		
FALCONIDAE	*Falco tinnunculus*	Eurasian Kestrel		
GLAREOLIDAE	*Cursorius temminckii*	Temminck's Courser		
GLAREOLIDAE	*Glareola pratincola*	Collared Pratincole		
GLAREOLIDAE	*Pluvianus aegyptius*	Egyptian Plover		
GLAREOLIDAE	*Rhinoptilus chalcopterus*	Bronze-winged Courser		
GRUIDAE	*Balearica pavonina*	Black Crowned-Crane	VU	
GRUIDAE	*Grus grus*	Common Crane		
HAEMATOPODIDAE	*Haematopus ostralegus*	Eurasian Oystercatcher		
HIRUNDINIDAE	*Cecropis abyssinica*	Lesser Striped-Swallow		
HIRUNDINIDAE	*Cecropis daurica*	Red-rumped Swallow		
HIRUNDINIDAE	*Cecropis semirufa*	Rufous-chested Swallow		
HIRUNDINIDAE	*Cecropis senegalensis*	Mosque Swallow		
HIRUNDINIDAE	*Delichon urbicum*	Common House-Martin		
HIRUNDINIDAE	*Hirundo leucosoma*	Pied-winged Swallow		
HIRUNDINIDAE	*Hirundo lucida*	Red-chested Swallow		
HIRUNDINIDAE	*Hirundo nigrita*	White-throated Blue Swallow		

Family	Species	Common name	IUCN status	Recorded
HIRUNDINIDAE	*Hirundo rustica*	Barn Swallow		
HIRUNDINIDAE	*Hirundo smithii*	Wire-tailed Swallow		
HIRUNDINIDAE	*Petrochelidon preussi*	Preuss's Swallow		
HIRUNDINIDAE	*Psalidoprocne obscura*	Fanti Sawwing		
HIRUNDINIDAE	*Pseudhirundo griseopyga*	Gray-rumped Swallow		
HYDROBATIDAE	*Hydrobates pelagicus*	European Storm-Petrel		
HYDROBATIDAE	*Oceanites oceanicus*	Wilson's Storm-Petrel		
HYLIOTIDAE	*Hyliota flavigaster*	Yellow-bellied Hyliota		
INDICATORIDAE	*Indicator exilis*	Least Honeyguide		
INDICATORIDAE	*Indicator indicator*	Greater Honeyguide		
INDICATORIDAE	*Indicator maculatus*	Spotted Honeyguide		
INDICATORIDAE	*Indicator minor*	Lesser Honeyguide		X
INDICATORIDAE	*Indicator willcocksi*	Willcock's Honeyguide		
INDICATORIDAE	*Melichneutes robustus*	Lyre-tailed Honeyguide		
JACANIDAE	*Actophilornis africanus*	African Jacana		X
LANIIDAE	*Corvinella corvina*	Yellow-billed Shrike		
LANIIDAE	*Lanius gubernator*	Emin's Shrike		
LARIDAE	*Anous minutus*	Black Noddy		
LARIDAE	*Anous stolidus*	Brown Noddy		
LARIDAE	*Chlidonias hybrida*	Whiskered Tern		
LARIDAE	*Chlidonias leucopterus*	White-winged Tern		
LARIDAE	*Chlidonias niger*	Black Tern		
LARIDAE	*Chroicocephalus cirrocephalus*	Gray-hooded Gull		
LARIDAE	*Gelochelidon nilotica*	Gull-billed Tern		
LARIDAE	*Hydroprogne caspia*	Caspian Tern		
LARIDAE	*Larus fuscus*	Lesser Black-backed Gull		
LARIDAE	*Onychoprion anaethetus*	Bridled Tern		
LARIDAE	*Onychoprion fuscatus*	Sooty Tern		
LARIDAE	*Sterna dougallii*	Roseate Tern		
LARIDAE	*Sterna hirundo*	Common Tern		
LARIDAE	*Sterna paradisaea*	Arctic Tern		
LARIDAE	*Sternula albifrons*	Little Tern		
LARIDAE	*Thalasseus maximus*	Royal Tern		
LARIDAE	*Thalasseus sandvicensis*	Sandwich Tern		
LARIDAE	*Xema sabini*	Sabine's Gull		
LEIOTHRICHIDAE	*Phyllanthus atripennis*	Capuchin Babbler		
LEIOTHRICHIDAE	*Turdoides plebejus*	Brown Babbler		
LEIOTHRICHIDAE	*Turdoides reinwardtii*	Blackcap Babbler		

Family	Species	Common name	IUCN status	Recorded
LYBIIDAE	*Lybius bidentatus*	Double-toothed Barbet		
LYBIIDAE	*Lybius dubius*	Bearded Barbet		X
LYBIIDAE	*Lybius vieilloti*	Vieillot's Barbet		
LYBIIDAE	*Pogoniulus bilineatus*	Yellow-rumped Tinkerbird		
LYBIIDAE	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird		
MACROSPHENIDAE	*Melocichla mentalis*	Moustached Grass-Warbler		
MACROSPHENIDAE	*Sylvietta brachyura*	Northern Crombec		
MALACONOTIDAE	*Dryoscopus gambensis*	Northern Puffback		
MALACONOTIDAE	*Laniarius barbarus*	Common Gonolek		
MALACONOTIDAE	*Laniarius turatii*	Turati's Boubou		
MALACONOTIDAE	*Malaconotus blanchoti*	Gray-headed Bushshrike		
MALACONOTIDAE	*Nilaus afer*	Brubru		
MALACONOTIDAE	*Tchagra senegalus*	Black-crowned Tchagra		X
MALACONOTIDAE	*Telophorus sulfureopectus*	Sulphur-breasted Bushshrike		
MEROPIDAE	*Merops albicollis*	White-throated Bee-eater		
MEROPIDAE	*Merops apiaster*	European Bee-eater		X
MEROPIDAE	*Merops bulocki*	Red-throated Bee-eater		
MEROPIDAE	*Merops hirundineus*	Swallow-tailed Bee-eater		
MEROPIDAE	*Merops nubicus*	Northern Carmine Bee-eater		
MEROPIDAE	*Merops orientalis*	Green Bee-eater		
MEROPIDAE	*Merops persicus*	Blue-cheeked Bee-eater		
MEROPIDAE	*Merops pusillus*	Little Bee-eater		X
MONARCHIDAE	*Ptilostomus afer*	Piapiac		
MONARCHIDAE	*Terpsiphone rufiventer*	Black-headed Paradise-Flycatcher		
MONARCHIDAE	*Terpsiphone viridis*	African Paradise-Flycatcher		
MOTACILLIDAE	*Anthus leucophrys*	Plain-backed Pipit		
MOTACILLIDAE	*Macronyx croceus*	Yellow-throated Longclaw		
MOTACILLIDAE	*Motacilla aguimp*	African Pied Wagtail		X
MOTACILLIDAE	*Motacilla clara*	Mountain Wagtail		
MOTACILLIDAE	*Motacilla flava*	Western Yellow Wagtail		X
MUSCICAPIDAE	*Alethe diademata*	Fire-crested Alethe		
MUSCICAPIDAE	*Bradornis pallidus*	Pale Flycatcher		
MUSCICAPIDAE	*Cercotrichas podobe*	Black Scrub-Robin		X
MUSCICAPIDAE	*Cossypha albicapilla*	White-crowned Robin-Chat		
MUSCICAPIDAE	*Cossypha niveicapilla*	Snowy-crowned Robin-Chat		
MUSCICAPIDAE	*Ficedula hypoleuca*	European Pied Flycatcher		X
MUSCICAPIDAE	*Fraseria cinerascens*	White-browed Forest-Flycatcher		
MUSCICAPIDAE	*Luscinia megarhynchos*	Common Nightingale		

Family	Species	Common name	IUCN status	Recorded
MUSCICAPIDAE	*Melaenornis edolioides*	Northern Black-Flycatcher		
MUSCICAPIDAE	*Monticola saxatilis*	Rufous-tailed Rock-Thrush		
MUSCICAPIDAE	*Muscicapa aquatica*	Swamp Flycatcher		
MUSCICAPIDAE	*Muscicapa striata*	Spotted Flycatcher		
MUSCICAPIDAE	*Myioparus plumbeus*	Gray Tit-Flycatcher		
MUSCICAPIDAE	*Myrmecocichla albifrons*	White-fronted Black-Chat		
MUSCICAPIDAE	*Oenanthe oenanthe*	Northern Wheatear		
MUSCICAPIDAE	*Phoenicurus phoenicurus*	Common Redstart		
MUSCICAPIDAE	*Saxicola rubetra*	Whinchat		
MUSOPHAGIDAE	*Corythaeola cristata*	Great Blue Turaco		X
MUSOPHAGIDAE	*Crinifer piscator*	Western Plantain-eater		X
MUSOPHAGIDAE	*Musophaga violacea*	Violet Turaco		
MUSOPHAGIDAE	*Tauraco persa*	Guinea Turaco		
NECTARINIIDAE	*Anthreptes gabonicus*	Mouse-brown Sunbird		
NECTARINIIDAE	*Anthreptes longuemarei*	Western Violet-backed Sunbird		
NECTARINIIDAE	*Chalcomitra senegalensis*	Scarlet-chested Sunbird		
NECTARINIIDAE	*Cinnyris chloropygius*	Olive-bellied Sunbird		
NECTARINIIDAE	*Cinnyris coccinigastrus*	Splendid Sunbird		
NECTARINIIDAE	*Cinnyris cupreus*	Copper Sunbird		
NECTARINIIDAE	*Cinnyris pulchellus*	Beautiful Sunbird		
NECTARINIIDAE	*Cinnyris venustus*	Variable Sunbird		
NECTARINIIDAE	*Cyanomitra obscura*	Western Olive Sunbird		X
NECTARINIIDAE	*Cyanomitra olivacea*	Eastern Olive Sunbird		
NECTARINIIDAE	*Cyanomitra verticalis*	Green-headed Sunbird		
NECTARINIIDAE	*Hedydipna collaris*	Collared Sunbird		
NECTARINIIDAE	*Hedydipna platura*	Pygmy Sunbird		
NICATORIDAE	*Nicator chloris*	Yellow-spotted Nicator		
NUMIDIDAE	*Guttera pucherani*	Crested Guineafowl		
NUMIDIDAE	*Numida meleagris*	Helmeted Guineafowl		
ORIOLIDAE	*Oriolus auratus*	African Golden Oriole		X
ORIOLIDAE	*Oriolus oriolus*	Eurasian Golden Oriole		
OTIDIDAE	*Eupodotis senegalensis*	White-bellied Bustard		
OTIDIDAE	*Lissotis melanogaster*	Black-bellied Bustard		
OTIDIDAE	*Neotis denhami*	Stanley Bustard	NT	
PANDIONIDAE	*Pandion haliaetus*	Osprey		
PARIDAE	*Melaniparus guineensis*	White-shouldered Black-Tit		
PASSERIDAE	*Passer domesticus*	House Sparrow		X
PASSERIDAE	*Passer griseus*	Northern Gray-headed Sparrow		

Family	Species	Common name	IUCN status	Recorded
PASSERIDAE	*Petronia dentata*	Bush Petronia		
PELECANIDAE	*Pelecanus onocrotalus*	Great White Pelican		
PELECANIDAE	*Pelecanus rufescens*	Pink-backed Pelican		
PELLORNEIDAE	*Illadopsis fulvescens*	Brown Illadopsis		
PELLORNEIDAE	*Illadopsis puveli*	Puvel's Illadopsis		
PHALACROCORACIDAE	*Phalacrocorax africanus*	Long-tailed Cormorant		
PHALACROCORACIDAE	*Phalacrocorax carbo*	Great Cormorant		X
PHASIANIDAE	*Francolinus ahantensis*	Ahanta Francolin		
PHASIANIDAE	*Francolinus bicalcaratus*	Double-spurred Francolin		X
PHASIANIDAE	*Ptilopachus petrosus*	Stone Partridge		
PHOENICOPTERIDAE	*Phoenicopterus minor*	Lesser Flamingo	NT	
PHOENICOPTERIDAE	*Phoenicopterus roseus*	Greater Flamingo		
PHOENICULIDAE	*Phoeniculus purpureus*	Green Woodhoopoe		
PHOENICULIDAE	*Rhinopomastus aterrimus*	Black Scimitar-bill		
PHYLLOSCOPIDAE	*Phylloscopus sibilatrix*	Wood Warbler		
PHYLLOSCOPIDAE	*Phylloscopus trochilus*	Willow Warbler		
PICIDAE	*Campethera abingoni*	Golden-tailed Woodpecker		X
PICIDAE	*Campethera caroli*	Brown-eared Woodpecker		
PICIDAE	*Campethera maculosa*	Little Green Woodpecker		
PICIDAE	*Campethera nivosa*	Buff-spotted Woodpecker		
PICIDAE	*Campethera punctuligera*	Fine-spotted Woodpecker		
PICIDAE	*Dendropicos fuscescens*	Cardinal Woodpecker		X
PICIDAE	*Dendropicos goertae*	Gray Woodpecker		
PICIDAE	*Dendropicos obsoletus*	Brown-backed Woodpecker		
PICIDAE	*Jynx torquilla*	Eurasian Wryneck		
PLATYSTEIRIDAE	*Batis senegalensis*	Senegal Batis		X
PLATYSTEIRIDAE	*Bias musicus*	Black-and-white Shrike-flycatcher		
PLATYSTEIRIDAE	*Platysteira cyanea*	Brown-throated Wattle-eye		
PLOCEIDAE	*Anaplectes rubriceps*	Red-headed Weaver		X
PLOCEIDAE	*Bubalornis albirostris*	White-billed Buffalo-Weaver		
PLOCEIDAE	*Euplectes afer*	Yellow-crowned Bishop		
PLOCEIDAE	*Euplectes franciscanus*	Orange Bishop		X
PLOCEIDAE	*Euplectes hordeaceus*	Black-winged Bishop		X
PLOCEIDAE	*Euplectes macroura*	Yellow-shouldered Widowbird		
PLOCEIDAE	*Malimbus nitens*	Gray's Malimbe		
PLOCEIDAE	*Malimbus rubricollis*	Red-headed Malimbe		
PLOCEIDAE	*Pachyphantes superciliosus*	Compact Weaver		
PLOCEIDAE	*Plocepasser superciliosus*	Chestnut-crowned Sparrow-Weaver		X

Family	Species	Common name	IUCN status	Recorded
PLOCEIDAE	*Ploceus cucullatus*	Village Weaver		X
PLOCEIDAE	*Ploceus heuglini*	Heuglin's Masked-Weaver		
PLOCEIDAE	*Ploceus luteolus*	Little Weaver		
PLOCEIDAE	*Ploceus melanocephalus*	Black-headed Weaver		
PLOCEIDAE	*Ploceus nigricollis*	Black-necked Weaver		
PLOCEIDAE	*Quelea erythrops*	Red-headed Quelea		
PLOCEIDAE	*Quelea quelea*	Red-billed Quelea		X
PLOCEIDAE	*Sporopipes frontalis*	Speckle-fronted Weaver		
PODICIPEDIDAE	*Tachybaptus ruficollis*	Little Grebe		
PRIONOPIDAE	*Prionops plumatus*	White Helmetshrike		
PROCELLARIIDAE	*Calonectris diomedea*	Cory's Shearwater		
PROCELLARIIDAE	*Pterodroma feae*	Fea's Petrel	NT	
PROCELLARIIDAE	*Puffinus mauretanicus*	Balearic Shearwater	CR	
PROCELLARIIDAE	*Puffinus puffinus*	Manx Shearwater		
PSITTACIDAE	*Poicephalus robustus*	Brown-necked Parrot		
PSITTACIDAE	*Poicephalus senegalus*	Senegal Parrot		
PSITTACIDAE	*Psittacula krameri*	Rose-ringed Parakeet		
PSITTACIDAE	*Psittacus erithacus*	Gray Parrot	NT	
PTEROCLIDAE	*Pterocles quadricinctus*	Four-banded Sandgrouse		
PYCNONOTIDAE	*Atimastillas flavicollis*	Yellow-throated Greenbul		
PYCNONOTIDAE	*Bleda canicapillus*	Gray-headed Bristlebill		
PYCNONOTIDAE	*Chlorocichla simplex*	Simple Greenbul		
PYCNONOTIDAE	*Criniger calurus*	Red-tailed Greenbul		
PYCNONOTIDAE	*Eurillas virens*	Little Greenbul		
PYCNONOTIDAE	*Phyllastrephus scandens*	Leaf-love		
PYCNONOTIDAE	*Pycnonotus barbatus*	Common Bulbul		
PYCNONOTIDAE	*Stelgidillas gracilirostris*	Slender-billed Greenbul		
PYCNONOTIDAE	*Thescelocichla leucopleura*	Swamp Greenbul		
RALLIDAE	*Amaurornis flavirostra*	Black Crake		
RALLIDAE	*Crecopsis egregia*	African Crake		
RALLIDAE	*Gallinula chloropus*	Eurasian Moorhen		X
RALLIDAE	*Porphyrio alleni*	Allen's Gallinule		
RALLIDAE	*Porzana parva*	Little Crake		
RALLIDAE	*Porzana pusilla*	Baillon's Crake		
RALLIDAE	*Sarothrura pulchra*	White-spotted Flufftail		
RECURVIROSTRIDAE	*Himantopus himantopus*	Black-winged Stilt		
RECURVIROSTRIDAE	*Recurvirostra avosetta*	Pied Avocet		X
REMIZIDAE	*Anthoscopus parvulus*	Yellow Penduline-Tit		

Family	Species	Common name	IUCN status	Recorded
ROSTRATULIDAE	*Rostratula benghalensis*	Greater Painted-snipe		
SAGITTARIIDAE	*Sagittarius serpentarius*	Secretary-bird		
SCOLOPACIDAE	*Actitis hypoleucos*	Common Sandpiper		X
SCOLOPACIDAE	*Arenaria interpres*	Ruddy Turnstone		
SCOLOPACIDAE	*Calidris alba*	Sanderling		
SCOLOPACIDAE	*Calidris alpina*	Dunlin		
SCOLOPACIDAE	*Calidris canutus*	Red Knot		
SCOLOPACIDAE	*Calidris ferruginea*	Curlew Sandpiper		
SCOLOPACIDAE	*Calidris minuta*	Little Stint		
SCOLOPACIDAE	*Calidris temminckii*	Temminck's Stint		
SCOLOPACIDAE	*Gallinago gallinago*	Common Snipe		
SCOLOPACIDAE	*Gallinago media*	Great Snipe	NT	
SCOLOPACIDAE	*Limosa lapponica*	Bar-tailed Godwit		
SCOLOPACIDAE	*Limosa limosa*	Black-tailed Godwit	NT	
SCOLOPACIDAE	*Lymnocryptes minimus*	Jack Snipe		
SCOLOPACIDAE	*Numenius arquata*	Eurasian Curlew	NT	
SCOLOPACIDAE	*Numenius phaeopus*	Whimbrel		
SCOLOPACIDAE	*Phalaropus fulicarius*	Red Phalarope		
SCOLOPACIDAE	*Philomachus pugnax*	Ruff		
SCOLOPACIDAE	*Tringa erythropus*	Spotted Redshank		
SCOLOPACIDAE	*Tringa glareola*	Wood Sandpiper		
SCOLOPACIDAE	*Tringa nebularia*	Common Greenshank		
SCOLOPACIDAE	*Tringa ochropus*	Green Sandpiper		
SCOLOPACIDAE	*Tringa stagnatilis*	Marsh Sandpiper		
SCOLOPACIDAE	*Tringa totanus*	Common Redshank		
SCOPIDAE	*Scopus umbretta*	Hamerkop		X
STENOSTIRIDAE	*Elminia longicauda*	African Blue-Flycatcher		
STERCORARIIDAE	*Stercorarius parasiticus*	Parasitic Jaeger		
STRIGIDAE	*Bubo cinerascens*	Grayish Eagle-Owl		
STRIGIDAE	*Bubo lacteus*	Verreaux's Eagle-Owl		
STRIGIDAE	*Glaucidium perlatum*	Pearl-spotted Owlet		
STRIGIDAE	*Otus scops*	European Scops-Owl		
STRIGIDAE	*Otus senegalensis*	African Scops-Owl		
STRIGIDAE	*Ptilopsis leucotis*	Northern White-faced Owl		
STRIGIDAE	*Scotopelia peli*	Pel's Fishing-Owl		
STRIGIDAE	*Strix woodfordii*	African Wood-Owl		
STURNIDAE	*Cinnyricinclus leucogaster*	Violet-backed Starling		
STURNIDAE	*Lamprotornis caudatus*	Long-tailed Glossy-Starling		X

Family	Species	Common name	IUCN status	Recorded
STURNIDAE	*Lamprotornis chalcurus*	Bronze-tailed Glossy-Starling		
STURNIDAE	*Lamprotornis chloropterus*	Lesser Blue-eared Glossy-Starling		X
STURNIDAE	*Lamprotornis pulcher*	Chestnut-bellied Starling		
STURNIDAE	*Lamprotornis purpureus*	Purple Glossy-Starling		X
STURNIDAE	*Lamprotornis splendidus*	Splendid Glossy-Starling		
SYLVIIDAE	*Hylia prasina*	Green Hylia		
SYLVIIDAE	*Sylvia atricapilla*	Blackcap		
SYLVIIDAE	*Sylvia borin*	Garden Warbler		
THRESKIORNITHIDAE	*Bostrychia hagedash*	Hadada Ibis		X
THRESKIORNITHIDAE	*Platalea alba*	African Spoonbill		
THRESKIORNITHIDAE	*Plegadis falcinellus*	Glossy Ibis		
THRESKIORNITHIDAE	*Threskiornis aethiopicus*	Sacred Ibis		
TURDIDAE	*Turdus pelios*	African Thrush		X
TURNICIDAE	*Turnix sylvaticus*	Small Buttonquail		
TYTONIDAE	*Tyto alba*	Barn Owl		
UPUPIDAE	*Upupa epops*	Eurasian Hoopoe		
VIDUIDAE	*Vidua camerunensis*	Cameroon Indigobird		
VIDUIDAE	*Vidua chalybeata*	Village Indigobird		
VIDUIDAE	*Vidua funerea*	Variable Indigobird		X
VIDUIDAE	*Vidua larvaticola*	Baka Indigobird		
VIDUIDAE	*Vidua macroura*	Pin-tailed Whydah		
VIDUIDAE	*Vidua raricola*	Jambandu Indigobird		
VIDUIDAE	*Vidua wilsoni*	Pale-winged Indigobird		
ZOSTEROPIDAE	*Zosterops senegalensis*	African Yellow White-eye		X

APPENDIX E6

Mammal Species in Guinea-Bissau

January 2014
Report No. 13514950200.550/B.0

Family	Species	Common name	IUCN status	Recorded
ANOMALURIDAE	*Anomalurops beechcrofti*	Beechcroft's Scaly-tailed Squirrel		
BOVIDAE	*Alcelaphus buselaphus*	Hartebeest		
BOVIDAE	*Cephalophus dorsalis*	Bay Duiker		
BOVIDAE	*Cephalophus maxwellii*	Maxwell's Duiker		
BOVIDAE	*Cephalophus monticola*	Blue Duiker		x
BOVIDAE	*Cephalophus niger*	Black Duiker		
BOVIDAE	*Cephalophus ogilbyi*	Ogilby's Duiker		
BOVIDAE	*Cephalophus rufilatus*	Red-flanked Duiker		
BOVIDAE	*Cephalophus silvicultor*	Yellow-backed Duiker		
BOVIDAE	*Cephalophus zebra*	Zebra Duiker		
BOVIDAE	*Hippotragus equinus*	Roan Antilope		
BOVIDAE	*Kobus ellipsiprymnus*	Waterbuck		
BOVIDAE	*Neotragus pygmaeus*	Royal Antelope		
BOVIDAE	*Ourebia ourebi*	Oribi		
BOVIDAE	*Redunca redunca*	Bohor Reedbuck		
BOVIDAE	*Silvicapra grimmia*	Common Duiker		
BOVIDAE	*Syncerus caffer*	Cape (African) Buffalo, Bushcow		
BOVIDAE	*Tragelaphus eurycerus*	Bongo		
BOVIDAE	*Tragelaphus spekii*	Sitatunga		
BOVIDAE	*Tragelaphus scriptus*	Bushbuck, Harnessed Antelope		
CANIDAE	*Lycaon pictus*	African Wild Dog	EN	
CANIDAE	*Vulpes pallida*	Pale Fox		
CERCOPITHECIDAE	*Cercocebus atys*	Sooty Mangabey	VU	
CERCOPITHECIDAE	*Cercocebus torquatus*	Collared Mangabey		
CERCOPITHECIDAE	*Cercopithecus campbelli*	Campbell's Mona Monkey		
CERCOPITHECIDAE	*Cercopithecus aethiops*	Vervet Monkey		x
CERCOPITHECIDAE	*Cercopithecus diana*	Diana Monkey		
CERCOPITHECIDAE	*Cercopithecus petaurista*	Lesser Spot-nosed Guenon		x
CERCOPITHECIDAE	*Colobus polykomos*	King Colobus	VU	
CERCOPITHECOIDEA	*Erythrocebus patas*	Patas, Hussar Monkey, Nisnas		
CERCOPITHECOIDEA	*Papio anubis*	Olive Baboon		
CERCOPITHECOIDEA	*Papio papio*	Guinea Baboon	NT	
CERCOPITHECOIDEA	*Procolubus badius*	Red Colobus	EN	x
CERCOPITHECOIDEA	*Procolubus verus*	Van Beden's Colobus		
ELEPHANTIDAE	*Loxodonta africana*	African Bush Elephant	VU	
EMBALLONURIDAE	*Coleura afra*	African Sheath-tailed Bat		
EMBALLONURIDAE	*Saccolaimus peli*	Pel's Pouched Bat		
ERINACEIDAE	*Atelerix albiventris*	Four-toed (African) Hedgehog		

FELIDAE	*Caracal caracal*	Caracal		
FELIDAE	*Felis silvestris*	Common Wild Cat		
FELIDAE	*Leptailurus serval*	Serval		
FELIDAE	*Panthera leo*	Lion	VU	
FELIDAE	*Panthera pardus*	Leopard	NT	
FELIDAE	*Profelis aurata*	African Golden Cat		
GALAGIDAE	*Galago senegalensis*	Senegal Bushbaby		x
GALAGIDAE	*Galago demidoff*	Demidoff's dwarf Galago		
GIRAFFIDAE	*Giraffa cameliopardis*	Giraffe		
HEPESTIDAE	*Herpestes ichneumon*	Egyptian Mongoose		
HEPESTIDAE	*Liberiictis kuhni*	Liberian Mongoose		
HIPPOPOTAMIDAE	*Hippopotamus amphibius*	Common Hippopotamus	VU	
HOMINIDAE	*Pan troglodytes*	Common Chimpanzee	EN	
HYAENIDAE	*Crocuta crocuta*	Spotted Hyaena		
HYSTRICIDAE	*Atherurus africanus*	African Bush-tailed Porcupine		x
LEPORIDAE	*Lepus capensis*	Cape Hare		
LEPORIDAE	*Lepus microtis*	African Savanna Hare		
LORISIDAE	*Perodicticus potto*	Potto		
MANIDAE	*Manis gigantea*	Giant Pangolin		
MANIDAE	*Manis tricuspis*	Tree Pangolin		
MOLOSSIDAE	*Chaerephon bemmeleni*	Gland-tailed Free-tailed Bat		
MOLOSSIDAE	*Chaerephon major*	Lappet-eared Free-tailed Bat		
MOLOSSIDAE	*Chaerephon pumila*	Little Free-tailed Bat		
MOLOSSIDAE	*Mops brachypterus*	Sierra Leone Free-tailed Bat		
MOLOSSIDAE	*Mops condylurus*	Angolan Free-tailed Bat		
MOLOSSIDAE	*Mops nanulus*	Dwarf Free-tailed Bat		
MOLOSSIDAE	*Mops thersites*	Railer Bat		
MOLOSSIDAE	*Mops trevori*	Trevor's Free-tailed Bat		
MURIDAE	*Arvicanthis rufinus*	Guinean Arvicanthus		
MURIDAE	*Arvicanthis ansorgei*	Sudanian Arvicanthis		
MURIDAE	*Dasymys rufulus*	West African Shaggy Rat		
MURIDAE	*Dephomys defua*	Defua Rat		
MURIDAE	*Grammomys buntingi*	Bunting's Thicket Rat		
MURIDAE	*Grammomys rutilans*	Shining Thicket Rat		
MURIDAE	*Hybomys planifrons*	Miller's striped Mous		
MURIDAE	*Hybomys trivirgatus*	West African Habomys		
MURIDAE	*Hylomyscus alleni*	Allen's Wood Mouse		
MURIDAE	*Lemniscomys bellieri*	Zebra Mouse		
MURIDAE	*Lemniscomys linulus*	Senegal Grass Mouse		

MURIDAE	*Lemniscomys striatus*	Striped Grass Mouse		x
MURIDAE	*Lophuromys sikapusi*	Rusty-bellied Brush-furred Rat		
MURIDAE	*Malacomys edwardsi*	Edward's Swamp Rat		
MURIDAE	*Mastomys erythroleucus*	Gunea Multimammate Mouse		x
MURIDAE	*Mastomys natalensis*	Multimammate Mouse		x
MURIDAE	*Mus baoulei*	Baoule's Mouse		
MURIDAE	*Mus mattheyi*	Matthew's Mouse		
MURIDAE	*Mus minutoides*	African Pygmy Mouse		
MURIDAE	*Mus setulosus*	Peter's Mouse		
MURIDAE	*Mylomys dybowskii*	Mill Rat		
MURIDAE	*Oenomys ornatus*	Ghana Rufous-nosed Rat		
MURIDAE	*Praomys daltoni*	Dalton's Praomys		
MURIDAE	*Praomys jacksoni*	Jackson's Soft-furred Rat		
MURIDAE	*Praomys rostratus*	West African Praomys		x
MURIDAE	*Praomys tullbergi*	Tullberg's Soft-furred Mouse		
MURIDAE	*Tatera guineae*	Guinea Gerbil		
MURIDAE	*Tatera kempi*	Kemp's Gerbil		
MURIDAE	*Taterillus gracilis*	Slender Gerbil		
MURIDAE	*Uranomys ruddi*	Rudd's Mouse		
MUSTELIDAE	*Aonyx capensis*	African Clawless Otter		
MUSTELIDAE	*Ictonyx striatus*	Striped Polecat, Zorilla		
MUSTELIDAE	*Lutra maculicollis*	Speckle-throated Otter		
NANDINIIDAE	*Nandinia binotata*	African Palm Civet		
NESOMVIDAE	*Cricetomys gambianus*	Gambian Pouched Rat		x
NESOMVIDAE	*Cricetomys emini*	Emin's Pouched Rat		
NESOMVIDAE	*Dendromus melanotis*	Gray Climbing Mouse		x
NYCTERIDAE	*Nycteris arge*	Bate's Slit Faced Bat		
NYCTERIDAE	*Nycteris gambiensis*	Gambian Slit Faced Bat		x
NYCTERIDAE	*Nycteris grandis*	Greater Slit-faced Bat		
NYCTERIDAE	*Nycteris hispida*	Hairy Slit-faced Bat		
NYCTERIDAE	*Nycteris intermedia*	Intermediate Slit-faced Bat		
NYCTERIDAE	*Nycteris macrotis*	Greater Slit-faced Bat		
NYCTERIDAE	*Nycteris major*	Ja Slit Faced Bat		
NYCTERIDAE	*Nycteris thebaica*	Egiptian Slit-faced Bat		
PROCAVIIDAE	*Dendrohyrax dorsalis*	Western Tree Hyrax		
PROCAVIIDAE	*Procavia capensis*	Cape Hyrax		
PTEROPODIDAE	*Eidolon helvum*	Straw-coloured Fruit Bat	NT	
PTEROPODIDAE	*Epomophorus gambianus*	Gambian Epauletted Fruit Bat		
PTEROPODIDAE	*Epomops buettikoferi*	Buettikofer's Epauletted Fruit Bat		

PTEROPODIDAE	*Hypsignathus monstrosus*	Hammerhead Fruit Bat		
PTEROPODIDAE	*Lissonycteris smithi*	Smith's Fruit Bat		
PTEROPODIDAE	*Megaloglossus woermanni*	Woermann's Fruit Bat		
PTEROPODIDAE	*Mycropteropus pusillus*	Peter's Dwarf Epauletted Fruit Bat		
PTEROPODIDAE	*Myonycteris torquata*	Little Collared Fruit Bat		
PTEROPODIDAE	*Nanonycteris veldkampi*	Veldkamp's Bat		
PTEROPODIDAE	*Rousettus aegyptiacus*	Egyptian Fruit Bat		
PTEROPODIDAE	*Scotonycteris zenkeri*	Zenker's Fruit Bat		
RHINOLOPHIDAE	*Hipposideros abae*	Alba Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros beatus*	Benito Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros caffer*	Sundevall's Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros cyclops*	Cyclops Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros fuliginosus*	Sooty Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros gigas*			
RHINOLOPHIDAE	*Hipposideros jonesi*	Jones's Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros lamottei*	Lamotte's Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros marisae*	Aellen's Roundleaf Bat		
RHINOLOPHIDAE	*Hipposideros ruber*	Noack's Roundleaf Bat		
RHINOLOPHIDAE	*Rhinolophus alcyone*			
RHINOLOPHIDAE	*Rhinolophus denti*	Dent's Horseshoe Bat		
RHINOLOPHIDAE	*Rhinolophus fumigatus*	Ruppell's Horseshoe Bat		
RHINOLOPHIDAE	*Rhinolophus guineensis*	Guinean Horseshoe Bat		
RHINOLOPHIDAE	*Rhinolophus hillorum*	Hill's Horseshoe Bat		
RHINOLOPHIDAE	*Rhinolophus landeri*	Lander's Horseshoe Bat		
RHINOLOPHIDAE	*Rhinolophus maclaudi*	Maclaud's Bat		
RHINOLOPHIDAE	*Rhinolophus simulator*	Bushveld Horseshoe Bat		
RHINOLOPHIDAE	*Rhinolophus ziama*			
SCIURIDAE	*Funisciurus pyrropus*	Fire-footed Rope Squirrel		
SCIURIDAE	*Heliosciurus gambianus*	Gambian Sun Squirrel		
SCIURIDAE	*Heliosciurus punctatus*	Small Sun Squirrel		
SCIURIDAE	*Paraxerus poensis*	Green Bush Squirrel		
SCIURIDAE	*Xerus erythropus*	Striped Ground Squirrel		x
SCUIRIDAE	*Heliosciurus rufobrachium*	Red-legged Sun Squirrel		
SORICIDAE	*Crocidura buettikoferi*	Buettikofer's Forest Shrew		
SORICIDAE	*Crocidura crossei*	Crosse's Musk Shrew		
SORICIDAE	*Crocidura denti*	Dent's Shrew		
SORICIDAE	*Crocidura foxi*	Fox's Shrew		
SORICIDAE	*Crocidura fuscomurina*	Bicolored Shrew/Tiny Musk Shrew		
SORICIDAE	*Crocidura grassei*	Grasse's Shrew		

SORICIDAE	*Crocidura lamottei*	Lamotte's Shrew		
SORICIDAE	*Crocidura lusitania*	Mauritanian Shrew		
SORICIDAE	*Crocidura muricauda*	Mouse-tailed Shrew		
SORICIDAE	*Crocidura nanilla*	Tiny White-toothed Shrew		
SORICIDAE	*Crocidura nimbae*	Nimba Shrew		
SORICIDAE	*Crocidura obscurior*	Obscure Pygmy Shrew		
SORICIDAE	*Crocidura poensis*	Fraser's Musk Shrew		x
SORICIDAE	*Crocidura theresae*	Therese's Shrew		
SORICIDAE	*Sylvisorex megalura*	Climbing Shrew		
SUIDAE	*Hylochoerus meinertzhageni*	Giant forest Hog		
SUIDAE	*Phacochoerus africanus*	Warthog		
SUIDAE	*Potamochoerus porcus*	Red River Hog, African Bush Pig		
TANGULIDAE	*Hyemoschus aquaticus*			
THRYONOMYIDAE	*Thryonomys swinderianus*	Greater Cane Rat		
TRICHECHIDAE	*Trichechus senegalensis*	African Manatee		
VESPERTILIONIDAE	*Glauconycteris poensis*	Albo Bat		
VESPERTILIONIDAE	*Hypsugo crassulus*	Broad-headed Pipistrelle		
VESPERTILIONIDAE	*Kerivoula cuprosa*	Copper Woolly Bat		
VESPERTILIONIDAE	*Kerivoula lanosa*	Lesser Woolly Bat		
VESPERTILIONIDAE	*Kerivoula phalaena*	Spurell's Woolly Bat		
VESPERTILIONIDAE	*Mimertillus moloneyi*	Moloney's Flat Headed Bat		
VESPERTILIONIDAE	*Miniopterus inflatus*	Greater Long-fingered Bat		
VESPERTILIONIDAE	*Miniopterus schreibersi*	Schreiber's Long-fingered Bat		
VESPERTILIONIDAE	*Myotis bocagii*	Rufous Mouse-eared Bat		
VESPERTILIONIDAE	*Myotis welwitschii*	Welwitch's Bat		
VESPERTILIONIDAE	*Neoromicia capensis*	Cape Serotine		
VESPERTILIONIDAE	*Neoromicia guineensis*	Tiny Serotine		
VESPERTILIONIDAE	*Neoromicia nanus*	Banana Pipistrelle		
VESPERTILIONIDAE	*Neoromicia somalicus*	Somali Serotine		
VESPERTILIONIDAE	*Neoromicia tenuipinnis*	White-winged Serotine		
VESPERTILIONIDAE	*Pipistrellus nanulus*	Tiny Pipistrelle		x
VESPERTILIONIDAE	*Scotophilus dinganii*	African Yellow Bat		
VESPERTILIONIDAE	*Scotophilus leucogaster*	White-bellied Yellow Bat		
VESPERTILIONIDAE	*Scotophilus nux*	Nut-coloured Yellow Bat		
VIVERRIDAE	*Civettictis civetta*	African Civet Cat		
VIVERRIDAE	*Genetta genetta*	Common Genet		
VIVERRIDAE	*Genetta maculata*	Rusty-spotted Genet		

APPENDIX E7

Species of Concern – Data Sheets

GREEN TURTLE (*CHELONIA MYDAS*)

Description

Green sea turtles, *Chelonia mydas*, are Chelonians — which means they have four legs and a tough shell made of two parts which join at the sides.

The green sea turtle's legs are shaped like flippers. Their heads are lizard-like, with a hooked beak and toothless jaw. Adult green sea turtles may grow up to 99 cm long and weigh 180 kg (Fortes, et al., 1998).

The top half of their shell is called the carapace. It feels smooth and is gray, green, brown and/or black. It's tougher than the under shell, which is called the plastron and is yellowish white. Males have a larger tail than females, slightly longer, narrower carapaces than females and enlarged curved claws on the front flippers for gripping the female when mating (MarineBio Conservation Society, 2013a).

The top half of their shell is called the carapace. It feels smooth and is gray, green, brown and/or black. It's tougher than the under shell, which is called the plastron and is yellowish white. Males have a larger tail than females, slightly longer, narrower carapaces than females and enlarged curved claws on the front flippers for gripping the female when mating (MarineBio Conservation Society, 2013a).

Controversy rages about splitting *Chelonia mydas* into subspecies based on the many size differences between populations in different parts of the world. The population found in the eastern Pacific is often called the black sea turtle, and is sometimes described as a separate species (*Chelonia agassizi*). Individuals from the East Pacific are smaller than their counterparts in the Western Caribbean in a wide range of external measurements, and are particularly dark in color, a trait that has shown to be genetically influenced (MarineBio Conservation Society, 2013a).

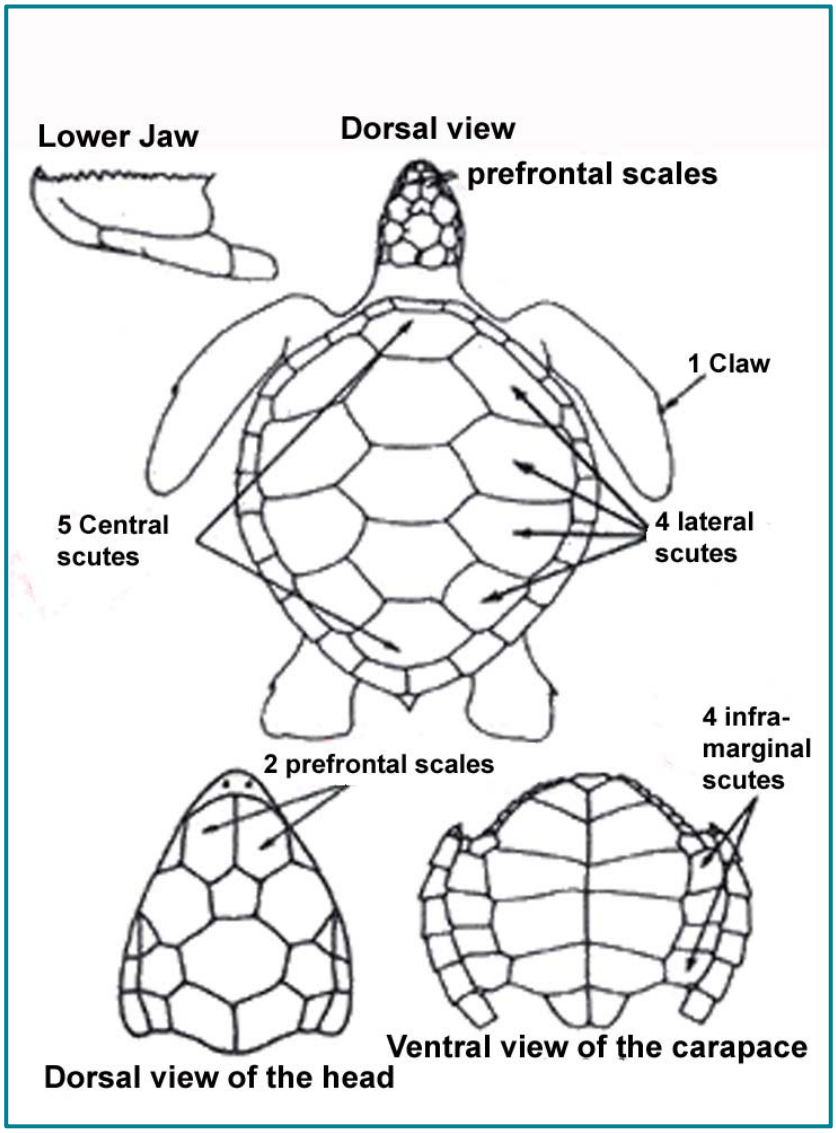

Figure 1: Descriptive characteristics of Chelonia mydas (reproduced from MarineBio Conservation Society, 2013)

Sea turtles spend almost all their lives submerged but must breathe air for the oxygen needed to meet the demands of vigorous activity. With a single explosive exhalation and rapid inhalation, sea turtles can quickly replace the air in their lungs. The lungs are adapted to permit a rapid exchange of oxygen and to prevent gasses from being trapped during deep dives. The blood of sea turtles can deliver oxygen efficiently to body tissues even at the pressures encountered during diving (MarineBio Conservation Society, 2013a).

Geographic Range

Range Description

The Green Turtle has a circum-global distribution (Figure 2), occurring throughout tropical and, to a lesser extent, subtropical waters (Atlantic Ocean – eastern central, northeast, northwest, southeast, southwest, western central; Indian Ocean – eastern, western; Mediterranean Sea; Pacific Ocean – eastern central, northwest, southwest, western central) (Seminoff, 2004). Green turtles are highly migratory and they undertake complex movements and migrations through geographically disparate habitats. Nesting occurs in more than 80 countries worldwide (Hirth, 1997). Their movements within the marine environment are less understood but it is believed that green turtles inhabit coastal waters of over 140 countries (Groombridge & Luxmoore, 1989).

Countries

According to Groombridge & Luxmoore, (1989), *C. mydas* occurs in American Samoa (American Samoa), Angola (Angola), Anguilla, Antigua and Barbuda, Australia (Ashmore-Cartier Is., Coral Sea Is. Territory, Northern Territory, Queensland, Western Australia), Bahrain, Bangladesh, Barbados, Belize, Brazil, British Indian Ocean Territory, China, Christmas Island, Cocos (Keeling) Islands, Colombia, Comoros, Cook Islands, Costa Rica, Cuba, Cyprus, Dominica, Dominican Republic, Ecuador (Galápagos), Egypt, Equatorial Guinea (Bioko), Eritrea, Fiji, French Guiana, French Polynesia, French Southern Territories (the) (Mozambique Channel Is.), Grenada, Guam, Guinea, Guinea-Bissau, Guyana, Haiti, India (Andaman Is., Gujarat, Laccadive Is., Nicobar Is.), Indonesia (Bali, Irian Jaya, Jawa, Kalimantan, Lesser Sunda Is., Maluku, Sulawesi, Sumatera), Iran, Islamic Republic of, Jamaica, Japan (Honshu, Nansei-shoto, Ogasawara-shoto), Kenya, Kiribati, Kuwait, Madagascar, Malaysia (Peninsular Malaysia, Sabah, Sarawak), Maldives, Marshall Islands, Martinique, Mauritania, Mayotte, Mexico (Baja California, Campeche, Michoacán, Quintana Roo, Revillagigedo Is., Sinaloa, Sonora, Tabasco, Tamaulipas, Veracruz, Yucatán), Micronesia, Federated States of, Mozambique, Myanmar, Netherlands Antilles (Bonaire, Netherlands Leeward Is.), New Caledonia, New Zealand (Kermadec Is., North Is., South Is.), Nicaragua, Niue, Northern Mariana Islands, Oman, Pakistan, Palau, Panama, Papua New Guinea, Peru, Philippines, Puerto Rico, Saint Helena, Ascension and Tristan da Cunha (Ascension), Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Sao Tomé and Principe, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Solomon Islands, Somalia, Sri Lanka, Suriname, Tanzania, United Republic of, Thailand, Timor-Leste, Tokelau, Tonga, Trinidad and Tobago, Turkey, Turks and Caicos Islands, Tuvalu, United Arab Emirates, United States (Florida, Hawaiian Is.), United States Minor Outlying Islands (Midway Is., US Line Is.), Vanuatu, Venezuela (Aves I., Venezuelan Antilles), Viet Nam, Virgin Islands, British, Virgin Islands, U.S. and Yemen.

FAO Marine Fishing areas

According to (Seminoff, 2004), *Chelonia mydas* is gound in the following FAO Marine fishing areas:

- Atlantic – southwest;
- Atlantic – northwest; Atlantic – northeast;
- Atlantic – western central;
- Atlantic – eastern central;
- Atlantic – southeast;
- Indian Ocean – eastern and western;
- Mediterranean and Black Sea;
- Pacific – southwest;
- Pacific – eastern central;
- Pacific – western central; and
- Pacific – northwest.

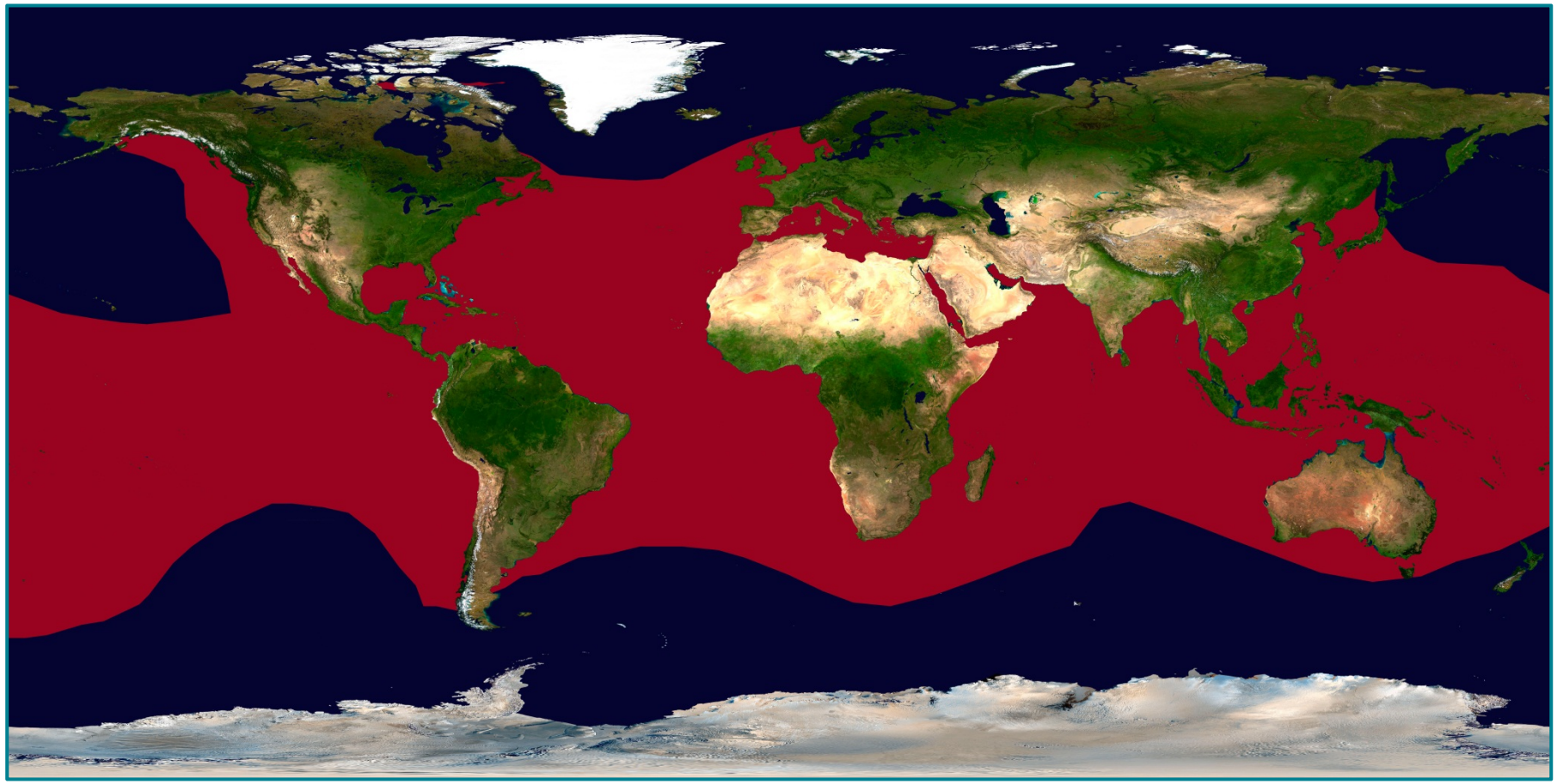

Figure 2: Geographic distribution range of Chelonia mydas

Population

The current global population of this species is difficult to determine due to a lack of substantial, dependable data. The population size is thought to have decreased rapidly over the last few decades (Seminoff, 2004).

Population Trend

Decreasing (Seminoff, 2004)

Habitat and Ecology

Habitats

Like most sea turtles, green turtles are highly migratory and use a wide range of broadly separated localities and habitats during their lifetimes (Hirth, 1997). Upon leaving the nesting beach, it has been hypothesized that hatchlings begin an oceanic phase (Carr, 1986), perhaps floating passively in major current systems (gyres) that serve as open-ocean developmental grounds (Carr & Meylan, 1980). After a number of years in the oceanic zone, these turtles recruit to neritic developmental areas rich in seagrass and/or marine algae where they forage and grow until maturity (Limpus & Walter, 1980). Upon attaining sexual maturity green turtles commence breeding migrations between foraging grounds and nesting areas that are undertaken every few years (Hirth, 1997). Migrations are carried out by both males and females and may traverse oceanic zones, often spanning thousands of kilometers (Carr, 1986). During non-breeding periods adults reside at coastal neritic feeding areas that sometimes coincide with juvenile developmental habitats (Limpus & Walter, 1980; Seminoff, 2004).

Demographic features / Reproduction

Nesting can take between one and three hours. After a female turtle drags herself up the beach, she hollows out a pit with her back legs and deposits from fifty to two hundred eggs. When the last egg is laid, the turtle covers the eggs with sand, tamps down the sand with her plastron, and flings more sand about with her flippers to erase any signs of the nest. The green sea turtle has also been observed often digging another "decoy" nest next to the real one to deceive predators and keep their eggs safe (Seminoff, 2004).

After about two months, the hatchling turtles emerge at night. The light reflected off the water from the sky guides them to the sea. These days, car headlights, street lamps, or lights on buildings near the beach cause some hatchlings to travel in the wrong direction. Waiting herons make fast meals of other hatchlings. Any babies still on the beach in the morning are easily picked off by predators or die in the hot sun. It is thought that when the surviving hatchlings reach maturity, they return to the beach where they hatched to lay their eggs (Seminoff, 2004).

The female green sea turtle lays 70-130 eggs - each one about the size of a ping-pong ball. About two months later the eggs hatch and the young turtles head straight for sea. Somehow they know that they must live in the water and not on land. Baby green sea turtles weigh about 1 ounce, and are about 5cm long (Groombridge & Luxmoore, 1989).

Feeding

Green sea turtles eat seaweed and algae, but they also eat sea creatures like jellyfish, comb jellies, crayfish, and crabs (Limpus & Walter, 1980).

Systems

Marine and terrestrial (Seminoff, 2004).

Threats

Green turtles, like other sea turtle species, are particularly susceptible to population declines because of their vulnerability to anthropogenic impacts during all life-stages: from eggs to adults. Perhaps the most detrimental human threats to green turtles are the intentional harvests of eggs and adults from nesting beaches and juveniles and adults from foraging grounds. Unfortunately, harvest remains legal in several countries despite substantial subpopulation declines (Seminoff, 2004). In addition, a number of incidental

threats impact green turtles around the world. These threats affect both terrestrial and marine environments, and include bycatch in marine fisheries, habitat degradation at nesting beaches and feeding areas, and disease. Mortality associated with entanglement in marine fisheries is the primary incidental threat; the responsible fishing techniques include drift netting, shrimp trawling, dynamite fishing, and long-lining. Degradation of both nesting beach habitat and marine habitats also play a role in the decline of many Green Turtle stocks. Nesting habitat degradation results from the construction of buildings, beach armoring, re-nourishment and/or sand extraction (Seminoff, 2004). These factors may directly, through loss of beach habitat, or indirectly, through changing thermal profiles and increasing erosion, serve to decrease the quantity and quality of nesting area available to females, and may evoke a change in the natural behaviors of adults and hatchlings (Seminoff, 2004). The presence of lights on or adjacent to nesting beaches alters the behavior of nesting adults (Seminoff, 2004) and is often fatal to emerging hatchlings as they are attracted to light sources and drawn away from the water (Seminoff, 2004). Habitat degradation in the marine environment results from increased effluent and contamination from coastal development, construction of marinas, increased boat traffic, and harvest of nearshore marine algae resources. Combined, these impacts diminish the health of coastal marine ecosystems and may, in turn, adversely affect green turtles. For example, degradation of marine habitats has been implicated in the increasing prevalence of the tumor-causing Fibropapilloma disease (Seminoff, 2004).

Conservation Actions

Green turtles have been afforded legislative protection under a number of treaties and laws (Seminoff, 2004). Among the more globally relevant designations are those of Endangered by the World Conservation Union (IUCN, 2013; Groombridge & Luxmoore, 1989; Hilton-Taylor, 2000); Annex II of the SPAW Protocol to the Cartagena Convention (a protocol concerning specially protected areas and wildlife); Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora); and Appendices I and II of the Convention on Migratory Species (CMS). A partial list of the International Instruments that benefit green turtles includes the Inter-American Convention for the Protection and Conservation of Sea Turtles, the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA), the Memorandum of Understanding on ASEAN Sea Turtle Conservation and Protection, the Memorandum of Agreement on the Turtle Islands Heritage Protected Area (TIHPA), and the Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa (Seminoff, 2004).

As a result of these designations and agreements, many of the intentional impacts directed at sea turtles have been lessened: harvest of eggs and adults has been slowed at several nesting areas through nesting beach conservation efforts and an increasing number of community-based initiatives are in place to slow the take of turtles in foraging areas. In regard to incidental take, the implementation of Turtle Excluder Devices has proved to be beneficial in some areas, primarily in the United States and South and Central America (National Research Council 1990). However, despite these advances, human impacts continue throughout the world. The lack of effective monitoring in pelagic and near-shore fisheries operations still allows substantial direct and indirect mortality, and the uncontrolled development of coastal and marine habitats threatens to destroy the supporting ecosystems of long-lived green turtles (Seminoff, 2004).

Regionally relevant knowledge

The peak reproductive period for *C.mydas* nesting on Poilão Island appears to be between July and October Figure 3. Expanding the survey effort and recording the number of activities resulting in nests between April and December is necessary to determine the actual size of the nesting population utilizing this site in any given season. In addition, night time surveys were not conducted on all beaches of the island. Both of these factors suggest that the population of *C.mydas* nesting on Poilão Island is far greater than the number of females tagged at this site. By the end of the survey period many untagged females were still being discovered, suggesting that this was the case.

During a study by Fortes *et al* (1998) valuable information was obtained on the *C. mydas* breeding population on the Poilão Island. On the Poilão Island, *Varanus* sp, ("monitor lizard") were observed preying upon marine turtle eggs. *Ocypode cursor*, ("ghost crab") and *Gypohierax angolensis*, ("palm-nut vulture") were also observed preying upon hatchlings (Fortes, et al., 1998).

Based on these preliminary data, they deduced that the *C.mydas* population of Poilão Island represents a large number of reproducing females. This area is one of the most significant nesting sites in the Atlantic and essential to the conservation of this species on the African continent. A more detailed study is likely to demonstrate this site as being among the most important for this species in the world (Fortes, et al., 1998).

Information gathered suggests that the greatest threat to *C.mydas* in Guinea Bissau is the capture of turtles (adults, sub-adults and juvenile) in fishing nets. *C.mydas* is considered a delicacy in the region (Fortes, et al., 1998).

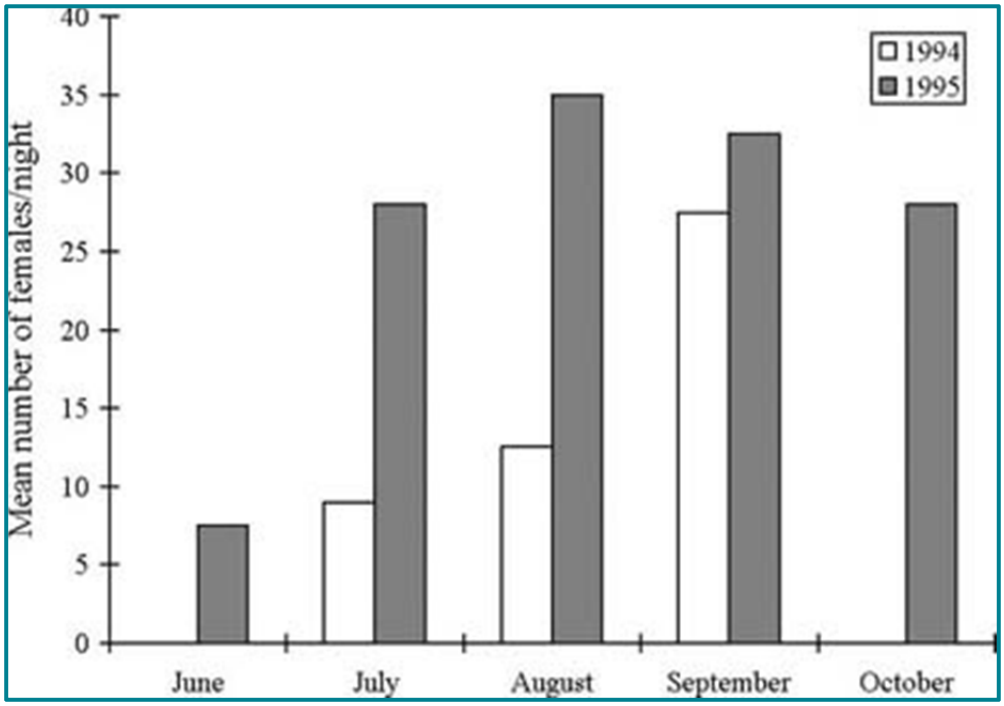

Figure 3: Mean number of female Chelonia mydas *observed per night for the months of surveying in 1994 and 1995.*

HAWKSBILL TURTLE (*ERETMOCHELYS IMB*RICATA)

Description

Hawksbill sea turtles, *Eretmochelys imbricata*, are small to medium-sized sea turtles that take their species name (*imbricata*) from the overlapping plates on their upper shell. Hawksbills get their common name from the shape of its hooked jaw. They reach a length of about 0.62-1.14m (MarineBio Conservation Society, 2013b).

In the U.S. Caribbean, nesting females average about 0.62-0.94m in straight carapace length. Weight is typically to 80 kg in the wider Caribbean, with a record weight of 127 kg. Hatchlings average about 42 mm straight carapace length and range in weight from 13.5-19.5 g. The following characteristics distinguish the hawksbill from other sea turtles: two pairs of prefrontal scales; thick, posteriorly overlapping scutes (plates) on the carapace; four pairs of coastal scutes; two claws on each flipper; and a beak-like mouth (MarineBio Conservation Society, 2013b). The carapace is heart-shaped in very young turtles, and becomes more elongate or subovate with maturity.

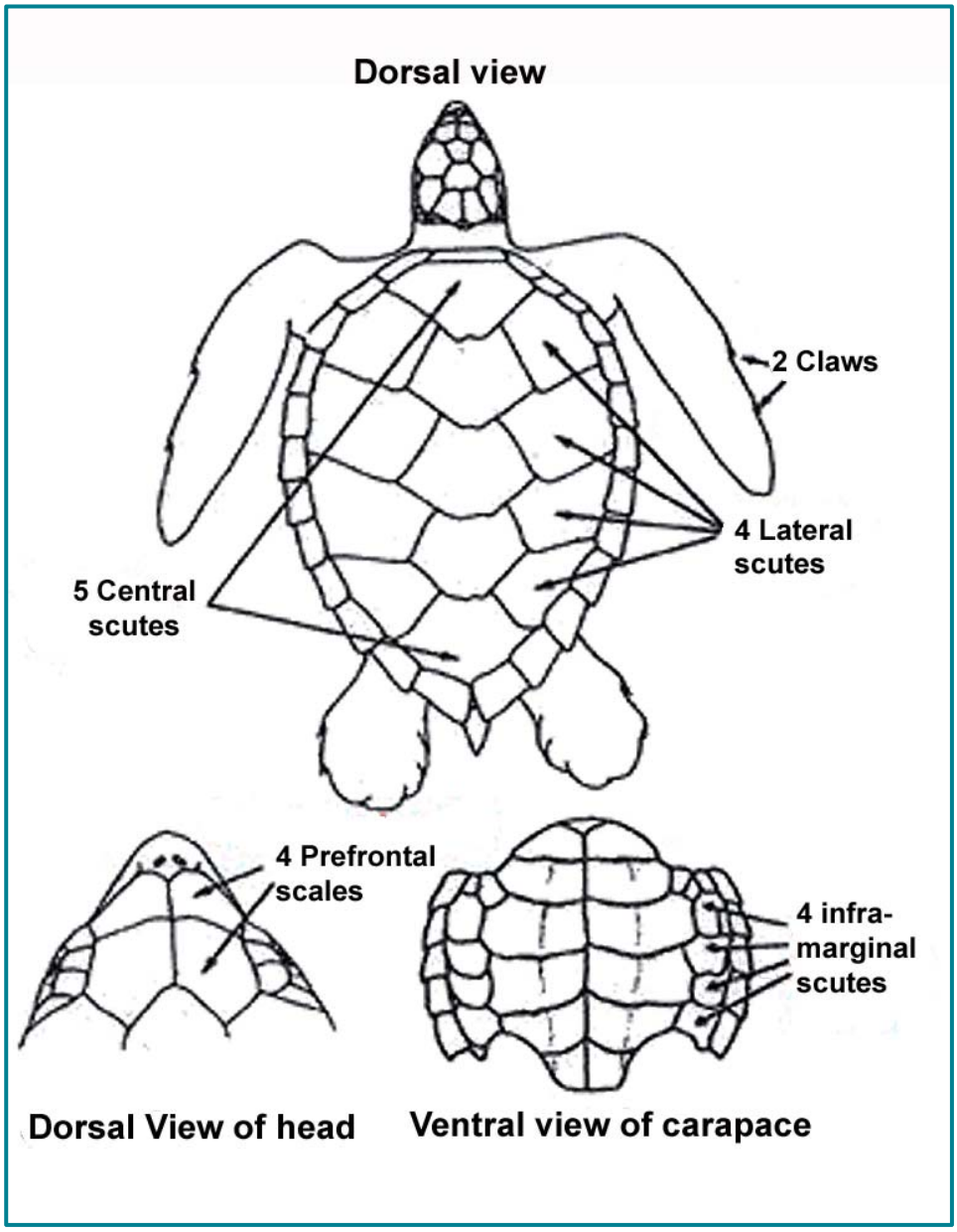

Figure 4: Descriptive characteristics of Eretmochelys imbricate (Reproduced from MarineBio Conservation Society, 2013b)

Its lateral and posterior margins are sharply serrated in all but very old individuals. The epidermal scutes that overlay the bones of the shell are the shells sold commercially. They are unusually thick and overlap posteriorly on the carapace in all but hatchlings and very old individuals. Carpacial scutes are often richly patterned with irregularly radiating streaks of brown or black on an amber background (MarineBio Conservation Society, 2013b). The scutes of the plastron of Atlantic hawksbills are usually clear yellow, with little or no dark pigmentation. The soft skin on the ventral side is cream or yellow and may be pinkish-orange in mature individuals. The scales of the head and forelimbs are dark brown or black with sharply defined yellow borders. There are typically four pairs of inframarginal scales. The head is elongate and tapers sharply to a point. The lower jaw is V-shaped (MarineBio Conservation Society, 2013b).

Eretmochelys imbricata have 5 features that distinguish them from other sea turtles. Their heads have two pairs of prefrontal scales. They also have two claws on each of their forelimbs. There are thick, overlapping

scutes on their carapaces, which also have four pairs of costal scutes. Their elongate mouths resemble a beak, that taper off to a sharp point at the end (MarineBio Conservation Society, 2013b).

Male turtles are distinguished by a brighter pigmentation, a concave plastron, long claws and a thicker tail (MarineBio Conservation Society, 2013b).

Geographic Range

Range Description

The Hawksbill has a circumglobal distribution throughout tropical and, to a lesser extent, subtropical waters of the Atlantic Ocean, Indian Ocean, and Pacific Ocean. Hawksbills are migratory and individuals undertake complex movements through geographically disparate habitats during their lifetimes. Hawksbill nesting occurs in at least 70 countries, although much of it now only at low densities. Their movements within the marine environment are less understood, but Hawksbills are believed to inhabit coastal waters in more than 108 countries ((Groombridge & Luxmoore, 1989).

Countries

Eretmochelys imbricata occur along the coasts of American Samoa (American Samoa), Antigua and Barbuda, Australia, Bahamas, Bahrain, Barbados, Belize, Brazil, British Indian Ocean Territory, Cambodia, China, Colombia, Comoros, Costa Rica, Cuba, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea (Bioko), Eritrea, Fiji, French Southern Territories (the) (Mozambique Channel Is.), Grenada, Guadeloupe, Guam, Honduras, India (Andaman Is., Nicobar Is.), Indonesia, Iran, Islamic Republic of, Jamaica, Japan, Kenya, Kuwait, Madagascar, Malaysia, Maldives, Martinique, Mauritius, Mayotte, Mexico (Campeche, Yucatán), Micronesia, Federated States of, Mozambique, Myanmar, Netherlands Antilles, Nicaragua, Oman, Palau, Panama, Papua New Guinea, Philippines, Puerto Rico, Qatar, Saint Kitts and Nevis, Samoa, Sao Tomé and Principe, Saudi Arabia, Seychelles, Solomon Islands, Somalia, Sri Lanka, Sudan, Taiwan, Province of China, Tanzania, United Republic of, Thailand, Trinidad and Tobago, United Arab Emirates, United States (Hawaiian Is.), Vanuatu, Venezuela, Viet Nam, Virgin Islands, British and Yemen (Seminoff, 2004).

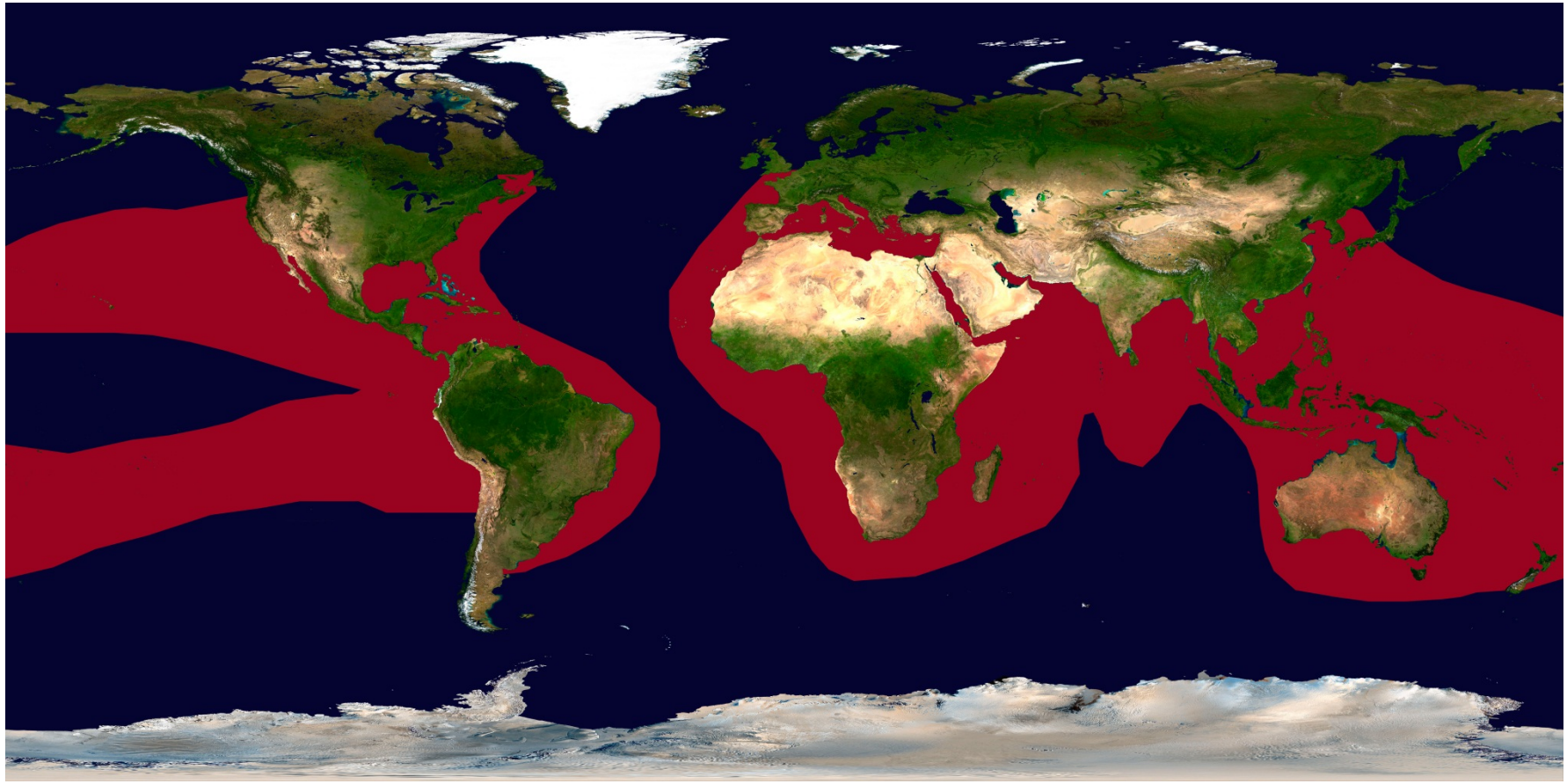

Figure 5: Geographic distribution range of Eretmochelys imbricata

FAO Marine fishing areas

According to Seminoff (2004), *Eretmochelys imbricata* is found in the following FAO marine fishing areas:

- Atlantic – western central;
- Atlantic – eastern central;
- Atlantic – southwest;
- Atlantic – southeast;
- Atlantic – northwest;
- Atlantic – northeast;
- Indian Ocean – eastern;
- Indian Ocean – western;
- Mediterranean and Black Sea;
- Pacific – southwest;
- Pacific – southeast;
- Pacific – northwest;
- Pacific – eastern central; and
- Pacific – western central.

Population

The current global population of this species is difficult to determine due to a lack of substantial, dependable data. The population size is thought to have decreased by approximately 80% over the last century.

Population Trend

In many parts of the world, Hawksbill populations have continued to decline since the publication of the previous Red List Assessment (Meylan & Donnelly, 1999.). Continuing losses in Southeast Asia are of particular concern. Hawksbills face multiple, severe threats. The volume of the tortoiseshell trade has diminished, yet it remains active and substantial, and the Japanese bekko industry remains intact.

In 2001 the IUCN Red List Standards and Petitions Subcommittee upheld the Critically Endangered listing of the Hawksbill, based on ongoing and long-term declines in excess of 80% within the time frame of three generations and ongoing exploitation (IUCN, 2001). The Subcommittee review cited “convincing evidence of reductions in excess of 80% over the last three generations at many, if not most of the important breeding sites throughout the global range of the species”. Not surprisingly, those declines reflect the intensity of the tortoiseshell trade in the 20th Century. Although some relatively large populations still exist, especially in Australia, this is not inconsistent with long-term global or even regional population reduction over three generations (IUCN, 2001).

The current assessment clearly demonstrates the importance of protection in both terrestrial and marine habitats. With protection, some populations have stabilized, and others are now increasing, most notably in the Caribbean. The increases documented in the Caribbean coincide with dramatic reductions in take on the foraging grounds of Cuba which have, in effect, spared tens of thousands of large Hawksbills since the early 1990s. Such increases provide hope for the future, but unfortunately are still the exception rather than the rule (IUCN, 2013).

Habitat and Ecology

Habitats

Hawksbills nest on insular and mainland sandy beaches throughout the tropics and subtropics. They are highly migratory and use a wide range of broadly separated localities and habitats during their lifetimes (Witzell, 1983.). Available data indicate that newly emerged hatchlings enter the sea and are carried by offshore currents into major gyre systems where they remain until reaching a carapace length of some 20 to 30 cm. At that point they recruit into a neritic developmental foraging habitat that may comprise coral reefs or other hard bottom habitats, sea grass, algal beds, or mangrove bays and creeks (Musick & Limus, 1997) or mud flats. As they increase in size, immature Hawksbills typically inhabit a series of developmental habitats, with some tendency for larger turtles to inhabit deeper sites (Bowen, et al., 2007; van Dam & Diez, 1997). Once sexually mature, they undertake breeding migrations between foraging grounds and breeding areas at intervals of several years (Mortimer & Bresson, 1999; Witzell, 1983.). Global population genetic studies have demonstrated the tendency of female sea turtles to return to breed at their natal rookery (Bowen & Karl, 1997), even though as juveniles they may have foraged at developmental habitats located hundreds or thousands of kilometers from the natal beach. While Hawksbills undertake long migrations, some portion of immature animals may settle into foraging habitats near their beaches of origin (Bowen, et al., 2007).

Demographic features / Reproduction

Also found around the Oceanic Islands and Indian Ocean. Hawksbill turtles are most commonly found in coral reef habitats where sponges, a food source for hawksbills, grow on solid substrate. They also reside in shoals, lagoons of oceanic islands and on continental shelves. They are most commonly found in water 18.3m or shallower. The habitats of hawksbills vary by stages in their life cycle. Young hawksbill turtles cannot dive into deep water and therefore live on masses of floating sea plants, such as sargassum. Hawksbills re-enter coastal waters when they reach approximately 20-25cm carapace length. The ledges and caves of the reef provide shelter for resting both during the day and night. Hawksbills are also found around rocky outcrops and high energy shoals, which are also optimum sites for sponge growth. In areas where there are no coral reefs, hawksbills are found in mangrove -fringed bays and estuaries (Bowen & Karl, 1997).

The actual age that hawksbill sea turtles reach sexual maturity is unknown. Mating occurs roughly every 2-3 years mainly in shallow waters. Copulation usually begins near the shore. Hawksbills leave the water only during the breeding season when females dig nests in the sand, typically near vegetation. The entire nesting process takes 1-3 hours. They clear the area and dig a pit in the sand. They lay their eggs in the pit then fill it with sand using their hind limbs. After the eggs are laid and buried, they immediately return to the sea (Bowen, et al., 2007).

After about two months, the hatchling turtles emerge at night. The light reflected off the water from the sky guides them to the sea. These days, car headlights, street lamps, or lights on buildings near the beach cause some hatchlings to travel in the wrong direction. Waiting herons make fast meals of other hatchlings. Any babies still on the beach in the morning are easily picked off by predators or die in the hot sun. It is thought that when the surviving hatchlings reach maturity, they return to the beach where they hatched to lay their eggs (Seminoff, 2004).

Like all turtles, the hard carapace of hawksbills discourages predators. Adult turtles are still consumed by humans, sharks and occasionally crocodiles. Nests are commonly robbed by terrestrial predators such as dogs, raccoons, rats, mongooses and humans. Directly after hatching, hawksbill turtles make the journey to water. Although this trip only takes a few minutes, many hatchlings are preyed upon by various gulls, herons and large crabs (Bowen, et al., 2007).

Feeding

Hawksbill sea turtles are omnivorous with a diet that consists primarily of sponges. They are selective feeders choosing only certain species of sponges of which are toxic to other animals. Sea jellies and other coelenterates are also common prey for hawksbill turtles. They also eat mollusks, fish, marine algae,

crustaceans and other sea plants and animals. A preferred feeding ground of the hawksbills is in shallow shoals abundant with brown algae (Bowen, et al., 2007).

Systems

Marine and terrestrial (Seminoff, 2004).

Threats

Tortoiseshell Trade

Recent and historical tortoiseshell trade statistics are key to understanding the enormous and enduring effect that trade has had on Hawksbill populations around the world. Within the last 100 years, millions of Hawksbills have been killed for the tortoiseshell markets of Europe, the United States and Asia. The global plight of the Hawksbill in the latter half of the 20th Century has been recognized by the inclusion of the species in the most threatened category of IUCN's Red List since 1968 and the listing of all Hawksbill populations on Appendix I of CITES, the Convention on International Trade in Endangered Species, since 1977. Nevertheless, trade continued at exceptionally high levels for years as major trading countries acceded to CITES and Japan, the world's largest consumer of bekko (tortoiseshell), continued to import shell under a CITES reservation (exception) until 1993. During the period 1950-1992, Japan's bekko imports were the equivalent of 1,329,044 large turtles (1,408,787 kg). Conservatively estimating that 30% of the turtles taken for the trade were nesting females, nearly 400,000 adult female Hawksbills were killed for the Japanese market in those years, a time frame that approximates a single Hawksbill generation. Significant domestic trade in Hawksbill products continues to be a major problem in many countries and, despite international and domestic prohibitions and the lessening of the volume in the last decade, trade remains an ongoing and pervasive threat in the Americas and southeast Asia ((Seminoff, 2004).

Egg Collection

Intense levels of egg exploitation continue in many parts of the world, especially Southeast Asia, where it approaches 100% in many areas (Seminoff, 2004).

Slaughter for Meat

Adult and juvenile Hawksbills are still killed for meat in many areas. In some places the meat is used by fishermen as shark bait (J. Mortimer unpubl. data, C. Lagueux, unpubl. data). Fishermen who target lobster and reef fish will commonly take whatever hawksbills they encounter (Seminoff, 2004).

Destruction of Nesting Habitat

Tropical coastlines are rapidly being developed for tourism which often leads to destruction of nesting habitat. Because Hawksbills prefer to nest under vegetation they are particularly impacted by beach-front development and clearing of dune vegetation. Daytime nesting Hawksbills in the Western Indian Ocean are particular sensitive to disturbance from human activity on the coast and in nearshore water (Seminoff, 2004). In other parts of the world such as the Middle East and Western Australia gas and oil refineries seriously disrupt nesting.

Destruction of Foraging Habitat

Hawksbills are typically associated with coral reefs, which are among the world's most endangered marine ecosystems (Seminoff, 2004). Climate change has led to massive coral bleaching events with permanent consequences for local habitats (Seminoff, 2004).

Hybridisation of Hawksbills with Other Species

At certain sites where Hawksbill numbers are particularly low, they regularly hybridise with other species of sea turtles (Seminoff, 2004).

Entanglement and Ingestion of Marine Debris - including Fishing Gear

Hawkbills are particularly susceptible to entanglement in gill nets and capture on fishing hooks. Juvenile Hawksbills comprised 47% of all turtles entangled in derelict fishing nets and other debris in northern

Australian waters (Seminoff, 2004). Ingestion of marine debris by Hawksbills is also significant (Seminoff, 2004).

Oil Pollution

There is evidence oil pollution has a greater impact on Hawksbills than on other species of turtle (Seminoff, 2004). In some parts of the world (especially the Middle East) oil pollution is a major problem.

Conservation Actions

Treaties and Agreements

Hawksbills benefit globally from inclusion in CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (listed on Appendix I) and CMS,the Convention on Migratory Species (listed on Appendices I and II). Regional agreements also help to conserve Hawksbills and their habitats (see Regional Summaries, Appendix II) (Seminoff, 2004).

Public Awareness

Interest in Hawksbills and other species of marine turtles is at an all-time high around the world. Interest in ecotourism is growing (Seminoff, 2004).

Capacity building

Increasing numbers of biologists and conservationists focusing their studies on sea turtles around the world benefit hawksbills (Seminoff, 2004).

Protected Areas

Nesting and foraging sanctuaries protect Hawksbills although effective enforcement remains an elusive goal in many (Seminoff, 2004).

Legislation and Enforcement

Numerous countries have temporarily or permanently banned all exploitation of sea turtles and their eggs and are attempting to improve enforcement of international bans on the tortoiseshell trade (Seminoff, 2004).

Regionally relevant knowledge

Hawksbill turtles have not been well studied in Guinea Bissau. There is a marked interspecific variability in nesting seasonality, with green and hawksbill (*Eretmochelys imbricata*) turtles nesting mostly during the rainy season and olive ridley (*Lepidochelys olivacea*) and leatherback turtles (*Dermochelys coriacea*) during the dry season. Informal interviews all over the coastal zone suggest that sea turtle populations have markedly declined within living memory (Barbosa, et al., 1998). Main threats are poaching of eggs and of nesting females and the incidental capture in fishing gear. Amongst the major achievements of sea turtle conservation efforts are that all species are protected by law, the most important nesting beaches have been included in the protected area network, and significant progress has been made in removing the presence of settlements of foreign fishermen from the areas near the turtle concentrations where accidental captures used to occur (Barbosa, et al., 1998). On the down side, it should be pointed out that protection in the national parks is insufficient. The main problem seems to be the weak enforcement of park and national rules by park authorities, which creates a feeling of relative impunity in park residents and visiting fishermen (Barbosa, et al., 1998).

OLIVE RIDLEY TURTLE (*LEPIDOCHELYS OLIVACEA*)

Description

Olive Ridley sea turtles, *Lepidochelys olivacea*, aka Pacific ridleys, are small, hard-shelled marine turtles, one of the two species of the genus *Lepidochelys*, and a member of the Family Cheloniidae. This species is unique in their variable numbers of vertebral (back) and costal (belly) scutes (bony plates), a characteristic that also varies by geographic location (MarineBio Conservation Society, 2013c). Some Lepidochelys olivacea have only five pairs of costals (the same number as *Lepidochelys kempii*, Kemp's ridley sea turtles); however, in this species a division of costal scutes occurs creating a possible 6-9 pairs (Figure 6) (MarineBio Conservation Society, 2013c). Division of the "standard" scutes occurs at the posterior (rear) end of the carapace. Asymmetry in the number of costal scutes is frequent. Geographic variation in *Lepidochelys olivacea* is subtle, and no subspecies are currently recognized. *Lepidochelys olivacea* with only five pairs of costal scutes are more abundant in the eastern Pacific (MarineBio Conservation Society, 2013c). Another difference that varies by location is the color of the carapace, which is often lighter in *Lepidochelys olivacea* found in the western Atlantic. *Lepidochelys olivacea* found in the eastern Pacific have a more "elevated" carapace (MarineBio Conservation Society, 2013c).

In addition to the division of the costal scutes, the vertebral scutes and scales on the dorsal (upper) surface of their heads also show frequent division. The prefrontal scales typically number two pairs. Juvenile and adult *Lepidochelys olivacea* have wide carapaces, similar to *L. kempii*. Their head is relatively large compared to other sea turtles in the Families Chelonia and *Eretmochelys*, but is smaller than that of adult *Caretta* (loggerheads), and slightly smaller than that of *L. kempii* (MarineBio Conservation Society, 2013c).

Geographic Range

The geographic distribution of the Olive Ridley shares interesting parallels with leatherback sea turtles, *Dermochelys coriacea*. Both species live in tropical open water and nest on Pacific shores of South America, with the Olive Ridley nesting from southern Sonora, Mexico, south to Colombia, and in moderate numbers in West Africa from about Mauritania south to the Congo . Both species occur but are rare in Australia and the Pacific islands. Non-nesting individuals also occur rarely in waters of the southwestern United States. They occur abundantly in Pacific Colombia and Ecuador, but only in small numbers in Peru and Chile (Abreu-Grobois & Plotkin, 2008). *Lepidochelys olivacea* have also been seen occasionally in Galapagos waters. In the Indian Ocean this species can be found in eastern India and Sri Lanka. Nesting has been observed on occasion alongside the green sea turtles at Hawke's Bay, Pakistan and some nesting also occurs in New Britain, Mozambique, Madagascar, peninsular Malaysia and various other localities. In the western Atlantic, nesting has been observed in eastern Surinam and in western French Guiana and northwestern Guyana.

Non-nesting turtles have been seen as far west as Isla Margarita and Trinidad (Abreu-Grobois & Plotkin, 2008).

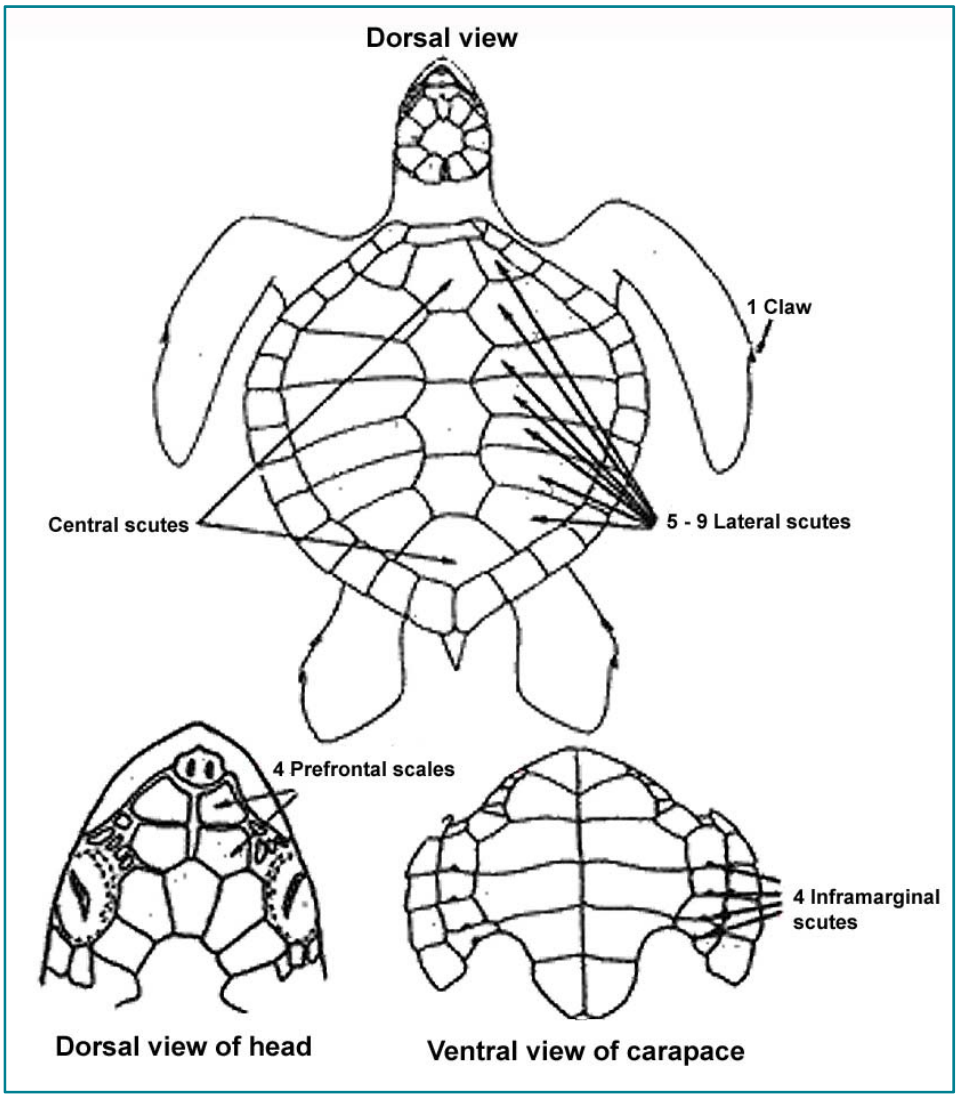

Figure 6: Descriptive characteristics of Lepidochelys olivacea (Reproduced from MarineBio Conservation Society, 2013b)

Range Description

The Olive Ridley sea turtle has a circumtropical distribution (Figure 7), with nesting occurring throughout tropical waters (except the Gulf of Mexico) and migratory circuits in tropical and some subtropical areas (Atlantic Ocean – eastern central, northeast, northwest, southeast, southwest, western central; Indian Ocean – eastern, western; Pacific Ocean – eastern central, northwest, southwest, western central) (Pritchard, 1969). Nesting occurs in nearly 60 countries worldwide. Migratory movements are less well studied than other marine turtle species but are known to involve coastal waters of over 80 countries (see Table 1 in the attached PDF, see link below). With very few exceptions they are not known to move between ocean basins or to cross from one ocean border to the other. Within a region, *Lepidochelys olivacea* may move between the oceanic and neritic zones (Plotkin, et al., 1995; Sarker, 2004) or just occupy neritic waters (Pritchard, 1976).

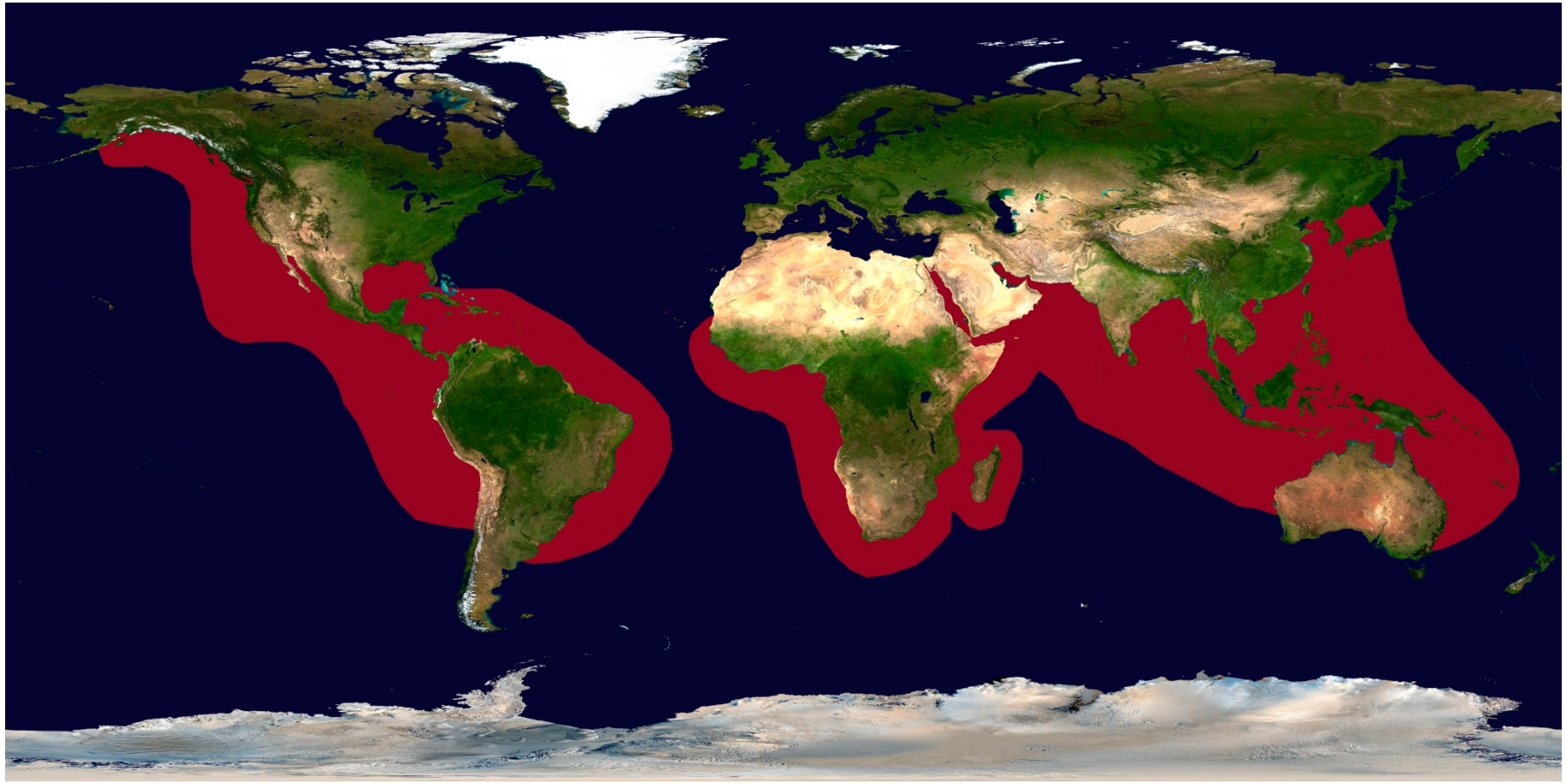

Figure 7: Geographic distribution range of Lepidochelys olivacea

Countries

Lepidochelys olivacea is found in Angola (Angola), Antigua and Barbuda, Australia, Bangladesh, Benin, Brazil, Brunei Darussalam, Cambodia, Cameroon, Cape Verde, Chile, Colombia, Congo, Costa Rica, Côte d'Ivoire, Cuba, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea (Bioko), Eritrea, French Guiana, Gabon, Gambia, Ghana, Guadeloupe, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, India (Andaman Is., Nicobar Is.), Indonesia, Iran, Islamic Republic of, Jamaica, Japan, Kenya, Liberia, Madagascar, Malaysia, Maldives, Martinique, Mauritania, Mexico, Micronesia, Federated States of, Morocco, Mozambique, Myanmar, Namibia, Nicaragua, Nigeria, Oman, Pakistan, Panama, Papua New Guinea, Peru, Philippines, Puerto Rico, Sao Tomé and Principe (São Tomé), Senegal, Sierra Leone, Somalia, South Africa, Sri Lanka, Sudan, Suriname, Taiwan, Province of China, Tanzania, United Republic of, Thailand, Togo, Trinidad and Tobago, United States (Hawaiian Is.), Uruguay, Venezuela (Venezuela (mainland), Venezuelan Antilles), Viet Nam and Yemen (Abreu-Grobois & Plotkin, 2008).

FAO Marine fishing areas

According to Abreu-Grobois & Plotkin (2008) *Lepidochelys olivacea* is found in the following FAO marine fishing areas:

- Atlantic – eastern central;
- Atlantic – southeast;
- Atlantic – southwest;
- Atlantic – western central;
- Indian Ocean – eastern;
- Indian Ocean – western;
- Pacific – eastern central;
- Pacific – southeast; Pacific – southwest; and
- Pacific – western central

Population

Declines in Olive Ridley populations have been observed attributed to commercial harvesting of adult turtles and eggs, incidental capture by commercial fisheries, particularly trawl fisheries, and coastal development resulting in a loss of nesting habitat (Abreu-Grobois & Plotkin, 2008). The Olive Ridley turtle was listed as endangered for the "Mexican nesting population" and threatened for all other populations on July 28, 1978. Since listing, there has been an additional decline in populations of this species, and was recommended that the Olive Ridley in the Western Atlantic be reclassified as endangered (Abreu-Grobois & Plotkin, 2008). This classification is needed based on reductions in populations in the Western Atlantic because this species is often caught in shrimp trawl nets (Abreu-Grobois & Plotkin, 2008). The western North Atlantic (Surinam and adjacent areas) nesting population has declined more than 80% since 1967. Declines have also been documented in Costa Rica (Abreu-Grobois & Plotkin, 2008); however other nesting populations along the Pacific coast of Mexico and Costa Rica appeared stable. In the Indian Ocean, Gahirmatha located in the Bhitarkanika Wildlife Sanctuary in India, supports perhaps the largest nesting population with an average of 398,000 females nesting in a given year (Abreu-Grobois & Plotkin, 2008).

Population Trend

Declining (Abreu-Grobois & Plotkin, 2008).

Habitat and Ecology

Habitats

Like most other sea turtles, *Lepidochelys olivacea* display a complex life cycle, which requires a range of geographically separated localities and multiple habitats (Márquez, et al., 1998). Females lay their nests on coastal sandy beaches from which neonates emerge and enter the marine environment to continue their development. They remain in a pelagic phase, drifting passively with major currents that disperse far from their natal sites, with juveniles sharing some of the adults' habitats (Kopitsky, et al., 2000) until sexual maturity is reached (Musick & Limus, 1997). Reproductively active males and females migrate toward coastal zones and concentrate near nesting beaches. However, some males appear to remain in oceanic waters and mate with females en route to their nesting beaches (Kopitsky, et al., 2000; Plotkin, et al., 1996). Their post-breeding migrations are complex, with pathways varying annually (Plotkin, 1994) and with no apparent migratory corridors, swimming hundreds or thousands of kilometers over large ocean expanses (Morreale, et al., 2007), commonly within the 20°C isotherms (Márquez, et al., 1998). In the East Pacific, they are present from 30°N to 15°S and often seen within 1,200 nautical miles from shore although they have been sighted as far as 140°W (IATTC, 2004). Western Atlantic *Lepidochelys olivacea* appear to remain in neritic waters after breeding (Pritchard, 1976; Reichart, 1993).

Demographic features / Reproduction

The species displays three modes of reproduction: arribada, dispersed nesting, and mixed strategy (Bernardo & Plotkin, 2007). The first mode represents a synchronous, mass nesting behaviour that may include hundreds to thousands of females over a period of days and occurs in fewer than a dozen places worldwide. The more common form of nesting is dispersed or "solitary" with no apparent synchronicity between individual events. At some localities, a mixture of these two forms of nesting can also occur. In general, individual *Lepidochelys olivacea* may nest one, two or three times per season, with approximately 100–110 eggs per clutch (Pritchard & Plotkin, 1995). For this assessment we have used an average number of 2.5 nests/female/season and 105 eggs/nest. In contrast to other sea turtle species, the reproductive cycle is nearly annual (over 60% of turtles nest every year) (Márquez, et al., 1998). Solitary nesters oviposit on 14 day cycles whereas arribada nesters approximately every 28 days (Pritchard, 1969; Kalb & Owens, 1994; Kalb, 1999). Kalb (1999) found that within a nesting season solitary nesters use multiple beaches for oviposition but arribada nesters display nest site fidelity. There are extreme variations in hatching rates between nesting beaches, however, in general they are much higher in solitary nesting beaches where around 80% is common and sometimes even higher (Gaos, et al., 2006). It is widely recognized that survivorship is extremely low on high-density arribada nesting beaches because of density-dependent mortality (Cornelius, et al., 1991) leading to hatching rates as low as 1 to 8% (Cornelius, et al., 1991). Moreover, turtles return approximately every month during a discrete nesting season (three to six months) and nests that remained intact during the previous month are again at risk when new waves of turtles crawl ashore. On solitary nesting beaches, where density-dependent mortality is not a factor, hatching rates are significantly higher (Gaos, et al., 2006; Castro, 1986). Post-hatching survivorship is unknown and there is no information available on recruitment rates. Presumably, like other sea turtles, *Lepidochelys olivacea* experience high mortality in their early life stages. Juveniles are believed to occur in similar habitats as the adults (i.e. pelagic waters) where they forage on gelatinous prey such as jellyfish, salps and tunicates (Kopitsky, et al., 2004).

Feeding

Despite its abundance, there is a surprising lack of data on the feeding habits of *Lepidochelys olivacea*. The data that does exist reports that the diet in the western Atlantic and eastern Pacific includes crabs, shrimp, rock lobsters, jellyfish and tunicates. Algae have also been reported as a principal food (Kopitsky, et al., 2004).

Systems

Terrestrial and Marine (Abreu-Grobois & Plotkin, 2008).

Threats

Like other long-lived species, *Lepidochelys olivacea* are prone to population declines because of slow intrinsic growth rate in combination with anthropogenic impacts. These can accumulate over a protracted development through various life stages, multiple habitats (nesting beaches, migratory routes and pelagic foraging zones) and vast geographic expanses (Abreu-Grobois & Plotkin, 2008).

Targeted exploitation

Egg harvest. *Lepidochelys olivacea* and their eggs have been harvested, mostly unsustainably, worldwide. However, the current impact is difficult to evaluate because of other simultaneous factors such as incidental take in commercial fisheries. Nonetheless, there is documentation of recent egg use causing declines (Cornelius, et al., 1991). From México to Colombia, Olive Ridley eggs have been and still are used for personal and commercial use (Cornelius, et al., 1991). Laws regulating turtle egg use vary among countries, and even where laws prohibit egg use, illegal use of Olive Ridley eggs is believed to be widespread because enforcement is either non-existent or insufficient.

Directed hunting of adults.

In the East Pacific, although *Lepidochelys olivacea* fisheries are now closed, illegal take of adult turtles still occurs widely with an unknown level of impact. There is evidence that thousands of *Lepidochelys olivacea* are still taken each year along the Pacific coast of México (Frazier, et al., 2007). In the West Atlantic, the direct take of adults has diminished over time to negligible levels (Cornelius, et al., 1991).

Bycatch in fisheries

The incidental capture of *Lepidochelys olivacea* occurs worldwide in trawl fisheries, longline fisheries, purse seines, gill net and other net fisheries and hook and line fisheries (Frazier, et al., 2007). The impact of the incidental capture of *Lepidochelys olivacea* in fisheries has been well documented for some regions but not for others. In some locations where by-catch statistics are unavailable from fisheries, cause and effect has been used to implicate a fishery in the decline of *Lepidochelys olivacea*.

Habitat impacts

Degradation, transformation and destruction of natural conditions at nesting beaches from coastal developments continue to threaten the long-term survival of many *Lepidochelys olivacea* rookeries. Transformation of nesting habitat comes from the construction of new aquaculture ponds, fishing harbours and tourist facilities, as well as growth of existing coastal villages which are increasing in many parts of the world within the range of the Olive Ridley, particularly along the east coast of India (Pandav & Choudhury, 1999) and in some zones in coastal México to Central America (Cornelius, et al., 1991). These impacts contribute stress directly through the loss of nesting habitat or indirectly through changes in the thermal profiles of the beach, increased light pollution (Witherington, 1992) and sewage effluents.

Global warming has the potential to impact the habitats and ecosystems of Olive Ridley populations worldwide (Hays, et al., 2003; Weishampel, et al., 2004) but the specific impacts are purely speculative at this time. Most accounts have focused on the impact of global warming on incubation temperatures of eggs, which influence the sex ratio of the embryos (Hays, et al., 2003).

Diseases and predation

Extremely little is known about diseases and their effects on Olive Ridley abundance. The only disease identified in the literature for *Lepidochelys olivacea* is fibropapilloma, a herpes-virus found in sea turtles nearly worldwide (Herbst, 1994). The incidence of fibropapilloma is not believed to be high in *Lepidochelys olivacea* but has been observed in *Lepidochelys olivacea* nesting in Costa Rica (Herbst, 1994) and in México (Vasconcelos, et al., 2000).

Conservation Actions

Most of the conservation actions on behalf of *Lepidochelys olivacea* at national and international levels have been based on the species' listing under the endangered category in the IUCN Red List. As an Appendix I

species under CITES (Convention on International Trade in Endangered Species) the international trade of skins from the species, which fuelled the large scale commercial exploitation of *Lepidochelys olivacea* from the 1960s into the 1980s was effectively halted. Other relevant international instruments that list *Lepidochelys olivacea* as threatened and hence obligate its conservation by member states include: the Convention on Migratory Species (CMS) and the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC). CMS-promoted Memoranda of Understanding for the conservation and management of marine turtles and their habitats have been signed by *Lepidochelys olivacea*'s range states in the Indian Ocean and South East Asia (known as IOSEA) as well as in other regions such as the Atlantic Coast of Africa under the Memorandum of Understanding concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa where 21 out of 26 range states participate (Abreu-Grobois & Plotkin, 2008).

On the basis of the species' classification in the IUCN Red List or in national endangered species lists, local legislatures of range states confer protection to *Lepidochelys olivacea*. Although this sanctions law-enforcement, the implementation remains patchy at the global scale because of paucity in enforcement capabilities. Successful conservation has usually relied on well-coordinated national programs in combination with local and non-governmental organizations incorporating public outreach. Statutory use and enforcement of the Turtle Excluder Devices in the shrimp trawlers has also proven critical in some areas with high levels of interaction with this fishery (Abreu-Grobois & Plotkin, 2008).

Despite the legislative efforts to protect *Lepidochelys olivacea*, human impacts continue to be significant. In some areas (such as West Africa and South East Asia), extensive monitoring needs to be implemented to identify regions and stressors requiring priority actions. Bycatch and illegal take particularly from the coastal, artisanal fisheries need to be evaluated through adequate on-board observer programs and properly addressed. The beetle infestation of the Escobilla rookery must be adequately evaluated and acceptable measures of biological control of the insect need to be implemented. The impact from the increasing development of much of the range state's coastline has to be evaluated and suitable mitigation measures implemented (Abreu-Grobois & Plotkin, 2008).

Regionally relevant knowledge

Data collected in recent years has shown the green turtle population nesting in the Bijagós to be of global importance. In 1995, 1650 females were tagged at Poilão Island during just part of the nesting season (Fortes, et al., 1998). In 2000, approximately 7000 clutches were laid between July and November (Catry, et al., 2002). This places Poilão amongst the most important rookeries for green turtles in the Atlantic. The only other large colony as yet described in West Africa is that of Bioko Island, (Tomás, et al., 2002) but numbers of nests appear to be in the region of an order of magnitude less than Poilão.

Poilão is a traditional sacred site in the Bijagós culture. This, allied with its remoteness has helped to conserve the turtles nesting there whereas other sites in the region have been exploited. In addition, its importance to sea turtles was one of the main supporting arguments for the creation of one of the first marine protected areas of Guinea-Bissau: the João Vieira and Poilão Marine National Park (August 2000).

The local threats to green turtles in Guinea Bissau have not yet been fully quantified but include harvest of eggs and adults and the incidental catch of turtles in artisanal and industrial fisheries (Barbosa, et al., 1998; Fortes, et al., 1998). Anecdotal accounts from local people of the Bijagós Archipelago reveal that, although turtles are still numerous at Poilão, in recent years they have noticed the decline and sometimes disappearance of marine turtles from some nesting grounds. Constructive steps are being taken to minimise these factors. These will all be in vain if the turtles are being critically impacted in other parts of their range.

The life cycle of marine turtles involves movements over great temporal and spatial scales (Musick & Limus, 1997), taking decades for turtles to reach adulthood. Although adults from this population are likely to forage widely in African coastal waters their life cycle will involve periods in seas of other nations and shared coastal foraging areas with individuals from other nesting populations as has been found in other regions (Lahanas, et al., 1994).

LEATHERBACK TURTLE (DERMOCHELYS CORIACEA)

Description

Leatherback turtles have the most hydrodynamic body design of any sea turtle, with a large, teardrop-shaped body. A large pair of front flippers powers the turtles through the water. Like other sea turtles, the leatherback has flattened forelimbs adapted for swimming in the open ocean. Claws are absent from both pairs of flippers (Figure 8). The leatherback's flippers are the largest in proportion to its body among extant sea turtles. Leatherback's front flippers can grow up to 2.7 metres in large specimens, the largest flippers (even in comparison to its body) (Fontanes, 2003)

The leatherback has several characteristics that distinguish it from other sea turtles. Its most notable feature is the lack of a bony carapace. Instead of scutes, it has thick, leathery skin with embedded minuscule osteoderms (Fontanes, 2003). Seven distinct ridges rise from the carapace, crossing from the anterior to posterior margin of the turtle's back (Fontanes, 2003). Leatherbacks are unique among reptiles in that their scales lack β-keratin. The entire turtle's dorsal surface is colored dark grey to black, with a scattering of white blotches and spots. Demonstrating countershading, the turtle's underside is lightly colored (Frazier, et al., 2007).

Instead of teeth, the leatherback turtle has points on the tomium of its upper lip, with backwards spines in its throat to help it swallow food and to stop its prey escaping once caught. The teeth are not used for mastication (Fontanes, 2003).

Dermochelys coriacea adults average 1–1.75 m in carapace length, 1.83–2.2 m in total length and weigh 250 to 700 kg (Fontanes, 2003). In the Caribbean, the mean size of adults was reported at 384 kg in weight and 1.55 m along the curve of the carapace. The largest ever found, however, was over 3 metres from head to tail, including a carapace length of over 2.2 metres, and weighed 916 kilograms (Eckert & Luginbuhl, 1988). The leatherback turtle is scarcely larger than any other sea turtle upon hatching, as they average 61.3 mm in carapace length and weigh around 46 g when freshly hatched (Spotila, et al., 1996).

Dermochelys coriacea exhibits a suite of anatomical characteristics believed to be associated with a life in cold waters, including an extensive covering of brown adipose tissue (Goff & Stenson, 1988) temperature

independent swimming muscles, counter-current heat exchangers between the large front flippers and the core body, as well as an extensive network of counter-current heat exchangers surrounding the trachea

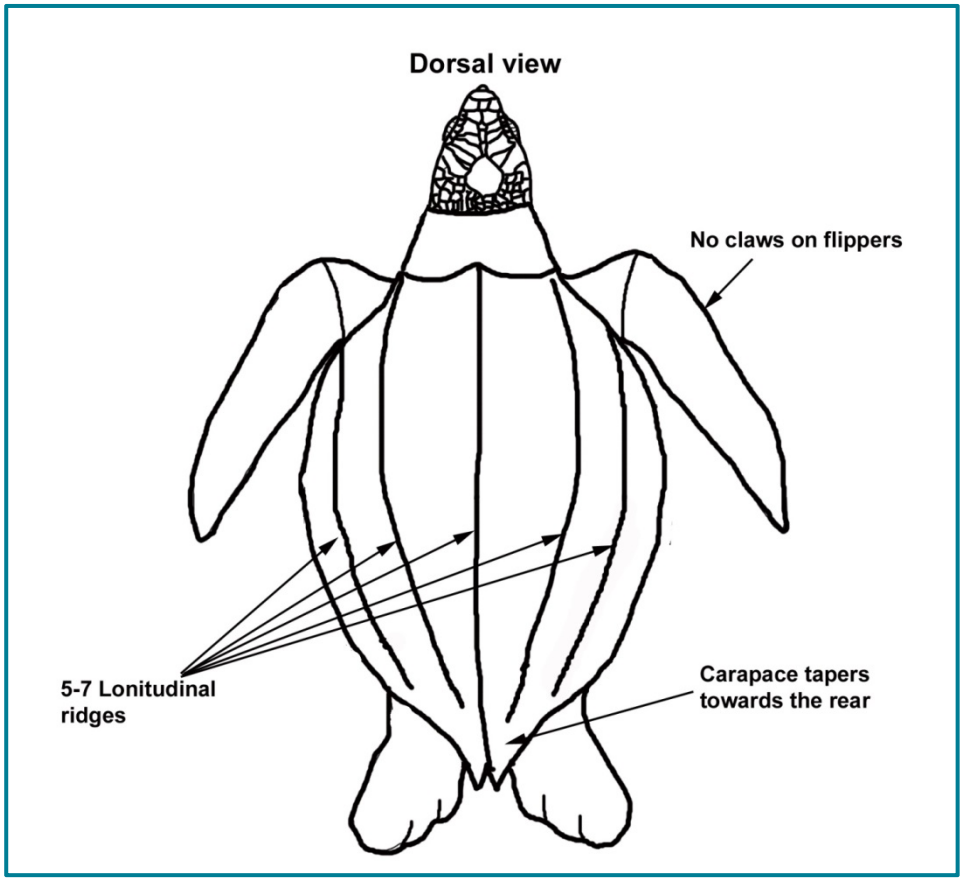

Figure 8: Descriptive characteristics of Dermochelys coriacea

Geographic Range

Range Description

The Leatherback turtle has a worldwide distribution (Figure 12). It is found from tropical to sub-polar oceans; nests on tropical (rarely subtropical) beaches. Very little is known about the distribution of post-hatchlings and juveniles. Leatherbacks smaller than 100 cm curved carapace length seem limited to regions warmer than 26°C. Sightings of turtles less than 145 cm show that some juveniles remain near to the coast in St. Lucia, E. Trop. Pacific, Mexico, Barbados, USA (east and west coast-Georgia, S. Carolina, Texas, Rhode Island, California) Puerto Rico, Amer. Samoa, Bonaire, Chile, Spain, Venezuela, Scotland, and England (Eckert, 1999).

Countries

According to Sarti Martinez (2000), *Dermochelys coriacea* occur in Albania; Angola (Angola); Antigua and Barbuda; Aruba; Australia; Bahamas; Bahrain; Barbados; Benin; Brazil; China; Colombia; Congo, The Democratic Republic of the; Costa Rica; Côte d'Ivoire; Cuba; Dominica; Dominican Republic; Ecuador; El Salvador; Eritrea; Fiji; French Guiana; Ghana; Grenada; Guadeloupe; Guatemala; Guyana; Haiti; Honduras; India; Indonesia; Italy; Liberia; Malaysia; Martinique; Mexico; Mozambique; Myanmar; Netherlands Antilles; Nicaragua; Panama; Papua New Guinea; Puerto Rico; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Senegal; Solomon Islands; South Africa; Sri Lanka; Suriname; Taiwan, Province of China; Thailand; Togo; Trinidad and Tobago; Turks and Caicos Islands; United States; Venezuela; Virgin Islands, British; Virgin Islands, U.S.

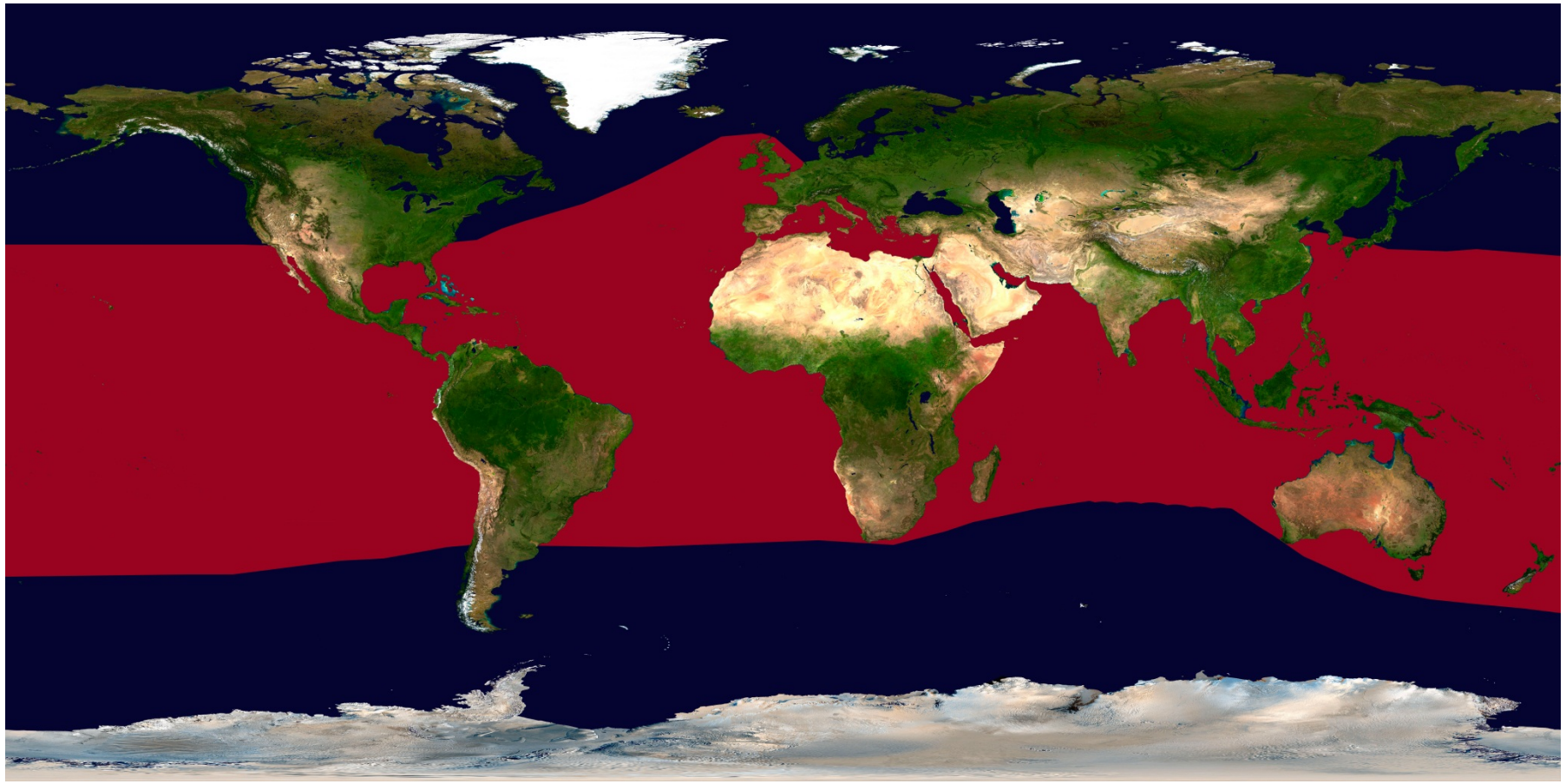

Figure 9: Geographic distribution range of Dermochelys coriacea

FAO Marine fishing areas

According to Sarti Martinez (2000), *Dermochelys coriacea* is found to occur in the following FAO marine fishing areas:

- Atlantic – western central;
- Atlantic – northeast;
- Atlantic – eastern central;
- Atlantic – southwest;
- Atlantic – southeast;
- Atlantic – northwest;
- Indian Ocean – eastern;
- Indian Ocean – western;
- Mediterranean and Black Sea;
- Pacific – southeast;
- Pacific – northeast;
- Pacific – northwest;
- Pacific – eastern central;
- Pacific – western central; and
- Pacific – southwest.

Population

Based on the number of nestings known to date, it has been mentioned that some of the most important populations have collapsed. For example, the rookery in Malaysia, which from 10,155 clutches in 1956 fell to 37 in 1995 in the same stretch of beach. The East Pacific leatherback population has been estimated to have collapsed to about 1,690 adult females, down from 4,638 in 1995 (Spotila, et al., 2000) with the Mexican population, which is in serious danger of collapse in spite of protection efforts applied for over a decade (e.g., number of nests have fallen from 5,080 to less than 100 annually in one of the main rookeries of the Pacific coast); and those in Costa Rica dropping from 1,646 nest to less than 500 nest in the main nesting beach on the Pacific coast. In the Pacific basin, only the Indonesian population remains as still somewhat abundant (2,983 nests in 1999 in a single beach from 13,000 nests in 1984) but with uncertain status and future prospects, since civil problems have hampered the continuation of monitoring and protection activities in the area, along with significant fisheries pressures that impacts the population (Spotila, et al., 1996).

There are areas in the Atlantic in which the number of nests per season has increased in the past few years, as is the case of the US Virgin Islands. However, these populations are relatively minor. Others populations in the Atlantic have decreased or fluctuated such as those in French Guyana or Surinam. In these two, the beach dynamics hinder an accurate evaluation of the population status, since whole beaches disappear, forcing females to search for alternative suitable nesting beaches (Spotila, et al., 1996). Along with this, the leatherback population is shared between Surinam, Guyana, French Guyana and maybe Trinidad and Brazil. Until a true international cooperation program exists, it won't be possible to have thorough evaluations of such population. For the coast of Africa, there are historical records for South Africa. In the Indian Ocean, the population is increasing but cannot be considered a large population, with around 100 nests per season in

56 km. in the last four years. Recent reports mention that West Africa has an important population with around 10,400 nests per season, but the total area occupied for the leatherbacks is not well known and there is no available historical information. J. Fretey mentioned (pers. comm.) that this population could currently be the most important in the world.

Population Trend

Decreasing (Sarti Martinez, 2000)

Habitat and Ecology

Habitats

Nest on sandy beaches. The juveniles may remain in tropical waters warmer than 26°C, near the coast, until they exceed 100 cm in curved carapace length. When adult, they are pelagic and live in the open ocean, sometimes in temperatures below 10°C. There are very few sighting of males near the coast during the breeding season, only the females are near to the coast during the breeding season and go to the beach to nest (Sarti Martinez, 2000).

Demographic features / Reproduction

The estimate of age to maturity for the species used by most authorities is based on a skeletochronological analysis by Zug and Parham (1996) that placed it at around 13-14 years. However, population-wide estimates of age are not currently practical and thus average age of parents are not known. Most authorities agree that the life-span of leatherback is 30 years or more, then age to maturity plus one half of the reproductive life span (22 years) is taken as a reasonable approximation of generation length. If density dependence applies, the severely depleted status (see below) would argue that current growth rates are higher than natural and natural generation time may be longer than 22 years (Zug & Parham, 1996).

Like all sea turtles, leatherbacks start as hatchlings, climbing out of the sands of their nesting beaches. Leatherback turtles face many predators in their early life. Eggs may be predated by a diversity of coastal predators, including ghost crabs, monitor lizards, raccoons, coatis, dogs, coyotes, genets, mongooses and shorebirds ranging from small plovers to large gulls (Zug & Parham, 1996). Many of the same predators will try to feed on tiny baby turtles as they try to get to the ocean, as well as frigate birds and varied raptors. Once in the ocean, young leatherbacks still face predation from cephalopods, requiem sharks and various large fish. Despite their lack of a hard shell, the huge adult faces fewer serious predators, though it is occasionally overwhelmed and preyed on by very large marine predators such as orcas, great white sharks and tiger sharks. Nesting females have been preyed upon by jaguars in the American tropics (Zug & Parham, 1996). Apparently, the adult leatherback aggressively defends itself at sea from predators. A medium-sized adult was observed chasing a shark that had attempted to bite it and then turned its aggression and attacked the boat containing the humans observing the prior interaction (Zug & Parham, 1996). *Dermochelys* juveniles spend more of their time in tropical waters than do adults (Sarti Martinez, 2000).

Adults are prone to long-distance migration. Migration occurs between the cold waters where mature leatherbacks feed, to the tropical and subtropical beaches in the regions where they hatch. In the Atlantic, females tagged in French Guiana have been recaptured on the other side of the ocean in Morocco and Spain (Zug & Parham, 1996; Sarti Martinez, 2000).

Mating takes place at sea. Males never leave the water once they enter it, unlike females which nest on land. After encountering a female (who possibly exudes a pheromone to signal her reproductive status), the male uses head movements, nuzzling, biting, or flipper movements to determine her receptiveness. Females mate every two to three years. However, leatherbacks can breed annually. Fertilization is internal, and multiple males usually mate with a single female. This polyandry does not provide the offspring with any special advantages (Sarti Martinez, 2000).

While other sea turtle species almost always return to their hatching beach, leatherbacks may choose another beach within the region. They choose beaches with soft sand because their softer shells and plastrons are easily damaged by hard rocks (Zug & Parham, 1996). Nesting beaches also have shallower

approach angles from the sea. This is vulnerability for the turtles because such beaches easily erode. They nest at night when the risk of predation is lowest. As leatherback turtles spend the vast majority of their lives in the ocean, their eyes are not well adapted to night vision on land. The typical nesting environment includes a dark forested area adjacent to the beach. The contrast between this dark forest and the brighter, moonlit ocean provides directionality for the females. They nest towards the dark and then return to the ocean and the light (Zug & Parham, 1996).

Females excavate a nest above the high-tide line with their flippers. One female may lay as many as nine clutches in one breeding season. About nine days pass between nesting events. Average clutch size is around 110 eggs, 85% of which are viable (Zug & Parham, 1996). After laying, the female carefully back-fills the nest, disguising it from predators with a scattering of sand (Zug & Parham, 1996).

Cleavage of the cell begins within hours of fertilization, but development is suspended during the gastrulation period of movements and infoldings of embryonic cells, while the eggs are being laid. Development then resumes, but embryos remain extremely susceptible to movement-induced mortality until the membranes fully develop after incubating for 20 to 25 days. The structural differentiation of body and organs (organogenesis) soon follows. The eggs hatch in about sixty to seventy days. As with other reptiles, the nest's ambient temperature determines the sex of the hatchings. After nightfall, the hatchings dig to the surface and walk to the sea (Zug & Parham, 1996).

Feeding

Adult *D. coriacea* turtles subsist almost entirely on jellyfish (Eckert, 1999). Due to their obligate feeding nature, leatherback turtles help control jellyfish populations (Eckert, 1999). Leatherbacks also feed on other soft-bodied organisms, such as tunicates and cephalopods (Eckert, 1999).

Pacific leatherbacks migrate about 9,700 kilometres (6,000 mi) across the Pacific from their nesting sites in Indonesia to eat California jellyfish. One cause for their endangered state is plastic bags floating in the ocean. Pacific leatherback sea turtles mistake these plastic bags for jellyfish; an estimated one third of adult leatherbacks have ingested plastic (Eckert & Luginbuhl, 1988). Plastic enters the oceans along the west coast of urban areas, where leatherbacks forage; with Californians using upwards of 19 billion plastic bags every year (Eckert & Luginbuhl, 1988). Several species of sea turtles commonly ingest plastic marine debris, and even small quantities of debris can kill sea turtles by obstructing their digestive tracts (Eckert & Luginbuhl, 1988). Nutrient dilution, which occurs when plastics displace food in the gut, affects the nutrient gain and consequently the growth of sea turtles (Zug & Parham, 1996). Ingestion of marine debris and slowed nutrient gain leads to increased time for sexual maturation that may affect future reproductive behaviors (Zug & Parham, 1996). These turtles have the highest risk of encountering and ingesting plastic bags offshore of San Francisco Bay, the Columbia River mouth, and Puget Sound.

Systems

Marine and terrestrial (Sarti Martinez, 2000).

Threats

The main threats have been a prolonged harvest of eggs and the incidental capture in oceanic fisheries. In some areas the egg harvest and illegal poaching has removed more than 95% of the clutches, and this has been recognized as the main cause for the collapse in the Malaysia population (Chan & Liew, 1996). Fishing activities using longline and driftnets are an important threat since juvenile and adult are captured in migratory routes (Zug & Parham, 1996). In some areas females are killed on the nesting beaches for oil extraction. Leatherback hunts, which have been stripped of their traditional customs and controls, are also serious threats (Suarez & Starbird, 1996). Oceanic pollution, basically by plastics is another cause of mortality. Phthalates, derived from plastics have been found in the leatherback egg yolk (Juárez-Cerón, 1998).

Conservation Actions

Extraction of sea turtles and their products has become illegal in most countries. In many, there are conservation programmes to protect egg clutches and nesting females from poaching. International trade of

all sea turtle products and sub-products is forbidden under CITES (Spotila, et al., 2000). However, the use of the Leatherback meat, oil or eggs is allowed in some nations, as part of internal traditional customs or rituals. While many international instruments (CMS, CBD, SPAW to name a few) require the protection of sea turtles in international waters, lack of effective monitoring in pelagic fishing operations still causes significant by catch mortality. As an unprecedented action, the United States government recently closed a very large area in the northern Pacific to the US longline fishery in order to protect leatherbacks from incidental capture (Spotila, et al., 2000).

Because of the decline in the world's populations of the leatherback turtle, full protection of all nesting beaches to eliminate poaching, avoid degradation of critical habitat, and increment hatchling recruitment (through enhancing hatching success and incrementing the number of nesting protection programs) will be necessary. However, as pointed out by Sarti et al. (2000) and Spotila et al. (2000) recovery of this population cannot be achieved by increasing hatchling production alone because of the very high mortalities as fisheries' bycatch (Spotila, et al., 2000). Due to the very drastic observed population declines in last few decades, pelagic and coastal fishing practices that impact leatherbacks must be changed or eliminated urgently to minimize leatherback mortality in these habitats. Further, because the migratory routes of leatherbacks cross territorial waters of many nations or occur in the high seas, international collaboration focused on sea turtle conservation is essential (Spotila, et al., 2000). In regions such as the Caribbean, where populations are shared and the dynamic nature of the nesting habitats provokes shifts in nesting sites, greater collaboration and data sharing will be necessary to derive a better understanding of population sizes and trends (Spotila, et al., 2000).

Regionally relevant knowledge

The leatherback turtle is poorly studied in Guinea-Bissau, but is known to occur in the area in relatively large numbers, using the islands of the Bijagós Archipelago for nesting purposes.

LOGGERHEAD TURTLE (*CARETTA CARETTA*)

Description

Caretta caretta (Linnaeus, 1758) are commonly called "loggerhead" sea turtles due to their overly large heads with a horny beak that is significantly thicker than in other sea turtles. This species is the largest hard-shelled turtle in the world (the leatherback sea turtle is the largest of all turtles) (Ernst, et al., 1994). Two subspecies have been recognized: *Caretta caretta gigas*, found in the Pacific and Indian Oceans, and *C. caretta caretta*, the Atlantic loggerhead. They may differ in the number of neural bones in the carapace and marginal scutes on the surface of the carapace, but the ranges overlap and many authorities do not support the distinction (Ernst, et al., 1994). Color patterns are reddish-brown with darker streaks and their front flippers possess two claws. Subadults have carapaces 45-90cm in length and adults weigh between 77-227kg and have a carapace 0.9-1 m in length (Ernst, et al., 1994).

Geographic Range

Range Description

Loggerhead sea turtles are found in coastal tropical and subtropical waters often extending to temperate waters in search of food. Found in the Atlantic Ocean from Argentina to Nova Scotia (Marine Turtle Specialist Group, 1996). The highest populations in North America are found on barrier islands from North Carolina to the Florida Keys. These Florida loggerheads migrate to the Bahamas in the winter. Small populations of the Atlantic loggerhead are also found on barrier islands off of the Texas coast. Primary habitat is in southeastern United States ranging southward to South America and extending eastward to Africa and the Mediterranean as well as areas of the western Pacific and Indian Oceans (Marine Turtle Specialist Group, 1996).

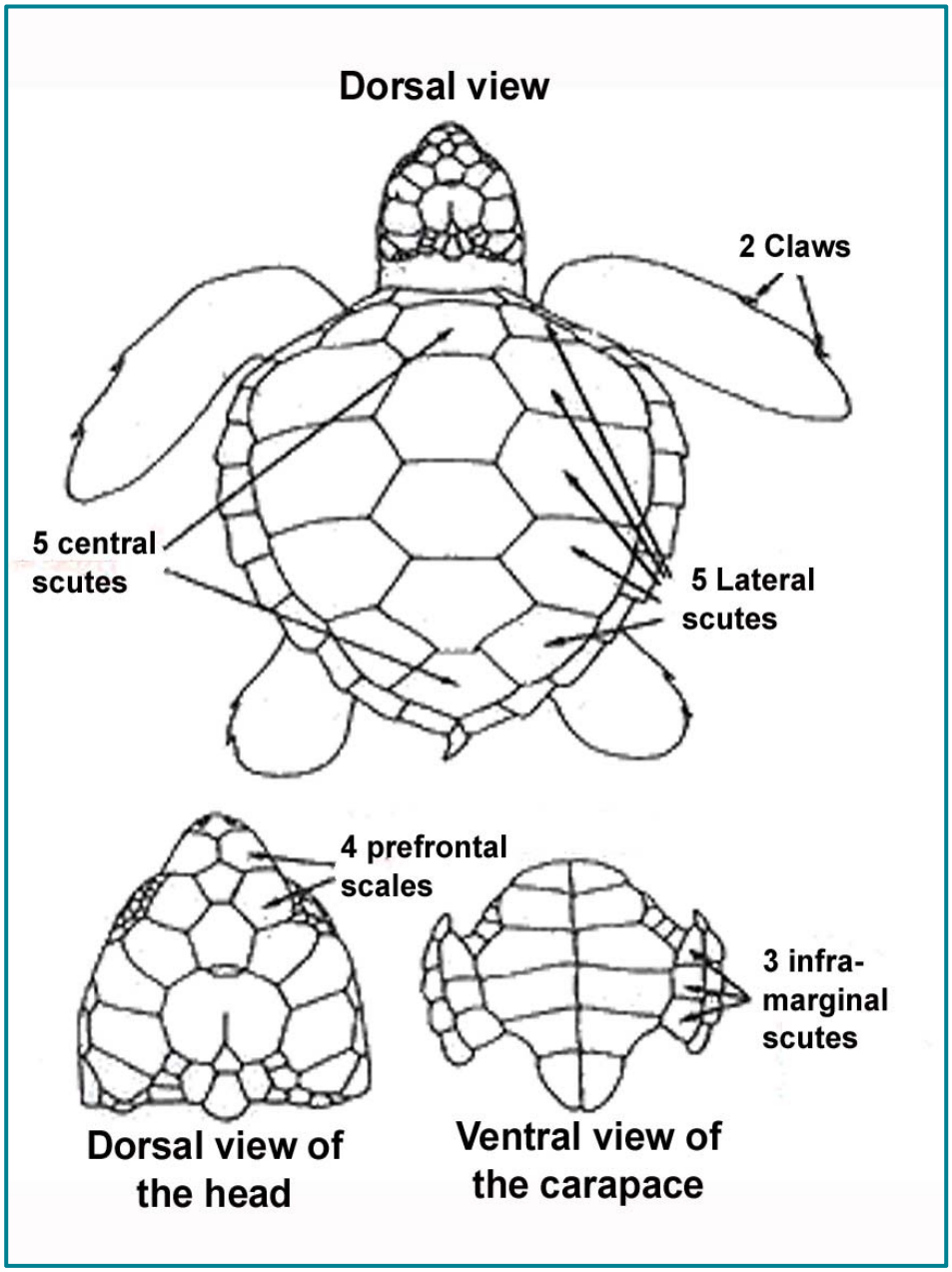

Figure 10: Descriptive characteristics of Caretta caretta(Reproduced from MarineBio Conservation Society, 2013b)

Countries

According to the Marine Turtle Specialist Group (1996) *Caretta caretta* occurs in Albania; Algeria; Australia; Bahamas; Bahrain; Bangladesh; Belize; Brazil; Cayman Islands; China; Colombia; Costa Rica; Cuba; Cyprus; Dominican Republic; Egypt; Eritrea; France; Greece; Grenada; Guadeloupe; Guatemala; Haiti; Honduras; Indonesia; Israel; Italy; Jamaica; Japan; Libya; Madagascar; Mexico; Montserrat; Morocco; Mozambique; Namibia; New Caledonia; Nicaragua; Oman; Panama; Philippines; Puerto Rico; Saint Lucia; Senegal; South Africa; Spain (Canary Is.); Sri Lanka; Tunisia; Turkey; Turks and Caicos Islands; United States; Uruguay; Venezuela; Virgin Islands, British

FAO Marine fishing areas

According to the Marine Turtle Specialist Group (1996)*Caretta caretta* is found to occur in the following FAO marine fishing areas:

- Atlantic – western central;
- Atlantic – northeast;
- Atlantic – eastern central;
- Atlantic – southwest;
- Atlantic – southeast;
- Atlantic – northwest;
- Indian Ocean – western;
- Indian Ocean – eastern;
- Mediterranean and Black Sea;
- Pacific – southeast;
- Pacific – northeast;
- Pacific – northwest;
- Pacific – eastern central;
- Pacific – western central; and
- Pacific – southwest.

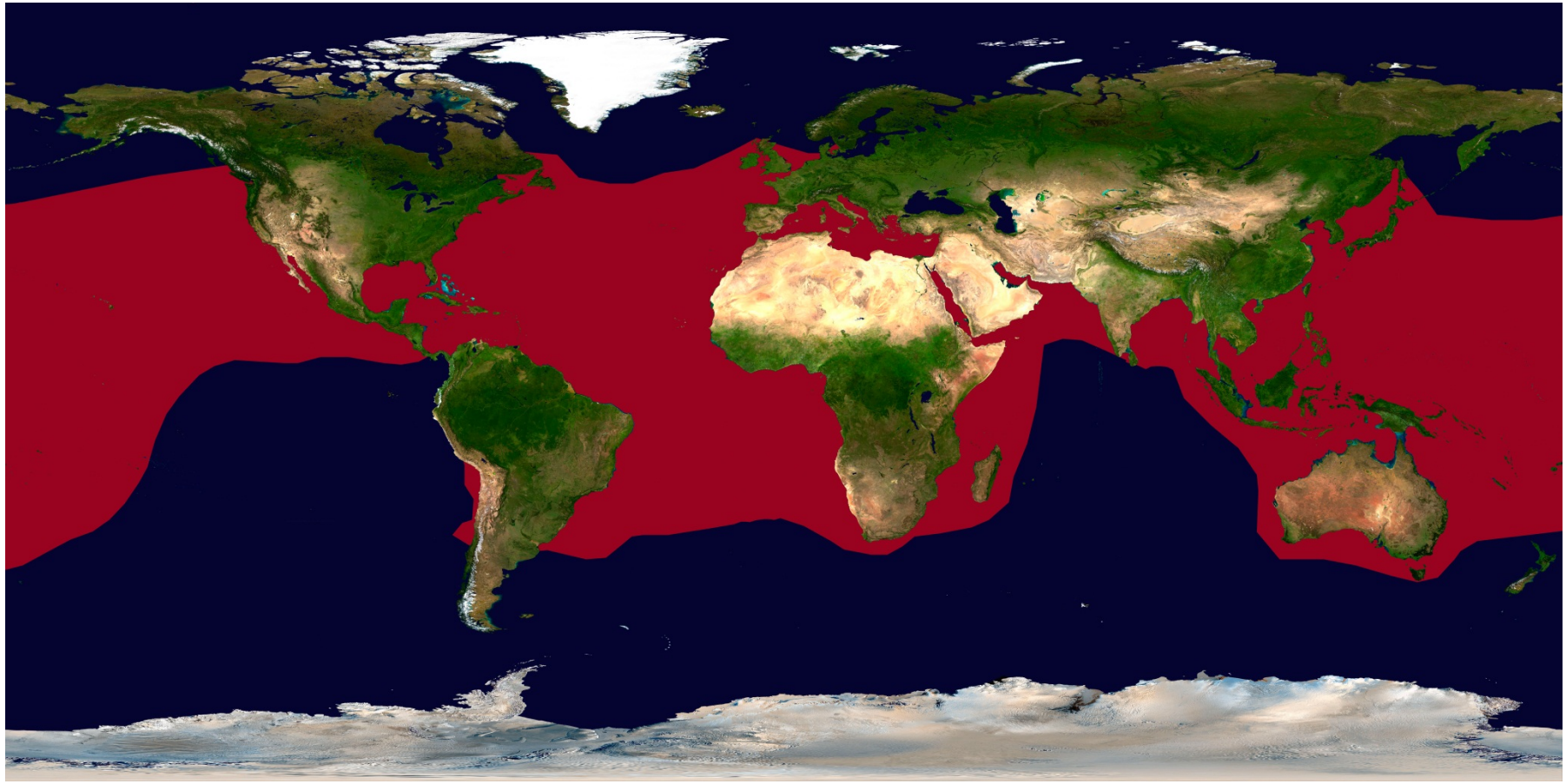

Figure 11: Geographic distribution range of Caretta caretta

Population

The current global population of this species is difficult to determine due to a lack of substantial, dependable data. The population size is thought to be stable in most areas, with significant populations in the U.S, Australia and other areas increasing (Marine Turtle Specialist Group, 1996).

Population Trend

Stable - Increasing (Marine Turtle Specialist Group, 1996)

Habitat and Ecology

Habitats

Hatchling habitat is primarily in warm ocean currents among flotsam such as sargassum mats. Adult habitat includes rock outcroppings and reefs near shore as well as in brackish lagoons and the mouths of inlets. Long migrations often occur, especially to return to nesting beaches (Marine Turtle Specialist Group, 1996).

Demographic features / Reproduction

Loggerheads nest on ocean beaches, generally preferring high energy, relatively narrow, steeply sloped, coarse-grained beaches. Females lay three to five nests, and sometimes more, during a single nesting season. The eggs incubate approximately two months before hatching. Hatchlings lack the reddish-brown coloration of adults and juveniles (Marine Turtle Specialist Group, 1996). Their flippers are dark gray to brown above with white to white-gray margins. The coloration of the plastron is generally yellowish to tan. Immediately after hatchlings emerge from the nest, they begin a period of frenzied activity. During this active period, hatchlings move from their nest to the surf, swim, and are swept through the surf zone, and continue swimming away from land for up to several days (Marine Turtle Specialist Group, 1996).

Somewhere between 7-12 years old, oceanic juveniles migrate to nearshore coastal areas (neritic zone) and continue maturing until adulthood. In addition to providing critically important habitat for juveniles, the neritic zone also provides crucial foraging habitat, inter-nesting habitat, and migratory habitat for adult loggerheads in the western North Atlantic (Marine Turtle Specialist Group, 1996). To a large extent, these habitats overlap with the juvenile stage, the exception being most of the bays, sounds, and estuaries along the Atlantic and Gulf coasts of the U.S. from Massachusetts to Texas, which are infrequently used by adults. However, adult loggerheads are present year-round in Florida Bay, an important feeding area, probably because of relatively easy access to open ocean and migratory routes (Marine Turtle Specialist Group, 1996).

Feeding

Loggerhead turtles are primarily carnivorous during most of their lives. Hatchlings often eat sponges, jellyfishes, sargassum weed, small gastropods and crustaceans. Juveniles, sub-adults and adults feed upon conch, clams, horseshoe crab as well as other crustaceans. They have powerful jaws that enable them to easily crush the hard shells of their prey. During migration through the open sea, loggerheads eat jellyfishes, pteropods, floating mollusks, floating egg clusters, squids and flying fishes (Marine Turtle Specialist Group, 1996).

Systems

Marine and terrestrial (Marine Turtle Specialist Group, 1996).

Threats

Loggerheads face threats on both nesting beaches and in the marine environment. The greatest cause of decline and the continuing primary threat to loggerhead turtle populations worldwide is incidental capture in fishing gear, primarily in longlines and gillnets, but also in trawls, traps and pots, and dredges (Marine Turtle Specialist Group, 1996).

Directed harvest for loggerheads still occurs in many places (for example, the Bahamas, Cuba, and Mexico) and is a serious and continuing threat to loggerhead recovery (Marine Turtle Specialist Group, 1996).

Conservation Actions

The highly migratory behavior of loggerheads makes them shared resources among many nations. Therefore, conservation efforts for loggerhead populations in one country may be jeopardized by activities in another (Marine Turtle Specialist Group, 1996).

Loggerhead turtles are protected by various international treaties and agreements as well as national laws. They are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), which means that international trade of this species is prohibited (Marine Turtle Specialist Group, 1996). Loggerheads are listed in Appendices I and II of the Convention on Migratory Species (CMS) and are protected under the following auspices of CMS: the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA) and the Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa (Marine Turtle Specialist Group, 1996). Loggerheads are also protected under Annex II of the Specially Protected Areas and Wildlife (SPAW) Protocol of the Cartagena Convention. Additionally, the U.S. is a party to the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC), which is the only binding international treaty dedicated exclusively to marine turtles (Marine Turtle Specialist Group, 1996).

Regionally relevant knowledge

Although they do occur in Guinea-Bissau, *Caretta caretta* are not known to breed in this area and therefore little is known about this species in the region other than the fact that they do occur there (Barbosa, et al., 1998).

THE NILE CROCODILE (*CROCODYLUS NILOTICUS*)

Description

Nile crocodiles have a dark bronze colouration above, with black spots on the back and a dirty purple on the belly. The flanks, which are yellowish-green in colour, have dark patches arranged in oblique stripes and green eyes. There is some variation relative to environment; specimens from swift-flowing waters tend to be lighter in colour than those dwelling in lakes or swamps.

Like all crocodiles, the Nile crocodile is a quadruped with four short, splayed legs, a long, powerful tail, a scaly hide with rows of ossified scutes running down its back and tail, and powerful jaws. It has nictitating membranes to protect the eyes and lachrymal glands to cleanse its eyes with tears. The nostrils, eyes, and ears are situated on the top of the head, so the rest of the body can remain concealed underwater. The coloration also helps to camouflage it; juveniles are grey, multicoloured, or brown, with dark cross-bands on the tail and body. As it matures, it becomes darker and the cross-bands fade, especially those on the body.

The Nile crocodile is the largest crocodilian in Africa and is the second-largest crocodilian after the saltwater crocodile. The male crocodile usually measure from 3.5 to 5 m long, but very old, mature ones can grow to 5.5 m or more (Somma, 2002). Mature female Nile crocodiles measure 2.4 to 3.8 m. Like all crocodiles they are sexually dimorphic, with the males up to 30% larger than the females, though the difference is less compared to some species, like the saltwater crocodile (Somma, 2002).

Typical Nile crocodile weight is from 225 to 550 kg, though exceptionally large males can range up to 900 kg or more, in weight (Somma, 2002).

Evidence exists of Nile crocodiles from cooler climates like the southern tip of Africa being smaller, and may reach lengths of only 4 m. Dwarf Nile crocodiles also exist in Mali and in the Sahara Desert, which reach only 2 to 3 m in length. Their reduced size is probably the result of the less than ideal environmental conditions, not genetics (Somma, 2002).

Geographic Range

Range Description

The Nile crocodile is the most common crocodilian found in Africa today. They are common throughout the continent. Their historic range however, was even wider. They were found as north as the Mediterranean coast in the Nile delta. Today they are common in Somalia, Ethiopia, Uganda, Kenya, Egypt, Central African Republic, Republic of the Congo, Democratic Republic of the Congo, Burkina Faso, Equatorial Guinea, Nigeria, Tanzania, Rwanda, Burundi, Zambia, Zimbabwe, Gabon, Angola, South Africa, Malawi, Mozambique, Sudan, South Sudan, Botswana, and Cameroon. Isolated populations also exist in Madagascar and in Senegal. They are recorded by Herodotus to have inhabited Lake Moeris. They are thought to have become extinct in the Seychelles in the early 19th century. They are known from fossil remains to have once inhabited Lake Edward (Guggisberg, 1972). The Nile crocodile's current range of distribution extends from the Senegal River, Lake Chad, Wadai and the Sudan to the Cunene and the Okavango Delta. In Madagascar, crocodiles occur in the western and southern parts from Sembirano to Port Dauphin. They have occasionally been spotted in Zanzibar and the Comoros (Guggisberg, 1972). Until recently, many permanent waters in the Sahara still housed relict populations (Hekkala, et al., 2011).

Countries

According to the Crocodile Specialist Group (1996a) , *C. niloticus* occurs in Angola (Angola), Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Congo, The Democratic Republic of the, Côte d'Ivoire, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, United Republic of, Togo, Uganda, Zambia and Zimbabwe.

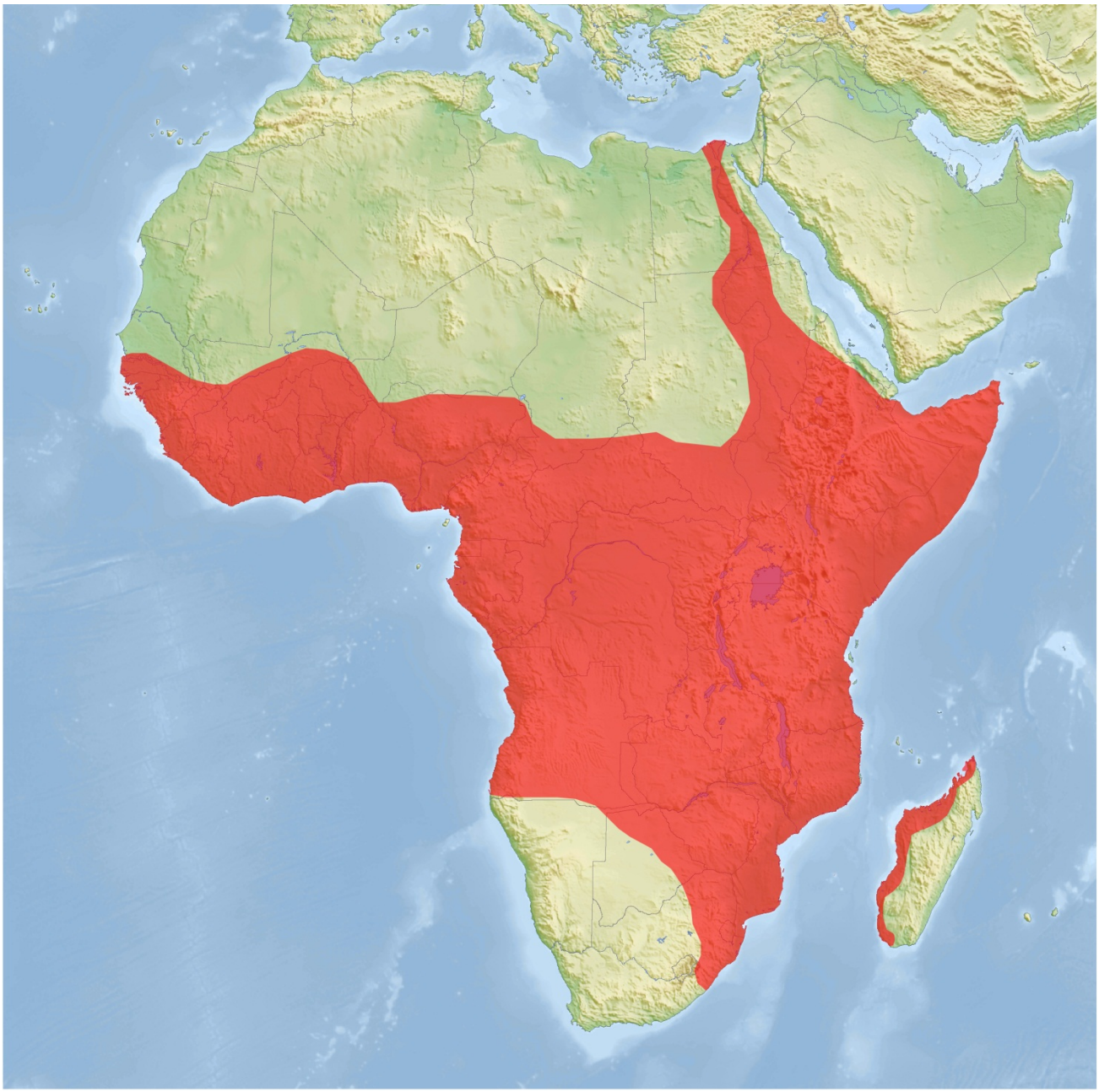

Figure 12: Geographic distribution range of Crocodylus niloticus

Population

From the 1940s to the 1960s, the Nile crocodile was hunted, primarily for high-quality leather, though also for meat with its purported curative properties. The population was severely depleted, and the species faced extinction. National laws, and international trade regulations have resulted in resurgence in many areas, and the species as a whole is no longer threatened with extinction. Crocodile 'protection programs' are artificial environments where crocodiles exist safely and without the threat of extermination from hunters (Crocodile Specialist Group, 1996a).

An estimated 250,000 to 500,000 individuals occur in the wild. The Nile crocodile is also widely distributed, with strong, documented populations in many countries in eastern and southern Africa, including Somalia, Ethiopia, Kenya, Zambia and Zimbabwe. Successful sustainable-yield programs focused on ranching crocodiles for their skins have been successfully implemented in this area, and even countries with quotas

are moving toward ranching. In 1993, 80,000 Nile crocodile skins were produced, the majority from ranches in Zimbabwe and South Africa (Crocodile Specialist Group, 1996a).

The situation is grimmer in central and west Africa, which makes up about two-thirds of the Nile crocodile's habitat. The crocodile population in this area is much sparser, and has not been adequately surveyed (Crocodile Specialist Group, 1996a).

The IUCN Red List assesses the Nile crocodile as "Least Concern (LR/lc)". [1] The CITES lists the Nile crocodile under Appendix I (threatened with extinction) in most of its range; and under Appendix II (not threatened, but trade must be controlled) in the remainder, which either allows ranching or sets an annual quota of skins taken from the wild. This species is farmed for its meat and leather in some parts of Africa (Crocodile Specialist Group, 1996a).

Population Trend

Decreasing (Crocodile Specialist Group, 1996a).

Habitat and Ecology

Habitats

In East Africa, they are found mostly in rivers, lakes, marshes, and dams. They have been known to enter the sea in some areas, with one specimen having been seen 11 kilometres (6.8 mi) off St Lucia Bay in 1917. In Madagascar, they have adapted to living in caves (Guggisberg, 1972).

Reproduction

For males, the onset of sexual maturity occurs when they are about 3 metres long, while for females, it occurs when they reach 2 to 2.5 metres in length. This takes about 10 years for either sex, under normal conditions. During the mating season, males attract females by bellowing, slapping their snouts in the water, blowing water out of their noses, and making a variety of other noises. The larger males of a population tend to be more successful. Once a female has been attracted, the pair warbles and rubs the undersides of their jaws together. Females lay their eggs about two months after mating (Crocodile Specialist Group, 1996a).

Nesting is in November or December, which is the dry season in the north of Africa, and the rainy season in the south. Preferred nesting locations are sandy shores, dry stream beds, or riverbanks. The female then digs a hole a few metres from the bank and up to 500 mm (20 in) deep, and lays between 25 and 80 eggs. The number of eggs varies, but averages around 50. Multiple females may nest close together (Crocodile Specialist Group, 1996a).

Unlike most other crocodilians, female Nile crocodiles bury their eggs in sand rather than incubate them in rotting vegetation (Guggisberg, 1972). After burying the eggs, the female then guards them for the three-month incubation period. The sire will often stay nearby, and both parents will fiercely attack anything approaching their eggs. The female will only leave the nest if she needs to cool off (thermoregulation) by taking a quick dip or seeking out a patch of shade. Despite the attentive care of both parents, the nests are often raided by humans and monitor lizards or other animals while she is temporarily absent (Crocodile Specialist Group, 1996a).

The hatchlings start to make a high-pitched chirping noise before hatching, which is the signal for the mother to rip open the nest. The parents may pick up the eggs in their mouths, and roll them between their tongue and the upper palate to help crack the shell and release their offspring. Once the eggs hatch, the female may lead the hatchlings to water, or even carry them there in her mouth, as female American alligators have been observed doing (Crocodile Specialist Group, 1996a).

Nile crocodiles have temperature-dependent sex determination (TSD), which means the sex of their hatchlings is determined not by genetics, but by the average temperature during the middle third of their incubation period. If the temperature inside the nest is below 31.7°C (89.1°F), or above 34.5°C (94.1°F), the offspring will be female. Males can only be born if the temperature is within that narrow range (Crocodile Specialist Group, 1996a).

Hatchlings are about 300 mm (12 in) long at birth, and grow that much each year. The new mother will protect her offspring for up to two years, and if there are multiple nests in the same area, the mothers may form a crèche. During this time, the mothers may pick up their offspring either in their mouths or gular fold (throat pouch), to keep the babies safe. The mother will sometimes carry her young on her back to avoid their being eaten by turtles or water snakes. At the end of the two years, the hatchlings will be about 1.2 m long, and will naturally depart the nest area, avoiding the territories of older and larger crocodiles (Crocodile Specialist Group, 1996a).

Systems

Freshwater and terrestrial (Crocodile Specialist Group, 1996a).

Threats

While the natural population in these areas may be lower due to a less-than-ideal environment and competition with sympatric slender-snouted and dwarf crocodiles, extirpation may be a serious threat in some of these areas. Additional factors are a loss of wetland habitats, and hunting in the 1970s. Additional ecological surveys and establishing management programs are necessary to resolve this (Crocodile Specialist Group, 1996a).

The Nile crocodile is the top predator in its environment, and is responsible for checking the population of species such as the barbel catfish, a predator that can over eat fish populations on which other species, like birds, depend. The Nile crocodile also consumes dead animals that would otherwise pollute the waters. The main threats to them, in turn, are pollution, loss of habitat, hunting, and human activities such as accidental entanglement in fishing nets (Crocodile Specialist Group, 1996a).

Much of the hunting stems from their reputation as a man-eater, which is not entirely unjustified. Unlike other "man-eating" crocodiles, such as the saltwater crocodile, the Nile crocodile lives in close proximity to human populations, so contact is more frequent. Although most attacks do not get reported, the Nile crocodile is estimated to kill hundreds (possibly thousands) of people each year, which is more than all other crocodilian species combined. One study posited the number of attacks by Nile crocodiles per year as 275 to 745, of which 63% are fatal, as opposed to an estimated 30 attacks per year by saltwater crocodiles, of which 50% are fatal. In both species, the mean size of crocodiles involved in nonfatal attacks was about 3 m as opposed to a reported range of 2.5–5 m or larger for crocodiles responsible for fatal attacks. The average estimated size of crocodiles involved in fatal attacks is 3.5 m. Since a majority of fatal attacks are believed to be predatory in nature, the Nile crocodile can be considered the most prolific predator of humans among wild animals (Crocodile Specialist Group, 1996a).

Conservation Actions

Crocodylus niloticus is listed on CITES Appendix I [except the populations of Botswana, Egypt (subject to a zero quota for wild specimens traded for commercial purposes), Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, South Africa, Uganda, the United Republic of Tanzania (subject to an annual export quota of no more than 1,600 wild specimens including hunting trophies, in addition to ranched specimens), Zambia and Zimbabwe, which are included in Appendix II] (Crocodile Specialist Group, 1996a).

Regionally relevant knowledge

Few studies have been conducted on *C. niloticus* in Guinea-Bissau; therefore regionally relevant knowledge on this species is negligible.

THE WEST AFRICAN DWARF CROCODILE (*OSTEOLAEMUS TETRASPIS*)

Description

As its name suggests, the dwarf crocodile is a diminutive species, with individuals rarely reaching lengths of 1.6 m (Crocodile Specialist Group, 1996b). It is a heavily armoured crocodile, which is dark in colour on the back and sides with a yellowish belly featuring many black patches (Crocodile Specialist Group, 1996b). Juveniles have light brown banding on the body and tail and yellowish patterns on the head. In all individuals, the snout is short and rather blunt (Crocodile Specialist Group, 1996b). The Congo dwarf crocodile subspecies (*O. t. osborni*) is poorly known. It is generally lighter in colour (Crocodile Specialist Group, 1996b) and has a flatter and more slender snout. It may yet prove to be a separate species

Geographic Range

Range Description

Osteolaemus tetraspis ranges across tropical lowland regions of sub-Saharan West Africa and West Central Africa (Figure 13). Such a distribution greatly overlaps with that of the slender-snouted crocodile, encompassing countries as far West as Senegal, reaching the Central African Republic in the East, and ranging as southerly as Angola. The subspecies O. t. tetraspis is found mainly in the westerly reaches of this range while *O. t. osborni* is restricted to the Democratic Republic of Congo's rain forest (Crocodile Specialist Group, 1996b).

Countries

According to the Crocodile Specialist Group (1996b), *Osteolaemus tetraspis* occurs in Angola (Angola); Benin; Burkina Faso; Cameroon; Central African Republic; Congo; Congo, The Democratic Republic of the; Côte d'Ivoire; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Liberia; Nigeria; Senegal; Sierra Leone; Togo.

Figure 13: Geographic distribution range of Osteolaemus tetraspis

Population

Dwarf crocodiles are a little-known species so, unlike their more studied relatives, conservationists aren't as aware of how their populations are faring under the growing human pressure over the ecosystems where they abide. Where survey data is available, it shows some degree of decline, either by hunting for bush meat or habitat loss due to deforestation. However, it is a widely spread, and presumably numerous, species so is not as endangered as other forest denizens (Crocodile Specialist Group, 1996b).

Population Trend

Decreasing.

Habitat and Ecology

Habitats

This crocodile is found mainly in swamps and swamp forests, with a preference for slow-moving bodies of water (Crocodile Specialist Group, 1996b). Occasionally, this species may occur in pools in savannah habitats, where they are reported to spend the dry season in burrows or hidden beneath extensive tree root structures (Crocodile Specialist Group, 1996b; Thorbjarnarson & Eaton, 2003). They also utilise isolated pools in forests (Crocodile Specialist Group, 1996b).

Reproduction

Interacting closely only in breeding season, female dwarf crocodiles build their nest mounds at the beginning of the wet season, which spans May and June. The nest, situated near the water, is a mound of wet, decaying vegetation that incubates the eggs due to the heat generated by the decomposition of the plant material (Crocodile Specialist Group, 1996b). A small number of eggs are laid, numbering about 10, though in extreme cases it can go up to 20 eggs, and they incubate in 85 to 105 days. Hatchlings measure 28 cm when emerging from the eggs. The female guards the nest during the incubation period and after the eggs hatch it watches over the young for an unknown period of time as young can be eaten by a great range of predators (birds, fish, mammals and reptiles, including other crocodiles) (Crocodile Specialist Group, 1996b).

Systems

Terrestrial and freshwater

Threats

The main threats facing this species include habitat destruction and hunting for meat for local consumption. Data collected from Congo show that tens of thousands of dwarf crocodiles are sold for food on local markets each year (Crocodile Specialist Group, 1996b). The small size and non-aggressive nature of the dwarf crocodile makes its capture and transport relatively easy, and so it is the most heavily hunted crocodile in the area. They are either bound and transported alive to markets or killed and stored on ice (Thorbjarnarson & Eaton, 2003). The hide of this species is of a relatively poor quality and so commercial hunting for this reason has not been a serious problem (Crocodile Specialist Group, 1996b). In some countries, including Gambia and Liberia, the population of this crocodile is severely depleted, and it may soon become extinct in these areas (Thorbjarnarson & Eaton, 2003). At present there is a lack of reliable survey data on this crocodile, and so the overall status of the species is unclear

Conservation Actions

This species is listed under Appendix I of the Convention on International Trade in Endangered Species (CITES) and so international trade in this species is controlled (Crocodile Specialist Group, 1996b). Plans are presently under discussion to set up captive breeding programmes for the dwarf crocodile. However, the most pressing requirement is for an extensive survey and monitoring scheme to establish the status of the species, with priority given to the countries where the species seems to be most at risk (Thorbjarnarson & Eaton, 2003). Preliminary surveys were carried out in 2003 by the Wildlife Conservation Society in Congo and Gabon to examine the potential for a research programme into the ecology of the three African species of crocodile and the impact of the bush meat trade on their populations

Regionally relevant knowledge

It is very likely that this species does not occur in Guinea–Bissau, and that the entry in the IUCN database is in error, but no conclusive studies have been conducted to determine this.

THE AFRICAN SLENDER-SNOUTED CROCODILE (*MECISTOPS CATAPHRACTUS*)

Description

The African slender-snouted crocodile (Mecistops cataphractus) is a species of crocodile. Recent studies in DNA and morphology suggest that it may belong in its own genus, *Mecistops.*

The African slender-snouted crocodile is among the least known of the world's crocodilians (Crocodile Specialist Group, 1996c). Its defining feature is its extremely slender snout, devoid of any bony ridges (Crocodile Specialist Group, 1996c). The leathery skin of the adult is brownish-yellow with large black spots, and the olive coloured head is spotted with brown. Young crocodiles are greenish-grey to greenish-yellow in colour with black blotches and markings (Crocodile Specialist Group, 1996c). Six or so rows of tough scales run down the crocodile's back, leading to the species name cataphractus, meaning 'clad in armour' in Greek

Geographic Range

Range Description

Occurs in the equatorial rainforest belt of Central and West Africa; from southern Mauritania, east to the Central African Republic and south to Angola and Tanzania (Figure 14) (Crocodile Specialist Group, 1996c)

Countries

Angola (Angola); Benin; Burkina Faso; Cameroon; Central African Republic; Chad; Congo; Congo, The Democratic Republic of the; Côte d'Ivoire; Equatorial Guinea; Gabon; Ghana; Guinea; Liberia; Mali; Mauritania; Nigeria; Sierra Leone; Tanzania, United Republic of; Togo; Zambia (Crocodile Specialist Group, 1996c).

Possibly extinct: Gambia; Guinea-Bissau; Senegal (Crocodile Specialist Group, 1996c).

Figure 14: Geographic distribution range of Mecistops cataphractus

Population

The fact this species is very poorly studied has led to little data being available, and therefore the global population of this species is currently unknown (Crocodile Specialist Group, 1996c).

Population Trend

Decreasing (Crocodile Specialist Group, 1996c).

Habitat and Ecology

Habitats

The African slender-snouted crocodile inhabits rivers, marshes, lakes and pools within rainforests (Crocodile Specialist Group, 1996c). While habitat data are not exhaustive, the slender-snouted crocodile is apparently confined to freshwater and typically prefers larger, swift-flowing streams (Crocodile Specialist Group, 1996c).

Reproduction

Depending on the region and its climatological patterns, mating is reported to begin in February; and from March the female constructs a nest by scraping vegetation together with her hind feet (Crocodile Specialist Group, 1996c). These large mounds, up to 80 centimetres high and two metres wide, are situated in a shady spot a few metres from small rainforest streams (Crocodile Specialist Group, 1996c). The female lays between 12 and 30 large, hard-shelled eggs in two layers in the mound, where a temperature of 27.4 to 34 degrees Celsius is maintained (Crocodile Specialist Group, 1996c). At the beginning of the rainy season, after 90 to 100 days of incubation, young crocodiles start to emerge from the elliptical eggs (Crocodile Specialist Group, 1996c). Their characteristic chirping instigates the mother to break open the nest and assist with the hatching process, causing the hatchlings to scatter over the flooded rainforest floor (Crocodile Specialist Group, 1996c). Slender-snouted crocodiles display some degree of parental care of hatchlings, with females aggressively defending their young when they emit distress calls. It is unknown for how many months this maternal care is given

Systems

Terrestrial and freshwater (Crocodile Specialist Group, 1996c).

Threats

The sparse information on the African slender-snouted crocodile makes it difficult to determine its conservation status, and thus the World Conservation Union (IUCN) has declared it Data Deficient (Crocodile Specialist Group, 1996c). However, the little survey data that is available suggests that many populations may be depleted, and possibly even extirpated in The Gambia, Senegal and Guinea-Bissau (Crocodile Specialist Group, 1996c). These declines are likely to be the result of hunting, for its hide and for food (Crocodile Specialist Group, 1996c), and the disruption of vital riverside vegetation (Crocodile Specialist Group, 1996c). Slender-snouted crocodiles are extremely vulnerable to being caught and drowned in fishing nets when attempting to eat fish struggling in the nets. Very few significant populations of this species exist in Central or West Africa, and additional data and protection is urgently required.

Conservation Actions

The African slender-snouted crocodile is legally protected in many of its range countries, although this is poorly enforced. The sparse information available indicates that populations of this rare ‘armour-clad’ crocodile are declining, so better enforcement of laws, changes in legal status, and firmer hunting regulations are clearly needed. However, the lack of definitive information on this species’ ecology, population dynamics and status makes such actions hard to develop, and the inaccessibility and political instability throughout much of its range hinders most efforts for further research or action (Crocodile Specialist Group, 1996c).

Regionally relevant knowledge

This species is thought to be extinct in Guinea-Bissau, Senegal and the Gambia (Crocodile Specialist Group, 1996c).

PALM-NUT VULTURE (GYPOHIERAX ANGOLENSIS)

Description

With its extensive white plumage, and black wing and tail feathers, the adult palm-nut vulture can be crudely mistaken for both the African fish eagle and the Egyptian vulture, but clearly lacks the chestnut body of the former and the white tail of the latter (Sinclair & Ryan, 2003; Sinclair, et al., 2002). While the head, throat and neck is well feathered, reddish bare skin, conspicuous around the face and eyes, is distinctly vulturine (Sinclair & Ryan, 2003; Sinclair, et al., 2002). The sexes are almost identical in appearance, with the female being only slightly larger than the male. Juveniles on the other hand are predominately brown with partially black wings and take a lengthy three to four years to make the transition into the adult plumage

Geographic Range

Range Description

The palm-nut vulture has a widespread and locally abundant distribution in Africa, from the Gambia across to Kenya, and south as far as north-east South Africa (BirdLife International , 2013)

Countries

According to BirdLife International (2013), *Gypohierax angolensis* occurs in Angola; Benin; Botswana; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; Congo; Congo, The Democratic Republic of the; Côte d'Ivoire; Equatorial Guinea; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Liberia; Malawi; Mali; Mozambique; Namibia; Niger; Nigeria; Rwanda; Senegal; Sierra Leone; South Africa; South Sudan; Sudan; Tanzania, United Republic of; Togo; Uganda; Zambia; Zimbabwe Vagrant: Lesotho.

Figure 15: Geographic distribution range of Gypohierax angolensis

Population

The population of palm-nut vultures appears to be stable with estimates in 2001 of approximately 240,000 individuals in Africa (BirdLife International , 2013).

Population Trend

Stable (BirdLife International , 2013)

Habitat and Ecology

Habitats

As the name suggests, the distribution of the palm-nut vulture closely tracks that of oil (*Elaeis* sp.) or raffia (*Raphia* sp.) palms (Thomson & Moreau, 1957). Consequently, it is most common in coastal forests and mangrove swamps below 1,500 metres, but also occurs in wet savannahs (BirdLife International , 2013).

Reproduction

Breeding pairs construct large stick nests high up in tall trees and will often exhibit a strong attachment to the nest site, staying within its vicinity year round. At the beginning of the breeding season, pairs soar together in an aerial display of rolling and diving, much more acrobatic than most vultures (Ferguson-Lees & Christie, 2001; Virani, et al., 2011; Sinclair, et al., 2002). During each breeding cycle, a single, white and chocolate-brown egg is laid, which is incubated by both sexes, over a period of four to six weeks (Ferguson-Lees & Christie, 2001; Virani, et al., 2011; Sinclair, et al., 2002). Normally around 85 to 90 days after hatching, the young brown chicks will fledge

Systems

Terrestrial and Freshwater (BirdLife International , 2013)

Threats

In West Africa this species is at risk from habitat destruction, in other areas its range is expanding in unison with spreading oil palm plantations (BirdLife International , 2013).

Conservation Actions

There are no known conservation measures in place for the palm-nut vulture (BirdLife International , 2013).

Regionally relevant knowledge

In the region *Gypohierax angolensis* is a locally common species, it feeds mainly on palm trees growing in wetland areas and rice paddies but is often seen fishing on larger rivers such as the Cacheu River.

HOODED VULTURE (*NECROSYRTES MONACHUS*)

Description

This species is a small (67-70 cm), scruffy-looking, mostly brown vulture, with long thin bill, bare crown, face and foreneck, conspicuous ear-holes, and downy nape and hindneck (Sinclair & Ryan, 2003). Perches hunched with wings drooping. Sexes are alike, while juveniles usually have a pale face blue and hood of short down dark brown rather than beige (Sinclair & Ryan, 2003).

Geographic Range

Range Description

Necrosyrtes monachus is widespread in sub-Saharan Africa; from Senegal and southern Mauritania east through southern Niger and Chad, to southern Sudan, South Sudan, Ethiopia and western Somalia, southwards to northern Namibia and Botswana, and through Zimbabwe to southern Mozambique and north-eastern South Africa (Ferguson-Lees & Christie, 2001). The species is generally sedentary, with some dispersal by non-breeders and immature birds, and movements in response to rainfall in the Sahel of West Africa (Ferguson-Lees & Christie, 2001). Data and observations of varying coverage and quality from various parts of its range suggest that the species is undergoing a very rapid decline in its global population (Ogada & Buij, 2011).

Countries

According to Birdlife international (BirdLife International , 2013), *Necrosyrtes monachus* occurs in: Angola; Benin; Botswana; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; Congo, The Democratic Republic of the; Côte d'Ivoire; Djibouti; Eritrea; Ethiopia; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Liberia; Malawi; Mali; Mauritania; Mozambique; Namibia; Niger; Nigeria; Rwanda; Senegal;

Sierra Leone; Somalia; South Africa; South Sudan; Sudan; Swaziland; Tanzania, United Republic of; Togo; Uganda; Zambia and Zimbabwe. This species also occurs as a vagrant in Morocco (BirdLife International , 2012).

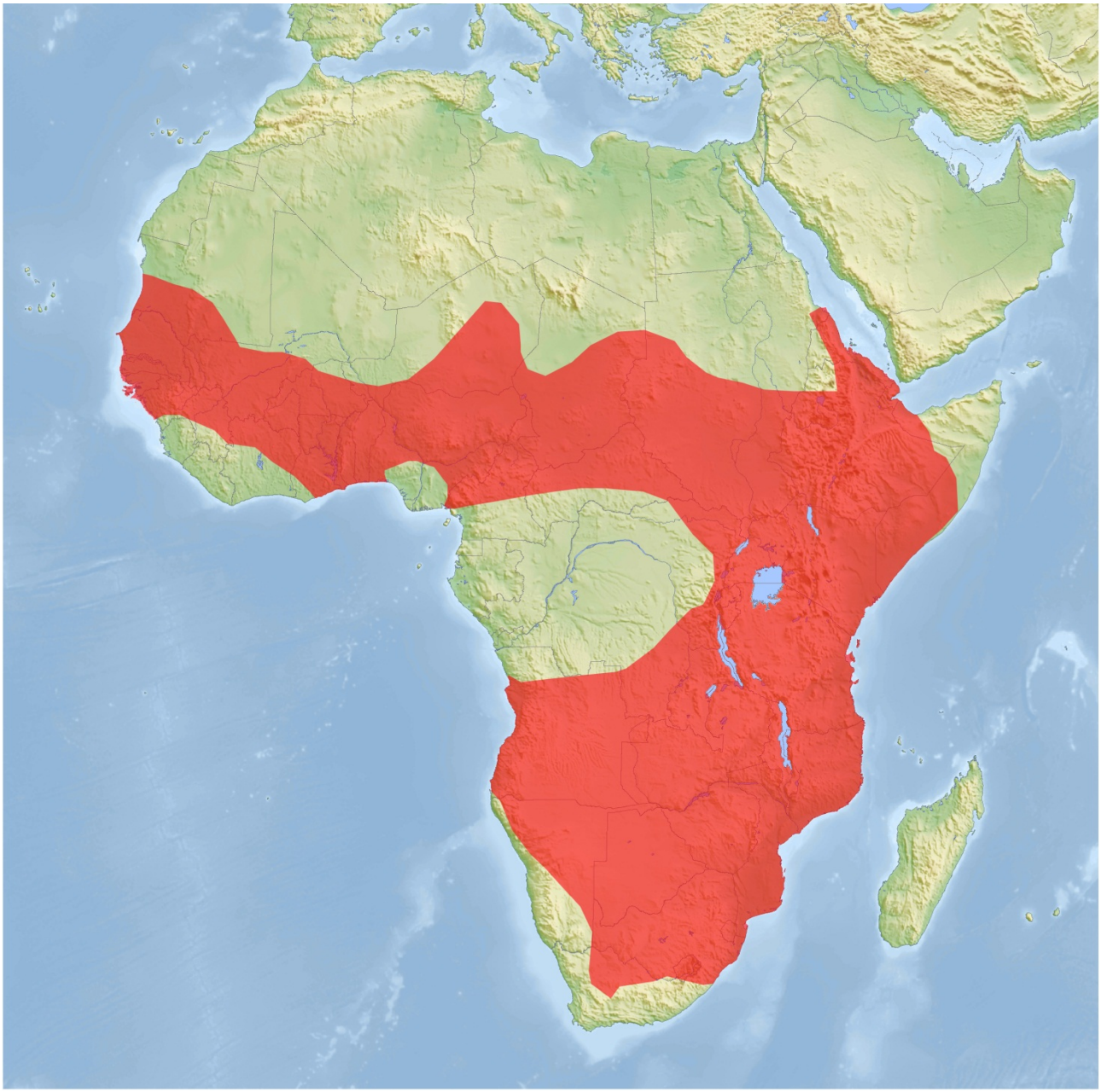

Figure 16: Geographic distribution range of Necrosyrtes monachus

Population

Given evidence of recent declines in various parts of its range, this species' population is estimated to number a maximum of 197,000 individuals (Ferguson-Lees & Christie, 2001; BirdLife International , 2012).

Population Trend

Declining (BirdLife International , 2012)

Habitat and Ecology

Habitats

The species is often associated with human settlements, but is also found in open grassland, forest edge, wooded savanna, desert and along coasts (Ferguson-Lees & Christie, 2001). It occurs up to 4,000 m, but is most numerous below 1,800 m. It feeds mainly on carrion, but also takes insects.

Reproduction

In West Africa and Kenya it breeds throughout the year, but especially from November to July. Breeding in north-east Africa occurs mainly in October-June, with birds in southern Africa tending to breed in May-December (Ogada & Buij, 2011). It is an arboreal nester and lays a clutch of one egg. Its incubation period lasts 46-54 days, followed by a fledging period of 80-130 days. Young are dependent on their parents for a further 3-4 months after fledging (Ferguson-Lees & Christie, 2001).

Systems

Terrestrial (BirdLife International , 2012)

Threats

Major threats to this species include non-target poisoning, capture for traditional medicine and bush meat, and direct persecution (Ogada & Buij, 2011). Hooded Vulture meat is reportedly sold as chicken in some places. Intentional poisoning of vultures may be carried out in some areas by poachers in order to hide the locations of their kills. Secondary poisoning with carbofuran pesticides at livestock baits being used to poison mammalian predators is also an issue in East Africa (Otieno, et al., 2010). Declines have also been attributed to land conversion through development and improvements to abattoir hygiene and rubbish disposal in some areas (Ogada & Buij, 2011). The species may also be threatened by avian influenza (H5N1), from which it appears to suffer some mortality and which it probably acquires from feeding on discarded dead poultry (Ducatez et al. 2007).

Conservation Actions

No targeted actions are known. This widespread species occurs in a large number of protected areas. Carry out systematic surveys throughout the species' range to acquire a more accurate population estimate and monitor trends. Raise awareness of the species' plight and the impact of hunting and persecution. Monitor rates of land-use change across its range. Monitor effects of poisoning on the species and its use in muti trade and for meat (Otieno, et al., 2010).

Regionally relevant knowledge

Necrosyrtes monachus is a locally common species in many countries in West Africa. It often occurs in large numbers in cities and large towns.

APPENDIX F1

Water Quality Data (Dry Season and Wet Season)

Table A1-1: Farim Project Dry Season Water Quality Data Collected

Date	Station ID	Depth (m)	Temp. (°C)	Sp.Cond. (mS/cm)	Salinity (ppt)	D.O. (mg/L)	pH	Sechi Disc Reading (m)
5/14/2013	STN 1	0.2	30.05	4.58	2.42	5.55	6.67	<1.0
5/16/2013	STN 2	0.2	30.17	5.06	2.70	5.92	7.31	0.9
		0.9	30.18	5.09	2.70	5.90	7.30	
		1.8	30.19	5.09	2.71	5.99	7.27	
		2.8	30.20	5.10	2.71	5.94	7.25	
		3.7	30.20	5.09	2.71	5.72	7.23	
		4.9	30.21	5.10	2.71	5.64	7.19	
		5.8	30.22	5.10	2.71	5.65	7.16	
		6.9	30.29	5.09	2.71	5.52	7.33	
5/15/2013	STN 3	0.2	30.10	5.52	2.96	6.01	7.04	<1.0
		1.1	30.02	5.53	2.96	6.06	6.98	
		2.3	30.01	5.55	2.97	5.86	6.84	
		3.0	30.02	5.53	2.96	6.21	6.73	
		4.3	30.02	5.52	2.96	5.86	6.56	
		5.4	30.03	5.52	2.96	5.85	6.37	
		6.2	30.05	5.52	2.95	5.83	6.26	
		7.2	30.11	5.51	2.95	5.80	5.93	
5/15/2013	STN 4	0.5	29.64	6.09	3.29	6.38	7.33	<1.0
		1.5	29.58	6.10	3.29	6.32	7.32	
		2.3	29.57	6.11	3.30	6.08	7.31	
		3.5	29.57	6.12	3.31	5.81	7.30	
		4.7	29.57	6.13	3.31	5.91	7.30	
		5.4	29.58	6.14	3.31	5.87	7.30	
		6.7	29.58	6.16	3.33	5.77	7.29	
		7.4	29.59	6.16	3.33	5.69	7.28	
5/16/2013	STN 5	0.2	29.07	6.40	3.45	6.04	7.03	0.9
		1.4	29.95	6.40	3.46	5.92	6.87	
		2.5	29.88	6.40	3.47	5.95	6.80	
		3.4	29.93	6.41	3.47	6.00	6.73	
		4.5	29.94	6.40	3.47	5.98	6.61	
		5.6	29.95	6.41	3.47	5.98	6.49	
		6.8	29.97	6.40	3.47	5.89	6.35	
		7.2	30.02	6.41	3.46	5.91	6.06	
		8.5	30.22	6.38	3.45	5.77	5.85	

Table A1-1: Farim Project Dry Season Water Quality Data Collected

Date	Station ID	Depth (m)	Temp. (°C)	Sp.Cond. (mS/cm)	Salinity (ppt)	D.O. (mg/L)	pH	Sechi Disc Reading (m)
5/16/2013	STN 6	0.2	29.20	8.65	4.79	5.43	7.20	0.9
		1.1	29.19	8.64	4.78	5.51	7.18	
		2.7	29.17	8.65	4.78	5.55	7.18	
		3.5	29.16	8.67	4.80	5.52	7.16	
		5.0	29.15	8.68	4.81	5.52	7.16	
		5.1	29.15	8.69	4.82	5.32	7.13	
		6.1	29.14	8.70	4.81	5.26	7.12	
		7.3	29.15	8.69	4.76	5.72	7.00	
		7.7	29.16	8.63	4.77	5.91	7.20	
		9.1	29.14	8.71	4.82	5.31	7.10	
		10.7	29.09	8.77	4.86	5.10	6.99	
5/17/2013	STN 7	0.3	28.80	21.13	12.59	3.71	6.98	<1.0
		1.0	28.65	21.15	12.62	3.47	6.93	
		2.1	28.64	21.19	12.64	3.45	6.91	
		3.2	28.64	21.25	12.68	3.44	6.88	
		4.1	28.62	21.33	12.72	3.42	6.86	
		5.1	28.62	21.33	12.73	3.41	6.83	
		6.1	28.62	21.34	12.73	3.40	6.80	
		7.2	28.63	21.35	12.75	3.44	6.76	
		8.0	28.63	21.37	12.75	3.43	6.71	
		9.0	28.64	21.36	12.75	3.44	6.63	
		10.0	28.65	21.38	12.76	3.50	6.57	
		11.2	28.66	21.40	12.77	3.53	6.49	
		12.4	28.67	21.41	12.78	3.72	6.37	
		13.5	28.71	21.40	12.77	3.85	5.97	
5/18/2013	STN 8	0.2	29.03	28.78	17.67	3.11	7.10	0.5
		1.0	28.98	28.83	17.71	3.13	7.00	
		2.0	28.99	28.83	17.69	3.09	7.00	
		3.0	28.97	28.90	17.75	3.09	6.99	
		4.0	28.96	28.92	17.77	3.06	6.99	
		5.1	28.96	29.02	17.83	3.03	6.99	
		6.0	28.97	29.02	17.83	3.06	6.98	
		7.0	28.97	29.05	17.81	3.07	6.98	
		8.0	28.98	29.12	17.91	3.01	6.97	
		9.0	28.98	29.15	17.91	3.06	6.96	
		10.0	28.98	29.17	17.95	3.07	6.95	
		11.0	28.99	29.16	17.91	3.00	6.95	
		12.3	29.10	29.28	18.01	2.84	6.95	

Table A1-1: Farim Project Dry Season Water Quality Data Collected

Date	Station ID	Depth (m)	Temp. (°C)	Sp.Cond. (mS/cm)	Salinity (ppt)	D.O. (mg/L)	pH	Sechi Disc Reading (m)
5/25/2013	STN 9	0.2	29.67	49.85	32.51	4.82	7.35	0.6
		1.1	29.53	49.97	32.55	4.69	7.32	
		2.0	29.50	50.01	32.62	4.71	7.30	
		3.0	29.49	50.01	32.61	4.67	7.29	
		4.0	29.49	50.00	32.60	4.66	7.28	
		5.1	29.49	49.99	32.60	4.72	7.28	
		6.2	29.49	49.96	32.58	4.68	7.27	
		7.0	29.49	49.95	32.58	4.78	7.27	
		7.9	29.49	49.95	32.57	4.63	7.26	
5/25/2013	STN 10	0.2	30.40	52.50	34.44	4.58	6.76	0.6
		1.1	30.42	52.57	34.51	4.66	6.79	
		2.0	30.41	52.61	34.50	4.68	6.83	
		3.1	30.49	52.71	34.63	4.66	6.85	
		4.0	30.60	52.90	34.71	4.50	6.88	
		4.9	30.62	52.91	34.71	4.52	6.90	
5/19/2013	STN 11	0.3	28.54	49.07	31.96	5.42	7.96	<1.0
		1.8	28.25	49.01	31.92	5.39	7.94	
		2.7	28.16	49.02	31.92	5.49	7.94	
		3.6	28.18	48.99	31.90	5.44	7.94	
		4.8	28.13	49.00	31.91	5.44	7.94	
		5.7	28.09	49.02	31.90	5.74	7.93	
		6.8	28.00	49.00	31.86	5.54	7.93	
		7.8	27.95	49.02	31.88	5.57	7.93	
		8.6	27.89	48.92	31.94	5.62	7.92	
		9.8	27.85	48.94	31.85	5.67	7.89	
		10.8	27.90	48.89	31.85	5.63	7.87	
		11.7	27.92	48.91	31.86	5.67	7.85	
		12.8	27.84	48.89	31.86	5.81	7.82	
5/20/2013	STN 12	0.3	27.90	48.95	31.92	5.24	8.05	<1.0
		1.1	27.77	48.96	31.88	5.23	8.06	
		2.0	27.71	48.93	31.86	5.31	8.06	
		3.0	27.68	48.94	31.89	5.26	8.06	
		4.1	27.63	48.88	31.88	5.12	8.06	
		5.1	27.63	48.89	31.86	5.28	8.06	
		6.0	27.60	48.88	31.86	5.19	8.07	
		7.0	27.70	48.81	31.82	5.02	8.09	

Table A1-1: Farim Project Dry Season Water Quality Data Collected

Date	Station ID	Depth (m)	Temp. (°C)	Sp.Cond. (mS/cm)	Salinity (ppt)	D.O. (mg/L)	pH	Sechi Disc Reading (m)
5/20/2013	STN 13	0.3	27.97	49.07	31.98	6.32	8.23	1.0
		1.1	27.97	49.07	31.98	6.27	8.24	
		2.1	27.94	49.06	31.97	6.31	8.25	
		3.0	27.94	49.06	31.97	6.31	8.30	
		3.8	27.94	49.07	31.97	6.36	8.31	
5/22/2013	STN 14	0.2	29.09	48.26	31.35	5.58	7.88	0.8
		1.0	29.00	48.25	31.35	5.53	7.86	
		2.1	28.52	48.31	31.41	5.21	7.78	
		3.1	28.50	48.37	31.45	5.18	7.77	
		4.0	28.48	48.49	31.54	5.23	7.76	
		5.0	28.48	48.58	31.60	5.19	7.74	
		6.2	28.49	48.61	31.63	5.05	7.72	
5/23/2013	STN 15	0.2	28.38	49.02	31.94	5.74	8.13	0.7
		1.0	28.39	49.01	31.94	5.76	8.13	
		2.0	28.37	49.01	31.93	5.75	8.13	
		3.0	28.60	49.01	31.92	5.74	8.13	
		4.0	28.16	49.00	31.92	5.97	8.13	
		5.0	28.37	49.02	31.92	5.91	8.13	
		6.0	28.27	49.08	31.92	5.95	8.12	
		6.8	28.16	49.01	31.91	5.78	8.12	
5/23/2013	STN 16	0.2	28.48	49.06	31.93	5.73	8.26	1.1
		1.1	28.48	49.04	31.94	5.96	8.25	
		2.0	28.48	49.03	31.94	6.04	8.24	
		3.0	28.48	49.02	31.93	6.05	8.23	
		4.1	28.46	49.02	31.92	6.03	8.23	
		5.0	28.46	49.03	31.94	6.01	8.22	
		5.8	28.46	49.03	31.93	5.99	8.21	
5/24/2013	STN 17	0.2	28.50	55.28	36.55	6.49	7.56	<1.0
		1.2	28.48	55.28	36.55	6.52	7.59	
		2.0	28.46	55.29	36.56	6.52	7.61	
		3.0	28.45	55.29	36.56	6.49	7.63	
		4.0	28.44	55.29	36.56	6.49	7.64	
		5.0	28.44	55.31	36.58	6.43	7.65	
		6.2	28.43	55.34	36.59	6.39	7.66	
		7.1	28.43	55.33	36.60	6.32	7.69	
		8.3	28.43	55.33	36.59	6.30	7.69	

Wet season Survey, August 2013

Table A2-1: Farim Project - Water Quality Data Collected

Date	Station ID	Depth (m)	Temp. (°C)	Sp.Cond. (µS/cm)	Salinity (ppt)	D.O. (mg/L)	pH	Sechi Disc Reading (m)
15/08/2013	STN 1	5.2	29.0	6.6	3.6	4.44	5.7	0.5
		4.0	28.9	6.6	3.6	4.4	5.9	
		3.0	28.9	6.6	3.6	4.5	6.0	
		2.0	28.9	6.6	3.6	4.5	6.0	
		1.0	28.9	6.6	3.6	4.5	6.1	
		0.2	29.2	6.6	3.7	4.6	6.1	
15/08/2013	STN 2	6.6	29.2	7.1	3.9	4.5	5.8	0.8
		6.0	29.1	7.1	3.9	4.4	5.9	
		5.0	29.1	7.1	3.9	4.4	5.9	
		4.0	29.1	7.1	3.9	4.4	6.0	
		3.0	29.1	7.1	3.9	4.4	6.1	
		2.0	29.1	7.1	3.9	4.4	6.1	
		1.0	29.1	7.1	3.9	4.4	6.2	
		0.2	29.1	7.0	3.8	4.4	6.3	
17/08/2013	STN 3	7.5	28.8	8.8	4.9	4.4	6.7	0.8
		7.0	28.8	8.8	4.9	4.4	6.7	
		6.0	28.8	8.8	4.9	4.3	6.7	
		5.0	28.9	8.8	4.9	4.5	6.7	
		4.0	28.9	8.8	4.9	4.5	6.6	
		3.0	28.9	8.7	4.8	4.5	6.7	
		2.0	28.9	8.7	4.8	4.5	6.7	
		1.0	29.0	8.6	4.8	4.6	6.6	
		0.2	29.0	8.6	4.8	4.6	6.6	
17/08/2013	STN 4	11.9	28.6	9.7	5.4	4.4	6.6	0.8
		11.0	28.6	9.7	5.4	4.3	6.6	
		10.0	28.6	9.7	5.4	4.4	6.7	
		9.0	28.6	9.7	5.4	4.5	6.6	
		8.0	28.6	9.7	5.4	4.5	6.6	
		7.0	28.7	9.7	5.4	4.4	6.6	
		6.0	28.7	9.7	5.4	4.3	6.6	
		5.0	28.7	9.7	5.4	4.6	6.6	
		4.0	28.7	9.7	5.4	4.4	6.6	
		3.0	28.7	9.7	5.4	4.3	6.6	
		2.0	28.7	9.7	5.4	4.6	6.6	
		1.0	28.7	9.6	5.4	4.6	6.7	
		0.2	28.7	9.6	5.4	4.5	6.7	
16/08/2013	STN 5	9.8	28.8	11.4	6.4	4.8	7.4	1.1
		9.0	28.8	11.4	6.4	4.8	7.3	
		8.0	28.8	11.4	6.4	4.8	7.3	
		7.0	28.8	11.3	6.4	4.9	7.2	
		6.0	28.8	11.3	6.4	4.9	7.2	
		5.0	28.8	11.3	6.4	4.9	7.1	
		4.0	28.8	11.3	6.4	4.9	7.1	
		3.0	28.9	11.3	6.4	4.9	7.1	
		2.0	28.9	11.2	6.3	5	7.0	
		1.0	28.8	11.2	6.3	5.2	7.0	
		0.2	28.8	11.2	6.3	5.2	7.0	
16/08/2013	STN 6	8.6	28.8	12.5	7.2	4.6	6.6	1.1
		8.0	28.2	12.5	7.2	4.6	6.7	
		7.0	28.2	12.5	7.2	4.6	6.7	
		6.0	28.2	12.5	7.1	4.6	6.7	
		5.0	28.9	12.5	7.1	4.7	6.7	
		4.0	28.9	12.5	7.1	4.7	6.7	
		3.0	28.5	12.5	7.1	4.7	6.7	
		2.0	28.9	12.4	7.1	4.7	6.7	
		1.0	28.9	12.4	7.1	4.7	6.7	
		0.2	28.9	12.4	7.1	4.8	6.7	
19/08/2013	STN 7	7.5	27.7	20.9	12.5	2.8	6.6	0.5
		7.0	27.7	20.9	12.5	2.8	6.6	
		6.0	27.7	20.9	12.5	2.9	6.6	
		5.0	27.6	21.0	12.5	2.9	6.6	
		4.0	27.6	21.0	12.5	2.8	6.6	
		3.0	27.7	21.0	12.5	2.9	6.6	
		2.0	27.7	20.9	12.5	2.9	6.6	
		1.0	27.7	20.9	12.5	2.9	6.6	
		0.2	27.7	20.9	12.5	2.9	6.5	
19/08/2013	STN 8	10.0	28.1	27.4	16.8	2.7	6.7	0.5
		9.0	28.1	27.4	16.8	2.7	6.7	
		8.0	28.1	27.5	16.8	2.8	6.7	
		7.0	28.1	27.5	16.8	2.7	6.7	
		6.0	28.1	27.4	16.8	2.8	6.7	
		5.0	28.1	27.4	16.7	2.9	6.7	
		3.0	28.1	27.3	16.7	2.8	6.7	
		4.0	28.1	27.3	16.7	2.7	67.0	
		2.0	28.1	27.0	16.5	2.9	6.7	
		1.0	28.1	26.9	16.4	2.9	6.7	
		0.2	28.1	26.6	16.2	3	6.7	
22/08/2013	STN 9	7.6	28.9	34.4	21.5	3.7	6.3	0.4
		7.0	28.9	34.5	21.6	3.8	6.4	
		6.0	28.9	34.5	21.6	3.8	6.4	
		5.0	28.9	34.6	21.6	3.8	6.4	
		4.0	28.9	34.6	21.7	3.8	6.5	
		3.0	28.9	34.4	21.5	3.8	6.5	
		2.0	28.8	34.3	21.5	3.7	6.5	
		1.0	28.8	34.2	21.4	3.6	6.6	
		0.2	29.0	34.0	21.3	3.7	6.5	

Table A2-1: Farim Project - Water Quality Data Collected

22/08/2013	STN 10	9.7	28.8	41.2	26.3	4	6.1	0.2
		9.0	28.8	41.2	26.3	4.1	6.1	
		8.0	28.8	41.2	26.3	4	6.2	
		7.0	28.8	41.2	26.3	4.1	6.3	
		6.0	28.8	41.1	26.2	4.1	6.3	
		5.0	28.9	41.1	26.2	4.1	6.4	
		4.0	28.9	41.0	26.9	4.1	6.4	
		3.0	29.1	40.6	25.8	4	6.5	
		2.0	29.2	40.5	25.8	4	6.6	
		1.0	29.4	40.1	25.5	4	6.6	
		0.2	29.6	39.9	25.3	4.1	6.7	
24/08/2013	STN 11	14.0	28.3	47.0	30.4	5.2	7.3	1.1
		13.0	28.2	47.0	30.5	5.2	7.4	
		12.0	28.2	47.0	30.5	5.2	7.3	
		11.0	28.2	47.0	30.5	5.2	7.3	
		10.0	28.2	47.0	30.5	5.2	7.2	
		9.0	28.2	47.0	30.4	5.2	7.3	
		8.0	28.2	47.0	30.4	5.1	7.4	
		7.0	28.2	46.9	30.4	5.1	7.4	
		6.0	28.2	46.9	30.4	5.1	7.4	
		5.0	28.2	46.8	30.4	5.1	7.4	
		4.0	28.3	46.8	30.3	5.1	7.4	
		3.0	28.3	46.8	30.3	5.1	7.4	
		2.0	28.3	46.8	30.3	5.2	7.4	
		1.0	28.9	46.7	30.2	5.5	7.5	
		0.2	28.2	46.6	30.1	5.5	7.6	
24/08/2013	STN 12	6.7	28.3	46.4	30.0	5.1	6.6	0.5
		6.0	28.3	46.4	30.0	5.2	6.6	
		5.0	28.3	46.4	30.0	5	6.7	
		4.0	28.3	46.4	30.0	5.1	6.8	
		3.0	28.3	46.4	30.0	5.2	6.8	
		2.0	28.3	46.4	30.0	5.2	6.9	
		1.0	28.3	46.4	30.0	5	7.0	
		0.2	28.3	46.4	30.0	5.1	7.0	
21/08/2013	STN 13	4.3	28.1	47.2	30.6	5.8	6.7	0.5
		4.0	28.0	47.2	30.6	5.8	6.8	
		3.0	28.0	47.2	30.6	5.9	6.9	
		2.0	28.0	47.2	30.6	5.9	6.9	
		1.0	28.0	47.2	30.6	5.9	7.0	
		0.2	28.0	47.2	30.6	5.9	7.0	
24/08/2013	STN 14	7.7	28.2	46.4	30.0	5.1	7.4	0.6
		7.0	28.2	46.4	30.0	5.1	7.4	
		6.0	28.2	46.4	30.0	5.2	7.4	
		5.0	28.2	46.4	30.0	5.1	7.4	
		4.0	28.2	46.4	30.0	5.2	7.4	
		3.0	28.2	46.4	30.0	5.2	7.4	
		2.0	28.3	46.4	30.0	5.2	7.5	
		1.0	28.4	46.5	30.1	5.3	7.5	
		0.2	28.6	46.4	30.0	5.3	7.5	
27/08/2013	STN 15	8.0	28.5	46.9	30.4	4.9	7.7	0.5
		7.0	28.5	46.9	30.4	4.9	7.6	
		6.0	28.5	46.9	30.4	4.8	7.6	
		5.0	28.5	46.9	30.4	4.9	7.6	
		4.0	28.5	46.9	30.4	4.9	7.6	
		3.0	28.5	46.9	30.4	5	7.6	
		2.0	28.6	46.9	30.4	5	7.6	
		1.0	28.6	46.9	30.4	4.5	7.6	
		0.2	28.6	46.9	30.4	4.9	7.6	
26/08/2013	STN 16	6.0	28.4	47.2	30.6	4.9	7.6	0.8
		5.0	28.4	47.2	30.6	4.9	7.5	
		4.0	28.4	47.1	30.6	4.9	7.5	
		3.0	28.7	47.2	30.6	5.1	7.5	
		2.0	28.9	47.2	30.5	5.1	7.6	
		1.0	28.9	47.2	30.6	5.2	7.6	
		0.2	29.0	47.2	30.6	5.2	7.6	
26/08/2013	STN 17	9.0	28.2	46.6	30.2	5	7.5	0.7
		8.0	28.2	46.6	30.2	5	7.5	
		7.0	28.2	46.6	30.2	5.1	7.5	
		6.0	28.2	46.6	30.2	5.1	7.5	
		5.0	28.2	46.6	30.2	5.1	7.5	
		4.0	28.2	46.6	30.2	5.1	7.5	
		3.0	28.2	46.6	30.2	5.1	7.5	
		2.0	28.2	46.6	30.2	5.1	7.5	
		1.0	28.3	46.6	30.2	5.1	7.5	
		0.2	28.4	46.7	30.2	5.1	7.5	

APPENDIX F2

Phytoplankton Data (Dry Season and Wet Season)

Table B1-1: Farim Project – Dry Season STN1 Summary Phytoplankton Data

STATION	SAMPLE	SAMPLE	GENUS AND SPECIES	DIVISION	NOTES
	DATE	TIME			
STN1	5/14/2013	1:45:00 PM	Actinocyclus cf. divisus	Bacillariophyta	High sediment.
			Aphanocapsa sp.	Cyanobacteria	High sediment.
			cf. Thalassiosira sp.	Bacillariophyta	High sediment.
			cf. Woronichinia sp.	Cyanobacteria	High sediment.
			Chaetoceros sp.	Bacillariophyta	High sediment.
			Chlamydomonas globosa	Chlorophyta	High sediment.
			Cyclotella cf. hakanssoniae	Bacillariophyta	High sediment.
			Cyclotella cf. striata	Bacillariophyta	High sediment.
			Cyclotella sp.	Bacillariophyta	High sediment.
			Gymnodinium sp.	Pyrrophyta	High sediment.
			Nitzschia punctata	Bacillariophyta	High sediment.
			Nitzschia sp.	Bacillariophyta	High sediment.
			Nitzschia supralitorea	Bacillariophyta	High sediment.
			Ochromonas sp.	Chrysophyta	High sediment.
			Oocystis sp.	Chlorophyta	High sediment.
			Planctonema lauterbornii	Chlorophyta	High sediment.
			Scenedesmus quadricauda	Chlorophyta	High sediment.
			Scenedesmus sp.	Chlorophyta	High sediment.
			Skeletonema cf. subsalsum	Bacillariophyta	High sediment.
			Tetrastrum glabrum	Chlorophyta	High sediment.
			Thalassiosira eccentrica	Bacillariophyta	High sediment.
			Thalassiosira visurgis	Bacillariophyta	High sediment.
			Tryblionella debilis	Bacillariophyta	High sediment.

Table B1-2: Farim Project – Dry Season STN2 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN2	5/16/2013	17:45:00 PM	Achnanthidium minutissimum	Bacillariophyta	
			Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus sp.	Bacillariophyta	
			Amphora sp.	Bacillariophyta	
			Aphanocapsa holsatica	Cyanobacteria	
			Aphanocapsa sp.	Cyanobacteria	
			Aulacoseira sp.	Bacillariophyta	
			Capartogramma crucicula	Bacillariophyta	
			Carteria sp.	Chlorophyta	
			cf. Conradiella sp.	Chrysophyta	
			cf. Coscinodiscus sp.	Bacillariophyta	
			cf. Gymnodinium sp.	Pyrrophyta	
			cf. Rhodomonas salina	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Tryblionella sp.	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chlorella sp.	Chlorophyta	
			Cyclotella cf. hakanssoniae	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella distinguenda var. mesoleia	Bacillariophyta	
			Cyclotella spp.	Bacillariophyta	
			Diploneis ovalis	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Nitzschia compressa	Bacillariophyta	
			Nitzschia fonticola	Bacillariophyta	
			Nitzschia inconspicua	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia supralitorea	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Oocystis sp.	Chlorophyta	
			Planctonema lauterbornii	Chlorophyta	
			Scenedesmus quadricauda	Chlorophyta	
			Scenedesmus sp.	Chlorophyta	
			Skeletonema cf. subsalsum	Bacillariophyta	
			Skeletonema subsalsum	Bacillariophyta	
			Surirella sp.	Bacillariophyta	
			Tetrastrum glabrum	Chlorophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-3: Farim Project – Dry Season STN3 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN3	5/15/2013	16:45	Actinocyclus cf. divisus	Bacillariophyta	
			Aphanocapsa holsatica	Cyanobacteria	
			Aphanocapsa sp.	Cyanobacteria	
			Aulacoseira sp.	Bacillariophyta	
			cf. Chlorella sp.	Chlorophyta	
			cf. Chroomonas sp.	Cryptophyta	
			cf. Monoraphidium nanum	Chlorophyta	
			cf. Oocystis sp.	Chlorophyta	
			cf. Opephora pacifica	Bacillariophyta	
			cf. Phormidium sp.	Cyanobacteria	
			cf. Rhodomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chlamydomonas grovei	Chlorophyta	
			Chlorella spp.	Chlorophyta	
			Coscinodiscus sp.	Bacillariophyta	
			Cyclotella cf. hakanssoniae	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella meneghiniana	Bacillariophyta	
			Dictyosphaerium chlorelloides	Chlorophyta	
			Hippodonta sp.	Bacillariophyta	
			Navicula sp.	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia supralitorea	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Oocystis sp.	Chlorophyta	
			Planctonema lauterbornii	Chlorophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Scenedesmus communis	Chlorophyta	
			Scenedesmus quadricauda	Chlorophyta	
			Skeletonema cf. subsalsum	Bacillariophyta	
			Staurosirella leptostauron var. dubia	Bacillariophyta	
			Stephanodiscus cf. minutulus	Bacillariophyta	
			Tetrastrum glabrum	Chlorophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-4: Farim Project – Dry Season STN4 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN4	5/15/2013	11:19	Achnanthidium minutissimum	Bacillariophyta	
			Actinocyclus cf. divisus	Bacillariophyta	
			Aphanocapsa cf. holsatica	Cyanobacteria	
			Aphanocapsa sp.	Cyanobacteria	
			Aulacoseira sp.	Bacillariophyta	
			cf. Monoraphidium nanum	Chlorophyta	
			cf. Phormidium sp.	Cyanobacteria	
			cf. Rhodomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chlamydomonas grovei	Chlorophyta	
			Chlorella sp.	Chlorophyta	
			Chroococcus sp.	Cyanobacteria	
			Chroomonas sp.	Cryptophyta	
			Cocconeis placentula	Bacillariophyta	
			Coscinodiscus sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella meneghiniana	Bacillariophyta	
			Diploneis cf. ovalis	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Hippodonta sp.	Bacillariophyta	
			Nitzschia constricta	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia inconspicua	Bacillariophyta	
			Nitzschia palea	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia supralitorea	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Ochromonas spp.	Chrysophyta	
			Oocystis sp.	Chlorophyta	
			Opephora olsenii	Bacillariophyta	
			Planctonema lauterbornii	Chlorophyta	
			Scenedesmus quadricauda	Chlorophyta	
			Scenedesmus sp.	Chlorophyta	
			Skeletonema cf. subsalsum	Bacillariophyta	
			Staurosirella leptostauron var. dubia	Bacillariophyta	
			Synedra parasitica	Bacillariophyta	
			Tetrastrum glabrum	Chlorophyta	
			Thalassiosira cf. eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-5: Farim Project – Dry Season STN5 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN5	5/16/2013	14:37	Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus sp.	Bacillariophyta	
			Aphanocapsa cf. holsatica	Bacillariophyta	
			Aphanocapsa sp.	Bacillariophyta	
			Aulacoseira sp.	Bacillariophyta	
			Aulacoseira spp.	Bacillariophyta	
			cf. Monoraphidium nanum	Chlorophyta	
			cf. Odontella sp.	Chlorophyta	
			cf. Rhodomonas sp.	Chlorophyta	
			cf. Thalassiosira sp.	Chlorophyta	
			Chaetoceros sp.	Chrysophyta	
			Chlamydomonas grovei	Cryptophyta	
			Chlorella sp.	Cryptophyta	
			Chroococcus sp.	Cyanobacteria	
			Chroomonas sp.	Cyanobacteria	
			Coscinodiscus sp.	Bacillariophyta	
			Cryptomonas sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Entomoneis cf. ornata	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Mastogloia smithii	Bacillariophyta	
			Monoraphidium arcuatum	Bacillariophyta	
			Monoraphidium sp.	Bacillariophyta	
			Monoraphidium tortile	Chlorophyta	
			Nitzschia compressa	Chlorophyta	
			Nitzschia lanceola	Chlorophyta	
			Nitzschia sp.	Chlorophyta	
			Nitzschia spp.	Chlorophyta	
			Nitzschia supralitorea	Chlorophyta	
			Ochromonas sp.	Chlorophyta	
			Oocystis lacustris	Cryptophyta	
			Oocystis parva	Bacillariophyta	
			Oocystis sp.	Bacillariophyta	
			Planctonema lauterbornii	Bacillariophyta	
			Scenedesmus quadricauda	Bacillariophyta	
			Scenedesmus sp.	Bacillariophyta	
			Synedra parasitica	Bacillariophyta	
			Tetrastrum triangulare	Chlorophyta	
			Thalassiosira eccentrica	Chlorophyta	
			Thalassiosira visurgis	Cyanobacteria	

Table B1-6: Farim Project – Dry Season STN6 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN6	5/15/2013	10:40	Achnanthidium sp.	Bacillariophyta	
			Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus sp.	Bacillariophyta	
			Aphanocapsa holsatica	Cyanobacteria	
			Aphanocapsa sp.	Cyanobacteria	
			cf. Diploneis sp.	Bacillariophyta	
			cf. Fragilariaforma sp.	Bacillariophyta	
			cf. Gymnodinium sp.	Pyrrophyta	
			cf. Monoraphidium nanum	Chlorophyta	
			cf. Rhodomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chlamydomonas grovei	Chlorophyta	
			Chlorella sp.	Chlorophyta	
			Chroococcus sp.	Cyanobacteria	
			Chroomonas sp.	Cryptophyta	
			Coscinodiscus sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella meneghiniana	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Monoraphidium arcuatum	Chlorophyta	
			Monoraphidium tortile	Chlorophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia spp.	Bacillariophyta	
			Nitzschia supralitorea	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Oocystis lacustris	Chlorophyta	
			Oocystis parva	Chlorophyta	
			Oocystis sp.	Chlorophyta	
			Opephora cf. mutabilis	Bacillariophyta	
			Planctonema lauterbornii	Chlorophyta	
			Scenedesmus quadricauda	Chlorophyta	
			Scenedesmus spp.	Chlorophyta	
			Skeletonema cf. subsalsum	Bacillariophyta	
			Tetrastrum triangulare	Chlorophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	
			Triceratium sp.	Bacillariophyta	

Table B1-7: Farim Project – Dry Season STN7 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN7	5/17/2013	14:57	Achnanthidium minutissimum	Bacillariophyta	
			Achnanthidium sp.	Bacillariophyta	
			Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus senarius	Bacillariophyta	
			Amphora cf. fogediana	Bacillariophyta	
			Aulacoseira sp.	Bacillariophyta	
			Bacillaria paxillifer	Bacillariophyta	
			cf. Coenochloris sp.	Chlorophyta	
			cf. Denticula sp.	Bacillariophyta	
			cf. Fragilariopsis sp.	Bacillariophyta	
			cf. Monoraphidium nanum	Chlorophyta	
			cf. Rhodomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chaetoceros cf. peruvianus	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chlamydomonas globosa	Chlorophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cryptomonas ovata	Cryptophyta	
			Cryptomonas sp.	Cryptophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella cf. stylorum	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Denticula sp.	Bacillariophyta	
			Diploneis ovalis	Bacillariophyta	
			Diploneis sp.	Bacillariophyta	
			Diploneis spp.	Bacillariophyta	
			Hippodonta sp.	Bacillariophyta	
			Nitzschia acicularis	Bacillariophyta	
			Nitzschia cf. lanceola	Bacillariophyta	
			Nitzschia compressa	Bacillariophyta	
			Nitzschia compressa var. vexans	Bacillariophyta	
			Nitzschia constricta	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia lanceola	Bacillariophyta	
			Nitzschia reversa	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia spp.	Bacillariophyta	
			Nitzschia supralitorea	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Oocystis parva	Chlorophyta	
			Opephora pacifica	Bacillariophyta	
			Planothidium sp.	Bacillariophyta	
			Pleurosigma salinarum	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhopalodia cf. acuminata	Bacillariophyta	
			Staurosira construens var. venter	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	
			Tryblionella angustata	Bacillariophyta	
			Tryblionella debilis	Bacillariophyta	

Table B1-8: Farim Project – Dry Season STN8 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN8	5/18/2013	12:20	Achnanthidium sp.	Bacillariophyta	
			Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus sp.	Bacillariophyta	
			Aulacoseira sp.	Bacillariophyta	
			Bacillaria paxillifer	Bacillariophyta	
			cf. Fragilariopsis sp.	Bacillariophyta	
			cf. Melosira sp.	Bacillariophyta	
			cf. Monoraphidium nanum	Chlorophyta	
			cf. Nitzschia lanceola	Bacillariophyta	
			cf. Stephanodiscus sp.	Bacillariophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chlamydomonas globosa	Chlorophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Diadesmis sp.	Bacillariophyta	
			Diploneis elliptica	Bacillariophyta	
			Diploneis ovalis	Bacillariophyta	
			Diploneis sp.	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Fragilariopsis sp.	Bacillariophyta	
			Navicula spp.	Bacillariophyta	
			Nitzschia acicularis	Bacillariophyta	
			Nitzschia compressa	Bacillariophyta	
			Nitzschia constricta	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia paleacea	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Nitzschia reversa	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Pinnularia sp.	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Rhodomonas sp.	Cryptophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	
			Tryblionella debilis	Bacillariophyta	

Table B1-9: Farim Project – Dry Season STN9 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN9	5/25/2013	10:28	Actinocyclus cf. divisus	Bacillariophyta	
			Ceratium furca	Pyrrophyta	
			cf. Fragilariopsis sp.	Bacillariophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Zygnema sp.	Chlorophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Coscinodiscus sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Entomoneis alata	Bacillariophyta	
			Entomoneis sp.	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Gymnodinium sp.	Pyrrophyta	
			Luticola goeppertiana	Bacillariophyta	
			Melosira sp.	Bacillariophyta	
			Nitzschia compressa	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia lanceola	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Odontella mobiliensis	Bacillariophyta	
			Odontella sinensis	Bacillariophyta	
			Odontella spp.	Bacillariophyta	
			Opephora pacifica	Bacillariophyta	
			Pleurosigma salinarum	Bacillariophyta	
			Pleurosigma sp.	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Schuettia annulata	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-10: Farim Project – Dry Season STN10 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN10	5/25/2013	14:40	Actinocyclus cf. divisus	Bacillariophyta	
			Aulacoseira sp.	Bacillariophyta	
			Bacillaria paxillifer	Bacillariophyta	
			Biddulphia cf. reticulata	Bacillariophyta	
			cf. Cerataulina sp.	Bacillariophyta	
			cf. Chlamydomonas sp.	Chlorophyta	
			cf. Coelastrum microporum	Chlorophyta	
			cf. Diploneis sp.	Bacillariophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Zygnema sp.	Chlorophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Cylindrotheca sp.	Bacillariophyta	
			Diploneis sp.	Bacillariophyta	
			Eunotia sp.	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Fragilariopsis sp.	Bacillariophyta	
			Guinardia sp.	Bacillariophyta	
			Mastogloia sp.	Bacillariophyta	
			Navicula sp.	Bacillariophyta	
			Nitzschia acicularis	Bacillariophyta	
			Nitzschia closterium	Bacillariophyta	
			Nitzschia coarctata	Bacillariophyta	
			Nitzschia compressa	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia inconspicua	Bacillariophyta	
			Nitzschia lanceola	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Opephora sp.	Bacillariophyta	
			Pleurosigma salinarum	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	
			Ulothrix sp.	Chlorophyta	

Table B1-11: Farim Project – Dry Season STN11 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN11	5/19/2013	12:25	Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus sp.	Bacillariophyta	
			Bacillaria paxillifer	Bacillariophyta	
			Campyloneis grevillei	Bacillariophyta	
			cf. Cerataulina sp.	Bacillariophyta	
			cf. Chlamydomonas grovei	Chlorophyta	
			cf. Chlorella sp.	Chlorophyta	
			cf. Cryptomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Trachelomonas sp.	Euglenophyta	
			Chaetoceros cf. peruvianus	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cryptomonas ovata	Cryptophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Eucampia sp.	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Guinardia sp.	Bacillariophyta	
			Navicula sp.	Bacillariophyta	
			Nitzschia compressa	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia supralitorea	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Opephora pacifica	Bacillariophyta	
			Pseudo-nitzschia sp.	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Thalassionema pseudonitzschioides	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-12: Farim Project – Dry Season STN12 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN12	5/20/2013	10:55	Amphora sp.	Bacillariophyta	
			Aulacoseira sp.	Bacillariophyta	
			Bacillaria paxillifer	Bacillariophyta	
			Cerataulina sp.	Bacillariophyta	
			cf. Actinoptychus sp.	Bacillariophyta	
			cf. Chlamydomonas sp.	Chlorophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cryptomonas sp.	Cryptophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Cyclotella stylorum	Bacillariophyta	
			Cymbella microcephala	Bacillariophyta	
			Ditylum sp.	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Fragilariopsis sp.	Bacillariophyta	
			Gyrosigma sp.	Bacillariophyta	
			Hippodonta sp.	Bacillariophyta	
			Mastogloia sp.	Bacillariophyta	
			Monoraphidium arcuatum	Chlorophyta	
			Navicula spp.	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia lanceola	Bacillariophyta	
			Nitzschia punctata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia spp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Opephora sp.	Bacillariophyta	
			Phacus sp.	Euglenophyta	
			Pseudo-nitzschia sp.	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhaphoneis amphiceros	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Thalassionema pseudonitzschioides	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-13: Farim Project – Dry Season STN13 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN13	5/22/2013	10:55	Actinocyclus cf. divisus	Bacillariophyta	
			Actinoptychus senarius	Bacillariophyta	
			Actinoptychus sp.	Bacillariophyta	
			Cerataulina sp.	Bacillariophyta	
			cf. Amphora sp.	Bacillariophyta	
			cf. Cerataulina sp.	Bacillariophyta	
			cf. Cosmarium sp.	Chlorophyta	
			cf. Gyrosigma sp.	Bacillariophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chaetoceros cf. peruvianus	Bacillariophyta	
			Chaetoceros spp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella ocellata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Cymatopleura elliptica	Bacillariophyta	
			Delphineis sp.	Bacillariophyta	
			Ditylum sp.	Bacillariophyta	
			Entomoneis sp.	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Fragilariopsis sp.	Bacillariophyta	
			Guinardia sp.	Bacillariophyta	
			Gymnodinium sp.	Pyrrophyta	
			Melosira sp.	Bacillariophyta	
			Navicula sp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Odontella mobiliensis	Bacillariophyta	
			Planothidium sp.	Bacillariophyta	
			Pseudo-nitzschia sp.	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Rhizosolenia spp.	Bacillariophyta	
			Staurodesmus sp.	Chlorophyta	
			Surirella sp.	Bacillariophyta	
			Synechococcus sp.	Cyanobacteria	
			Synedra sp.	Bacillariophyta	
			Thalassionema pseudonitzschioides	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-14: Farim Project – Dry Season STN14 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN14	5/22/2013	15:55	Azpeitia apiculata	Bacillariophyta	
			Campyloneis cf. grevillei	Bacillariophyta	
			cf. Chaetoceros sp.	Bacillariophyta	
			cf. Delphineis surirella	Bacillariophyta	
			cf. Frustulia sp.	Bacillariophyta	
			cf. Gymnodinium sp.	Pyrrophyta	
			cf. Hemidiscus cuneiformis	Bacillariophyta	
			cf. Nitzschia supralitorea	Bacillariophyta	
			cf. Spirogyra sp.	Chlorophyta	
			cf. Thalassionema sp.	Bacillariophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Thalassiothrix sp.	Bacillariophyta	
			cf. Ulothrix sp.	Chlorophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Coscinodiscus radiatus	Bacillariophyta	
			Cyclotella caspia	Bacillariophyta	
			Cyclotella cf. caspia	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella stylorum	Bacillariophyta	
			Diploneis sp.	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Odontella mobiliensis	Bacillariophyta	
			Paralia cf. costatum	Bacillariophyta	
			Paralia cf. sulcata	Bacillariophyta	
			Pleurosigma sp.	Bacillariophyta	
			Rhaphoneis nitida	Bacillariophyta	
			Rhaphoneis sp.	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Thalassionema pseudonitzschioides	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-15: Farim Project – Dry Season STN15 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN15	5/23/2013	12:55	Bacillaria paxillifer	Bacillariophyta	
			Campyloneis sp.	Bacillariophyta	
			cf. Achnanthes ventralis	Bacillariophyta	
			cf. Navicula lepta	Bacillariophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Thalassiothrix sp.	Bacillariophyta	
			cf. Tropidoneis sp.	Bacillariophyta	
			Chaetoceros cf. peruvianus	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cryptomonas sp.	Cryptophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella spp.	Bacillariophyta	
			Cymbella sp.	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Grammatophora cf. oceanica	Bacillariophyta	
			Nitzschia granulata	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Planothidium sp.	Bacillariophyta	
			Pleurosigma cf. salinarum	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhaphoneis sp.	Bacillariophyta	
			Rhizosolenia cf. shrubsolei	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-16: Farim Project – Dry Season STN16 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN16	5/23/2013	14:40	`	Bacillariophyta	
			Amphora spp.	Bacillariophyta	
			Bacillaria paxillifer	Bacillariophyta	
			Biddulphia sp.	Bacillariophyta	
			cf. Guinardia sp.	Bacillariophyta	
			cf. Rhodomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			Chaetoceros cf. peruvianus	Bacillariophyta	
			Chaetoceros debilis	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chaetoceros spp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis sp.	Bacillariophyta	
			Cryptomonas ovata	Cryptophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Cymatopleura sp.	Bacillariophyta	
			Dactyliosolen blavyanus	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Fragilariopsis sp.	Bacillariophyta	
			Gomphonema sp.	Bacillariophyta	
			Guinardia sp.	Bacillariophyta	
			Hippodonta sp.	Bacillariophyta	
			Melosira sp.	Bacillariophyta	
			Navicula sp.	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia spp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella aurita	Bacillariophyta	
			Paralia cf. sulcata	Bacillariophyta	
			Pleurosigma sp.	Bacillariophyta	
			Pseudo-nitzschia sp.	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhaphoneis sp.	Bacillariophyta	
			Rhizosolenia cf. shrubsolei	Bacillariophyta	
			Rhizosolenia cf. styliformis	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Thalassionema pseudonitzschioides	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira eccentrica	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	
			Thalassiothrix sp.	Bacillariophyta	

Table B1-17: Farim Project – Dry Season STN16 Summary Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS AND SPECIES	DIVISION	NOTES
STN17	5/24/2013	13:40	Amphiprora sp.	Bacillariophyta	
			Campyloneis sp.	Bacillariophyta	
			cf. Eucampia sp.	Bacillariophyta	
			cf. Rhodomonas sp.	Cryptophyta	
			cf. Thalassiosira sp.	Bacillariophyta	
			cf. Zygnema sp.	Chlorophyta	
			Chaetoceros cf. peruvianus	Bacillariophyta	
			Chaetoceros debilis	Bacillariophyta	
			Chaetoceros sp.	Bacillariophyta	
			Chaetoceros spp.	Bacillariophyta	
			Chroomonas sp.	Cryptophyta	
			Cocconeis placentula	Bacillariophyta	
			Cocconeis sp.	Bacillariophyta	
			Cocconeis spp.	Bacillariophyta	
			Coscinodiscus sp.	Bacillariophyta	
			Cyclotella cf. striata	Bacillariophyta	
			Cyclotella sp.	Bacillariophyta	
			Diatoma hiemale	Bacillariophyta	
			Fragilariopsis cf. kerguelensis	Bacillariophyta	
			Guinardia sp.	Bacillariophyta	
			Melosira sp.	Bacillariophyta	
			Navicula sp.	Bacillariophyta	
			Nitzschia cf. sigma	Bacillariophyta	
			Nitzschia sp.	Bacillariophyta	
			Nitzschia spp.	Bacillariophyta	
			Ochromonas sp.	Chrysophyta	
			Odontella cf. aurita	Bacillariophyta	
			Paralia sulcata	Bacillariophyta	
			Pleurosigma cf. salinarum	Bacillariophyta	
			Pleurosigma normanii	Bacillariophyta	
			Pseudostaurosira brevistriata	Bacillariophyta	
			Rhizosolenia cf. shrubsolei	Bacillariophyta	
			Rhizosolenia sp.	Bacillariophyta	
			Skeletonema cf. costatum	Bacillariophyta	
			Thalassionema sp.	Bacillariophyta	
			Thalassiosira sp.	Bacillariophyta	
			Thalassiosira visurgis	Bacillariophyta	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN1PPB	5/14/2013	13:45	10	Actinocyclus cf. divisus	Bacillariophyta	3	7.13E+04	1.15E+09	High sediment.
STN1PPB	5/14/2013	13:45	10	Cyclotella cf. striata	Bacillariophyta	2	4.75E+04	2.15E+08	High sediment.
STN1PPB	5/14/2013	13:45	10	Nitzschia punctata	Bacillariophyta	1	2.38E+04	7.61E+06	High sediment.
STN1PPB	5/14/2013	13:45	10	Nitzschia sp.	Bacillariophyta	2	4.75E+04	1.14E+07	High sediment.
STN1PPB	5/14/2013	13:45	10	Skeletonema cf. subsalsum	Bacillariophyta	49	1.16E+06	4.34E+08	High sediment.
STN1PPB	5/14/2013	13:45	10	Thalassiosira eccentrica	Bacillariophyta	1	2.38E+04	4.09E+08	High sediment.
STN1PPB	5/14/2013	13:45	10	cf. Thalassiosira sp.	Bacillariophyta	328	7.80E+06	1.10E+09	High sediment.
STN1PPB	5/14/2013	13:45	10	Thalassiosira visurgis	Bacillariophyta	25	5.94E+05	1.87E+08	High sediment.
STN1PPB	5/14/2013	13:45	10	Oocystis sp.	Chlorophyta	1	2.38E+04	2.49E+06	High sediment.
STN1PPB	5/14/2013	13:45	10	Scenedesmus quadricauda	Chlorophyta	4	9.51E+04	2.52E+07	High sediment.
STN1PPB	5/14/2013	13:45	10	Scenedesmus sp.	Chlorophyta	10	2.38E+05	1.99E+07	High sediment.
STN1PPB	5/14/2013	13:45	10	Tetrastrum glabrum	Chlorophyta	16	3.80E+05	1.59E+06	High sediment.
STN1PPB	5/14/2013	13:45	10	Ochromonas sp.	Chrysophyta	2	4.75E+04	4.48E+06	High sediment.
				TOTAL		444	1.06E+07	3.57E+09	
STN1PPA	5/14/2013	13:45	10	Actinocyclus cf. divisus	Bacillariophyta	3	4.58E+04	1.60E+09	High sediment.
STN1PPA	5/14/2013	13:45	10	Chaetoceros sp.	Bacillariophyta	1	1.53E+04	5.56E+07	High sediment.
STN1PPA	5/14/2013	13:45	10	Cyclotella cf. hakanssoniae	Bacillariophyta	1	1.53E+04	7.20E+06	High sediment.
STN1PPA	5/14/2013	13:45	10	Cyclotella cf. striata	Bacillariophyta	3	4.58E+04	4.20E+08	High sediment.
STN1PPA	5/14/2013	13:45	10	Nitzschia sp.	Bacillariophyta	1	1.53E+04	2.01E+07	High sediment.
STN1PPA	5/14/2013	13:45	10	Nitzschia supralitorea	Bacillariophyta	5	7.64E+04	2.18E+06	High sediment.
STN1PPA	5/14/2013	13:45	10	Skeletonema cf. subsalsum	Bacillariophyta	39	5.96E+05	2.70E+08	High sediment.
STN1PPA	5/14/2013	13:45	10	cf. Thalassiosira sp.	Bacillariophyta	324	4.95E+06	2.92E+08	High sediment.
STN1PPA	5/14/2013	13:45	10	Thalassiosira visurgis	Bacillariophyta	19	2.90E+05	1.60E+08	High sediment.
STN1PPA	5/14/2013	13:45	10	Tryblionella debilis	Bacillariophyta	1	1.53E+04	2.53E+07	High sediment.
STN1PPA	5/14/2013	13:45	10	Chlamydomonas globosa	Chlorophyta	1	1.53E+04	1.44E+06	High sediment.
STN1PPA	5/14/2013	13:45	10	Tetrastrum glabrum	Chlorophyta	8	1.22E+05	1.73E+06	High sediment.
STN1PPA	5/14/2013	13:45	10	Ochromonas sp.	Chrysophyta	9	1.38E+05	1.17E+07	High sediment.
STN1PPA	5/14/2013	13:45	10	Aphanocapsa sp.	Cyanobacteria	444	6.78E+06	3.55E+06	High sediment.
STN1PPA	5/14/2013	13:45	10	cf. Woronichinia sp.	Cyanobacteria	35	5.35E+05	2.24E+06	High sediment.
				TOTAL		894	1.37E+07	2.87E+09	
STN3PPA	5/15/2013	10:45	10	Actinocyclus cf. divisus	Bacillariophyta	18	1.07E+05	3.87E+09	
STN3PPA	5/15/2013	10:45	10	Chaetoceros sp.	Bacillariophyta	29	1.72E+05	1.52E+07	
STN3PPA	5/15/2013	10:45	10	Cyclotella cf. striata	Bacillariophyta	2	1.19E+04	3.29E+07	
STN3PPA	5/15/2013	10:45	10	Navicula sp.	Bacillariophyta	2	1.19E+04	1.03E+06	
STN3PPA	5/15/2013	10:45	10	Nitzschia sp.	Bacillariophyta	21	1.25E+05	5.99E+06	
STN3PPA	5/15/2013	10:45	10	Staurosirella leptostauron var. dubia	Bacillariophyta	1	5.94E+03	1.21E+06	
STN3PPA	5/15/2013	10:45	10	cf. Thalassiosira sp.	Bacillariophyta	107	6.36E+05	1.60E+07	
STN3PPA	5/15/2013	10:45	10	Thalassiosira eccentrica	Bacillariophyta	2	1.19E+04	3.61E+07	
STN3PPA	5/15/2013	10:45	10	Thalassiosira visurgis	Bacillariophyta	4	2.38E+04	1.89E+07	
STN3PPA	5/15/2013	10:45	10	Dictyosphaerium chlorelloides	Chlorophyta	16	9.51E+04	1.34E+06	
STN3PPA	5/15/2013	10:45	10	cf. Monoraphidium nanum	Chlorophyta	162	9.63E+05	1.01E+07	
STN3PPA	5/15/2013	10:45	10	Oocystis sp.	Chlorophyta	12	7.13E+04	1.68E+06	
STN3PPA	5/15/2013	10:45	10	Planctonema lauterbornii	Chlorophyta	40	2.38E+05	5.97E+06	
STN3PPA	5/15/2013	10:45	10	Tetrastrum glabrum	Chlorophyta	48	2.85E+05	4.03E+06	
STN3PPA	5/15/2013	10:45	10	Ochromonas sp.	Chrysophyta	2	1.19E+04	6.22E+05	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN3PPA	5/15/2013	10:45	10	Aphanocapsa sp.	Cyanobacteria	1072	6.37E+06	4.17E+05	
				TOTAL		1538	9.14E+06	4.02E+09	
STN1PPC	5/14/2013	13:45	10	Actinocyclus cf. divisus	Bacillariophyta	2	7.13E+04	2.61E+09	High sediment.
STN1PPC	5/14/2013	13:45	10	Chaetoceros sp.	Bacillariophyta	12	4.28E+05	4.30E+08	High sediment.
STN1PPC	5/14/2013	13:45	10	Cyclotella sp.	Bacillariophyta	1	3.56E+04	1.69E+07	High sediment.
STN1PPC	5/14/2013	13:45	10	Cyclotella cf. striata	Bacillariophyta	2	7.13E+04	1.98E+08	High sediment.
STN1PPC	5/14/2013	13:45	10	Nitzschia punctata	Bacillariophyta	2	7.13E+04	1.71E+07	High sediment.
STN1PPC	5/14/2013	13:45	10	Nitzschia supralitorea	Bacillariophyta	2	7.13E+04	4.06E+06	High sediment.
STN1PPC	5/14/2013	13:45	10	Skeletonema cf. subsalsum	Bacillariophyta	27	9.63E+05	2.65E+08	High sediment.
STN1PPC	5/14/2013	13:45	10	cf. Thalassiosira sp.	Bacillariophyta	313	1.12E+07	1.10E+09	High sediment.
STN1PPC	5/14/2013	13:45	10	Thalassiosira eccentrica	Bacillariophyta	2	7.13E+04	3.77E+08	High sediment.
STN1PPC	5/14/2013	13:45	10	Thalassiosira visurgis	Bacillariophyta	38	1.35E+06	6.38E+08	High sediment.
STN1PPC	5/14/2013	13:45	10	Scenedesmus sp.	Chlorophyta	2	7.13E+04	2.69E+06	High sediment.
STN1PPC	5/14/2013	13:45	10	Tetrastrum glabrum	Chlorophyta	4	1.43E+05	2.02E+06	High sediment.
STN1PPC	5/14/2013	13:45	10	Ochromonas sp.	Chrysophyta	4	1.43E+05	1.21E+07	High sediment.
STN1PPC	5/14/2013	13:45	10	Gymnodinium sp.	Pyrrophyta	1	3.56E+04	5.44E+07	High sediment.
STN1PPC	5/14/2013	13:45	10	Planctonema lauterbornii	Chlorophyta	34	1.21E+06	3.05E+07	High sediment.
				TOTAL		446	1.59E+07	5.76E+09	
STN2PPA	5/16/2013	17:45	10	Achnanthidium minutissimum	Bacillariophyta	1	7.64E+03	4.68E+05	
STN2PPA	5/16/2013	17:45	10	Actinocyclus cf. divisus	Bacillariophyta	7	5.35E+04	1.94E+09	
STN2PPA	5/16/2013	17:45	10	Aulacoseira sp.	Bacillariophyta	2	1.53E+04	6.91E+06	
STN2PPA	5/16/2013	17:45	10	Chaetoceros sp.	Bacillariophyta	1	7.64E+03	9.41E+06	
STN2PPA	5/16/2013	17:45	10	Cyclotella cf. striata	Bacillariophyta	5	3.82E+04	1.45E+08	
STN2PPA	5/16/2013	17:45	10	Nitzschia punctata	Bacillariophyta	1	7.64E+03	1.96E+06	
STN2PPA	5/16/2013	17:45	10	Nitzschia sp.	Bacillariophyta	6	4.58E+04	6.53E+06	
STN2PPA	5/16/2013	17:45	10	Skeletonema cf. subsalsum	Bacillariophyta	67	5.12E+05	1.41E+08	
STN2PPA	5/16/2013	17:45	10	Thalassiosira eccentrica	Bacillariophyta	3	2.29E+04	8.29E+07	
STN2PPA	5/16/2013	17:45	10	cf. Thalassiosira sp.	Bacillariophyta	238	1.82E+06	2.57E+08	
STN2PPA	5/16/2013	17:45	10	Thalassiosira visurgis	Bacillariophyta	17	1.30E+05	4.08E+07	
STN2PPA	5/16/2013	17:45	10	Oocystis sp.	Chlorophyta	4	3.06E+04	1.54E+06	
STN2PPA	5/16/2013	17:45	10	Planctonema lauterbornii	Chlorophyta	90	6.88E+05	4.32E+05	
STN2PPA	5/16/2013	17:45	10	Scenedesmus quadricauda	Chlorophyta	6	4.58E+04	2.16E+06	
STN2PPA	5/16/2013	17:45	10	Tetrastrum glabrum	Chlorophyta	20	1.53E+05	2.16E+06	
STN2PPA	5/16/2013	17:45	10	Ochromonas sp.	Chrysophyta	6	4.58E+04	2.40E+06	
STN2PPA	5/16/2013	17:45	10	cf. Gymnodinium sp.	Pyrrophyta	1	7.64E+03	1.22E+07	
				TOTAL		475	3.63E+06	2.65E+09	
STN3PPC	5/15/2013	16:45	15	Actinocyclus cf. divisus	Bacillariophyta	12	3.72E+04	1.82E+09	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Aulacoseira sp.	Bacillariophyta	1	3.10E+03	9.74E+05	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Cyclotella cf. hakanssoniae	Bacillariophyta	1	3.10E+03	1.53E+05	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Nitzschia supralitorea	Bacillariophyta	4	1.24E+04	9.42E+05	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	cf. Thalassiosira sp.	Bacillariophyta	175	5.42E+05	3.20E+07	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Thalassiosira eccentrica	Bacillariophyta	6	1.86E+04	3.37E+07	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Thalassiosira visurgis	Bacillariophyta	7	2.17E+04	1.02E+07	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Chlamydomonas grovei	Chlorophyta	4	1.24E+04	0.00E+00	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN3PPC	5/15/2013	16:45	15	Chlorella spp.	Chlorophyta	11	3.41E+04	4.82E+05	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	cf. Monoraphidium nanum	Chlorophyta	67	2.08E+05	1.74E+06	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	cf. Oocystis sp.	Chlorophyta	48	1.49E+05	1.75E+06	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Planctonema lauterbornii	Chlorophyta	90	2.79E+05	7.01E+06	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Scenedesmus quadricauda	Chlorophyta	28	8.68E+04	3.27E+06	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Tetrastrum glabrum	Chlorophyta	32	9.92E+04	4.16E+05	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Ochromonas sp.	Chrysophyta	4	1.24E+04	8.35E+05	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	cf. Chroomonas sp.	Cryptophyta	40	1.24E+05	5.19E+07	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	cf. Rhodomonas sp.	Cryptophyta	27	8.37E+04	7.10E+06	High sediment; many broken diatoms.
STN3PPC	5/15/2013	16:45	15	Aphanocapsa sp.	Cyanobacteria	472	1.46E+06	7.66E+05	High sediment; many broken diatoms.
				TOTAL		1029	3.19E+06	1.97E+09	
STN4PPB	5/15/2013	11:18	20	Actinocyclus cf. divisus	Bacillariophyta	30	5.73E+04	1.51E+09	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Aulacoseira sp.	Bacillariophyta	12	2.29E+04	1.23E+07	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Cyclotella cf. striata	Bacillariophyta	20	3.82E+04	4.12E+07	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Eunotia sp.	Bacillariophyta	1	1.91E+03	3.36E+06	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Nitzschia granulata	Bacillariophyta	4	7.64E+03	2.14E+06	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Nitzschia supralitorea	Bacillariophyta	6	1.15E+04	9.63E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Skeletonema cf. subsalsum	Bacillariophyta	26	4.97E+04	1.56E+07	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Staurosirella leptostauron var. dubia	Bacillariophyta	4	7.64E+03	1.56E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Synedra parasitica	Bacillariophyta	13	2.48E+04	3.90E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	cf. Thalassiosira sp.	Bacillariophyta	95	1.81E+05	2.05E+07	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Thalassiosira visurgis	Bacillariophyta	6	1.15E+04	1.22E+07	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Chlamydomonas grovei	Chlorophyta	15	2.86E+04	9.60E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	cf. Monoraphidium nanum	Chlorophyta	24	4.58E+04	4.80E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Oocystis sp.	Chlorophyta	24	4.58E+04	1.92E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Planctonema lauterbornii	Chlorophyta	97	1.85E+05	4.66E+06	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Scenedesmus quadricauda	Chlorophyta	20	3.82E+04	1.44E+06	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Tetrastrum glabrum	Chlorophyta	16	3.06E+04	2.50E+05	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Ochromonas spp.	Chrysophyta	67	1.28E+05	1.09E+07	High sediment; many broken diatoms.
STN4PPB	5/15/2013	11:18	20	Chroomonas sp.	Cryptophyta	32	6.11E+04	1.43E+07	High sediment; many broken diatoms.
				TOTAL		512	9.78E+05	1.65E+09	
STN3PPB	5/15/2013	16:45	15	Actinocyclus cf. divisus	Bacillariophyta	6	6.11E+04	1.96E+09	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Coscinodiscus sp.	Bacillariophyta	2	2.04E+04	9.22E+08	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Cyclotella cf. striata	Bacillariophyta	9	9.17E+04	8.47E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Cyclotella meneghiniana	Bacillariophyta	3	3.06E+04	2.82E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Hippodonta sp.	Bacillariophyta	2	2.04E+04	7.60E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Nitzschia granulata	Bacillariophyta	4	4.07E+04	3.58E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	cf. Opephora pacifica	Bacillariophyta	2	2.04E+04	1.06E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Pseudostaurosira brevistriata	Bacillariophyta	3	3.06E+04	7.80E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Skeletonema cf. subsalsum	Bacillariophyta	110	1.12E+06	4.12E+08	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Stephanodiscus cf. minutulus	Bacillariophyta	1	1.02E+04	6.00E+05	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	cf. Thalassiosira sp.	Bacillariophyta	82	8.35E+05	4.92E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Thalassiosira visurgis	Bacillariophyta	4	4.07E+04	2.32E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	cf. Chlorella sp.	Chlorophyta	6	6.11E+04	8.64E+05	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	cf. Monoraphidium nanum	Chlorophyta	33	3.36E+05	3.52E+06	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN3PPB	5/15/2013	16:45	15	Planctonema lauterbornii	Chlorophyta	162	1.65E+06	7.00E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Scenedesmus communis	Chlorophyta	16	1.63E+05	7.68E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Tetrastrum glabrum	Chlorophyta	40	4.07E+05	5.76E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Ochromonas sp.	Chrysophyta	14	1.43E+05	5.60E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	cf. Rhodomonas sp.	Cryptophyta	14	1.43E+05	7.47E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Aphanocapsa holsatica	Cyanobacteria	2324	2.37E+07	1.24E+07	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	Aphanocapsa sp.	Cyanobacteria	58	5.91E+05	2.47E+06	High sediment; many broken diatoms.
STN3PPB	5/15/2013	16:45	15	cf. Phormidium sp.	Cyanobacteria	44	4.48E+05	2.82E+06	High sediment; many broken diatoms.
				TOTAL		2939	2.99E+07	3.70E+09	
STN2PPB	5/16/2013	17:45	10	Achnanthidium minutissimum	Bacillariophyta	1	7.92E+03	4.85E+05	High sediment.
STN2PPB	5/16/2013	17:45	10	Actinocyclus cf. divisus	Bacillariophyta	26	2.06E+05	8.93E+09	High sediment.
STN2PPB	5/16/2013	17:45	10	Actinoptychus sp.	Bacillariophyta	1	7.92E+03	1.22E+08	High sediment.
STN2PPB	5/16/2013	17:45	10	Amphora sp.	Bacillariophyta	1	7.92E+03	3.59E+05	High sediment.
STN2PPB	5/16/2013	17:45	10	Aulacoseira sp.	Bacillariophyta	2	1.58E+04	4.98E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	Capartogramma crucicula	Bacillariophyta	1	7.92E+03	2.16E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	cf. Coscinodiscus sp.	Bacillariophyta	1	7.92E+03	8.01E+08	High sediment.
STN2PPB	5/16/2013	17:45	10	Cyclotella distinguenda var. mesoleia	Bacillariophyta	1	7.92E+03	1.98E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	Cyclotella cf. hakanssoniae	Bacillariophyta	4	3.17E+04	1.65E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	Diploneis ovalis	Bacillariophyta	1	7.92E+03	5.91E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	Nitzschia compressa	Bacillariophyta	2	1.58E+04	1.04E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	Nitzschia inconspicua	Bacillariophyta	1	7.92E+03	3.96E+04	High sediment.
STN2PPB	5/16/2013	17:45	10	Nitzschia supralitorea	Bacillariophyta	9	7.13E+04	5.42E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	Skeletonema subsalsum	Bacillariophyta	5	3.96E+04	1.79E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	cf. Thalassiosira sp.	Bacillariophyta	287	2.27E+06	1.34E+08	High sediment.
STN2PPB	5/16/2013	17:45	10	Thalassiosira sp.	Bacillariophyta	2	1.58E+04	3.05E+08	High sediment.
STN2PPB	5/16/2013	17:45	10	Thalassiosira visurgis	Bacillariophyta	19	1.51E+05	8.28E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	cf. Tryblionella sp.	Bacillariophyta	1	7.92E+03	1.22E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	Carteria sp.	Chlorophyta	1	7.92E+03	6.22E+05	High sediment.
STN2PPB	5/16/2013	17:45	10	Oocystis sp.	Chlorophyta	8	6.34E+04	1.79E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	Planctonema lauterbornii	Chlorophyta	4	3.17E+04	9.96E+05	High sediment.
STN2PPB	5/16/2013	17:45	10	Scenedesmus sp.	Chlorophyta	4	3.17E+04	1.19E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	Tetrastrum glabrum	Chlorophyta	4	3.17E+04	1.33E+05	High sediment.
STN2PPB	5/16/2013	17:45	10	Ochromonas sp.	Chrysophyta	2	1.58E+04	1.34E+06	High sediment.
STN2PPB	5/16/2013	17:45	10	cf. Rhodomonas salina	Cryptophyta	7	5.55E+04	2.99E+07	High sediment.
STN2PPB	5/16/2013	17:45	10	Aphanocapsa sp.	Cyanobacteria	35	2.77E+05	1.45E+05	High sediment.
				TOTAL		430	3.41E+06	1.05E+10	
STN4PPA	5/15/2013	11:17	15	Actinocyclus cf. divisus	Bacillariophyta	59	3.24E+05	1.32E+10	
STN4PPA	5/15/2013	11:17	15	Aulacoseira sp.	Bacillariophyta	11	6.03E+04	3.34E+07	
STN4PPA	5/15/2013	11:17	15	Cocconeis placentula	Bacillariophyta	1	5.48E+03	1.65E+06	
STN4PPA	5/15/2013	11:17	15	Coscinodiscus sp.	Bacillariophyta	2	1.10E+04	2.50E+07	
STN4PPA	5/15/2013	11:17	15	Cyclotella meneghiniana	Bacillariophyta	6	3.29E+04	1.88E+07	
STN4PPA	5/15/2013	11:17	15	Cyclotella cf. striata	Bacillariophyta	10	5.48E+04	1.56E+08	
STN4PPA	5/15/2013	11:17	15	Diploneis cf. ovalis	Bacillariophyta	3	1.65E+04	1.57E+07	
STN4PPA	5/15/2013	11:17	15	Eunotia sp.	Bacillariophyta	4	2.19E+04	4.14E+06	
STN4PPA	5/15/2013	11:17	15	Hippodonta sp.	Bacillariophyta	2	1.10E+04	1.42E+06	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN4PPA	5/15/2013	11:17	15	Nitzschia constricta	Bacillariophyta	1	5.48E+03	1.84E+06	
STN4PPA	5/15/2013	11:17	15	Nitzschia inconspicua	Bacillariophyta	2	1.10E+04	1.97E+05	
STN4PPA	5/15/2013	11:17	15	Nitzschia supralitorea	Bacillariophyta	9	4.94E+04	3.11E+06	
STN4PPA	5/15/2013	11:17	15	Opephora olsenii	Bacillariophyta	1	5.48E+03	9.48E+04	
STN4PPA	5/15/2013	11:17	15	Skeletonema cf. subsalsum	Bacillariophyta	75	4.11E+05	1.16E+08	
STN4PPA	5/15/2013	11:17	15	Thalassiosira cf. eccentrica	Bacillariophyta	5	2.74E+04	1.82E+07	
STN4PPA	5/15/2013	11:17	15	cf. Thalassiosira sp.	Bacillariophyta	46	2.52E+05	2.85E+07	
STN4PPA	5/15/2013	11:17	15	Chlorella sp.	Chlorophyta	10	5.48E+04	2.30E+05	
STN4PPA	5/15/2013	11:17	15	cf. Monoraphidium nanum	Chlorophyta	14	7.68E+04	8.04E+05	
STN4PPA	5/15/2013	11:17	15	Planctonema lauterbornii	Chlorophyta	244	1.34E+06	5.68E+07	
STN4PPA	5/15/2013	11:17	15	Scenedesmus sp.	Chlorophyta	16	8.78E+04	4.14E+06	
STN4PPA	5/15/2013	11:17	15	Tetrastrum glabrum	Chlorophyta	32	1.76E+05	2.48E+06	
STN4PPA	5/15/2013	11:17	15	Ochromonas sp.	Chrysophyta	16	8.78E+04	9.10E+06	
STN4PPA	5/15/2013	11:17	15	cf. Rhodomonas sp.	Cryptophyta	34	1.86E+05	9.76E+06	
STN4PPA	5/15/2013	11:17	15	Aphanocapsa cf. holsatica	Cyanobacteria	2766	1.52E+07	7.94E+06	
STN4PPA	5/15/2013	11:17	15	Chroococcus sp.	Cyanobacteria	8	4.39E+04	6.20E+05	
STN4PPA	5/15/2013	11:17	15	cf. Phormidium sp.	Cyanobacteria	95	5.21E+05	3.27E+06	
				TOTAL		3472	1.90E+07	1.37E+10	
STN2PPC	5/16/2013	17:45	10	Achnanthidium minutissimum	Bacillariophyta	3	3.56E+04	3.36E+05	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Actinocyclus cf. divisus	Bacillariophyta	9	1.07E+05	5.16E+08	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Aulacoseira sp.	Bacillariophyta	1	1.19E+04	3.70E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Cyclotella spp.	Bacillariophyta	4	4.75E+04	6.47E+07	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Cyclotella cf. striata	Bacillariophyta	6	7.13E+04	1.12E+08	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Diploneis ovalis	Bacillariophyta	4	4.75E+04	1.19E+07	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Eunotia sp.	Bacillariophyta	2	2.38E+04	2.94E+07	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Nitzschia fonticola	Bacillariophyta	4	4.75E+04	1.14E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Nitzschia punctata	Bacillariophyta	2	2.38E+04	5.70E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Nitzschia supralitorea	Bacillariophyta	6	7.13E+04	8.13E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Skeletonema cf. subsalsum	Bacillariophyta	106	1.26E+06	3.46E+08	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Surirella sp.	Bacillariophyta	1	1.19E+04	4.76E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Thalassiosira eccentrica	Bacillariophyta	2	2.38E+04	3.24E+07	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	cf. Thalassiosira sp.	Bacillariophyta	213	2.53E+06	2.48E+08	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Thalassiosira visurgis	Bacillariophyta	18	2.14E+05	1.01E+08	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Chlorella sp.	Chlorophyta	1	1.19E+04	3.98E+05	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Planctonema lauterbornii	Chlorophyta	84	9.98E+05	2.51E+07	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Scenedesmus sp.	Chlorophyta	4	4.75E+04	1.79E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Tetrastrum glabrum	Chlorophyta	16	1.90E+05	2.69E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	cf. Conradiella sp.	Chrysophyta	1	1.19E+04	6.22E+06	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Ochromonas sp.	Chrysophyta	12	1.43E+05	3.11E+07	Very high sediment; many broken diatoms
STN2PPC	5/16/2013	17:45	10	Aphanocapsa holsatica	Cyanobacteria	848	1.01E+07	5.28E+06	Very high sediment; many broken diatoms
				TOTAL		1347	1.60E+07	1.56E+09	
STN4PPC	5/15/2013	11:19	10	Achnanthidium minutissimum	Bacillariophyta	6	1.26E+04	1.30E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	Actinocyclus cf. divisus	Bacillariophyta	53	1.11E+05	4.54E+09	High sediment.
STN4PPC	5/15/2013	11:19	10	Chaetoceros sp.	Bacillariophyta	17	3.56E+04	4.90E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	Cyclotella cf. striata	Bacillariophyta	9	1.89E+04	2.28E+07	High sediment.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN4PPC	5/15/2013	11:19	10	Nitzschia palea	Bacillariophyta	1	2.10E+03	7.17E+05	High sediment.
STN4PPC	5/15/2013	11:19	10	Nitzschia punctata	Bacillariophyta	4	8.39E+03	3.19E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	Nitzschia sp.	Bacillariophyta	8	1.68E+04	2.11E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	cf. Thalassiosira sp.	Bacillariophyta	148	3.10E+05	2.63E+07	High sediment.
STN4PPC	5/15/2013	11:19	10	Thalassiosira visurgis	Bacillariophyta	34	7.13E+04	2.24E+07	High sediment.
STN4PPC	5/15/2013	11:19	10	Oocystis sp.	Chlorophyta	24	5.03E+04	5.27E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	Planctonema lauterbornii	Chlorophyta	347	7.28E+05	1.83E+07	High sediment.
STN4PPC	5/15/2013	11:19	10	Scenedesmus sp.	Chlorophyta	16	3.36E+04	1.58E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	Ochromonas sp.	Chrysophyta	46	9.65E+04	8.18E+06	High sediment.
STN4PPC	5/15/2013	11:19	10	Aphanocapsa sp.	Cyanobacteria	92	1.93E+05	1.01E+05	High sediment.
				TOTAL		805	1.69E+06	4.66E+09	
STN5PPA	5/16/2013	14:37	20	Achnanthes brevipes	Bacillariophyta	2	5.94E+03	7.09E+06	
STN5PPA	5/16/2013	14:37	20	Actinocyclus cf. divisus	Bacillariophyta	26	7.72E+04	2.83E+09	
STN5PPA	5/16/2013	14:37	20	Aulacoseira sp.	Bacillariophyta	3	8.91E+03	4.03E+06	
STN5PPA	5/16/2013	14:37	20	Coscinodiscus sp.	Bacillariophyta	1	2.97E+03	1.57E+07	
STN5PPA	5/16/2013	14:37	20	Cyclotella cf. striata	Bacillariophyta	7	2.08E+04	4.74E+07	
STN5PPA	5/16/2013	14:37	20	Eunotia sp.	Bacillariophyta	2	5.94E+03	6.72E+05	
STN5PPA	5/16/2013	14:37	20	Nitzschia compressa	Bacillariophyta	8	2.38E+04	1.93E+07	
STN5PPA	5/16/2013	14:37	20	Nitzschia spp.	Bacillariophyta	6	1.78E+04	3.21E+05	
STN5PPA	5/16/2013	14:37	20	Nitzschia supralitorea	Bacillariophyta	10	2.97E+04	1.69E+06	
STN5PPA	5/16/2013	14:37	20	cf. Thalassiosira sp.	Bacillariophyta	49	1.46E+05	8.57E+06	
STN5PPA	5/16/2013	14:37	20	Thalassiosira eccentrica	Bacillariophyta	4	1.19E+04	5.60E+06	
STN5PPA	5/16/2013	14:37	20	Chlorella sp.	Chlorophyta	10	2.97E+04	4.20E+05	
STN5PPA	5/16/2013	14:37	20	cf. Monoraphidium nanum	Chlorophyta	96	2.85E+05	2.99E+06	
STN5PPA	5/16/2013	14:37	20	Monoraphidium sp.	Chlorophyta	16	4.75E+04	2.69E+06	
STN5PPA	5/16/2013	14:37	20	Oocystis lacustris	Chlorophyta	14	4.16E+04	3.27E+06	
STN5PPA	5/16/2013	14:37	20	Oocystis parva	Chlorophyta	48	1.43E+05	8.96E+05	
STN5PPA	5/16/2013	14:37	20	Planctonema lauterbornii	Chlorophyta	258	7.66E+05	7.22E+06	
STN5PPA	5/16/2013	14:37	20	Scenedesmus sp.	Chlorophyta	20	5.94E+04	1.40E+06	
STN5PPA	5/16/2013	14:37	20	Tetrastrum triangulare	Chlorophyta	72	2.14E+05	3.02E+06	
STN5PPA	5/16/2013	14:37	20	Ochromonas sp.	Chrysophyta	14	4.16E+04	9.06E+06	
STN5PPA	5/16/2013	14:37	20	Chroomonas sp.	Cryptophyta	8	2.38E+04	1.28E+07	
STN5PPA	5/16/2013	14:37	20	cf. Rhodomonas sp.	Cryptophyta	24	7.13E+04	6.72E+06	
STN5PPA	5/16/2013	14:37	20	Aphanocapsa cf. holsatica	Cyanobacteria	1948	5.79E+06	3.03E+06	
STN5PPA	5/16/2013	14:37	20	Aphanocapsa sp.	Cyanobacteria	101	3.00E+05	1.26E+06	
STN5PPA	5/16/2013	14:37	20	Chroococcus sp.	Cyanobacteria	28	8.32E+04	1.18E+06	
				TOTAL		2775	8.24E+06	3.00E+09	
STN6PPA	5/15/2013	10:40	15	Achnanthidium sp.	Bacillariophyta	1	2.55E+03	1.32E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Actinocyclus cf. divisus	Bacillariophyta	121	3.08E+05	1.62E+10	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Coscinodiscus sp.	Bacillariophyta	2	5.09E+03	1.54E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Cyclotella sp.	Bacillariophyta	6	1.53E+04	3.84E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Cyclotella cf. striata	Bacillariophyta	18	4.58E+04	6.24E+07	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	cf. Fragilariaforma sp.	Bacillariophyta	1	2.55E+03	1.10E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Nitzschia spp.	Bacillariophyta	7	1.78E+04	3.21E+05	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN6PPA	5/15/2013	10:40	15	Opephora cf. mutabilis	Bacillariophyta	8	2.04E+04	6.80E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Skeletonema cf. subsalsum	Bacillariophyta	35	8.91E+04	1.92E+07	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	cf. Thalassiosira sp.	Bacillariophyta	33	8.40E+04	7.13E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Thalassiosira eccentrica	Bacillariophyta	4	1.02E+04	3.00E+07	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Thalassiosira visurgis	Bacillariophyta	9	2.29E+04	1.31E+07	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Chlorella sp.	Chlorophyta	9	2.29E+04	3.24E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Monoraphidium arcuatum	Chlorophyta	13	3.31E+04	8.74E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	cf. Monoraphidium nanum	Chlorophyta	4	1.02E+04	1.28E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Oocystis lacustris	Chlorophyta	10	2.55E+04	1.71E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Oocystis parva	Chlorophyta	48	1.22E+05	2.88E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Planctonema lauterbornii	Chlorophyta	344	8.76E+05	6.19E+07	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Scenedesmus spp.	Chlorophyta	20	5.09E+04	5.33E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Tetrastrum triangulare	Chlorophyta	136	3.46E+05	1.45E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Ochromonas sp.	Chrysophyta	8	2.04E+04	2.11E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Chroomonas sp.	Cryptophyta	10	2.55E+04	1.00E+07	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	cf. Rhodomonas sp.	Cryptophyta	4	1.02E+04	5.33E+05	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Aphanocapsa holsatica	Cyanobacteria	1547	3.94E+06	2.06E+06	High sediment; many broken diatoms.
STN6PPA	5/15/2013	10:40	15	Chroococcus sp.	Cyanobacteria	62	1.58E+05	2.23E+06	High sediment; many broken diatoms.
				TOTAL		2460	6.26E+06	1.64E+10	
STN6PPB	5/15/2013	10:40	15	Actinocyclus cf. divisus	Bacillariophyta	51	1.25E+05	1.50E+10	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Cyclotella meneghiniana	Bacillariophyta	2	4.92E+03	3.27E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Cyclotella cf. striata	Bacillariophyta	22	5.41E+04	4.89E+07	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	cf. Diploneis sp.	Bacillariophyta	1	2.46E+03	2.51E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Eunotia sp.	Bacillariophyta	1	2.46E+03	1.85E+05	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Nitzschia granulata	Bacillariophyta	5	1.23E+04	3.45E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Nitzschia supralitorea	Bacillariophyta	1	2.46E+03	1.25E+05	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Thalassiosira eccentrica	Bacillariophyta	4	9.83E+03	2.79E+07	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	cf. Thalassiosira sp.	Bacillariophyta	24	5.90E+04	3.48E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Thalassiosira visurgis	Bacillariophyta	4	9.83E+03	6.54E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Triceratium sp.	Bacillariophyta	1	2.46E+03	4.18E+07	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Chlamydomonas grovei	Chlorophyta	18	4.43E+04	6.26E+05	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Monoraphidium arcuatum	Chlorophyta	10	2.46E+04	3.09E+05	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	cf. Monoraphidium nanum	Chlorophyta	28	6.88E+04	5.77E+05	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Monoraphidium tortile	Chlorophyta	33	8.11E+04	8.92E+05	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Oocystis lacustris	Chlorophyta	40	9.83E+04	2.32E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Planctonema lauterbornii	Chlorophyta	384	9.44E+05	4.63E+07	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Scenedesmus quadricauda	Chlorophyta	18	4.43E+04	2.29E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Tetrastrum triangulare	Chlorophyta	64	1.57E+05	1.29E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Ochromonas sp.	Chrysophyta	83	2.04E+05	1.73E+07	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN6PPB	5/15/2013	10:40	15	Chroomonas sp.	Cryptophyta	4	9.83E+03	2.92E+06	High sediment; many broken diatoms.
STN6PPB	5/15/2013	10:40	15	Aphanocapsa sp.	Cyanobacteria	200	4.92E+05	2.57E+05	High sediment; many broken diatoms.
				TOTAL		998	2.45E+06	1.52E+10	
STN5PPC	5/16/2013	14:37	15	Actinoptychus sp.	Bacillariophyta	1	1.98E+03	2.86E+07	High sediment.
STN5PPC	5/16/2013	14:37	15	Actinocyclus cf. divisus	Bacillariophyta	57	1.13E+05	4.79E+09	High sediment.
STN5PPC	5/16/2013	14:37	15	Aulacoseira sp.	Bacillariophyta	8	1.58E+04	2.61E+07	High sediment.
STN5PPC	5/16/2013	14:37	15	Chaetoceros sp.	Bacillariophyta	12	2.38E+04	4.70E+06	High sediment.
STN5PPC	5/16/2013	14:37	15	Cyclotella cf. striata	Bacillariophyta	33	6.54E+04	4.62E+08	High sediment.
STN5PPC	5/16/2013	14:37	15	Entomoneis cf. ornata	Bacillariophyta	2	3.96E+03	2.62E+08	High sediment.
STN5PPC	5/16/2013	14:37	15	Nitzschia sp.	Bacillariophyta	16	3.17E+04	2.03E+06	High sediment.
STN5PPC	5/16/2013	14:37	15	cf. Odontella sp.	Bacillariophyta	4	7.92E+03	8.63E+07	High sediment.
STN5PPC	5/16/2013	14:37	15	cf. Thalassiosira sp.	Bacillariophyta	56	1.11E+05	4.18E+06	High sediment.
STN5PPC	5/16/2013	14:37	15	Thalassiosira eccentrica	Bacillariophyta	1	1.98E+03	4.49E+06	High sediment.
STN5PPC	5/16/2013	14:37	15	cf. Monoraphidium nanum	Chlorophyta	33	6.54E+04	8.21E+05	High sediment.
STN5PPC	5/16/2013	14:37	15	Oocystis sp.	Chlorophyta	68	1.35E+05	1.41E+07	High sediment.
STN5PPC	5/16/2013	14:37	15	Planctonema lauterbornii	Chlorophyta	200	3.96E+05	9.96E+06	High sediment.
STN5PPC	5/16/2013	14:37	15	Scenedesmus sp.	Chlorophyta	104	2.06E+05	3.45E+06	High sediment.
STN5PPC	5/16/2013	14:37	15	Tetrastrum triangulare	Chlorophyta	48	9.51E+04	3.98E+05	High sediment.
STN5PPC	5/16/2013	14:37	15	Ochromonas sp.	Chrysophyta	68	1.35E+05	1.27E+07	High sediment.
STN5PPC	5/16/2013	14:37	15	Aphanocapsa sp.	Cyanobacteria	1415	2.80E+06	1.47E+06	High sediment.
				TOTAL		2126	4.21E+06	5.72E+09	
STN5PPB	5/16/2013	14:37	15	Actinocyclus cf. divisus	Bacillariophyta	38	8.74E+04	7.41E+09	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Aulacoseira spp.	Bacillariophyta	14	3.22E+04	2.28E+07	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Cyclotella cf. striata	Bacillariophyta	44	1.01E+05	9.40E+07	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Mastogloia smithii	Bacillariophyta	1	2.30E+03	1.17E+06	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Nitzschia lanceola	Bacillariophyta	1	2.30E+03	7.66E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Nitzschia supralitorea	Bacillariophyta	7	1.61E+04	4.11E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Synedra parasitica	Bacillariophyta	4	9.20E+03	1.73E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	cf. Thalassiosira sp.	Bacillariophyta	109	2.51E+05	1.48E+07	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Thalassiosira eccentrica	Bacillariophyta	6	1.38E+04	1.55E+08	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Thalassiosira visurgis	Bacillariophyta	1	2.30E+03	1.53E+06	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Chlamydomonas grovei	Chlorophyta	12	2.76E+04	1.30E+06	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Monoraphidium arcuatum	Chlorophyta	1	2.30E+03	4.58E+04	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	cf. Monoraphidium nanum	Chlorophyta	11	2.53E+04	2.12E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Monoraphidium tortile	Chlorophyta	1	2.30E+03	1.54E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Oocystis sp.	Chlorophyta	40	9.20E+04	3.85E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Planctonema lauterbornii	Chlorophyta	164	3.77E+05	2.04E+07	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Scenedesmus quadricauda	Chlorophyta	16	3.68E+04	1.91E+06	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Tetrastrum triangulare	Chlorophyta	24	5.52E+04	4.52E+05	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Ochromonas sp.	Chrysophyta	58	1.33E+05	1.13E+07	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Chroomonas sp.	Cryptophyta	29	6.67E+04	1.45E+07	High sediment; many broken diatoms.
STN5PPB	5/16/2013	14:37	15	Cryptomonas sp.	Cryptophyta	4	9.20E+03	6.78E+06	High sediment; many broken diatoms.
				TOTAL		585	1.35E+06	7.76E+09	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN7PPA	5/17/2013	14:57	20	Achnanthidium minutissimum	Bacillariophyta	9	3.01E+04	3.07E+06	
STN7PPA	5/17/2013	14:57	20	Actinocyclus cf. divisus	Bacillariophyta	27	9.02E+04	1.81E+09	
STN7PPA	5/17/2013	14:57	20	Amphora cf. fogediana	Bacillariophyta	1	3.34E+03	2.27E+06	
STN7PPA	5/17/2013	14:57	20	Aulacoseira sp.	Bacillariophyta	22	7.35E+04	7.39E+07	
STN7PPA	5/17/2013	14:57	20	Chaetoceros sp.	Bacillariophyta	12	4.01E+04	7.37E+06	
STN7PPA	5/17/2013	14:57	20	Cocconeis sp.	Bacillariophyta	20	6.68E+04	2.95E+07	
STN7PPA	5/17/2013	14:57	20	Cyclotella cf. striata	Bacillariophyta	24	8.02E+04	9.10E+08	
STN7PPA	5/17/2013	14:57	20	Cyclotella sp.	Bacillariophyta	8	2.67E+04	1.77E+07	
STN7PPA	5/17/2013	14:57	20	Cyclotella cf. stylorum	Bacillariophyta	3	1.00E+04	4.84E+07	
STN7PPA	5/17/2013	14:57	20	cf. Denticula sp.	Bacillariophyta	1	3.34E+03	1.26E+05	
STN7PPA	5/17/2013	14:57	20	Diploneis spp.	Bacillariophyta	4	1.34E+04	2.77E+06	
STN7PPA	5/17/2013	14:57	20	Hippodonta sp.	Bacillariophyta	1	3.34E+03	1.05E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia acicularis	Bacillariophyta	2	6.68E+03	1.91E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia compressa	Bacillariophyta	2	6.68E+03	2.77E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia constricta	Bacillariophyta	9	3.01E+04	3.52E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia granulata	Bacillariophyta	4	1.34E+04	7.82E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia lanceola	Bacillariophyta	2	6.68E+03	4.68E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia spp.	Bacillariophyta	24	8.02E+04	6.02E+06	
STN7PPA	5/17/2013	14:57	20	Nitzschia supralitorea	Bacillariophyta	1	3.34E+03	7.27E+05	
STN7PPA	5/17/2013	14:57	20	Opephora pacifica	Bacillariophyta	1	3.34E+03	2.05E+05	
STN7PPA	5/17/2013	14:57	20	Pseudostaurosira brevistriata	Bacillariophyta	2	6.68E+03	2.94E+06	
STN7PPA	5/17/2013	14:57	20	Staurosira construens var. venter	Bacillariophyta	3	1.00E+04	9.45E+05	
STN7PPA	5/17/2013	14:57	20	Thalassionema sp.	Bacillariophyta	4	1.34E+04	4.81E+06	
STN7PPA	5/17/2013	14:57	20	cf. Thalassiosira sp.	Bacillariophyta	43	1.44E+05	1.22E+07	
STN7PPA	5/17/2013	14:57	20	Thalassiosira visurgis	Bacillariophyta	79	2.64E+05	1.51E+08	
STN7PPA	5/17/2013	14:57	20	Tryblionella angustata	Bacillariophyta	4	1.34E+04	2.41E+06	
STN7PPA	5/17/2013	14:57	20	cf. Monoraphidium nanum	Chlorophyta	5	1.67E+04	1.75E+05	
STN7PPA	5/17/2013	14:57	20	Ochromonas sp.	Chrysophyta	17	5.68E+04	2.68E+07	
STN7PPA	5/17/2013	14:57	20	Chroomonas sp.	Cryptophyta	135	4.51E+05	3.83E+07	
STN7PPA	5/17/2013	14:57	20	cf. Rhodomonas sp.	Cryptophyta	10	3.34E+04	3.46E+06	
				TOTAL		479	1.60E+06	3.18E+09	
STN6PPC	5/15/2013	10:40	15	Actinocyclus cf. divisus	Bacillariophyta	59	8.41E+04	6.44E+09	High sediment.
STN6PPC	5/15/2013	10:40	15	Actinoptychus sp.	Bacillariophyta	2	2.85E+03	4.39E+07	High sediment.
STN6PPC	5/15/2013	10:40	15	Cyclotella cf. striata	Bacillariophyta	22	3.14E+04	1.80E+08	High sediment.
STN6PPC	5/15/2013	10:40	15	Nitzschia punctata	Bacillariophyta	4	5.70E+03	2.38E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	Nitzschia sp.	Bacillariophyta	4	5.70E+03	7.19E+05	High sediment.
STN6PPC	5/15/2013	10:40	15	Thalassiosira visurgis	Bacillariophyta	6	8.56E+03	2.69E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	cf. Thalassiosira sp.	Bacillariophyta	22	3.14E+04	2.66E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	Monoraphidium arcuatum	Chlorophyta	27	3.85E+04	2.34E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	cf. Monoraphidium nanum	Chlorophyta	4	5.70E+03	7.17E+04	High sediment.
STN6PPC	5/15/2013	10:40	15	Oocystis sp.	Chlorophyta	22	3.14E+04	2.46E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	Planctonema lauterbornii	Chlorophyta	658	9.38E+05	8.62E+07	High sediment.
STN6PPC	5/15/2013	10:40	15	Scenedesmus spp.	Chlorophyta	24	3.42E+04	9.68E+05	High sediment.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN6PPC	5/15/2013	10:40	15	Tetrastrum triangulare	Chlorophyta	76	1.08E+05	1.53E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	Ochromonas sp.	Chrysophyta	72	1.03E+05	8.71E+06	High sediment.
STN6PPC	5/15/2013	10:40	15	Aphanocapsa sp.	Cyanobacteria	482	6.87E+05	3.60E+05	High sediment.
STN6PPC	5/15/2013	10:40	15	Chroococcus sp.	Cyanobacteria	28	3.99E+04	5.64E+05	High sediment.
STN6PPC	5/15/2013	10:40	15	cf. Gymnodinium sp.	Pyrrophyta	22	3.14E+04	7.88E+06	High sediment.
				TOTAL		1534	2.19E+06	6.78E+09	
STN7PPB	5/17/2013	14:57	20	Achnanthidium sp.	Bacillariophyta	5	1.41E+04	1.26E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Actinoptychus senarius	Bacillariophyta	1	2.81E+03	4.07E+07	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Actinocyclus cf. divisus	Bacillariophyta	24	6.75E+04	2.26E+09	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Cyclotella cf. striata	Bacillariophyta	33	9.29E+04	1.14E+08	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Diploneis ovalis	Bacillariophyta	4	1.13E+04	8.17E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	cf. Fragilariopsis sp.	Bacillariophyta	4	1.13E+04	2.69E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Nitzschia compressa	Bacillariophyta	1	2.81E+03	1.39E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Nitzschia granulata	Bacillariophyta	8	2.25E+04	9.93E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Nitzschia sp.	Bacillariophyta	9	2.53E+04	2.43E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Rhopalodia cf. acuminata	Bacillariophyta	8	2.25E+04	8.89E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Thalassiosira eccentrica	Bacillariophyta	10	2.81E+04	3.16E+08	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	cf. Thalassiosira sp.	Bacillariophyta	34	9.57E+04	2.40E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Thalassiosira visurgis	Bacillariophyta	102	2.87E+05	2.67E+08	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Tryblionella debilis	Bacillariophyta	14	3.94E+04	6.62E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Chlamydomonas globosa	Chlorophyta	1	2.81E+03	2.65E+05	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Ochromonas sp.	Chrysophyta	129	3.63E+05	3.08E+07	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Chroomonas sp.	Cryptophyta	6	1.69E+04	7.07E+06	High sediment; many broken diatoms.
STN7PPB	5/17/2013	14:57	20	Cryptomonas sp.	Cryptophyta	10	2.81E+04	1.55E+07	High sediment; many broken diatoms.
				TOTAL		403	1.13E+06	3.09E+09	
STN8PPB	5/18/2013	12:20	10	Achnanthidium sp.	Bacillariophyta	4	1.16E+04	9.08E+05	High sediment.
STN8PPB	5/18/2013	12:20	10	Actinocyclus cf. divisus	Bacillariophyta	15	4.34E+04	1.26E+09	High sediment.
STN8PPB	5/18/2013	12:20	10	Actinoptychus sp.	Bacillariophyta	2	5.78E+03	1.64E+07	High sediment.
STN8PPB	5/18/2013	12:20	10	Cocconeis sp.	Bacillariophyta	22	6.36E+04	3.70E+07	High sediment.
STN8PPB	5/18/2013	12:20	10	Cyclotella sp.	Bacillariophyta	4	1.16E+04	5.49E+06	High sediment.
STN8PPB	5/18/2013	12:20	10	Cyclotella cf. striata	Bacillariophyta	10	2.89E+04	1.10E+08	High sediment.
STN8PPB	5/18/2013	12:20	10	Diadesmis sp.	Bacillariophyta	1	2.89E+03	7.95E+05	High sediment.
STN8PPB	5/18/2013	12:20	10	Diploneis elliptica	Bacillariophyta	1	2.89E+03	3.78E+06	High sediment.
STN8PPB	5/18/2013	12:20	10	Diploneis sp.	Bacillariophyta	1	2.89E+03	2.83E+06	High sediment.
STN8PPB	5/18/2013	12:20	10	Fragilariopsis sp.	Bacillariophyta	2	5.78E+03	5.72E+06	High sediment.
STN8PPB	5/18/2013	12:20	10	cf. Melosira sp.	Bacillariophyta	18	5.20E+04	1.15E+08	High sediment.
STN8PPB	5/18/2013	12:20	10	Nitzschia acicularis	Bacillariophyta	2	5.78E+03	6.94E+05	High sediment.
STN8PPB	5/18/2013	12:20	10	Nitzschia granulata	Bacillariophyta	6	1.73E+04	8.45E+06	High sediment.
STN8PPB	5/18/2013	12:20	10	Nitzschia punctata	Bacillariophyta	2	5.78E+03	9.71E+05	High sediment.
STN8PPB	5/18/2013	12:20	10	Odontella aurita	Bacillariophyta	24	6.94E+04	2.64E+08	High sediment.
STN8PPB	5/18/2013	12:20	10	Pinnularia sp.	Bacillariophyta	1	2.89E+03	1.40E+07	High sediment.
STN8PPB	5/18/2013	12:20	10	Pseudostaurosira brevistriata	Bacillariophyta	12	3.47E+04	8.72E+06	High sediment.
STN8PPB	5/18/2013	12:20	10	cf. Stephanodiscus sp.	Bacillariophyta	8	2.31E+04	8.79E+06	High sediment.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN8PPB	5/18/2013	12:20	10	cf. Thalassiosira sp.	Bacillariophyta	199	5.75E+05	1.45E+07	High sediment.
STN8PPB	5/18/2013	12:20	10	Thalassiosira eccentrica	Bacillariophyta	6	1.73E+04	1.83E+08	High sediment.
STN8PPB	5/18/2013	12:20	10	Thalassiosira visurgis	Bacillariophyta	61	1.76E+05	5.54E+07	High sediment.
STN8PPB	5/18/2013	12:20	10	Ochromonas sp.	Chrysophyta	16	4.62E+04	3.92E+06	High sediment.
				TOTAL		417	1.21E+06	2.12E+09	
STN8PPC	5/18/2013	12:20	5	Achnanthidium sp.	Bacillariophyta	4	4.89E+04	3.23E+06	
STN8PPC	5/18/2013	12:20	5	Actinocyclus cf. divisus	Bacillariophyta	38	4.64E+05	7.80E+10	
STN8PPC	5/18/2013	12:20	5	Bacillaria paxillifer	Bacillariophyta	8	9.78E+04	1.43E+08	
STN8PPC	5/18/2013	12:20	5	Cyclotella cf. striata	Bacillariophyta	12	1.47E+05	2.03E+08	
STN8PPC	5/18/2013	12:20	5	Diploneis ovalis	Bacillariophyta	7	8.56E+04	1.63E+07	
STN8PPC	5/18/2013	12:20	5	cf. Fragilariopsis sp.	Bacillariophyta	14	1.71E+05	1.33E+07	
STN8PPC	5/18/2013	12:20	5	Nitzschia compressa	Bacillariophyta	4	4.89E+04	7.48E+06	
STN8PPC	5/18/2013	12:20	5	Nitzschia constricta	Bacillariophyta	1	1.22E+04	3.23E+06	
STN8PPC	5/18/2013	12:20	5	Nitzschia granulata	Bacillariophyta	12	1.47E+05	9.15E+07	
STN8PPC	5/18/2013	12:20	5	Nitzschia reversa	Bacillariophyta	7	8.56E+04	7.06E+07	
STN8PPC	5/18/2013	12:20	5	Nitzschia sp.	Bacillariophyta	9	1.10E+05	9.90E+06	
STN8PPC	5/18/2013	12:20	5	Rhizosolenia sp.	Bacillariophyta	6	7.33E+04	2.41E+08	
STN8PPC	5/18/2013	12:20	5	Thalassiosira eccentrica	Bacillariophyta	18	2.20E+05	2.71E+08	
STN8PPC	5/18/2013	12:20	5	cf. Thalassiosira sp.	Bacillariophyta	156	1.91E+06	4.79E+07	
STN8PPC	5/18/2013	12:20	5	Thalassiosira visurgis	Bacillariophyta	71	8.68E+05	5.77E+08	
STN8PPC	5/18/2013	12:20	5	Tryblionella debilis	Bacillariophyta	4	4.89E+04	6.45E+06	
STN8PPC	5/18/2013	12:20	5	Chlamydomonas globosa	Chlorophyta	1	1.22E+04	1.15E+06	
STN8PPC	5/18/2013	12:20	5	Ochromonas sp.	Chrysophyta	36	4.40E+05	3.73E+07	
STN8PPC	5/18/2013	12:20	5	Chroomonas sp.	Cryptophyta	2	2.44E+04	2.38E+07	
				TOTAL		410	5.01E+06	7.97E+10	
STN7PPC	5/17/2013	14:57	20	Achnanthidium minutissimum	Bacillariophyta	4	1.34E+04	6.93E+05	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Actinocyclus cf. divisus	Bacillariophyta	20	6.68E+04	1.57E+09	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Aulacoseira sp.	Bacillariophyta	10	3.34E+04	3.19E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Bacillaria paxillifer	Bacillariophyta	1	3.34E+03	7.92E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Chaetoceros sp.	Bacillariophyta	25	8.36E+04	6.72E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Chaetoceros cf. peruvianus	Bacillariophyta	29	9.69E+04	1.33E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Cocconeis sp.	Bacillariophyta	12	4.01E+04	1.66E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Cyclotella cf. striata	Bacillariophyta	21	7.02E+04	2.13E+08	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Cyclotella cf. stylorum	Bacillariophyta	3	1.00E+04	3.63E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Cyclotella sp.	Bacillariophyta	9	3.01E+04	4.25E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Denticula sp.	Bacillariophyta	4	1.34E+04	3.15E+05	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Diploneis sp.	Bacillariophyta	1	3.34E+03	1.91E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia acicularis	Bacillariophyta	4	1.34E+04	4.27E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia compressa var. vexans	Bacillariophyta	7	2.34E+04	2.98E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia constricta	Bacillariophyta	21	7.02E+04	8.42E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia granulata	Bacillariophyta	3	1.00E+04	3.31E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia cf. lanceola	Bacillariophyta	2	6.68E+03	4.28E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia reversa	Bacillariophyta	3	1.00E+04	2.38E+06	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN7PPC	5/17/2013	14:57	20	Nitzschia spp.	Bacillariophyta	6	2.01E+04	1.19E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Nitzschia supralitorea	Bacillariophyta	3	1.00E+04	1.14E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Opephora pacifica	Bacillariophyta	1	3.34E+03	2.20E+05	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Planothidium sp.	Bacillariophyta	2	6.68E+03	2.10E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Pleurosigma salinarum	Bacillariophyta	2	6.68E+03	1.02E+08	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Pseudostaurosira brevistriata	Bacillariophyta	7	2.34E+04	1.05E+08	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Thalassionema sp.	Bacillariophyta	4	1.34E+04	2.23E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Thalassiosira eccentrica	Bacillariophyta	21	7.02E+04	1.60E+08	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	cf. Thalassiosira sp.	Bacillariophyta	39	1.30E+05	5.12E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Thalassiosira visurgis	Bacillariophyta	87	2.91E+05	1.93E+08	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	cf. Coenochloris sp.	Chlorophyta	24	8.02E+04	3.36E+05	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Oocystis parva	Chlorophyta	4	1.34E+04	3.15E+05	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Ochromonas sp.	Chrysophyta	29	9.69E+04	5.22E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Chroomonas sp.	Cryptophyta	69	2.31E+05	1.21E+07	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Cryptomonas ovata	Cryptophyta	2	6.68E+03	5.95E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	Cryptomonas sp.	Cryptophyta	6	2.01E+04	6.05E+06	High sediment; many broken diatoms.
STN7PPC	5/17/2013	14:57	20	cf. Rhodomonas sp.	Cryptophyta	10	3.34E+04	1.75E+06	High sediment; many broken diatoms.
				TOTAL		495	1.65E+06	2.72E+09	
STN10PPA	5/25/2013	14:40	10	Aulacoseira sp.	Bacillariophyta	2	1.13E+04	5.31E+06	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Chaetoceros sp.	Bacillariophyta	32	1.80E+05	1.53E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Cocconeis sp.	Bacillariophyta	8	4.50E+04	1.98E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Cyclotella cf. striata	Bacillariophyta	12	6.75E+04	3.26E+08	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Cyclotella sp.	Bacillariophyta	14	7.88E+04	4.49E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Nitzschia compressa	Bacillariophyta	9	5.07E+04	1.28E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Nitzschia granulata	Bacillariophyta	4	2.25E+04	1.62E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Nitzschia inconspicua	Bacillariophyta	3	1.69E+04	4.39E+05	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Nitzschia lanceola	Bacillariophyta	7	3.94E+04	3.39E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Odontella aurita	Bacillariophyta	4	2.25E+04	3.29E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Opephora sp.	Bacillariophyta	2	1.13E+04	8.49E+05	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Pseudostaurosira brevistriata	Bacillariophyta	22	1.24E+05	2.04E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Thalassionema sp.	Bacillariophyta	16	9.01E+04	2.92E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Thalassiosira eccentrica	Bacillariophyta	2	1.13E+04	3.06E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	cf. Thalassiosira sp.	Bacillariophyta	227	1.28E+06	7.53E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Thalassiosira sp.	Bacillariophyta	35	1.97E+05	1.39E+09	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Thalassiosira visurgis	Bacillariophyta	7	3.94E+04	1.87E+07	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	cf. Chlamydomonas sp.	Chlorophyta	2	1.13E+04	1.27E+06	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Ochromonas sp.	Chrysophyta	1	5.63E+03	2.21E+06	High sediment; many broken diatoms.
STN10PPA	5/25/2013	14:40	10	Chroomonas sp.	Cryptophyta	23	1.29E+05	1.34E+07	High sediment; many broken diatoms.
				TOTAL		432	2.43E+06	2.09E+09	
STN11PPB	5/19/2013	12:25	10	Actinoptychus sp.	Bacillariophyta	4	2.14E+04	4.37E+07	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Chaetoceros sp.	Bacillariophyta	2	1.07E+04	1.07E+07	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Cocconeis sp.	Bacillariophyta	1	5.35E+03	1.46E+06	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Cyclotella cf. striata	Bacillariophyta	1	5.35E+03	5.68E+06	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	8	4.28E+04	2.62E+06	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Navicula sp.	Bacillariophyta	4	2.14E+04	6.30E+06	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN11PPB	5/19/2013	12:25	10	Pseudo-nitzschia sp.	Bacillariophyta	31	1.66E+05	1.27E+08	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Rhizosolenia sp.	Bacillariophyta	6	3.21E+04	8.62E+07	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Thalassionema pseudonitzschioides	Bacillariophyta	12	6.42E+04	4.23E+06	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	cf. Thalassiosira sp.	Bacillariophyta	287	1.53E+06	9.04E+07	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Thalassiosira visurgis	Bacillariophyta	7	3.74E+04	3.97E+07	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Ochromonas sp.	Chrysophyta	59	3.15E+05	1.65E+07	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Chroomonas sp.	Cryptophyta	1	5.35E+03	2.45E+05	High sediment; many broken diatoms.
STN11PPB	5/19/2013	12:25	10	Cryptomonas ovata	Cryptophyta	1	5.35E+03	1.04E+07	High sediment; many broken diatoms.
				TOTAL		424	2.27E+06	4.45E+08	
STN9PPA	5/25/2013	10:28	10	Actinocyclus cf. divisus	Bacillariophyta	8	6.58E+04	3.24E+09	
STN9PPA	5/25/2013	10:28	10	Coscinodiscus sp.	Bacillariophyta	2	1.65E+04	5.21E+09	
STN9PPA	5/25/2013	10:28	10	Chaetoceros sp.	Bacillariophyta	9	7.40E+04	7.44E+07	
STN9PPA	5/25/2013	10:28	10	Cyclotella cf. striata	Bacillariophyta	11	9.05E+04	6.22E+08	
STN9PPA	5/25/2013	10:28	10	Melosira sp.	Bacillariophyta	12	9.87E+04	5.36E+08	
STN9PPA	5/25/2013	10:28	10	Nitzschia punctata	Bacillariophyta	4	3.29E+04	7.90E+06	
STN9PPA	5/25/2013	10:28	10	Nitzschia sp.	Bacillariophyta	1	8.23E+03	5.31E+06	
STN9PPA	5/25/2013	10:28	10	Odontella mobiliensis	Bacillariophyta	2	1.65E+04	7.69E+07	
STN9PPA	5/25/2013	10:28	10	Odontella sinensis	Bacillariophyta	6	4.94E+04	1.79E+09	
STN9PPA	5/25/2013	10:28	10	Odontella spp.	Bacillariophyta	4	3.29E+04	1.72E+08	
STN9PPA	5/25/2013	10:28	10	Pleurosigma sp.	Bacillariophyta	8	6.58E+04	1.26E+09	
STN9PPA	5/25/2013	10:28	10	Thalassiosira eccentrica	Bacillariophyta	8	6.58E+04	5.63E+08	
STN9PPA	5/25/2013	10:28	10	cf. Thalassiosira sp.	Bacillariophyta	275	2.26E+06	8.88E+07	
STN9PPA	5/25/2013	10:28	10	Thalassiosira visurgis	Bacillariophyta	17	1.40E+05	4.39E+07	
STN9PPA	5/25/2013	10:28	10	cf. Zygnema sp.	Chlorophyta	80	6.58E+05	9.13E+09	
				TOTAL		447	3.68E+06	2.28E+10	
STN10PPB	5/25/2013	14:40	5	Actinocyclus cf. divisus	Bacillariophyta	1	1.78E+04	1.85E+09	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Bacillaria paxillifer	Bacillariophyta	1	1.78E+04	2.86E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Chaetoceros sp.	Bacillariophyta	11	1.96E+05	3.73E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Cyclotella cf. striata	Bacillariophyta	32	5.70E+05	3.87E+09	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Eunotia sp.	Bacillariophyta	1	1.78E+04	8.40E+06	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Fragilariopsis cf. kerguelensis	Bacillariophyta	4	7.13E+04	7.39E+06	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Navicula sp.	Bacillariophyta	1	1.78E+04	1.68E+08	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Nitzschia acicularis	Bacillariophyta	1	1.78E+04	6.13E+06	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Nitzschia closterium	Bacillariophyta	4	7.13E+04	6.51E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Nitzschia coarctata	Bacillariophyta	1	1.78E+04	9.30E+06	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Nitzschia granulata	Bacillariophyta	9	1.60E+05	7.15E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Nitzschia lanceola	Bacillariophyta	4	7.13E+04	3.65E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Rhizosolenia sp.	Bacillariophyta	1	1.78E+04	5.85E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Thalassionema sp.	Bacillariophyta	20	3.56E+05	2.57E+07	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Thalassiosira eccentrica	Bacillariophyta	14	2.50E+05	3.97E+08	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	cf. Thalassiosira sp.	Bacillariophyta	188	3.35E+06	1.97E+08	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Thalassiosira visurgis	Bacillariophyta	69	1.23E+06	1.11E+09	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	cf. Coelastrum microporum	Chlorophyta	32	5.70E+05	1.53E+08	High sediment; many broken diatoms.
STN10PPB	5/25/2013	14:40	5	Ochromonas sp.	Chrysophyta	34	6.06E+05	5.14E+07	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
				TOTAL		428	7.63E+06	8.16E+09	
STN11PPA	5/19/2013	12:25	5	cf. Cerataulina sp.	Bacillariophyta	1	1.65E+04	8.14E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Chaetoceros sp.	Bacillariophyta	16	2.63E+05	5.21E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Cocconeis sp.	Bacillariophyta	13	2.14E+05	1.64E+08	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Cyclotella sp.	Bacillariophyta	4	6.58E+04	7.46E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Eucampia sp.	Bacillariophyta	3	4.94E+04	9.23E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Nitzschia supralitorea	Bacillariophyta	7	1.15E+05	4.84E+06	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Odontella aurita	Bacillariophyta	2	3.29E+04	6.87E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Pseudo-nitzschia sp.	Bacillariophyta	9	1.48E+05	8.44E+06	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Pseudostaurosira brevistriata	Bacillariophyta	18	2.96E+05	5.58E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Thalassionema sp.	Bacillariophyta	14	2.30E+05	1.52E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	cf. Thalassiosira sp.	Bacillariophyta	266	4.38E+06	3.71E+08	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Thalassiosira visurgis	Bacillariophyta	30	4.94E+05	2.35E+08	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	cf. Chlorella sp.	Chlorophyta	33	5.43E+05	3.55E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Ochromonas sp.	Chrysophyta	2	3.29E+04	7.72E+06	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	Chroomonas sp.	Cryptophyta	27	4.44E+05	4.61E+07	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	cf. Cryptomonas sp.	Cryptophyta	1	1.65E+04	1.01E+06	High sediment; many broken diatoms.
STN11PPA	5/19/2013	12:25	5	cf. Trachelomonas sp.	Euglenophyta	2	3.29E+04	5.51E+06	High sediment; many broken diatoms.
				TOTAL		448	7.37E+06	1.32E+09	
STN9PPC	5/25/2013	10:28	15	Actinocyclus cf. divisus	Bacillariophyta	7	8.32E+04	7.79E+09	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Cyclotella cf. striata	Bacillariophyta	5	5.94E+04	7.32E+07	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Entomoneis alata	Bacillariophyta	1	1.19E+04	9.48E+08	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	cf. Fragilariopsis sp.	Bacillariophyta	1	1.19E+04	1.06E+06	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Nitzschia compressa	Bacillariophyta	1	1.19E+04	4.71E+06	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Odontella mobiliensis	Bacillariophyta	1	1.19E+04	3.88E+08	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Odontella sinensis	Bacillariophyta	1	1.19E+04	7.60E+08	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Rhizosolenia sp.	Bacillariophyta	2	2.38E+04	1.70E+08	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Thalassiosira eccentrica	Bacillariophyta	3	3.56E+04	4.26E+07	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	cf. Thalassiosira sp.	Bacillariophyta	365	4.34E+06	2.55E+08	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Thalassiosira sp.	Bacillariophyta	10	1.19E+05	1.65E+08	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Thalassiosira visurgis	Bacillariophyta	9	1.07E+05	5.04E+07	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	cf. Zygnema sp.	Chlorophyta	43	5.11E+05	3.99E+09	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Ochromonas sp.	Chrysophyta	9	1.07E+05	9.07E+06	High sediment; many broken diatoms.
STN9PPC	5/25/2013	10:28	15	Chroomonas sp.	Cryptophyta	1	1.19E+04	1.16E+07	High sediment; many broken diatoms.
				TOTAL		459	5.45E+06	1.47E+10	
STN9PPB	5/25/2013	10:28	10	Cyclotella sp.	Bacillariophyta	4	7.13E+04	3.44E+08	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Cyclotella cf. striata	Bacillariophyta	2	3.56E+04	7.41E+07	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Entomoneis sp.	Bacillariophyta	4	7.13E+04	6.59E+08	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Eunotia sp.	Bacillariophyta	1	1.78E+04	6.44E+07	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Luticola goeppertiana	Bacillariophyta	1	1.78E+04	8.82E+06	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Nitzschia granulata	Bacillariophyta	3	5.35E+04	1.85E+07	High sediment; many broken diatoms.

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STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN9PPB	5/25/2013	10:28	10	Nitzschia lanceola	Bacillariophyta	1	1.78E+04	8.02E+06	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Nitzschia sp.	Bacillariophyta	2	3.56E+04	2.11E+07	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Odontella mobiliensis	Bacillariophyta	4	7.13E+04	4.06E+09	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Odontella aurita	Bacillariophyta	7	1.25E+05	4.90E+08	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Odontella sinensis	Bacillariophyta	4	7.13E+04	6.73E+09	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Opephora pacifica	Bacillariophyta	2	3.56E+04	2.18E+06	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Pleurosigma salinarum	Bacillariophyta	1	1.78E+04	5.45E+07	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Pseudostaurosira brevistriata	Bacillariophyta	9	1.60E+05	2.65E+07	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Schuettia annulata	Bacillariophyta	2	3.56E+04	1.30E+09	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Thalassiosira eccentrica	Bacillariophyta	10	1.78E+05	3.03E+08	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	cf. Thalassiosira sp.	Bacillariophyta	332	5.92E+06	5.02E+08	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	cf. Zygnema sp.	Chlorophyta	8	1.43E+05	1.42E+09	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Ceratium furca	Pyrrophyta	2	3.56E+04	3.62E+08	High sediment; many broken diatoms.
STN9PPB	5/25/2013	10:28	10	Gymnodinium sp.	Pyrrophyta	1	1.78E+04	1.29E+08	High sediment; many broken diatoms.
				TOTAL		400	7.13E+06	1.66E+10	
STN14PPA	5/22/2013	15:05	20	Azpeitia apiculata	Bacillariophyta	4	2.67E+04	4.09E+08	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	cf. Chaetoceros sp.	Bacillariophyta	8	5.35E+04	1.08E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Chaetoceros sp.	Bacillariophyta	1	6.68E+03	7.56E+05	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Coscinodiscus radiatus	Bacillariophyta	2	1.34E+04	2.73E+09	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Cyclotella cf. caspia	Bacillariophyta	9	6.02E+04	4.57E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Cyclotella stylorum	Bacillariophyta	1	6.68E+03	1.08E+08	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	cf. Delphineis surirella	Bacillariophyta	1	6.68E+03	4.33E+06	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	cf. Hemidiscus cuneiformis	Bacillariophyta	6	4.01E+04	1.10E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Odontella aurita	Bacillariophyta	2	1.34E+04	5.29E+06	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Rhaphoneis nitida	Bacillariophyta	6	4.01E+04	1.02E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Thalassionema pseudonitzschioides	Bacillariophyta	8	5.35E+04	8.66E+06	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	cf. Thalassionema sp.	Bacillariophyta	15	1.00E+05	2.29E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Thalassiosira eccentrica	Bacillariophyta	9	6.02E+04	2.05E+08	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	cf. Thalassiosira sp.	Bacillariophyta	221	1.48E+06	8.70E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Thalassiosira visurgis	Bacillariophyta	14	9.36E+04	6.23E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Ochromonas sp.	Chrysophyta	76	5.08E+05	1.49E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	Chroomonas sp.	Cryptophyta	25	1.67E+05	1.42E+07	High sediment; many broken diatoms.
STN14PPA	5/22/2013	15:05	20	cf. Gymnodinium sp.	Pyrrophyta	2	1.34E+04	1.40E+07	High sediment; many broken diatoms.
				TOTAL		410	2.74E+06	3.76E+09	
STN12PPC	5/20/2013	10:55	10	Amphora sp.	Bacillariophyta	4	2.85E+04	4.02E+07	
STN12PPC	5/20/2013	10:55	10	Bacillaria paxillifer	Bacillariophyta	27	1.93E+05	2.74E+08	
STN12PPC	5/20/2013	10:55	10	Cyclotella sp.	Bacillariophyta	3	2.14E+04	1.70E+07	
STN12PPC	5/20/2013	10:55	10	Ditylum sp.	Bacillariophyta	4	2.85E+04	5.12E+09	
STN12PPC	5/20/2013	10:55	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	46	3.28E+05	4.25E+07	
STN12PPC	5/20/2013	10:55	10	Nitzschia punctata	Bacillariophyta	2	1.43E+04	3.25E+06	
STN12PPC	5/20/2013	10:55	10	Pseudo-nitzschia sp.	Bacillariophyta	12	8.56E+04	4.88E+07	
STN12PPC	5/20/2013	10:55	10	Thalassiosira eccentrica	Bacillariophyta	6	4.28E+04	1.82E+09	
STN12PPC	5/20/2013	10:55	10	cf. Thalassiosira sp.	Bacillariophyta	239	1.70E+06	4.28E+07	
STN12PPC	5/20/2013	10:55	10	Thalassiosira visurgis	Bacillariophyta	64	4.56E+05	3.63E+08	
STN12PPC	5/20/2013	10:55	10	Ochromonas sp.	Chrysophyta	21	1.50E+05	1.27E+07	

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STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
				TOTAL		428	3.05E+06	7.78E+09	
STN13PPC	5/22/2013	10:55	15	Actinocyclus cf. divisus	Bacillariophyta	4	2.85E+04	8.26E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Actinoptychus senarius	Bacillariophyta	1	7.13E+03	1.30E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	cf. Cerataulina sp.	Bacillariophyta	4	2.85E+04	7.11E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Chaetoceros cf. peruvianus	Bacillariophyta	2	1.43E+04	2.44E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Chaetoceros spp.	Bacillariophyta	69	4.92E+05	1.95E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Cocconeis sp.	Bacillariophyta	10	7.13E+04	4.15E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Cyclotella ocellata	Bacillariophyta	3	2.14E+04	1.02E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Cyclotella sp.	Bacillariophyta	19	1.35E+05	1.63E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Delphineis sp.	Bacillariophyta	7	4.99E+04	1.65E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Ditylum sp.	Bacillariophyta	4	2.85E+04	2.29E+10	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Entomoneis sp.	Bacillariophyta	6	4.28E+04	1.02E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Fragilariopsis sp.	Bacillariophyta	9	6.42E+04	8.32E+06	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Guinardia sp.	Bacillariophyta	12	8.56E+04	9.29E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	cf. Gyrosigma sp.	Bacillariophyta	3	2.14E+04	3.47E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Melosira sp.	Bacillariophyta	4	2.85E+04	1.70E+09	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Pseudo-nitzschia sp.	Bacillariophyta	13	9.27E+04	3.06E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Rhizosolenia spp.	Bacillariophyta	23	1.64E+05	8.48E+08	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Thalassionema pseudonitzschioides	Bacillariophyta	1	7.13E+03	2.35E+06	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Thalassiosira eccentrica	Bacillariophyta	1	7.13E+03	6.59E+06	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	cf. Thalassiosira sp.	Bacillariophyta	183	1.30E+06	7.69E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Thalassiosira visurgis	Bacillariophyta	16	1.14E+05	7.57E+07	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Ochromonas sp.	Chrysophyta	2	1.43E+04	1.48E+06	High detritus and sediment.
STN13PPC	5/22/2013	10:55	15	Chroomonas sp.	Cryptophyta	18	1.28E+05	4.37E+07	High detritus and sediment.
				TOTAL		414	2.95E+06	2.82E+10	
STN14PPB	5/22/2013	15:05	15	Campyloneis cf. grevillei	Bacillariophyta	2	1.19E+04	5.20E+07	
STN14PPB	5/22/2013	15:05	15	Cocconeis sp.	Bacillariophyta	2	1.19E+04	6.92E+06	
STN14PPB	5/22/2013	15:05	15	Cyclotella cf. striata	Bacillariophyta	10	5.94E+04	2.69E+08	
STN14PPB	5/22/2013	15:05	15	Diploneis sp.	Bacillariophyta	1	5.94E+03	1.13E+07	
STN14PPB	5/22/2013	15:05	15	Fragilariopsis cf. kerguelensis	Bacillariophyta	48	2.85E+05	9.41E+07	
STN14PPB	5/22/2013	15:05	15	cf. Frustulia sp.	Bacillariophyta	1	5.94E+03	1.87E+08	
STN14PPB	5/22/2013	15:05	15	Nitzschia sp.	Bacillariophyta	1	5.94E+03	4.49E+06	
STN14PPB	5/22/2013	15:05	15	Odontella mobiliensis	Bacillariophyta	6	3.56E+04	1.23E+08	
STN14PPB	5/22/2013	15:05	15	Paralia cf. sulcata	Bacillariophyta	32	1.90E+05	9.03E+07	
STN14PPB	5/22/2013	15:05	15	Pleurosigma sp.	Bacillariophyta	1	5.94E+03	6.18E+06	
STN14PPB	5/22/2013	15:05	15	Rhaphoneis sp.	Bacillariophyta	2	1.19E+04	6.49E+06	
STN14PPB	5/22/2013	15:05	15	Rhizosolenia sp.	Bacillariophyta	6	3.56E+04	4.30E+08	
STN14PPB	5/22/2013	15:05	15	Thalassionema sp.	Bacillariophyta	30	1.78E+05	3.53E+07	
STN14PPB	5/22/2013	15:05	15	Thalassiosira eccentrica	Bacillariophyta	7	4.16E+04	1.15E+08	
STN14PPB	5/22/2013	15:05	15	cf. Thalassiosira sp.	Bacillariophyta	207	1.23E+06	4.83E+07	
STN14PPB	5/22/2013	15:05	15	Thalassiosira visurgis	Bacillariophyta	27	1.60E+05	8.52E+07	
STN14PPB	5/22/2013	15:05	15	cf. Thalassiothrix sp.	Bacillariophyta	1	5.94E+03	8.56E+07	
STN14PPB	5/22/2013	15:05	15	cf. Spirogyra sp.	Chlorophyta	6	3.56E+04	4.58E+09	
STN14PPB	5/22/2013	15:05	15	cf. Ulothrix sp.	Chlorophyta	9	5.35E+04	1.11E+07	
STN14PPB	5/22/2013	15:05	15	Ochromonas sp.	Chrysophyta	19	1.13E+05	9.58E+06	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN14PPB	5/22/2013	15:05	15	Chroomonas sp.	Cryptophyta	10	5.94E+04	3.11E+06	
				TOTAL		428	2.54E+06	6.25E+09	
STN13PPB	5/22/2013	10:55	15	Chaetoceros spp.	Bacillariophyta	74	3.30E+05	3.06E+08	
STN13PPB	5/22/2013	10:55	15	Cocconeis sp.	Bacillariophyta	1	4.46E+03	4.03E+06	
STN13PPB	5/22/2013	10:55	15	Cyclotella cf. striata	Bacillariophyta	4	1.78E+04	6.06E+07	
STN13PPB	5/22/2013	10:55	15	Fragilariopsis cf. kerguelensis	Bacillariophyta	18	8.02E+04	8.57E+06	
STN13PPB	5/22/2013	10:55	15	Odontella mobiliensis	Bacillariophyta	1	4.46E+03	5.73E+07	
STN13PPB	5/22/2013	10:55	15	Pseudo-nitzschia sp.	Bacillariophyta	16	7.13E+04	4.04E+07	
STN13PPB	5/22/2013	10:55	15	Rhizosolenia sp.	Bacillariophyta	12	5.35E+04	6.01E+08	
STN13PPB	5/22/2013	10:55	15	Thalassionema pseudonitzschioides	Bacillariophyta	10	4.46E+04	2.67E+06	
STN13PPB	5/22/2013	10:55	15	cf. Thalassiosira sp.	Bacillariophyta	221	9.85E+05	2.48E+07	
STN13PPB	5/22/2013	10:55	15	Thalassiosira visurgis	Bacillariophyta	11	4.90E+04	8.30E+07	
STN13PPB	5/22/2013	10:55	15	cf. Cosmarium sp.	Chlorophyta	1	4.46E+03	2.26E+06	
STN13PPB	5/22/2013	10:55	15	Ochromonas sp.	Chrysophyta	29	1.29E+05	3.79E+06	
STN13PPB	5/22/2013	10:55	15	Chroomonas sp.	Cryptophyta	4	1.78E+04	1.51E+06	
				TOTAL		402	1.79E+06	1.20E+09	
STN8PPA	5/18/2013	12:20	10	Actinocyclus cf. divisus	Bacillariophyta	31	8.72E+04	8.38E+09	
STN8PPA	5/18/2013	12:20	10	Aulacoseira sp.	Bacillariophyta	1	2.81E+03	6.37E+05	
STN8PPA	5/18/2013	12:20	10	Cyclotella cf. striata	Bacillariophyta	31	8.72E+04	1.58E+08	
STN8PPA	5/18/2013	12:20	10	Eunotia sp.	Bacillariophyta	2	5.63E+03	3.65E+06	
STN8PPA	5/18/2013	12:20	10	Navicula spp.	Bacillariophyta	6	1.69E+04	6.35E+06	
STN8PPA	5/18/2013	12:20	10	Nitzschia compressa	Bacillariophyta	1	2.81E+03	9.02E+05	
STN8PPA	5/18/2013	12:20	10	cf. Nitzschia lanceola	Bacillariophyta	2	5.63E+03	1.14E+06	
STN8PPA	5/18/2013	12:20	10	Nitzschia paleacea	Bacillariophyta	1	2.81E+03	3.72E+05	
STN8PPA	5/18/2013	12:20	10	Rhizosolenia sp.	Bacillariophyta	4	1.13E+04	4.20E+07	
STN8PPA	5/18/2013	12:20	10	Thalassiosira eccentrica	Bacillariophyta	13	3.66E+04	5.17E+08	
STN8PPA	5/18/2013	12:20	10	cf. Thalassiosira sp.	Bacillariophyta	125	3.52E+05	2.07E+07	
STN8PPA	5/18/2013	12:20	10	Thalassiosira visurgis	Bacillariophyta	132	3.72E+05	4.58E+08	
STN8PPA	5/18/2013	12:20	10	Tryblionella debilis	Bacillariophyta	12	3.38E+04	7.52E+06	
STN8PPA	5/18/2013	12:20	10	Chlamydomonas globosa	Chlorophyta	13	3.66E+04	3.45E+06	
STN8PPA	5/18/2013	12:20	10	cf. Monoraphidium nanum	Chlorophyta	11	3.10E+04	3.97E+06	
STN8PPA	5/18/2013	12:20	10	Ochromonas sp.	Chrysophyta	28	7.88E+04	6.68E+06	
STN8PPA	5/18/2013	12:20	10	Rhodomonas sp.	Cryptophyta	2	5.63E+03	1.23E+06	
				TOTAL		415	1.17E+06	9.61E+09	
STN15PPA	5/23/2013	12:05	10	Bacillaria paxillifer	Bacillariophyta	23	1.54E+05	2.38E+08	
STN15PPA	5/23/2013	12:05	10	Chaetoceros sp.	Bacillariophyta	4	2.67E+04	7.06E+07	
STN15PPA	5/23/2013	12:05	10	Cocconeis sp.	Bacillariophyta	2	1.34E+04	9.58E+06	
STN15PPA	5/23/2013	12:05	10	Cyclotella cf. striata	Bacillariophyta	6	4.01E+04	2.83E+08	
STN15PPA	5/23/2013	12:05	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	27	1.80E+05	1.66E+07	
STN15PPA	5/23/2013	12:05	10	Odontella aurita	Bacillariophyta	2	1.34E+04	2.79E+07	
STN15PPA	5/23/2013	12:05	10	Pleurosigma cf. salinarum	Bacillariophyta	4	2.67E+04	4.13E+07	
STN15PPA	5/23/2013	12:05	10	Rhizosolenia sp.	Bacillariophyta	4	2.67E+04	8.51E+09	
STN15PPA	5/23/2013	12:05	10	Thalassionema sp.	Bacillariophyta	2	1.34E+04	2.65E+06	
STN15PPA	5/23/2013	12:05	10	cf. Thalassiosira sp.	Bacillariophyta	358	2.39E+06	3.04E+08	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN15PPA	5/23/2013	12:05	10	Thalassiosira visurgis	Bacillariophyta	11	7.35E+04	5.86E+07	
STN15PPA	5/23/2013	12:05	10	Ochromonas sp.	Chrysophyta	15	1.00E+05	8.50E+06	
STN15PPA	5/23/2013	12:05	10	Chroomonas sp.	Cryptophyta	2	1.34E+04	7.00E+05	
				TOTAL		460	3.07E+06	9.57E+09	
STN10PPC	5/25/2013	14:40	5	Bacillaria paxillifer	Bacillariophyta	2	1.65E+04	2.34E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Biddulphia cf. reticulata	Bacillariophyta	2	1.65E+04	1.81E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	cf. Cerataulina sp.	Bacillariophyta	1	8.23E+03	2.77E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Cocconeis sp.	Bacillariophyta	2	1.65E+04	8.57E+06	High sediment.
STN10PPC	5/25/2013	14:40	5	Cyclotella cf. striata	Bacillariophyta	17	1.40E+05	8.24E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Cylindrotheca sp.	Bacillariophyta	2	1.65E+04	1.06E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	cf. Diploneis sp.	Bacillariophyta	4	3.29E+04	1.88E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Diploneis sp.	Bacillariophyta	1	8.23E+03	4.26E+06	High sediment.
STN10PPC	5/25/2013	14:40	5	Fragilariopsis cf. kerguelensis	Bacillariophyta	56	4.61E+05	1.74E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Fragilariopsis sp.	Bacillariophyta	1	8.23E+03	3.72E+06	High sediment.
STN10PPC	5/25/2013	14:40	5	Guinardia sp.	Bacillariophyta	4	3.29E+04	1.19E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Mastogloia sp.	Bacillariophyta	2	1.65E+04	2.99E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Nitzschia punctata	Bacillariophyta	6	4.94E+04	1.97E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Pleurosigma salinarum	Bacillariophyta	2	1.65E+04	1.41E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Thalassionema sp.	Bacillariophyta	4	3.29E+04	1.38E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Thalassiosira eccentrica	Bacillariophyta	4	3.29E+04	1.79E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	cf. Thalassiosira sp.	Bacillariophyta	250	2.06E+06	5.17E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	Thalassiosira sp.	Bacillariophyta	37	3.04E+05	2.81E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Thalassiosira visurgis	Bacillariophyta	18	1.48E+05	1.18E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Ulothrix sp.	Chlorophyta	26	2.14E+05	3.64E+07	High sediment.
STN10PPC	5/25/2013	14:40	5	cf. Zygnema sp.	Chlorophyta	8	6.58E+04	7.26E+08	High sediment.
STN10PPC	5/25/2013	14:40	5	Ochromonas sp.	Chrysophyta	20	1.65E+05	1.40E+07	High sediment.
				TOTAL		469	3.86E+06	3.00E+09	
STN13PPA	5/22/2013	10:55	20	Actinoptychus sp.	Bacillariophyta	2	1.34E+04	3.87E+08	High detritus.
STN13PPA	5/22/2013	10:55	20	cf. Amphora sp.	Bacillariophyta	3	2.01E+04	2.60E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Cerataulina sp.	Bacillariophyta	13	8.69E+04	1.40E+08	High detritus.
STN13PPA	5/22/2013	10:55	20	Chaetoceros spp.	Bacillariophyta	113	7.55E+05	3.92E+08	High detritus.
STN13PPA	5/22/2013	10:55	20	Cocconeis sp.	Bacillariophyta	6	4.01E+04	2.91E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Cyclotella ocellata	Bacillariophyta	13	8.69E+04	1.31E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Cyclotella sp.	Bacillariophyta	10	6.68E+04	4.44E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Cymatopleura elliptica	Bacillariophyta	1	6.68E+03	7.76E+06	High detritus.
STN13PPA	5/22/2013	10:55	20	Fragilariopsis sp.	Bacillariophyta	31	2.07E+05	5.86E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Navicula sp.	Bacillariophyta	2	1.34E+04	4.57E+06	High detritus.
STN13PPA	5/22/2013	10:55	20	Odontella aurita	Bacillariophyta	9	6.02E+04	1.03E+08	High detritus.
STN13PPA	5/22/2013	10:55	20	Planothidium sp.	Bacillariophyta	2	1.34E+04	1.73E+06	High detritus.
STN13PPA	5/22/2013	10:55	20	Pseudo-nitzschia sp.	Bacillariophyta	21	1.40E+05	2.82E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Rhizosolenia spp.	Bacillariophyta	11	7.35E+04	6.56E+09	High detritus.
STN13PPA	5/22/2013	10:55	20	Surirella sp.	Bacillariophyta	3	2.01E+04	2.27E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Synedra sp.	Bacillariophyta	5	3.34E+04	4.37E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Thalassionema sp.	Bacillariophyta	18	1.20E+05	5.78E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Thalassiosira eccentrica	Bacillariophyta	2	1.34E+04	6.05E+07	High detritus.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN13PPA	5/22/2013	10:55	20	cf. Thalassiosira sp.	Bacillariophyta	163	1.09E+06	9.24E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Thalassiosira visurgis	Bacillariophyta	1	6.68E+03	3.18E+06	High detritus.
STN13PPA	5/22/2013	10:55	20	Staurodesmus sp.	Chlorophyta	1	6.68E+03	1.50E+06	High detritus.
STN13PPA	5/22/2013	10:55	20	Ochromonas sp.	Chrysophyta	2	1.34E+04	1.65E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Chroomonas sp.	Cryptophyta	9	6.02E+04	3.15E+06	High detritus.
STN13PPA	5/22/2013	10:55	20	Synechococcus sp.	Cyanobacteria	155	1.04E+06	1.46E+07	High detritus.
STN13PPA	5/22/2013	10:55	20	Gymnodinium sp.	Pyrrophyta	1	6.68E+03	1.24E+08	High detritus.
				TOTAL		597	3.99E+06	8.24E+09	
STN16PPB	5/23/2013	14:40	15	Amphora spp.	Bacillariophyta	4	2.38E+04	1.48E+07	
STN16PPB	5/23/2013	14:40	15	Bacillaria paxillifer	Bacillariophyta	13	7.72E+04	1.39E+08	
STN16PPB	5/23/2013	14:40	15	Biddulphia sp.	Bacillariophyta	6	3.56E+04	2.16E+07	
STN16PPB	5/23/2013	14:40	15	Chaetoceros debilis	Bacillariophyta	96	5.70E+05	6.45E+07	
STN16PPB	5/23/2013	14:40	15	Chaetoceros cf. peruvianus	Bacillariophyta	1	5.94E+03	9.56E+06	
STN16PPB	5/23/2013	14:40	15	Chaetoceros spp.	Bacillariophyta	32	1.90E+05	5.97E+07	
STN16PPB	5/23/2013	14:40	15	Cocconeis sp.	Bacillariophyta	2	1.19E+04	9.22E+06	
STN16PPB	5/23/2013	14:40	15	Cyclotella sp.	Bacillariophyta	1	5.94E+03	5.65E+06	
STN16PPB	5/23/2013	14:40	15	Cyclotella cf. striata	Bacillariophyta	3	1.78E+04	2.43E+07	
STN16PPB	5/23/2013	14:40	15	Dactyliosolen blavyanus	Bacillariophyta	4	2.38E+04	3.64E+08	
STN16PPB	5/23/2013	14:40	15	Fragilariopsis cf. kerguelensis	Bacillariophyta	20	1.19E+05	7.84E+06	
STN16PPB	5/23/2013	14:40	15	Guinardia sp.	Bacillariophyta	8	4.75E+04	4.59E+08	
STN16PPB	5/23/2013	14:40	15	Melosira sp.	Bacillariophyta	1	5.94E+03	6.45E+07	
STN16PPB	5/23/2013	14:40	15	Navicula sp.	Bacillariophyta	5	2.97E+04	2.59E+07	
STN16PPB	5/23/2013	14:40	15	Paralia cf. sulcata	Bacillariophyta	10	5.94E+04	2.18E+07	
STN16PPB	5/23/2013	14:40	15	Pleurosigma sp.	Bacillariophyta	1	5.94E+03	2.02E+07	
STN16PPB	5/23/2013	14:40	15	Pseudo-nitzschia sp.	Bacillariophyta	4	2.38E+04	4.16E+06	
STN16PPB	5/23/2013	14:40	15	Rhaphoneis sp.	Bacillariophyta	3	1.78E+04	5.46E+06	
STN16PPB	5/23/2013	14:40	15	Rhizosolenia cf. shrubsolei	Bacillariophyta	4	2.38E+04	9.44E+07	
STN16PPB	5/23/2013	14:40	15	Rhizosolenia sp.	Bacillariophyta	3	1.78E+04	6.01E+08	
STN16PPB	5/23/2013	14:40	15	Rhizosolenia cf. styliformis	Bacillariophyta	4	2.38E+04	6.47E+09	
STN16PPB	5/23/2013	14:40	15	Thalassionema sp.	Bacillariophyta	13	7.72E+04	1.67E+07	
STN16PPB	5/23/2013	14:40	15	Thalassiosira eccentrica	Bacillariophyta	2	1.19E+04	4.12E+07	
STN16PPB	5/23/2013	14:40	15	cf. Thalassiosira sp.	Bacillariophyta	113	6.71E+05	1.69E+07	
STN16PPB	5/23/2013	14:40	15	Thalassiosira sp.	Bacillariophyta	19	1.13E+05	1.92E+07	
STN16PPB	5/23/2013	14:40	15	Thalassiosira visurgis	Bacillariophyta	15	8.91E+04	1.79E+08	
STN16PPB	5/23/2013	14:40	15	Thalassiothrix sp.	Bacillariophyta	1	5.94E+03	5.88E+07	
STN16PPB	5/23/2013	14:40	15	Ochromonas sp.	Chrysophyta	12	7.13E+04	6.05E+06	
				TOTAL		400	2.38E+06	8.82E+09	
STN17PPB	5/24/2013	13:40	10	Chaetoceros debilis	Bacillariophyta	224	2.99E+06	3.39E+08	
STN17PPB	5/24/2013	13:40	10	Chaetoceros spp.	Bacillariophyta	48	6.42E+05	3.93E+08	
STN17PPB	5/24/2013	13:40	10	Cocconeis placentula	Bacillariophyta	2	2.67E+04	1.92E+07	
STN17PPB	5/24/2013	13:40	10	Cyclotella cf. striata	Bacillariophyta	2	2.67E+04	6.07E+07	
STN17PPB	5/24/2013	13:40	10	cf. Eucampia sp.	Bacillariophyta	2	2.67E+04	2.42E+08	
STN17PPB	5/24/2013	13:40	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	32	4.28E+05	3.93E+07	
STN17PPB	5/24/2013	13:40	10	Melosira sp.	Bacillariophyta	5	6.68E+04	1.99E+09	
STN17PPB	5/24/2013	13:40	10	Nitzschia sp.	Bacillariophyta	1	1.34E+04	2.81E+06	

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN17PPB	5/24/2013	13:40	10	Odontella cf. aurita	Bacillariophyta	2	2.67E+04	2.62E+07	
STN17PPB	5/24/2013	13:40	10	Pleurosigma cf. salinarum	Bacillariophyta	1	1.34E+04	6.05E+07	
STN17PPB	5/24/2013	13:40	10	Thalassionema sp.	Bacillariophyta	3	4.01E+04	1.19E+07	
STN17PPB	5/24/2013	13:40	10	cf. Thalassiosira sp.	Bacillariophyta	91	1.22E+06	3.06E+07	
STN17PPB	5/24/2013	13:40	10	cf. Zygnema sp.	Chlorophyta	8	1.07E+05	1.40E+09	
STN17PPB	5/24/2013	13:40	10	Ochromonas sp.	Chrysophyta	6	8.02E+04	6.80E+06	
STN17PPB	5/24/2013	13:40	10	Chroomonas sp.	Cryptophyta	2	2.67E+04	1.40E+06	
				TOTAL		429	5.74E+06	4.63E+09	
STN12PPA	5/20/2013	10:55	15	Cocconeis sp.	Bacillariophyta	4	1.24E+04	7.22E+06	
STN12PPA	5/20/2013	10:55	15	Cyclotella cf. striata	Bacillariophyta	10	3.10E+04	4.29E+07	
STN12PPA	5/20/2013	10:55	15	Fragilariopsis cf. kerguelensis	Bacillariophyta	26	8.06E+04	1.94E+07	
STN12PPA	5/20/2013	10:55	15	Gyrosigma sp.	Bacillariophyta	1	3.10E+03	4.65E+06	
STN12PPA	5/20/2013	10:55	15	Nitzschia lanceola	Bacillariophyta	1	3.10E+03	2.73E+06	
STN12PPA	5/20/2013	10:55	15	Nitzschia sp.	Bacillariophyta	1	3.10E+03	1.49E+05	
STN12PPA	5/20/2013	10:55	15	Odontella aurita	Bacillariophyta	1	3.10E+03	4.53E+06	
STN12PPA	5/20/2013	10:55	15	Pseudo-nitzschia sp.	Bacillariophyta	34	1.05E+05	3.79E+06	
STN12PPA	5/20/2013	10:55	15	Thalassionema pseudonitzschioides	Bacillariophyta	8	2.48E+04	1.79E+06	
STN12PPA	5/20/2013	10:55	15	Thalassiosira eccentrica	Bacillariophyta	7	2.17E+04	5.42E+07	
STN12PPA	5/20/2013	10:55	15	cf. Thalassiosira sp.	Bacillariophyta	254	7.87E+05	1.98E+07	
STN12PPA	5/20/2013	10:55	15	Thalassiosira sp.	Bacillariophyta	41	1.27E+05	3.19E+07	
STN12PPA	5/20/2013	10:55	15	Thalassiosira visurgis	Bacillariophyta	11	3.41E+04	8.51E+07	
STN12PPA	5/20/2013	10:55	15	Monoraphidium arcuatum	Chlorophyta	1	3.10E+03	1.10E+05	
STN12PPA	5/20/2013	10:55	15	Ochromonas sp.	Chrysophyta	18	5.58E+04	1.64E+06	
STN12PPA	5/20/2013	10:55	15	Chroomonas sp.	Cryptophyta	4	1.24E+04	1.05E+06	
				TOTAL		422	1.31E+06	2.81E+08	
STN15PPB	5/23/2013	12:05	15	Campyloneis sp.	Bacillariophyta	4	1.78E+04	2.22E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Chaetoceros sp.	Bacillariophyta	45	2.01E+05	4.72E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Chaetoceros cf. peruvianus	Bacillariophyta	3	1.34E+04	2.43E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Cocconeis sp.	Bacillariophyta	8	3.56E+04	2.47E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Cyclotella spp.	Bacillariophyta	12	5.35E+04	1.26E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Grammatophora cf. oceanica	Bacillariophyta	2	8.91E+03	2.31E+06	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Nitzschia granulata	Bacillariophyta	4	1.78E+04	4.06E+06	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Nitzschia sp.	Bacillariophyta	2	8.91E+03	3.48E+05	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Odontella aurita	Bacillariophyta	6	2.67E+04	9.64E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Planothidium sp.	Bacillariophyta	4	1.78E+04	8.78E+06	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Pseudostaurosira brevistriata	Bacillariophyta	29	1.29E+05	2.89E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Rhaphoneis sp.	Bacillariophyta	1	4.46E+03	1.25E+06	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Rhizosolenia cf. shrubsolei	Bacillariophyta	21	9.36E+04	2.54E+08	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Rhizosolenia sp.	Bacillariophyta	2	8.91E+03	2.27E+09	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Thalassionema sp.	Bacillariophyta	10	4.46E+04	1.60E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Thalassiosira eccentrica	Bacillariophyta	3	1.34E+04	2.27E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	cf. Thalassiosira sp.	Bacillariophyta	257	1.15E+06	6.75E+07	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	Thalassiosira visurgis	Bacillariophyta	6	2.67E+04	6.30E+06	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	cf. Thalassiothrix sp.	Bacillariophyta	2	8.91E+03	1.23E+08	High sediment; many broken diatoms.
STN15PPB	5/23/2013	12:05	15	cf. Tropidoneis sp.	Bacillariophyta	2	8.91E+03	2.26E+08	High sediment; many broken diatoms.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN15PPB	5/23/2013	12:05	15	Chroomonas sp.	Cryptophyta	6	2.67E+04	1.40E+06	High sediment; many broken diatoms.
				TOTAL		429	1.91E+06	3.26E+09	
STN14PPC	5/22/2013	15:05	10	Azpeitia apiculata	Bacillariophyta	4	4.28E+04	2.11E+08	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Campyloneis cf. grevillei	Bacillariophyta	4	4.28E+04	1.61E+08	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Cyclotella caspia	Bacillariophyta	7	7.49E+04	4.98E+07	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	62	6.63E+05	7.81E+07	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	cf. Hemidiscus cuneiformis	Bacillariophyta	1	1.07E+04	2.59E+06	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	cf. Nitzschia supralitorea	Bacillariophyta	1	1.07E+04	2.98E+06	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Odontella aurita	Bacillariophyta	2	2.14E+04	1.77E+07	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Paralia cf. costatum	Bacillariophyta	17	1.82E+05	8.57E+07	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Thalassionema pseudonitzschioides	Bacillariophyta	12	1.28E+05	2.07E+07	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	cf. Thalassiosira sp.	Bacillariophyta	205	2.19E+06	1.29E+08	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Thalassiosira sp.	Bacillariophyta	50	5.35E+05	3.81E+07	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Thalassiosira visurgis	Bacillariophyta	16	1.71E+05	2.11E+08	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Ochromonas sp.	Chrysophyta	19	2.03E+05	5.96E+06	High sediment; many broken diatoms.
STN14PPC	5/22/2013	15:05	10	Chroomonas sp.	Cryptophyta	12	1.28E+05	1.09E+07	High sediment; many broken diatoms.
				TOTAL		412	4.41E+06	1.02E+09	
STN15PPC	5/23/2013	12:05	15	cf. Achnanthes ventralis	Bacillariophyta	1	7.13E+03	1.18E+06	
STN15PPC	5/23/2013	12:05	15	Chaetoceros sp.	Bacillariophyta	47	3.35E+05	1.05E+08	
STN15PPC	5/23/2013	12:05	15	Chaetoceros cf. peruvianus	Bacillariophyta	4	2.85E+04	8.74E+06	
STN15PPC	5/23/2013	12:05	15	Cocconeis sp.	Bacillariophyta	4	2.85E+04	1.98E+07	
STN15PPC	5/23/2013	12:05	15	Cymbella sp.	Bacillariophyta	2	1.43E+04	1.57E+06	
STN15PPC	5/23/2013	12:05	15	Fragilariopsis cf. kerguelensis	Bacillariophyta	44	3.14E+05	7.02E+07	
STN15PPC	5/23/2013	12:05	15	cf. Navicula lepta	Bacillariophyta	1	7.13E+03	1.04E+07	
STN15PPC	5/23/2013	12:05	15	Nitzschia sp.	Bacillariophyta	3	2.14E+04	1.54E+06	
STN15PPC	5/23/2013	12:05	15	Pseudostaurosira brevistriata	Bacillariophyta	4	2.85E+04	4.37E+06	
STN15PPC	5/23/2013	12:05	15	Rhaphoneis sp.	Bacillariophyta	2	1.43E+04	4.49E+06	
STN15PPC	5/23/2013	12:05	15	Rhizosolenia sp.	Bacillariophyta	7	4.99E+04	2.60E+10	
STN15PPC	5/23/2013	12:05	15	Thalassionema sp.	Bacillariophyta	12	8.56E+04	3.85E+07	
STN15PPC	5/23/2013	12:05	15	Thalassiosira sp.	Bacillariophyta	6	4.28E+04	9.70E+07	
STN15PPC	5/23/2013	12:05	15	cf. Thalassiosira sp.	Bacillariophyta	261	1.86E+06	1.10E+08	
STN15PPC	5/23/2013	12:05	15	Chroomonas sp.	Cryptophyta	19	1.35E+05	7.09E+06	
STN15PPC	5/23/2013	12:05	15	Cryptomonas sp.	Cryptophyta	2	1.43E+04	1.42E+07	
				TOTAL		419	2.99E+06	2.65E+10	
STN16PPA	5/23/2013	14:40	10	Chaetoceros cf. peruvianus	Bacillariophyta	2	1.34E+04	1.57E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Chaetoceros sp.	Bacillariophyta	25	1.67E+05	6.14E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Cocconeis sp.	Bacillariophyta	1	6.68E+03	3.29E+06	High detritus.
STN16PPA	5/23/2013	14:40	10	Cyclotella sp.	Bacillariophyta	4	2.67E+04	2.06E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Cymatopleura sp.	Bacillariophyta	2	1.34E+04	4.76E+08	High detritus.
STN16PPA	5/23/2013	14:40	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	22	1.47E+05	6.58E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Fragilariopsis sp.	Bacillariophyta	14	9.36E+04	1.72E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	cf. Guinardia sp.	Bacillariophyta	10	6.68E+04	1.34E+10	High detritus.
STN16PPA	5/23/2013	14:40	10	Hippodonta sp.	Bacillariophyta	4	2.67E+04	2.20E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Navicula sp.	Bacillariophyta	6	4.01E+04	2.65E+07	High detritus.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN16PPA	5/23/2013	14:40	10	Nitzschia sp.	Bacillariophyta	2	1.34E+04	6.42E+05	High detritus.
STN16PPA	5/23/2013	14:40	10	Odontella aurita	Bacillariophyta	2	1.34E+04	2.59E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Pseudo-nitzschia sp.	Bacillariophyta	10	6.68E+04	1.02E+08	High detritus.
STN16PPA	5/23/2013	14:40	10	Rhizosolenia sp.	Bacillariophyta	10	6.68E+04	1.50E+10	High detritus.
STN16PPA	5/23/2013	14:40	10	Rhizosolenia cf. shrubsolei	Bacillariophyta	18	1.20E+05	2.43E+08	High detritus.
STN16PPA	5/23/2013	14:40	10	Thalassionema sp.	Bacillariophyta	10	6.68E+04	8.42E+06	High detritus.
STN16PPA	5/23/2013	14:40	10	cf. Thalassiosira sp.	Bacillariophyta	198	1.32E+06	1.12E+08	High detritus.
STN16PPA	5/23/2013	14:40	10	Thalassiosira sp.	Bacillariophyta	58	3.88E+05	5.85E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Thalassiosira visurgis	Bacillariophyta	18	1.20E+05	6.86E+07	High detritus.
STN16PPA	5/23/2013	14:40	10	Chroomonas sp.	Cryptophyta	12	8.02E+04	4.20E+06	High detritus.
STN16PPA	5/23/2013	14:40	10	Cryptomonas ovata	Cryptophyta	2	1.34E+04	2.60E+07	High detritus.
				TOTAL		430	2.87E+06	2.97E+10	
STN16PPC	5/23/2013	14:40	10	Chaetoceros spp.	Bacillariophyta	109	1.30E+06	6.10E+08	
STN16PPC	5/23/2013	14:40	10	Fragilariopsis sp.	Bacillariophyta	6	7.13E+04	6.55E+06	
STN16PPC	5/23/2013	14:40	10	Gomphonema sp.	Bacillariophyta	2	2.38E+04	2.40E+06	
STN16PPC	5/23/2013	14:40	10	Melosira sp.	Bacillariophyta	2	2.38E+04	1.34E+08	
STN16PPC	5/23/2013	14:40	10	Navicula sp.	Bacillariophyta	4	4.75E+04	1.31E+08	
STN16PPC	5/23/2013	14:40	10	Nitzschia spp.	Bacillariophyta	25	2.97E+05	8.91E+06	
STN16PPC	5/23/2013	14:40	10	Pleurosigma sp.	Bacillariophyta	1	1.19E+04	2.97E+07	
STN16PPC	5/23/2013	14:40	10	Pseudostaurosira brevistriata	Bacillariophyta	2	2.38E+04	1.46E+06	
STN16PPC	5/23/2013	14:40	10	Rhaphoneis sp.	Bacillariophyta	1	1.19E+04	4.31E+06	
STN16PPC	5/23/2013	14:40	10	Rhizosolenia sp.	Bacillariophyta	2	2.38E+04	6.38E+07	
STN16PPC	5/23/2013	14:40	10	Thalassionema pseudonitzschioides	Bacillariophyta	4	4.75E+04	4.06E+07	
STN16PPC	5/23/2013	14:40	10	Thalassionema sp.	Bacillariophyta	6	7.13E+04	9.41E+06	
STN16PPC	5/23/2013	14:40	10	Thalassiosira eccentrica	Bacillariophyta	7	8.32E+04	2.86E+09	
STN16PPC	5/23/2013	14:40	10	cf. Thalassiosira sp.	Bacillariophyta	215	2.55E+06	1.50E+08	
STN16PPC	5/23/2013	14:40	10	Thalassiosira sp.	Bacillariophyta	19	2.26E+05	5.32E+07	
STN16PPC	5/23/2013	14:40	10	Thalassiosira visurgis	Bacillariophyta	13	1.54E+05	1.03E+08	
STN16PPC	5/23/2013	14:40	10	cf. Rhodomonas sp.	Cryptophyta	2	2.38E+04	2.02E+06	
				TOTAL		420	4.99E+06	4.21E+09	
STN11PPC	5/19/2013	12:25	25	Actinocyclus cf. divisus	Bacillariophyta	2	9.51E+03	2.63E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Bacillaria paxillifer	Bacillariophyta	12	5.70E+04	9.14E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Campyloneis grevillei	Bacillariophyta	14	6.65E+04	1.55E+08	High sediment.
STN11PPC	5/19/2013	12:25	25	Chaetoceros sp.	Bacillariophyta	6	2.85E+04	4.03E+06	High sediment.
STN11PPC	5/19/2013	12:25	25	Chaetoceros cf. peruvianus	Bacillariophyta	7	3.33E+04	2.34E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Cocconeis sp.	Bacillariophyta	13	6.18E+04	3.60E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Cyclotella sp.	Bacillariophyta	12	5.70E+04	3.58E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Cyclotella cf. striata	Bacillariophyta	6	2.85E+04	3.44E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Guinardia sp.	Bacillariophyta	6	2.85E+04	2.46E+08	High sediment.
STN11PPC	5/19/2013	12:25	25	Nitzschia compressa	Bacillariophyta	2	9.51E+03	8.56E+05	High sediment.
STN11PPC	5/19/2013	12:25	25	Nitzschia granulata	Bacillariophyta	10	4.75E+04	9.13E+06	High sediment.
STN11PPC	5/19/2013	12:25	25	Odontella aurita	Bacillariophyta	2	9.51E+03	1.59E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Opephora pacifica	Bacillariophyta	8	3.80E+04	2.51E+06	High sediment.
STN11PPC	5/19/2013	12:25	25	Pseudo-nitzschia sp.	Bacillariophyta	17	8.08E+04	5.70E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Rhizosolenia sp.	Bacillariophyta	3	1.43E+04	6.73E+07	High sediment.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN11PPC	5/19/2013	12:25	25	Thalassionema sp.	Bacillariophyta	12	5.70E+04	9.24E+06	High sediment.
STN11PPC	5/19/2013	12:25	25	Thalassiosira eccentrica	Bacillariophyta	4	1.90E+04	5.50E+08	High sediment.
STN11PPC	5/19/2013	12:25	25	cf. Thalassiosira sp.	Bacillariophyta	234	1.11E+06	1.28E+08	High sediment.
STN11PPC	5/19/2013	12:25	25	Thalassiosira visurgis	Bacillariophyta	25	1.19E+05	6.78E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	cf. Chlamydomonas grovei	Chlorophyta	1	4.75E+03	3.11E+05	High sediment.
STN11PPC	5/19/2013	12:25	25	Chroomonas sp.	Cryptophyta	28	1.33E+05	1.38E+07	High sediment.
STN11PPC	5/19/2013	12:25	25	Cryptomonas ovata	Cryptophyta	2	9.51E+03	3.76E+06	High sediment.
				TOTAL		426	2.02E+06	1.58E+09	
STN12PPB	5/20/2013	10:55	10	cf. Actinoptychus sp.	Bacillariophyta	1	7.13E+03	3.02E+07	
STN12PPB	5/20/2013	10:55	10	Aulacoseira sp.	Bacillariophyta	2	1.43E+04	1.11E+06	
STN12PPB	5/20/2013	10:55	10	Bacillaria paxillifer	Bacillariophyta	21	1.50E+05	8.09E+07	
STN12PPB	5/20/2013	10:55	10	Cerataulina sp.	Bacillariophyta	4	2.85E+04	6.22E+08	
STN12PPB	5/20/2013	10:55	10	Chaetoceros sp.	Bacillariophyta	1	7.13E+03	1.11E+06	
STN12PPB	5/20/2013	10:55	10	Cocconeis sp.	Bacillariophyta	8	5.70E+04	3.32E+07	
STN12PPB	5/20/2013	10:55	10	Cyclotella stylorum	Bacillariophyta	1	7.13E+03	1.94E+07	
STN12PPB	5/20/2013	10:55	10	Cyclotella sp.	Bacillariophyta	4	2.85E+04	1.89E+07	
STN12PPB	5/20/2013	10:55	10	Cyclotella cf. striata	Bacillariophyta	10	7.13E+04	5.31E+08	
STN12PPB	5/20/2013	10:55	10	Cymbella microcephala	Bacillariophyta	2	1.43E+04	1.50E+06	
STN12PPB	5/20/2013	10:55	10	Fragilariopsis sp.	Bacillariophyta	3	2.14E+04	8.32E+06	
STN12PPB	5/20/2013	10:55	10	Gyrosigma sp.	Bacillariophyta	2	1.43E+04	1.54E+07	
STN12PPB	5/20/2013	10:55	10	Hippodonta sp.	Bacillariophyta	2	1.43E+04	2.86E+06	
STN12PPB	5/20/2013	10:55	10	Mastogloia sp.	Bacillariophyta	3	2.14E+04	1.11E+07	
STN12PPB	5/20/2013	10:55	10	Navicula spp.	Bacillariophyta	10	7.13E+04	3.19E+07	
STN12PPB	5/20/2013	10:55	10	Nitzschia granulata	Bacillariophyta	3	2.14E+04	1.31E+07	
STN12PPB	5/20/2013	10:55	10	Nitzschia spp.	Bacillariophyta	14	9.98E+04	5.69E+06	
STN12PPB	5/20/2013	10:55	10	Odontella aurita	Bacillariophyta	4	2.85E+04	3.15E+07	
STN12PPB	5/20/2013	10:55	10	Opephora sp.	Bacillariophyta	2	1.43E+04	7.39E+05	
STN12PPB	5/20/2013	10:55	10	Pseudo-nitzschia sp.	Bacillariophyta	9	6.42E+04	1.21E+07	
STN12PPB	5/20/2013	10:55	10	Pseudostaurosira brevistriata	Bacillariophyta	10	7.13E+04	1.18E+07	
STN12PPB	5/20/2013	10:55	10	Rhaphoneis amphiceros	Bacillariophyta	1	7.13E+03	4.44E+06	
STN12PPB	5/20/2013	10:55	10	Rhizosolenia sp.	Bacillariophyta	2	1.43E+04	3.83E+07	
STN12PPB	5/20/2013	10:55	10	Thalassionema sp.	Bacillariophyta	18	1.28E+05	3.47E+07	
STN12PPB	5/20/2013	10:55	10	Thalassiosira eccentrica	Bacillariophyta	2	1.43E+04	4.20E+07	
STN12PPB	5/20/2013	10:55	10	cf. Thalassiosira sp.	Bacillariophyta	234	1.67E+06	9.83E+07	
STN12PPB	5/20/2013	10:55	10	Thalassiosira visurgis	Bacillariophyta	17	1.21E+05	5.76E+07	
STN12PPB	5/20/2013	10:55	10	cf. Chlamydomonas sp.	Chlorophyta	8	5.70E+04	6.45E+06	
STN12PPB	5/20/2013	10:55	10	Chroomonas sp.	Cryptophyta	16	1.14E+05	5.97E+06	
STN12PPB	5/20/2013	10:55	10	Cryptomonas sp.	Cryptophyta	2	1.43E+04	4.57E+06	
STN12PPB	5/20/2013	10:55	10	Phacus sp.	Euglenophyta	1	7.13E+03	2.18E+06	
				TOTAL		417	2.97E+06	1.78E+09	
STN17PPA	5/24/2013	13:40	10	Campyloneis sp.	Bacillariophyta	2	2.25E+04	8.06E+06	High detritus.
STN17PPA	5/24/2013	13:40	10	Chaetoceros cf. peruvianus	Bacillariophyta	1	1.13E+04	4.05E+07	High detritus.
STN17PPA	5/24/2013	13:40	10	Chaetoceros spp.	Bacillariophyta	147	1.65E+06	3.90E+08	High detritus.
STN17PPA	5/24/2013	13:40	10	Cocconeis sp.	Bacillariophyta	9	1.01E+05	4.97E+07	High detritus.
STN17PPA	5/24/2013	13:40	10	Cyclotella sp.	Bacillariophyta	3	3.38E+04	1.02E+07	High detritus.

Table B1-18: Farim Project - Dry Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	SAMPLE ALIQUOT (mL)	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN17PPA	5/24/2013	13:40	10	Fragilariopsis cf. kerguelensis	Bacillariophyta	26	2.93E+05	7.47E+07	High detritus.
STN17PPA	5/24/2013	13:40	10	Guinardia sp.	Bacillariophyta	16	1.80E+05	3.75E+09	High detritus.
STN17PPA	5/24/2013	13:40	10	Navicula sp.	Bacillariophyta	6	6.75E+04	7.85E+07	High detritus.
STN17PPA	5/24/2013	13:40	10	Nitzschia sp.	Bacillariophyta	7	7.88E+04	1.00E+07	High detritus.
STN17PPA	5/24/2013	13:40	10	Nitzschia cf. sigma	Bacillariophyta	1	1.13E+04	3.31E+06	High detritus.
STN17PPA	5/24/2013	13:40	10	Rhizosolenia cf. shrubsolei	Bacillariophyta	15	1.69E+05	1.22E+09	High detritus.
STN17PPA	5/24/2013	13:40	10	Thalassionema sp.	Bacillariophyta	21	2.36E+05	1.04E+08	High detritus.
STN17PPA	5/24/2013	13:40	10	Thalassiosira visurgis	Bacillariophyta	12	1.35E+05	1.08E+08	High detritus.
STN17PPA	5/24/2013	13:40	10	Thalassiosira sp.	Bacillariophyta	14	1.58E+05	7.49E+07	High detritus.
STN17PPA	5/24/2013	13:40	10	cf. Thalassiosira sp.	Bacillariophyta	147	1.65E+06	1.40E+08	High detritus.
STN17PPA	5/24/2013	13:40	10	Ochromonas sp.	Chrysophyta	1	1.13E+04	6.06E+06	High detritus.
STN17PPA	5/24/2013	13:40	10	Chroomonas sp.	Cryptophyta	16	1.80E+05	9.43E+06	High detritus.
STN17PPA	5/24/2013	13:40	10	cf. Rhodomonas sp.	Cryptophyta	1	1.13E+04	1.17E+06	High detritus.
				TOTAL		445	5.01E+06	6.08E+09	
STN17PPC	5/24/2013	13:40	10	Amphiprora sp.	Bacillariophyta	4	7.78E+04	1.77E+08	
STN17PPC	5/24/2013	13:40	10	Chaetoceros sp.	Bacillariophyta	103	2.00E+06	6.23E+08	
STN17PPC	5/24/2013	13:40	10	Cocconeis spp.	Bacillariophyta	11	2.14E+05	2.42E+07	
STN17PPC	5/24/2013	13:40	10	Coscinodiscus sp.	Bacillariophyta	3	5.83E+04	5.67E+09	
STN17PPC	5/24/2013	13:40	10	Cyclotella sp.	Bacillariophyta	3	5.83E+04	1.76E+07	
STN17PPC	5/24/2013	13:40	10	Diatoma hiemale	Bacillariophyta	2	3.89E+04	1.61E+07	
STN17PPC	5/24/2013	13:40	10	Guinardia sp.	Bacillariophyta	4	7.78E+04	1.69E+09	
STN17PPC	5/24/2013	13:40	10	Navicula sp.	Bacillariophyta	1	1.94E+04	6.11E+06	
STN17PPC	5/24/2013	13:40	10	Nitzschia spp.	Bacillariophyta	4	7.78E+04	1.11E+07	
STN17PPC	5/24/2013	13:40	10	Paralia sulcata	Bacillariophyta	4	7.78E+04	4.89E+07	
STN17PPC	5/24/2013	13:40	10	Pleurosigma normanii	Bacillariophyta	2	3.89E+04	2.99E+08	
STN17PPC	5/24/2013	13:40	10	Pseudostaurosira brevistriata	Bacillariophyta	6	1.17E+05	3.48E+07	
STN17PPC	5/24/2013	13:40	10	Rhizosolenia sp.	Bacillariophyta	4	7.78E+04	1.91E+08	
STN17PPC	5/24/2013	13:40	10	Skeletonema cf. costatum	Bacillariophyta	2	3.89E+04	4.58E+06	
STN17PPC	5/24/2013	13:40	10	Thalassionema sp.	Bacillariophyta	2	3.89E+04	5.60E+06	
STN17PPC	5/24/2013	13:40	10	cf. Thalassiosira sp.	Bacillariophyta	217	4.22E+06	6.36E+08	
STN17PPC	5/24/2013	13:40	10	Thalassiosira sp.	Bacillariophyta	11	2.14E+05	1.98E+08	
STN17PPC	5/24/2013	13:40	10	Thalassiosira visurgis	Bacillariophyta	3	5.83E+04	1.21E+08	
STN17PPC	5/24/2013	13:40	10	Chroomonas sp.	Cryptophyta	23	4.47E+05	2.34E+07	
				TOTAL		409	7.95E+06	9.79E+09	

Table B2-1: Farim Project - Wet Season STN1 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN1	8/15/2013	*Achnanthidium minutissimum*	Bacillariophyta
		Achnanthidium sp.	Bacillariophyta
		Actinocyclus sp.	Bacillariophyta
		Aphanocapsa sp.	Cyanobacteria
		Aulacoseira sp.	Bacillariophyta
		cf. *Actinocyclus divisus*	Bacillariophyta
		cf. *Chlorella* sp.	Chlorophyta
		cf. *Coenochloris* sp.	Chlorophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlamydomonas globosa	Chlorophyta
		Chlamydomonas grovei	Chlorophyta
		Chlorella sp.	Chlorophyta
		Chroomonas sp.	Cryptophyta
		Cosmarium sp.	Chlorophyta
		Crucigenia quadrata	Chlorophyta
		Crucigenia tetrapedia	Chlorophyta
		Cryptomonas ovata	Cryptophyta
		Cyclotella spp.	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Monoraphidium arcuatum	Chlorophyta
		Monoraphidium cf. *komarkovae*	Chlorophyta
		Nitzschia cf. *inconspicua*	Bacillariophyta
		Nitzschia cf. *microcephala*	Bacillariophyta
		Nitzschia fonticola	Bacillariophyta
		Nitzschia punctata	Bacillariophyta
		Nitzschia supralitorea	Bacillariophyta
		Planctonema lauterbornii	Chlorophyta
		Pseudostaurosira brevistriata	Bacillariophyta
		Rhodomonas cf. *salina*	Cryptophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Scenedesmus communis	Chlorophyta
		Scenedesmus sp.	Chlorophyta
		Scenedesmus spp.	Chlorophyta
		Synedra sp.	Bacillariophyta
		Tetrastrum glabrum	Chlorophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta

Table B2-2: Farim Project - Wet Season STN2 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN2	8/15/2013	*Achnanthes* sp.	Bacillariophyta
		Achnanthidium minutissimum	Bacillariophyta
		Achnanthidium sp.	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Actinocyclus divisus	Bacillariophyta
		Aphanocapsa sp.	Cyanobacteria
		Aulacoseira sp.	Bacillariophyta
		Aulacoseira spp.	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chroomonas sp.	Cryptophyta
		Cosmarium sp.	Chlorophyta
		Crucigenia quadrata	Chlorophyta
		Cryptomonas ovata	Cryptophyta
		Cyclostephanos sp.	Bacillariophyta
		Cyclotella ocellata	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Mallomonas sp.	Chrysophyta
		Monoraphidium arcuatum	Chlorophyta
		Nitzschia cf. *bacillum*	Bacillariophyta
		Nitzschia cf. *microcephala*	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia punctata	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Nitzschia supralitorea	Bacillariophyta
		Oocystis borgei	Chlorophyta
		Planctonema lauterbornii	Chlorophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Scenedesmus communis	Chlorophyta
		Scenedesmus dimorphus	Chlorophyta
		Scenedesmus intermedius var. balatonicus	Chlorophyta
		Scenedesmus sp.	Chlorophyta
		Tetrastrum glabrum	Chlorophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-3: Farim Project - Wet Season STN3 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN3	8/17/2013	*Achnanthes brevipes*	Bacillariophyta
		Achnanthes sp.	Bacillariophyta
		Achnanthidium sp.	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Aphanocapsa sp.	Cyanobacteria
		Aulacoseira sp.	Bacillariophyta
		Aulacoseira spp.	Bacillariophyta
		cf. *Actinocyclus divisus*	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Pannus* sp.	Cyanobacteria
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlamydomonas globosa	Chlorophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Chroococcus dispersus	Cyanobacteria
		Chroomonas sp.	Cryptophyta
		Cosmarium sp.	Chlorophyta
		Crucigenia quadrata	Chlorophyta
		Cyclotella sp.	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Gomphonema eriense var. variabile	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gymnodinium sp.	Pyrrophyta
		Mallomonas sp.	Chrysophyta
		Melosira sp.	Bacillariophyta
		Nitzschia cf. *rosenstockii*	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia inconspicua	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Planctonema lauterbornii	Chlorophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Scenedesmus communis	Chlorophyta
		Scenedesmus sp.	Chlorophyta
		Skeletonema cf. *subsalsum*	Bacillariophyta
		Tetrastrum glabrum	Chlorophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-4: Farim Project - Wet Season STN4 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN4	8/17/2013	*Achnanthidium* sp.	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Amphora sp.	Bacillariophyta
		Aphanocapsa sp.	Cyanobacteria
		Aulacoseira sp.	Bacillariophyta
		cf. *Actinocyclus divisus*	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Oocystis borgei*	Chlorophyta
		cf. *Pseudanabaena* sp.	Cyanobacteria
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlamydomonas globosa	Chlorophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Chroomonas sp.	Cryptophyta
		Cocconeis sp.	Bacillariophyta
		Crucigenia quadrata	Chlorophyta
		Cryptomonas ovata	Cryptophyta
		Cryptomonas sp.	Cryptophyta
		Cyclotella ocellata	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Eunotia sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gymnodinium sp.	Pyrrophyta
		Monoraphidium komarkovae	Chlorophyta
		Nitzschia cf. *microcephala*	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia microcephala	Bacillariophyta
		Nitzschia punctata	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Nitzschia supralitorea	Bacillariophyta
		Opephora sp.	Bacillariophyta
		Planctonema lauterbornii	Chlorophyta
		Pleurosigma sp.	Bacillariophyta
		Pseudostaurosira brevistriata	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Scenedesmus communis	Chlorophyta
		Scenedesmus sp.	Chlorophyta
		Tetrastrum glabrum	Chlorophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta
		Tryblionella littoralis	Bacillariophyta
		Tryblionella sp.	Bacillariophyta
		Westella botryoides	Chlorophyta

Table B2-5: Farim Project - Wet Season STN5 Summary Phytoplankton Data

STATION	SAMPLE DATE	GENUS AND SPECIES	DIVISION
STN5	8/16/2013	*Actinocyclus* cf. *divisus*	Bacillariophyta
		Aulacoseira sp.	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Navicula* sp.	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Oocystis borgei*	Chlorophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlamydomonas grovei	Chlorophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Chroococcus sp.	Cyanobacteria
		Cocconeis placentula	Bacillariophyta
		Craticula submolesta	Bacillariophyta
		Cryptomonas sp.	Cryptophyta
		Cyclotella striata	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Eunotia sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gymnodinium sp.	Pyrrophyta
		Nitzschia cf. *microcephala*	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Planctonema lauterbornii	Chlorophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Skeletonema sp.	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta
		Tryblionella littoralis	Bacillariophyta
		Westella botryoides	Chlorophyta

Table B2-6: Farim Project - Wet Season STN6 Summary Phytoplankton Data

STATION	SAMPLE DATE	GENUS AND SPECIES	DIVISION
STN6	8/16/2013	*Achnanthidium* sp.	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Adlafia minuscula var. muralis	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chaetoceros spp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cocconeis sp.	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Diploneis parma	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gymnodinium sp.	Pyrrophyta
		Navicula cf. *cryptotenella*	Bacillariophyta
		Nitzschia cf. *microcephala*	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia punctata	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Planctonema lauterbornii	Chlorophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta
		Tryblionella littoralis	Bacillariophyta

Table B2-7: Farim Project - Wet Season STN7 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN7	8/19/2013	*Achnanthidium minutissimum*	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Actinoptychus sp.	Bacillariophyta
		Adlafia minuscula var. muralis	Bacillariophyta
		Amphora sp.	Bacillariophyta
		cf. *Fragilariopsis* sp.	Bacillariophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Luticola nivalis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Coscinodiscus sp.	Bacillariophyta
		Craticula elkab	Bacillariophyta
		Craticula molestiformis	Bacillariophyta
		Cryptomonas sp.	Cryptophyta
		Cyclotella striata	Bacillariophyta
		Denticula sp.	Bacillariophyta
		Diploneis cf. *modica*	Bacillariophyta
		Diploneis parma	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Diploneis spp.	Bacillariophyta
		Encyonema sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gyrosigma balticum	Bacillariophyta
		Mastogloia sp.	Bacillariophyta
		Navicula cryptotenella	Bacillariophyta
		Navicula sp.	Bacillariophyta
		Navicula spp.	Bacillariophyta
		Nitzschia cf. *clausii*	Bacillariophyta
		Nitzschia cf. *ignorata*	Bacillariophyta
		Nitzschia cf. *inconspicua*	Bacillariophyta
		Nitzschia dissipata	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia laevis	Bacillariophyta
		Nitzschia palea	Bacillariophyta
		Nitzschia punctata	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Nitzschia subacicularis	Bacillariophyta
		Nitzschia supralitorea	Bacillariophyta
		Planothidium sp.	Bacillariophyta
		Pleurosigma spp.	Bacillariophyta
		Rhodomonas spp.	Cryptophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta
		Tryblionella calida	Bacillariophyta

Table B2-8: Farim Project - Wet Season STN8 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN8	8/19/2013	*Achnanthidium minutissimum*	Bacillariophyta
		Achnanthidium sp.	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Aulacoseira sp.	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Luticola nivalis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		cf. *Tryblionella* sp.	Bacillariophyta
		Chaetoceros spp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Craticula cf. *molestiformis*	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Navicula cryptotenella	Bacillariophyta
		Neidium sp.	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia laevis	Bacillariophyta
		Nitzschia lanceola	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Rhizosolenia sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-9: Farim Project - Wet Season STN9 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN9	8/22/2013	*Actinocyclus* cf. *divisus*	Bacillariophyta
		Actinoptychus undulatus	Bacillariophyta
		Amphiprora sp.	Bacillariophyta
		Bacillaria paxillifer	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Actinoptychus* sp.	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cocconeis sp.	Bacillariophyta
		Cyclotella ocellata	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Cymbella sp.	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Ditylum sp.	Bacillariophyta
		Fragilariopsis kerguelensis	Bacillariophyta
		Mallomonas sp.	Chrysophyta
		Navicula sp.	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Odontella sp.	Bacillariophyta
		Opephora sp.	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Pseudanabaena sp.	Cyanobacteria
		Pseudo-nitzschia sp.	Bacillariophyta
		Pseudostaurosira brevistriata	Bacillariophyta
		Rhaphoneis sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Schuettia annulata	Bacillariophyta
		Staurosirella pinnata	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira cf. *baltica*	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-10: Farim Project - Wet Season STN10 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN10	8/22/2013	*Actinocyclus* cf. *divisus*	Bacillariophyta
		Actinoptychus s sp.	Bacillariophyta
		Asterionella formosa	Bacillariophyta
		Bacillaria paxillifer	Bacillariophyta
		Campyloneis sp.	Bacillariophyta
		cf. *Chlorella* sp.	Chlorophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chroomonas sp.	Cryptophyta
		Cocconeis placentula	Bacillariophyta
		Cocconeis sp.	Bacillariophyta
		Coscinodiscus sp.	Bacillariophyta
		Cyclotella meneghiniana	Bacillariophyta
		Cyclotella ocellata	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Fragilariopsis kerguelensis	Bacillariophyta
		Navicula sp.	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia inconspicua	Bacillariophyta
		Nitzschia punctata	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Odontella sp.	Bacillariophyta
		Odontella spp.	Bacillariophyta
		Opephora sp.	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Pseudostaurosira brevistriata	Bacillariophyta
		Rhaphoneis sp.	Bacillariophyta
		Rhizosolenia sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Schuettia annulata	Bacillariophyta
		Staurosirella pinnata	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-11: Farim Project - Wet Season STN11 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN11	8/24/2013	*Amphora* sp.	Bacillariophyta
		Aphanocapsa sp.	Cyanobacteria
		Asterionella formosa	Bacillariophyta
		Asterionellopsis glacialis	Bacillariophyta
		Campyloneis sp.	Bacillariophyta
		cf. *Chlorella* spp.	Chlorophyta
		cf. *Delphineis* sp.	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cocconeis sp.	Bacillariophyta
		Cryptomonas ovata	Cryptophyta
		Cyclotella ocellata	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Fragilariopsis kerguelensis	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gymnodinium sp.	Pyrrophyta
		Leptocylindrus danicus	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia laevis	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Pseudo-nitzschia sp.	Bacillariophyta
		Rhizosolenia sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-12: Farim Project - Wet Season STN12 Summary Phytoplankton Data

STATION	SAMPLE DATE	GENUS AND SPECIES	DIVISION
STN12	8/24/2013	*Actinocyclus* cf. *divisus*	Bacillariophyta
		Actinoptychus cf. *adriaticus*	Bacillariophyta
		Bacillaria paxillifer	Bacillariophyta
		Cerataulina sp.	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Delphineis* sp.	Bacillariophyta
		cf. *Goniothecium* sp.	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Rhaphoneis* sp.	Bacillariophyta
		cf. *Staurosirella* sp.	Bacillariophyta
		cf. *Thalassionema* sp.	Bacillariophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros cf. *peruvianus*	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cocconeis sp.	Bacillariophyta
		Coscinodiscus sp.	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Delphineis sp.	Bacillariophyta
		Fragilariopsis kerguelensis	Bacillariophyta
		Fragilariopsis sp.	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Planothidium oestrupii	Bacillariophyta
		Pseudostaurosira brevistriata	Bacillariophyta
		Rhizosolenia sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira baltica	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-13: Farim Project - Wet Season STN13 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN13	9/21/2013	*Achnanthidium* sp.	Bacillariophyta
		Actinocyclus sp.	Bacillariophyta
		Asterionellopsis glacialis	Bacillariophyta
		Aulacoseira sp.	Bacillariophyta
		Cerataulina sp.	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Campyloneis* sp.	Bacillariophyta
		cf. *Cymatosira lorenziana*	Bacillariophyta
		cf. *Delphineis* sp.	Bacillariophyta
		cf. *Fragilariopsis kerguelensis*	Bacillariophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Staurosirella* sp.	Bacillariophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		cf. *Triceratium* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Cocconeis sp.	Bacillariophyta
		Coscinodiscus sp.	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Delphineis sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Navicula sp.	Bacillariophyta
		Navicula spp.	Bacillariophyta
		Nitzschia spp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Odontella sp.	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Rhaphoneis sp.	Bacillariophyta
		Rhizosolenia sp.	Bacillariophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira cf. *visurgis*	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira sp.	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-14: Farim Project - Wet Season STN14 Summary Phytoplankton Data

STATION	SAMPLE DATE	GENUS AND SPECIES	DIVISION
STN14	9/24/2013	*Achnanthes* sp.	Bacillariophyta
		Actinocyclus cf. *divisus*	Bacillariophyta
		Asterionellopsis glacialis	Bacillariophyta
		Ceratium hirundinella	Pyrrophyta
		cf. *Amphiprora* sp.	Bacillariophyta
		cf. *Campyloneis* sp.	Bacillariophyta
		cf. *Delphineis* sp.	Bacillariophyta
		cf. *Fragilariopsis kerguelensis*	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Rhaphoneis* sp.	Bacillariophyta
		cf. *Staurosirella* sp.	Bacillariophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cyclotella striata	Bacillariophyta
		Fragilariopsis sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Gymnodinium sp.	Pyrrophyta
		Nitzschia laevis	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Odontella sp.	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Pseudo-nitzschia sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Rhodomonas spp.	Cryptophyta
		Rhopalodia sp.	Bacillariophyta
		Skeletonema sp.	Bacillariophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta
		Tryblionella constricta	Bacillariophyta

Table B2-15: Farim Project - Wet Season STN15 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN15	8/27/2013	*Asterionellopsis glacialis*	Bacillariophyta
		Campyloneis sp.	Bacillariophyta
		Cerataulina sp.	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Cymatosira lorenziana*	Bacillariophyta
		cf. *Delphineis* sp.	Bacillariophyta
		cf. *Fragilariopsis kerguelensis*	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlamydomonas sp.	Chlorophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cyclotella striata	Bacillariophyta
		Fragilariopsis sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Navicula sp.	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Rhaphoneis sp.	Bacillariophyta
		Rhizosolenia sp.	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Skeletonema sp.	Bacillariophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-16: Farim Project - Wet Season STN16 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN16	8/26/2013	*Achnanthes* sp.	Bacillariophyta
		Asterionellopsis glacialis	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Campyloneis* sp.	Bacillariophyta
		cf. *Fragilariopsis kerguelensis*	Bacillariophyta
		cf. *Gymnodinium discoidale*	Pyrrophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Cyclotella striata	Bacillariophyta
		Fragilariopsis cf. *kerguelensis*	Bacillariophyta
		Fragilariopsis sp.	Bacillariophyta
		Gymnodinium sp.	Pyrrophyta
		Navicula sp.	Bacillariophyta
		Odontella sp.	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Peridinium sp.	Pyrrophyta
		Pleurosigma salinarum	Bacillariophyta
		Rhodomonas sp.	Cryptophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-17: Farim Project - Wet Season STN16 Summary Phytoplankton Data

STATION	SAMPLE	GENUS AND SPECIES	DIVISION
	DATE		
STN17	8/26/2013	*Achnanthes* sp.	Bacillariophyta
		Aulacoseira sp.	Bacillariophyta
		Campyloneis sp.	Bacillariophyta
		Cerataulina sp.	Bacillariophyta
		Ceratoneis closterium	Bacillariophyta
		cf. *Cymatosira lorenziana*	Bacillariophyta
		cf. *Delphineis* sp.	Bacillariophyta
		cf. *Fragilariopsis kerguelensis*	Bacillariophyta
		cf. *Hemidiscus cuneiformis*	Bacillariophyta
		cf. *Ochromonas* sp.	Chrysophyta
		cf. *Staurosirella* sp.	Bacillariophyta
		cf. *Thalassiosira* sp.	Bacillariophyta
		Chaetoceros sp.	Bacillariophyta
		Chlamydomonas sp.	Chlorophyta
		Chlorella sp.	Chlorophyta
		Chlorella spp.	Chlorophyta
		Coscinodiscus sp.	Bacillariophyta
		Cyclotella striata	Bacillariophyta
		Delphineis sp.	Bacillariophyta
		Diploneis sp.	Bacillariophyta
		Fragilariopsis cf. *kerguelensis*	Bacillariophyta
		Fragilariopsis sp.	Bacillariophyta
		Gymnodinium discoidale	Pyrrophyta
		Navicula sp.	Bacillariophyta
		Navicula spp.	Bacillariophyta
		Nitzschia granulata	Bacillariophyta
		Nitzschia sp.	Bacillariophyta
		Odontella aurita	Bacillariophyta
		Odontella sp.	Bacillariophyta
		Paralia cf. *sulcata*	Bacillariophyta
		Pseudo-nitzschia sp.	Bacillariophyta
		Thalassionema nitzschioides	Bacillariophyta
		Thalassionema sp.	Bacillariophyta
		Thalassiosira eccentrica	Bacillariophyta
		Thalassiosira visurgis	Bacillariophyta

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN1PPA	8/15/2013	11:57	*Achnanthidium* sp.	Bacillariophyta	2	1.78E+04	8.40E+05	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Aulacoseira* sp.	Bacillariophyta	1	8.91E+03	7.55E+06	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Chaetoceros* sp.	Bacillariophyta	30	2.67E+05	6.02E+08	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Cyclotella striata*	Bacillariophyta	11	9.80E+04	6.52E+07	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Nitzschia* cf. *microcephala*	Bacillariophyta	12	1.07E+05	3.85E+06	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Nitzschia supralitorea*	Bacillariophyta	1	8.91E+03	6.77E+05	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Thalassiosira eccentrica*	Bacillariophyta	2	1.78E+04	1.49E+08	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	cf. *Thalassiosira* sp.	Bacillariophyta	98	8.73E+05	9.88E+07	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Chlamydomonas grovei*	Chlorophyta	1	8.91E+03	4.67E+05	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Chlorella* sp.	Chlorophyta	89	7.93E+05	6.49E+06	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Cosmarium* sp.	Chlorophyta	8	7.13E+04	3.36E+06	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Crucigenia quadrata*	Chlorophyta	24	2.14E+05	1.03E+07	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Monoraphidium* cf. *komarkovae*	Chlorophyta	1	8.91E+03	7.47E+05	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Planctonema lauterbornii*	Chlorophyta	16	1.43E+05	1.31E+07	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	cf. *Ochromonas* sp.	Chrysophyta	71	6.33E+05	3.31E+07	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Cryptomonas ovata*	Cryptophyta	4	3.56E+04	3.61E+07	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Rhodomonas* spp.	Cryptophyta	67	5.97E+05	1.30E+08	Very High sediment. Many broken diatoms.
STN1PPA	8/15/2013	11:57	*Aphanocapsa* sp.	Cyanobacteria	28	2.50E+05	1.05E+06	Very High sediment. Many broken diatoms.
			TOTAL		466	4.15E+06	1.16E+09	
STN1PPB	8/15/2013	12:01	*Achnanthidium minutissimum*	Bacillariophyta	5	5.94E+04	3.08E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	cf. *Actinocyclus divisus*	Bacillariophyta	1	1.19E+04	8.89E+08	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Actinocyclus* sp.	Bacillariophyta	4	4.75E+04	1.12E+09	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Aulacoseira* sp.	Bacillariophyta	4	4.75E+04	2.39E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Chaetoceros* sp.	Bacillariophyta	69	8.20E+05	1.75E+09	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Cyclotella* spp.	Bacillariophyta	13	1.54E+05	2.33E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Nitzschia fonticola*	Bacillariophyta	1	1.19E+04	1.87E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Nitzschia* cf. *inconspicua*	Bacillariophyta	2	2.38E+04	2.85E+05	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Nitzschia* cf. *microcephala*	Bacillariophyta	7	8.32E+04	4.99E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Pseudostaurosira brevistriata*	Bacillariophyta	6	7.13E+04	2.69E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Synedra* sp.	Bacillariophyta	1	1.19E+04	1.33E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	cf. *Thalassiosira* sp.	Bacillariophyta	56	6.65E+05	1.57E+08	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Chlorella* sp.	Chlorophyta	144	1.71E+06	2.42E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	cf. *Coenochloris* sp.	Chlorophyta	3	3.56E+04	2.92E+05	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Crucigenia tetrapedia*	Chlorophyta	8	9.51E+04	2.85E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Planctonema lauterbornii*	Chlorophyta	89	1.06E+06	5.98E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Scenedesmus* spp.	Chlorophyta	12	1.43E+05	1.49E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	cf. *Ochromonas* sp.	Chrysophyta	67	7.96E+05	9.38E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Chroomonas* sp.	Cryptophyta	3	3.56E+04	4.02E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Rhodomonas* cf. *salina*	Cryptophyta	4	4.75E+04	2.56E+07	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Rhodomonas* sp.	Cryptophyta	6	7.13E+04	7.39E+06	Very High sediment. Many broken diatoms.
STN1PPB	8/15/2013	12:01	*Aphanocapsa* sp.	Cyanobacteria	203	2.41E+06	1.01E+07	Very High sediment. Many broken diatoms.
			TOTAL		708	8.41E+06	4.17E+09	
STN1PPC	8/15/2013	12:02	*Chaetoceros* sp.	Bacillariophyta	14	5.99E+04	1.28E+08	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Nitzschia punctata*	Bacillariophyta	2	8.56E+03	2.40E+06	Very high sediment. Tally cannot be reached

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN1PPC	8/15/2013	12:02	cf. *Thalassiosira* sp.	Bacillariophyta	79	3.38E+05	1.99E+07	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Thalassiosira* sp.	Bacillariophyta	4	1.71E+04	1.36E+07	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Chlamydomonas globosa*	Chlorophyta	1	4.28E+03	1.68E+05	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	cf. *Chlorella* sp.	Chlorophyta	43	1.84E+05	2.60E+06	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Monoraphidium arcuatum*	Chlorophyta	2	8.56E+03	7.35E+05	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Planctonema lauterbornii*	Chlorophyta	24	1.03E+05	7.98E+06	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Scenedesmus communis*	Chlorophyta	16	6.84E+04	3.55E+06	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Scenedesmus* sp.	Chlorophyta	16	6.84E+04	1.15E+06	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	*Tetrastrum glabrum*	Chlorophyta	16	6.84E+04	5.60E+05	Very high sediment. Tally cannot be reached
STN1PPC	8/15/2013	12:02	cf. *Ochromonas* sp.	Chrysophyta	8	3.42E+04	3.55E+06	Very high sediment. Tally cannot be reached
			TOTAL		225	9.63E+05	1.85E+08	
STN2PPA	8/15/2013	14:33	*Achnanthidium minutissimum*	Bacillariophyta	1	1.07E+04	5.04E+05	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Actinocyclus divisus*	Bacillariophyta	21	2.25E+05	1.27E+10	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Aulacoseira* spp.	Bacillariophyta	13	1.39E+05	6.99E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Chaetoceros* sp.	Bacillariophyta	97	1.04E+06	3.01E+09	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Cyclotella ocellata*	Bacillariophyta	1	1.07E+04	1.51E+05	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Cyclotella striata*	Bacillariophyta	19	2.03E+05	1.63E+09	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Nitzschia* cf. *microcephala*	Bacillariophyta	13	1.39E+05	5.56E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Nitzschia punctata*	Bacillariophyta	6	6.42E+04	1.25E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Nitzschia supralitorea*	Bacillariophyta	4	4.28E+04	2.18E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	cf. *Thalassiosira* sp.	Bacillariophyta	34	3.64E+05	7.31E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Thalassiosira visurgis*	Bacillariophyta	5	5.35E+04	3.55E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Chlorella* sp.	Chlorophyta	101	1.08E+06	8.84E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Monoraphidium arcuatum*	Chlorophyta	1	1.07E+04	8.51E+05	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Oocystis borgei*	Chlorophyta	4	4.28E+04	5.60E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Planctonema lauterbornii*	Chlorophyta	51	5.45E+05	3.08E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Scenedesmus dimorphus*	Chlorophyta	4	4.28E+04	3.23E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Scenedesmus intermedius var. balator*	Chlorophyta	4	4.28E+04	1.61E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Tetrastrum glabrum*	Chlorophyta	16	1.71E+05	2.42E+06	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Mallomonas* sp.	Chrysophyta	1	1.07E+04	5.04E+05	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	cf. *Ochromonas* sp.	Chrysophyta	41	4.38E+05	2.30E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Chroomonas* sp.	Cryptophyta	6	6.42E+04	3.46E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Cryptomonas ovata*	Cryptophyta	5	5.35E+04	4.48E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Rhodomonas* sp.	Cryptophyta	7	7.49E+04	1.63E+07	High sediment. Many broken diatoms.
STN2PPA	8/15/2013	14:33	*Aphanocapsa* sp.	Cyanobacteria	719	7.69E+06	3.22E+07	High sediment. Many broken diatoms.
			TOTAL		1174	1.26E+07	1.77E+10	
STN2PPB	8/15/2013	14:34	*Achnanthes* sp.	Bacillariophyta	2	1.43E+04	1.06E+07	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Aulacoseira* sp.	Bacillariophyta	2	1.43E+04	1.36E+07	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Chaetoceros* sp.	Bacillariophyta	64	4.56E+05	4.90E+08	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Cyclostephanos* sp.	Bacillariophyta	1	7.13E+03	3.36E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Cyclotella striata*	Bacillariophyta	16	1.14E+05	1.38E+08	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Nitzschia* cf. *bacillum*	Bacillariophyta	2	1.43E+04	2.03E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Nitzschia* cf. *microcephala*	Bacillariophyta	14	9.98E+04	2.40E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Nitzschia punctata*	Bacillariophyta	2	1.43E+04	2.74E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Thalassiosira eccentrica*	Bacillariophyta	4	2.85E+04	1.29E+08	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Thalassiosira* sp.	Bacillariophyta	2	1.43E+04	8.13E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	cf. *Thalassiosira* sp.	Bacillariophyta	80	5.70E+05	8.06E+07	High sediment. Many broken diatoms.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN2PPB	8/15/2013	14:34	*Chlorella* sp.	Chlorophyta	178	1.27E+06	1.04E+07	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Planctonema lauterbornii*	Chlorophyta	16	1.14E+05	8.06E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Scenedesmus communis*	Chlorophyta	16	1.14E+05	1.94E+07	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Scenedesmus* sp.	Chlorophyta	12	8.56E+04	2.42E+06	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Tetrastrum glabrum*	Chlorophyta	8	5.70E+04	8.06E+05	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	cf. *Ochromonas* sp.	Chrysophyta	19	1.35E+05	1.15E+07	High sediment. Many broken diatoms.
STN2PPB	8/15/2013	14:34	*Rhodomonas* spp.	Cryptophyta	12	8.56E+04	5.60E+06	High sediment. Many broken diatoms.
			TOTAL		450	3.21E+06	9.39E+08	
STN2PPC	8/15/2013	14:34	*Achnanthidium* sp.	Bacillariophyta	7	4.68E+04	2.43E+06	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Actinocyclus* cf. *divisus*	Bacillariophyta	10	6.68E+04	1.30E+09	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Chaetoceros* sp.	Bacillariophyta	20	1.34E+05	2.27E+08	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Cyclotella striata*	Bacillariophyta	26	1.74E+05	2.21E+09	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Diploneis* sp.	Bacillariophyta	1	6.68E+03	3.94E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Nitzschia granulata*	Bacillariophyta	1	6.68E+03	5.04E+06	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Nitzschia* cf. *microcephala*	Bacillariophyta	8	5.35E+04	1.93E+06	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Nitzschia* sp.	Bacillariophyta	1	6.68E+03	8.02E+05	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Nitzschia supralitorea*	Bacillariophyta	2	1.34E+04	1.07E+06	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Thalassiosira eccentrica*	Bacillariophyta	1	6.68E+03	6.18E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	cf. *Thalassiosira* sp.	Bacillariophyta	77	5.15E+05	5.82E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Thalassiosira visurgis*	Bacillariophyta	9	6.02E+04	1.89E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Chlorella* sp.	Chlorophyta	111	7.42E+05	1.05E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Cosmarium* sp.	Chlorophyta	4	2.67E+04	1.68E+06	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Crucigenia quadrata*	Chlorophyta	8	5.35E+04	3.42E+06	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Monoraphidium arcuatum*	Chlorophyta	4	2.67E+04	2.66E+05	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Planctonema lauterbornii*	Chlorophyta	40	2.67E+05	2.65E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	cf. *Ochromonas* sp.	Chrysophyta	57	3.81E+05	1.99E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Rhodomonas* spp.	Cryptophyta	59	3.94E+05	8.59E+07	High sediment. Many broken diatoms.
STN2PPC	8/15/2013	14:34	*Aphanocapsa* sp.	Cyanobacteria	244	1.63E+06	6.83E+06	High sediment. Many broken diatoms.
			TOTAL		690	4.61E+06	4.08E+09	
STN3PPA	8/17/2013	11:57	*Achnanthes brevipes*	Bacillariophyta	4	3.17E+04	2.61E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Achnanthidium* sp.	Bacillariophyta	6	4.75E+04	2.24E+06	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	cf. *Actinocyclus divisus*	Bacillariophyta	29	2.30E+05	1.11E+10	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Aulacoseira* spp.	Bacillariophyta	15	1.19E+05	3.03E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Chaetoceros* sp.	Bacillariophyta	62	4.91E+05	1.03E+09	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Cyclotella* sp.	Bacillariophyta	4	3.17E+04	3.82E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Cyclotella striata*	Bacillariophyta	13	1.03E+05	1.41E+09	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Diploneis* sp.	Bacillariophyta	2	1.58E+04	3.14E+06	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Melosira* sp.	Bacillariophyta	1	7.92E+03	1.95E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Nitzschia granulata*	Bacillariophyta	1	7.92E+03	4.79E+06	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Nitzschia inconspicua*	Bacillariophyta	5	3.96E+04	7.13E+05	High sediment. Many broken diatoms.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN3PPA	8/17/2013	11:57	*Nitzschia* cf. *rosenstockii*	Bacillariophyta	4	3.17E+04	3.09E+06	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Thalassiosira visurgis*	Bacillariophyta	21	1.66E+05	1.32E+08	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	cf. *Thalassiosira* sp.	Bacillariophyta	30	2.38E+05	5.97E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Chlorella* sp.	Chlorophyta	103	8.16E+05	1.15E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Planctonema lauterbornii*	Chlorophyta	84	6.65E+05	2.82E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Tetrastrum glabrum*	Chlorophyta	4	3.17E+04	4.48E+05	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	cf. *Ochromonas* sp.	Chrysophyta	73	5.78E+05	1.26E+08	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Chroomonas* sp.	Cryptophyta	7	5.55E+04	5.15E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Rhodomonas* spp.	Cryptophyta	15	1.19E+05	4.67E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Aphanocapsa* sp.	Cyanobacteria	767	6.08E+06	1.86E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Chroococcus dispersus*	Cyanobacteria	2	1.58E+04	1.04E+06	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	cf. *Gymnodinium discoidale*	Pyrrophyta	29	2.30E+05	8.47E+07	High sediment. Many broken diatoms.
STN3PPA	8/17/2013	11:57	*Gymnodinium* sp.	Pyrrophyta	27	2.14E+05	1.36E+09	High sediment. Many broken diatoms.
			TOTAL		1308	1.04E+07	1.56E+10	
STN3PPB	8/17/2013	11:57	*Achnanthidium* sp.	Bacillariophyta	4	1.86E+04	9.64E+05	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Actinocyclus* cf. *divisus*	Bacillariophyta	6	2.79E+04	5.41E+08	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Aulacoseira* sp.	Bacillariophyta	1	4.65E+03	6.51E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Chaetoceros* sp.	Bacillariophyta	28	1.30E+05	2.45E+08	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Cyclotella striata*	Bacillariophyta	9	4.18E+04	1.89E+08	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Gomphonema eriense var. variabile*	Bacillariophyta	1	4.65E+03	3.19E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Thalassiosira eccentrica*	Bacillariophyta	6	2.79E+04	2.03E+08	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	cf. *Thalassiosira* sp.	Bacillariophyta	16	7.44E+04	8.41E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Thalassiosira visurgis*	Bacillariophyta	7	3.25E+04	1.86E+07	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Chlamydomonas globosa*	Chlorophyta	1	4.65E+03	3.51E+05	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Chlorella* spp.	Chlorophyta	111	5.16E+05	7.30E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Cosmarium* sp.	Chlorophyta	4	1.86E+04	1.17E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Crucigenia quadrata*	Chlorophyta	8	3.72E+04	6.70E+05	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Planctonema lauterbornii*	Chlorophyta	50	2.32E+05	2.30E+07	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Scenedesmus communis*	Chlorophyta	8	3.72E+04	1.93E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Scenedesmus* sp.	Chlorophyta	4	1.86E+04	7.01E+05	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Tetrastrum glabrum*	Chlorophyta	8	3.72E+04	2.43E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	cf. *Ochromonas* sp.	Chrysophyta	61	2.84E+05	1.49E+07	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Rhodomonas* spp.	Cryptophyta	54	2.51E+05	5.47E+07	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Aphanocapsa* sp.	Cyanobacteria	264	1.23E+06	5.14E+06	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	cf. *Gymnodinium discoidale*	Pyrrophyta	40	1.86E+05	2.34E+07	High sediment. Many broken diatoms.
STN3PPB	8/17/2013	11:57	*Gymnodinium* sp.	Pyrrophyta	29	1.35E+05	2.16E+08	High sediment. Many broken diatoms.
			TOTAL		720	3.35E+06	1.57E+09	

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN3PPC	8/17/2013	11:57	*Achnanthes* sp.	Bacillariophyta	2	1.26E+04	3.76E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Chaetoceros* sp.	Bacillariophyta	12	7.55E+04	1.51E+08	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Cyclotella striata*	Bacillariophyta	1	6.29E+03	2.39E+07	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Diploneis* sp.	Bacillariophyta	2	1.26E+04	4.74E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Nitzschia* sp.	Bacillariophyta	1	6.29E+03	8.21E+05	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Skeletonema* cf. *subsalsum*	Bacillariophyta	19	1.20E+05	1.41E+07	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	cf. *Thalassiosira* sp.	Bacillariophyta	12	7.55E+04	6.40E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Thalassiosira* sp.	Bacillariophyta	2	1.26E+04	4.94E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Chlorella* sp.	Chlorophyta	164	1.03E+06	8.44E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Planctonema lauterbornii*	Chlorophyta	111	6.98E+05	5.43E+07	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Scenedesmus communis*	Chlorophyta	14	8.81E+04	3.32E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Scenedesmus* sp.	Chlorophyta	12	7.55E+04	7.91E+05	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Tetrastrum glabrum*	Chlorophyta	32	2.01E+05	2.85E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Mallomonas* sp.	Chrysophyta	2	1.26E+04	5.90E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	cf. *Ochromonas* sp.	Chrysophyta	51	3.21E+05	2.72E+07	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Rhodomonas* sp.	Cryptophyta	18	1.13E+05	4.74E+07	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Aphanocapsa* sp.	Cyanobacteria	343	2.16E+06	1.41E+05	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	cf. *Pannus* sp.	Cyanobacteria	40	2.52E+05	1.05E+06	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Gymnodinium discoidale*	Pyrrophyta	55	3.46E+05	4.35E+07	High sediment. Many broken diatoms.
STN3PPC	8/17/2013	11:57	*Gymnodinium* sp.	Pyrrophyta	25	1.57E+05	2.11E+08	High sediment. Many broken diatoms.
			TOTAL		918	5.78E+06	6.15E+08	
STN4PPA	8/17/2013	10:02	*Achnanthidium* sp.	Bacillariophyta	4	2.59E+04	1.34E+06	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	cf. *Actinocyclus divisus*	Bacillariophyta	53	3.44E+05	1.17E+10	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Amphora* sp.	Bacillariophyta	1	6.48E+03	1.43E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Chaetoceros* sp.	Bacillariophyta	18	1.17E+05	2.23E+08	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Cocconeis* sp.	Bacillariophyta	2	1.30E+04	3.42E+06	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Cyclotella ocellata*	Bacillariophyta	2	1.30E+04	7.64E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Cyclotella striata*	Bacillariophyta	6	3.89E+04	4.07E+08	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Eunotia* sp.	Bacillariophyta	3	1.94E+04	1.73E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Nitzschia granulata*	Bacillariophyta	2	1.30E+04	6.48E+06	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Nitzschia* cf. *microcephala*	Bacillariophyta	2	1.30E+04	4.28E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Nitzschia supralitorea*	Bacillariophyta	1	6.48E+03	8.26E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Opephora* sp.	Bacillariophyta	1	6.48E+03	4.89E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Pleurosigma* sp.	Bacillariophyta	1	6.48E+03	1.75E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Pseudostaurosira brevistriata*	Bacillariophyta	3	1.94E+04	9.16E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Thalassiosira eccentrica*	Bacillariophyta	14	9.07E+04	1.09E+08	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	cf. *Thalassiosira* sp.	Bacillariophyta	17	1.10E+05	1.66E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Thalassiosira visurgis*	Bacillariophyta	7	4.54E+04	3.49E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Tryblionella* sp.	Bacillariophyta	1	6.48E+03	1.95E+06	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Chlorella* sp.	Chlorophyta	122	7.91E+05	1.12E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	cf. *Oocystis borgei*	Chlorophyta	8	5.19E+04	3.53E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Planctonema lauterbornii*	Chlorophyta	89	5.77E+05	2.45E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Scenedesmus communis*	Chlorophyta	4	2.59E+04	1.71E+06	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Scenedesmus* sp.	Chlorophyta	2	1.30E+04	1.36E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Tetrastrum glabrum*	Chlorophyta	8	5.19E+04	7.33E+05	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Westella botryoides*	Chlorophyta	4	2.59E+04	3.67E+05	High sediment. Many broken diatoms.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN4PPA	8/17/2013	10:02	cf. *Ochromonas* sp.	Chrysophyta	65	4.21E+05	2.21E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Chroomonas* sp.	Cryptophyta	1	6.48E+03	5.45E+06	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Rhodomonas* spp.	Cryptophyta	37	2.40E+05	5.22E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Gymnodinium discoidale*	Pyrrophyta	7	4.54E+04	3.74E+07	High sediment. Many broken diatoms.
STN4PPA	8/17/2013	10:02	*Gymnodinium* sp.	Pyrrophyta	33	2.14E+05	1.30E+09	High sediment. Many broken diatoms.
			TOTAL		518	3.36E+06	1.40E+10	
STN4PPB	8/17/2013	10:02	*Achnanthidium* sp.	Bacillariophyta	7	6.24E+04	3.23E+06	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Aulacoseira* sp.	Bacillariophyta	4	3.56E+04	2.74E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Chaetoceros* sp.	Bacillariophyta	1	8.91E+03	1.68E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Cocconeis* sp.	Bacillariophyta	2	1.78E+04	1.05E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Cyclotella striata*	Bacillariophyta	14	1.25E+05	9.89E+08	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Nitzschia granulata*	Bacillariophyta	4	3.56E+04	2.12E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Nitzschia* cf. *microcephala*	Bacillariophyta	1	8.91E+03	3.21E+05	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Thalassiosira eccentrica*	Bacillariophyta	2	1.78E+04	9.46E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	cf. *Thalassiosira* sp.	Bacillariophyta	24	2.14E+05	2.42E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Thalassiosira visurgis*	Bacillariophyta	12	1.07E+05	5.08E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Chlamydomonas globosa*	Chlorophyta	7	6.24E+04	3.27E+06	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Chlorella* spp.	Chlorophyta	86	7.66E+05	1.08E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Crucigenia quadrata*	Chlorophyta	8	7.13E+04	1.28E+06	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Monoraphidium komarkovae*	Chlorophyta	1	8.91E+03	7.47E+05	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Planctonema lauterbornii*	Chlorophyta	106	9.45E+05	9.35E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	cf. *Ochromonas* sp.	Chrysophyta	92	8.20E+05	4.29E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Cryptomonas ovata*	Cryptophyta	4	3.56E+04	1.67E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Rhodomonas* spp.	Cryptophyta	69	6.15E+05	1.34E+08	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	cf. *Pseudanabaena* sp.	Cyanobacteria	28	2.50E+05	3.92E+06	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	cf. *Gymnodinium discoidale*	Pyrrophyta	40	3.56E+05	4.48E+07	High sediment. Many broken diatoms.
STN4PPB	8/17/2013	10:02	*Gymnodinium* sp.	Pyrrophyta	14	1.25E+05	2.49E+08	High sediment. Many broken diatoms.
			TOTAL		526	4.69E+06	1.84E+09	
STN4PPC	8/17/2013	10:02	*Actinocyclus* cf. *divisus*	Bacillariophyta	2	9.72E+03	3.52E+08	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Chaetoceros* sp.	Bacillariophyta	4	1.94E+04	4.57E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Cyclotella striata*	Bacillariophyta	4	1.94E+04	3.31E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Nitzschia microcephala*	Bacillariophyta	3	1.46E+04	4.38E+05	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Nitzschia punctata*	Bacillariophyta	2	9.72E+03	6.74E+06	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Nitzschia* sp.	Bacillariophyta	16	7.78E+04	1.24E+06	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Thalassiosira eccentrica*	Bacillariophyta	7	3.40E+04	1.54E+08	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Thalassiosira* sp.	Bacillariophyta	24	1.17E+05	9.29E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Tryblionella littoralis*	Bacillariophyta	1	4.86E+03	1.10E+06	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Chlorella* sp.	Chlorophyta	217	1.05E+06	8.63E+06	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Planctonema lauterbornii*	Chlorophyta	235	1.14E+06	8.88E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Tetrastrum glabrum*	Chlorophyta	24	1.17E+05	1.65E+06	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	cf. *Ochromonas* sp.	Chrysophyta	54	2.63E+05	1.37E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Cryptomonas* sp.	Cryptophyta	12	5.83E+04	1.54E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Rhodomonas* sp.	Cryptophyta	42	2.04E+05	1.34E+07	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Aphanocapsa* sp.	Cyanobacteria	47	2.28E+05	1.50E+04	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Gymnodinium discoidale*	Pyrrophyta	12	5.83E+04	3.91E+06	High sediment. Many broken diatoms.
STN4PPC	8/17/2013	10:02	*Gymnodinium* sp.	Pyrrophyta	23	1.12E+05	1.57E+08	High sediment. Many broken diatoms.
			TOTAL		729	3.54E+06	9.90E+08	

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN5PPA	8/16/2013	12:59	*Actinocyclus* cf. *divisus*	Bacillariophyta	13	9.27E+04	4.62E+09	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Chaetoceros* sp.	Bacillariophyta	4	2.85E+04	3.35E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Cocconeis placentula*	Bacillariophyta	1	7.13E+03	4.07E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Craticula submolesta*	Bacillariophyta	1	7.13E+03	3.70E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Cyclotella striata*	Bacillariophyta	4	2.85E+04	1.89E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Diploneis* sp.	Bacillariophyta	1	7.13E+03	6.35E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Eunotia* sp.	Bacillariophyta	2	1.43E+04	2.42E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Nitzschia* spp.	Bacillariophyta	60	4.28E+05	1.54E+08	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Skeletonema* sp.	Bacillariophyta	8	5.70E+04	4.03E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Thalassiosira eccentrica*	Bacillariophyta	2	1.43E+04	5.60E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	cf. *Thalassiosira* sp.	Bacillariophyta	4	2.85E+04	1.68E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Thalassiosira visurgis*	Bacillariophyta	13	9.27E+04	5.29E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Chlorella* sp.	Chlorophyta	37	2.64E+05	3.73E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	cf. *Oocystis borgei*	Chlorophyta	2	1.43E+04	1.49E+06	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Planctonema lauterbornii*	Chlorophyta	223	1.59E+06	6.74E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Westella botryoides*	Chlorophyta	3	2.14E+04	8.96E+04	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	cf. *Ochromonas* sp.	Chrysophyta	173	1.23E+06	6.46E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Cryptomonas* sp.	Cryptophyta	4	2.85E+04	1.24E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Rhodomonas* spp.	Cryptophyta	74	5.28E+05	1.15E+08	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Chroococcus* sp.	Cyanobacteria	4	2.85E+04	4.03E+05	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Gymnodinium discoidale*	Pyrrophyta	17	1.21E+05	2.28E+07	High sediment. Many broken diatoms.
STN5PPA	8/16/2013	12:59	*Gymnodinium* sp.	Pyrrophyta	1	7.13E+03	5.87E+06	High sediment. Many broken diatoms.
			TOTAL		651	4.64E+06	5.25E+09	
STN5PPB	8/16/2013	12:59	*Chaetoceros* sp.	Bacillariophyta	7	5.76E+04	3.55E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Cyclotella striata*	Bacillariophyta	4	3.29E+04	1.49E+08	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	cf. *Navicula* sp.	Bacillariophyta	1	8.23E+03	1.03E+06	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	cf. *Thalassiosira* sp.	Bacillariophyta	12	9.87E+04	1.12E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Thalassiosira visurgis*	Bacillariophyta	4	3.29E+04	1.29E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Chlamydomonas grovei*	Chlorophyta	1	8.23E+03	2.07E+05	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Chlorella* spp.	Chlorophyta	109	8.97E+05	3.00E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Planctonema lauterbornii*	Chlorophyta	32	2.63E+05	2.42E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	cf. *Ochromonas* sp.	Chrysophyta	62	5.10E+05	2.67E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Rhodomonas* spp.	Cryptophyta	69	5.68E+05	1.24E+08	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	cf. *Gymnodinium discoidale*	Pyrrophyta	41	3.37E+05	2.83E+07	High sediment. Many broken diatoms.
STN5PPB	8/16/2013	12:59	*Gymnodinium* sp.	Pyrrophyta	84	6.91E+05	7.09E+07	High sediment. Many broken diatoms.
			TOTAL		426	3.50E+06	5.13E+08	

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN5PPC	8/16/2013	12:59	*Actinocyclus* cf. *divisus*	Bacillariophyta	8	6.11E+04	1.14E+09	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Aulacoseira* sp.	Bacillariophyta	1	7.64E+03	8.11E+06	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Chaetoceros* sp.	Bacillariophyta	2	1.53E+04	4.80E+06	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Cyclotella striata*	Bacillariophyta	2	1.53E+04	6.05E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Nitzschia* cf. *microcephala*	Bacillariophyta	1	7.64E+03	2.52E+05	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Nitzschia* spp.	Bacillariophyta	77	5.88E+05	1.12E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	cf. *Thalassiosira* sp.	Bacillariophyta	13	9.93E+04	5.85E+06	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Thalassiosira visurgis*	Bacillariophyta	10	7.64E+04	6.08E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Tryblionella littoralis*	Bacillariophyta	2	1.53E+04	4.90E+06	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Chlorella* sp.	Chlorophyta	115	8.79E+05	1.24E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Planctonema lauterbornii*	Chlorophyta	83	6.34E+05	2.69E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	cf. *Ochromonas* sp.	Chrysophyta	133	1.02E+06	5.32E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Rhodomonas* sp.	Cryptophyta	30	2.29E+05	1.23E+08	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Gymnodinium discoidale*	Pyrrophyta	9	6.88E+04	1.08E+07	High sediment. Many broken diatoms.
STN5PPC	8/16/2013	12:59	*Gymnodinium* sp.	Pyrrophyta	2	1.53E+04	2.51E+07	High sediment. Many broken diatoms.
			TOTAL		488	3.73E+06	1.55E+09	
STN6PPA	8/16/2013	11:24	*Achnanthidium* sp.	Bacillariophyta	1	5.94E+03	1.03E+05	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Adlafia minuscula var. muralis*	Bacillariophyta	4	2.38E+04	1.87E+06	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Chaetoceros* sp.	Bacillariophyta	4	2.38E+04	4.53E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	cf. *Hemidiscus cuneiformis*	Bacillariophyta	1	5.94E+03	2.00E+06	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Nitzschia* sp.	Bacillariophyta	71	4.22E+05	1.31E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Thalassiosira eccentrica*	Bacillariophyta	1	5.94E+03	2.26E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	cf. *Thalassiosira* sp.	Bacillariophyta	33	1.96E+05	1.15E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Thalassiosira visurgis*	Bacillariophyta	14	8.32E+04	2.12E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Tryblionella littoralis*	Bacillariophyta	2	1.19E+04	2.35E+06	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Chlorella* spp.	Chlorophyta	127	7.55E+05	2.53E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	cf. *Ochromonas* sp.	Chrysophyta	83	4.93E+05	2.58E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Rhodomonas* spp.	Cryptophyta	42	2.50E+05	5.44E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	cf. *Gymnodinium discoidale*	Pyrrophyta	22	1.31E+05	1.64E+07	Moderate sediment.
STN6PPA	8/16/2013	11:24	*Gymnodinium* sp.	Pyrrophyta	4	2.38E+04	3.07E+07	Moderate sediment.
			TOTAL		409	2.43E+06	2.73E+08	
STN6PPB	8/16/2013	11:24	*Actinocyclus* cf. *divisus*	Bacillariophyta	21	9.98E+04	5.91E+09	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Ceratoneis closterium*	Bacillariophyta	2	9.51E+03	1.22E+06	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Chaetoceros* spp.	Bacillariophyta	13	6.18E+04	5.30E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Cocconeis* sp.	Bacillariophyta	1	4.75E+03	1.97E+06	Moderate sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN6PPB	8/16/2013	11:24	*Cyclotella striata*	Bacillariophyta	7	3.33E+04	1.64E+08	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Diploneis parma*	Bacillariophyta	4	1.90E+04	1.46E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Navicula* cf. *cryptotenella*	Bacillariophyta	1	4.75E+03	1.51E+06	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Nitzschia granulata*	Bacillariophyta	4	1.90E+04	1.67E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Nitzschia* cf. *microcephala*	Bacillariophyta	1	4.75E+03	1.28E+05	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Nitzschia punctata*	Bacillariophyta	8	3.80E+04	7.42E+06	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Nitzschia* spp.	Bacillariophyta	135	6.42E+05	4.04E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Thalassiosira eccentrica*	Bacillariophyta	2	9.51E+03	1.15E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	cf. *Thalassiosira* sp.	Bacillariophyta	47	2.23E+05	1.32E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Thalassiosira visurgis*	Bacillariophyta	17	8.08E+04	3.84E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Tryblionella littoralis*	Bacillariophyta	2	9.51E+03	1.88E+06	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Chlorella* sp.	Chlorophyta	47	2.23E+05	3.16E+06	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Planctonema lauterbornii*	Chlorophyta	93	4.42E+05	2.50E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	cf. *Ochromonas* sp.	Chrysophyta	92	4.37E+05	2.29E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Rhodomonas* sp.	Cryptophyta	21	9.98E+04	2.17E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Gymnodinium discoidale*	Pyrrophyta	17	8.08E+04	2.64E+07	Moderate sediment.
STN6PPB	8/16/2013	11:24	*Gymnodinium* sp.	Pyrrophyta	8	3.80E+04	8.12E+07	Moderate sediment.
			TOTAL		543	2.58E+06	6.46E+09	
STN6PPC	8/16/2013	11:24	*Cyclotella striata*	Bacillariophyta	12	7.13E+04	3.55E+08	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Nitzschia granulata*	Bacillariophyta	5	2.97E+04	7.28E+06	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Nitzschia* sp.	Bacillariophyta	54	3.21E+05	7.70E+06	Moderate sediment.
STN6PPC	8/16/2013	11:24	cf. *Thalassiosira* sp.	Bacillariophyta	47	2.79E+05	1.64E+07	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Thalassiosira visurgis*	Bacillariophyta	1	5.94E+03	1.51E+06	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Chlorella* spp.	Chlorophyta	112	6.65E+05	2.23E+07	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Planctonema lauterbornii*	Chlorophyta	26	1.54E+05	2.72E+07	Moderate sediment.
STN6PPC	8/16/2013	11:24	cf. *Ochromonas* sp.	Chrysophyta	128	7.61E+05	3.98E+07	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Rhodomonas* spp.	Cryptophyta	26	1.54E+05	3.36E+07	Moderate sediment.
STN6PPC	8/16/2013	11:24	cf. *Gymnodinium discoidale*	Pyrrophyta	15	8.91E+04	1.12E+07	Moderate sediment.
STN6PPC	8/16/2013	11:24	*Gymnodinium* sp.	Pyrrophyta	6	3.56E+04	4.89E+07	Moderate sediment.
			TOTAL		432	2.57E+06	5.71E+08	
STN7PPA	8/19/2013	12:02	*Amphora* sp.	Bacillariophyta	2	2.67E+04	8.82E+05	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Coscinodiscus* sp.	Bacillariophyta	2	2.67E+04	1.32E+09	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Cyclotella striata*	Bacillariophyta	2	2.67E+04	9.68E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Diploneis* spp.	Bacillariophyta	9	1.20E+05	6.86E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	cf. *Hemidiscus cuneiformis*	Bacillariophyta	4	5.35E+04	1.57E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Navicula* spp.	Bacillariophyta	4	5.35E+04	6.55E+06	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Nitzschia granulata*	Bacillariophyta	8	1.07E+05	8.98E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Nitzschia* cf. *ignorata*	Bacillariophyta	1	1.34E+04	6.18E+06	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Nitzschia punctata*	Bacillariophyta	2	2.67E+04	1.15E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Nitzschia* spp.	Bacillariophyta	7	9.36E+04	7.49E+06	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Thalassiosira* sp.	Bacillariophyta	8	1.07E+05	3.36E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	cf. *Thalassiosira* sp.	Bacillariophyta	12	1.60E+05	4.03E+06	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Chlorella* sp.	Chlorophyta	329	4.40E+06	3.60E+07	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	cf. *Ochromonas* sp.	Chrysophyta	9	1.20E+05	6.30E+06	Very High sediment. Many broken diatoms.
STN7PPA	8/19/2013	12:02	*Gymnodinium discoidale*	Pyrrophyta	4	5.35E+04	7.00E+06	Very High sediment. Many broken diatoms.
			TOTAL		403	5.39E+06	1.71E+09	

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STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN7PPB	8/19/2013	12:02	*Actinocyclus* cf. *divisus*	Bacillariophyta	6	8.02E+04	1.01E+09	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Actinoptychus* sp.	Bacillariophyta	1	1.34E+04	3.95E+08	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Cyclotella striata*	Bacillariophyta	2	2.67E+04	1.29E+08	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Diploneis* sp.	Bacillariophyta	4	5.35E+04	2.63E+07	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	cf. *Hemidiscus cuneiformis*	Bacillariophyta	2	2.67E+04	6.18E+06	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Navicula* sp.	Bacillariophyta	7	9.36E+04	1.68E+07	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Nitzschia* spp.	Bacillariophyta	6	8.02E+04	4.69E+06	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Thalassiosira eccentrica*	Bacillariophyta	2	2.67E+04	1.29E+08	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	cf. *Thalassiosira* sp.	Bacillariophyta	4	5.35E+04	6.05E+06	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Thalassiosira visurgis*	Bacillariophyta	11	1.47E+05	4.62E+07	Very High sediment. Many broken diatoms.
STN7PPB	8/19/2013	12:02	*Chlorella* sp.	Chlorophyta	396	5.29E+06	4.33E+07	Very High sediment. Many broken diatoms.
			TOTAL		441	5.90E+06	1.81E+09	
STN7PPC	8/19/2013	12:02	*Achnanthidium minutissimum*	Bacillariophyta	5	3.15E+04	1.63E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Actinocyclus* cf. *divisus*	Bacillariophyta	22	1.38E+05	4.01E+09	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Adlafia minuscula var. muralis*	Bacillariophyta	9	5.66E+04	2.93E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Craticula elkab*	Bacillariophyta	2	1.26E+04	4.74E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Craticula molestiformis*	Bacillariophyta	7	4.40E+04	6.54E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Cyclotella striata*	Bacillariophyta	16	1.01E+05	1.21E+08	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Denticula* sp.	Bacillariophyta	1	6.29E+03	7.56E+05	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Diploneis* cf. *modica*	Bacillariophyta	7	4.40E+04	2.41E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Diploneis parma*	Bacillariophyta	15	9.44E+04	6.60E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Diploneis* sp.	Bacillariophyta	2	1.26E+04	2.49E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Encyonema* sp.	Bacillariophyta	1	6.29E+03	2.20E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	cf. *Fragilariopsis* sp.	Bacillariophyta	6	3.77E+04	7.12E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Gyrosigma balticum*	Bacillariophyta	4	2.52E+04	1.79E+08	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	cf. *Hemidiscus cuneiformis*	Bacillariophyta	1	6.29E+03	7.24E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	cf. *Luticola nivalis*	Bacillariophyta	1	6.29E+03	2.37E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Mastogloia* sp.	Bacillariophyta	1	6.29E+03	2.25E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Navicula cryptotenella*	Bacillariophyta	2	1.26E+04	2.52E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Navicula* sp.	Bacillariophyta	2	1.26E+04	1.76E+08	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia* cf. *clausii*	Bacillariophyta	2	1.26E+04	3.59E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia dissipata*	Bacillariophyta	4	2.52E+04	3.47E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia granulata*	Bacillariophyta	15	9.44E+04	2.96E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia* cf. *inconspicua*	Bacillariophyta	16	1.01E+05	6.04E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia laevis*	Bacillariophyta	25	1.57E+05	2.26E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia palea*	Bacillariophyta	5	3.15E+04	1.51E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia punctata*	Bacillariophyta	9	5.66E+04	1.78E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia* spp.	Bacillariophyta	29	1.82E+05	2.19E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia subacicularis*	Bacillariophyta	2	1.26E+04	2.68E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Nitzschia supralitorea*	Bacillariophyta	21	1.32E+05	1.13E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Planothidium* sp.	Bacillariophyta	1	6.29E+03	1.04E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Pleurosigma* spp.	Bacillariophyta	6	3.77E+04	8.83E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Thalassiosira eccentrica*	Bacillariophyta	2	1.26E+04	1.74E+09	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	cf. *Thalassiosira* sp.	Bacillariophyta	86	5.41E+05	4.59E+07	Very High sediment. Many broken diatoms.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN7PPC	8/19/2013	12:02	*Thalassiosira visurgis*	Bacillariophyta	37	2.33E+05	1.33E+08	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Tryblionella calida*	Bacillariophyta	4	2.52E+04	4.74E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Chlorella* sp.	Chlorophyta	41	2.58E+05	8.64E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	cf. *Ochromonas* sp.	Chrysophyta	60	3.77E+05	1.98E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Cryptomonas* sp.	Cryptophyta	2	1.26E+04	7.59E+06	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Rhodomonas* spp.	Cryptophyta	9	5.66E+04	1.23E+07	Very High sediment. Many broken diatoms.
STN7PPC	8/19/2013	12:02	*Gymnodinium discoidale*	Pyrrophyta	1	6.29E+03	9.49E+05	Very High sediment. Many broken diatoms.
			TOTAL		481	3.03E+06	6.86E+09	
STN8PPA	8/19/2013	14:57	*Actinocyclus* cf. *divisus*	Bacillariophyta	1	8.23E+03	2.05E+08	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Aulacoseira* sp.	Bacillariophyta	4	3.29E+04	4.14E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Craticula* cf. *molestiformis*	Bacillariophyta	1	8.23E+03	7.24E+05	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Cyclotella striata*	Bacillariophyta	8	6.58E+04	4.20E+08	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Navicula cryptotenella*	Bacillariophyta	6	4.94E+04	6.20E+06	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Nitzschia granulata*	Bacillariophyta	4	3.29E+04	2.21E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Nitzschia lanceola*	Bacillariophyta	1	8.23E+03	6.25E+06	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Nitzschia laevis*	Bacillariophyta	4	3.29E+04	5.87E+06	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Nitzschia* sp.	Bacillariophyta	9	7.40E+04	4.22E+06	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Rhizosolenia* sp.	Bacillariophyta	1	8.23E+03	6.63E+06	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Thalassiosira eccentrica*	Bacillariophyta	4	3.29E+04	4.78E+08	Moderate sediment.
STN8PPA	8/19/2013	14:57	cf. *Thalassiosira* sp.	Bacillariophyta	65	5.35E+05	4.54E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Thalassiosira visurgis*	Bacillariophyta	13	1.07E+05	8.52E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Chlorella* spp.	Chlorophyta	235	1.93E+06	6.48E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	cf. *Ochromonas* sp.	Chrysophyta	43	3.54E+05	1.85E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	*Rhodomonas* sp.	Cryptophyta	12	9.87E+04	2.15E+07	Moderate sediment.
STN8PPA	8/19/2013	14:57	cf. *Gymnodinium discoidale*	Pyrrophyta	14	1.15E+05	1.63E+07	Moderate sediment.
			TOTAL		425	3.50E+06	1.45E+09	
STN8PPB	8/19/2013	14:57	*Achnanthidium* sp.	Bacillariophyta	1	1.53E+04	1.15E+06	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Actinocyclus* cf. *divisus*	Bacillariophyta	2	3.06E+04	5.20E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Chaetoceros* spp.	Bacillariophyta	19	2.90E+05	4.56E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Cyclotella striata*	Bacillariophyta	4	6.11E+04	3.24E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Neidium* sp.	Bacillariophyta	1	1.53E+04	1.36E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Nitzschia granulata*	Bacillariophyta	6	9.17E+04	4.29E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Nitzschia* spp.	Bacillariophyta	9	1.38E+05	6.60E+06	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Rhizosolenia* sp.	Bacillariophyta	2	3.06E+04	6.66E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	cf. *Thalassiosira* sp.	Bacillariophyta	84	1.28E+06	3.23E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Thalassiosira visurgis*	Bacillariophyta	4	6.11E+04	1.92E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	*Chlorella* sp.	Chlorophyta	264	4.03E+06	3.30E+07	Moderate sediment.
STN8PPB	8/19/2013	14:57	cf. *Ochromonas* sp.	Chrysophyta	8	1.22E+05	6.40E+06	Moderate sediment.
			TOTAL		404	6.17E+06	3.52E+08	

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN8PPC	8/19/2013	14:57	*Achnanthidium minutissimum*	Bacillariophyta	1	7.64E+03	1.32E+05	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Craticula* cf. *molestiformis*	Bacillariophyta	4	3.06E+04	5.76E+06	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Cyclotella striata*	Bacillariophyta	12	9.17E+04	2.08E+08	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Diploneis* sp.	Bacillariophyta	1	7.64E+03	2.62E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	cf. *Luticola nivalis*	Bacillariophyta	1	7.64E+03	3.60E+06	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Navicula cryptotenella*	Bacillariophyta	7	5.35E+04	1.51E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Nitzschia* spp.	Bacillariophyta	25	1.91E+05	1.83E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Thalassiosira eccentrica*	Bacillariophyta	2	1.53E+04	5.23E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	cf. *Thalassiosira* sp.	Bacillariophyta	90	6.88E+05	5.83E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Thalassiosira visurgis*	Bacillariophyta	18	1.38E+05	6.84E+08	Moderate sediment.
STN8PPC	8/19/2013	14:57	cf. *Tryblionella* sp.	Bacillariophyta	1	7.64E+03	1.10E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Chlorella* spp.	Chlorophyta	225	1.72E+06	5.76E+07	Moderate sediment.
STN8PPC	8/19/2013	14:57	cf. *Ochromonas* sp.	Chrysophyta	10	7.64E+04	4.00E+06	Moderate sediment.
STN8PPC	8/19/2013	14:57	*Rhodomonas* sp.	Cryptophyta	5	3.82E+04	8.32E+06	Moderate sediment.
STN8PPC	8/19/2013	14:57	cf. *Gymnodinium discoidale*	Pyrrophyta	4	3.06E+04	4.32E+06	Moderate sediment.
			TOTAL		406	3.10E+06	1.16E+09	
STN9PPA	8/22/2013	11:45	*Amphiprora* sp.	Bacillariophyta	1	2.14E+04	8.43E+07	High sediment.
STN9PPA	8/22/2013	11:45	*Ceratoneis closterium*	Bacillariophyta	1	2.14E+04	4.04E+06	High sediment.
STN9PPA	8/22/2013	11:45	*Ditylum* sp.	Bacillariophyta	1	2.14E+04	5.85E+09	High sediment.
STN9PPA	8/22/2013	11:45	*Fragilariopsis kerguelensis*	Bacillariophyta	1	2.14E+04	1.45E+07	High sediment.
STN9PPA	8/22/2013	11:45	cf. *Hemidiscus cuneiformis*	Bacillariophyta	2	4.28E+04	7.53E+06	High sediment.
STN9PPA	8/22/2013	11:45	*Nitzschia* spp.	Bacillariophyta	6	1.28E+05	5.78E+06	High sediment.
STN9PPA	8/22/2013	11:45	*Odontella aurita*	Bacillariophyta	1	2.14E+04	2.23E+07	High sediment.
STN9PPA	8/22/2013	11:45	*Odontella* sp.	Bacillariophyta	1	2.14E+04	1.92E+08	High sediment.
STN9PPA	8/22/2013	11:45	*Thalassionema* sp.	Bacillariophyta	1	2.14E+04	2.05E+07	High sediment.
STN9PPA	8/22/2013	11:45	*Thalassiosira* sp.	Bacillariophyta	324	6.93E+06	2.61E+08	High sediment.
STN9PPA	8/22/2013	11:45	*Thalassiosira visurgis*	Bacillariophyta	5	1.07E+05	4.20E+07	High sediment.
STN9PPA	8/22/2013	11:45	*Chlorella* sp.	Chlorophyta	224	4.79E+06	3.92E+07	High sediment.
STN9PPA	8/22/2013	11:45	*Mallomonas* sp.	Chrysophyta	1	2.14E+04	3.60E+07	High sediment.
STN9PPA	8/22/2013	11:45	cf. *Ochromonas* sp.	Chrysophyta	1	2.14E+04	1.26E+06	High sediment.
			TOTAL		570	1.22E+07	6.58E+09	
STN9PPB	8/22/2013	11:45	*Cyclotella striata*	Bacillariophyta	7	8.32E+04	1.51E+08	High sediment.
STN9PPB	8/22/2013	11:45	*Cymbella* sp.	Bacillariophyta	1	1.19E+04	4.18E+06	High sediment.
STN9PPB	8/22/2013	11:45	*Nitzschia* spp.	Bacillariophyta	16	1.90E+05	1.48E+07	High sediment.
STN9PPB	8/22/2013	11:45	cf. *Thalassiosira* sp.	Bacillariophyta	278	3.30E+06	2.80E+08	High sediment.
STN9PPB	8/22/2013	11:45	*Thalassiosira visurgis*	Bacillariophyta	6	7.13E+04	1.45E+08	High sediment.
STN9PPB	8/22/2013	11:45	*Chlorella* spp.	Chlorophyta	107	1.27E+06	4.26E+07	High sediment.
STN9PPB	8/22/2013	11:45	cf. *Ochromonas* sp.	Chrysophyta	6	7.13E+04	3.73E+06	High sediment.
STN9PPB	8/22/2013	11:45	*Pseudanabaena* sp.	Cyanobacteria	18	2.14E+05	3.36E+06	High sediment.
STN9PPB	8/22/2013	11:45	cf. *Gymnodinium discoidale*	Pyrrophyta	6	7.13E+04	8.96E+06	High sediment.
			TOTAL		445	5.29E+06	6.54E+08	
STN9PPC	8/22/2013	11:45	*Actinocyclus* cf. *divisus*	Bacillariophyta	1	1.78E+04	1.21E+09	High sediment.
STN9PPC	8/22/2013	11:45	cf. *Actinoptychus* sp.	Bacillariophyta	1	1.78E+04	4.54E+06	High sediment.
STN9PPC	8/22/2013	11:45	*Actinoptychus undulatus*	Bacillariophyta	4	7.13E+04	3.55E+08	High sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN9PPC	8/22/2013	11:45	*Cyclotella striata*	Bacillariophyta	9	1.60E+05	2.26E+08	High sediment.
STN9PPC	8/22/2013	11:45	cf. *Hemidiscus cuneiformis*	Bacillariophyta	4	7.13E+04	1.71E+07	High sediment.
STN9PPC	8/22/2013	11:45	*Nitzschia granulata*	Bacillariophyta	1	1.78E+04	1.37E+07	High sediment.
STN9PPC	8/22/2013	11:45	*Nitzschia* spp.	Bacillariophyta	6	1.07E+05	1.09E+07	High sediment.
STN9PPC	8/22/2013	11:45	*Pseudo-nitzschia* sp.	Bacillariophyta	6	1.07E+05	5.13E+06	High sediment.
STN9PPC	8/22/2013	11:45	*Thalassiosira* cf. *baltica*	Bacillariophyta	2	3.56E+04	7.28E+07	High sediment.
STN9PPC	8/22/2013	11:45	cf. *Thalassiosira* sp.	Bacillariophyta	256	4.56E+06	5.16E+08	High sediment.
STN9PPC	8/22/2013	11:45	*Thalassiosira visurgis*	Bacillariophyta	1	1.78E+04	1.41E+07	High sediment.
STN9PPC	8/22/2013	11:45	*Chlorella* spp.	Chlorophyta	111	1.98E+06	6.63E+07	High sediment.
STN9PPC	8/22/2013	11:45	*Rhodomonas* sp.	Cryptophyta	1	1.78E+04	3.88E+06	High sediment.
STN9PPC	8/22/2013	11:45	cf. *Gymnodinium discoidale*	Pyrrophyta	4	7.13E+04	8.96E+06	High sediment.
			TOTAL		407	7.25E+06	2.52E+09	
STN10PPA	8/22/2013	15:07	*Actinocyclus* cf. *divisus*	Bacillariophyta	22	3.62E+05	1.79E+09	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Bacillaria paxillifer*	Bacillariophyta	2	3.29E+04	4.25E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Cocconeis* sp.	Bacillariophyta	8	1.32E+05	3.47E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Cyclotella ocellata*	Bacillariophyta	4	6.58E+04	3.75E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Cyclotella striata*	Bacillariophyta	24	3.95E+05	8.96E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Diploneis* sp.	Bacillariophyta	4	6.58E+04	7.60E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Fragilariopsis kerguelensis*	Bacillariophyta	23	3.78E+05	2.85E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Navicula* sp.	Bacillariophyta	2	3.29E+04	2.79E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Nitzschia* spp.	Bacillariophyta	25	4.11E+05	1.33E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Odontella aurita*	Bacillariophyta	6	9.87E+04	1.16E+09	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Odontella* sp.	Bacillariophyta	1	1.65E+04	3.65E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Opephora* sp.	Bacillariophyta	2	3.29E+04	2.02E+06	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Paralia* cf. *sulcata*	Bacillariophyta	14	2.30E+05	1.31E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Pseudostaurosira brevistriata*	Bacillariophyta	18	2.96E+05	5.44E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Rhaphoneis* sp.	Bacillariophyta	4	6.58E+04	1.67E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Schuettia annulata*	Bacillariophyta	1	1.65E+04	8.75E+07	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Staurosirella pinnata*	Bacillariophyta	17	2.80E+05	5.93E+06	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Thalassiosira eccentrica*	Bacillariophyta	22	3.62E+05	1.10E+09	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	cf. *Thalassiosira* sp.	Bacillariophyta	237	3.90E+06	2.30E+08	Very High sediment. Many broken diatoms.
STN10PPA	8/22/2013	15:07	*Thalassiosira visurgis*	Bacillariophyta	16	2.63E+05	1.24E+08	Very High sediment. Many broken diatoms.
			TOTAL		452	7.44E+06	6.75E+09	
STN10PPB	8/22/2013	15:07	*Cyclotella striata*	Bacillariophyta	9	2.47E+05	2.98E+08	Very high sediment.
STN10PPB	8/22/2013	15:07	*Nitzschia granulata*	Bacillariophyta	2	5.48E+04	2.08E+07	Very high sediment.
STN10PPB	8/22/2013	15:07	*Nitzschia* spp.	Bacillariophyta	4	1.10E+05	4.28E+06	Very high sediment.
STN10PPB	8/22/2013	15:07	*Thalassionema* sp.	Bacillariophyta	4	1.10E+05	1.81E+07	Very high sediment.
STN10PPB	8/22/2013	15:07	*Thalassiosira* sp.	Bacillariophyta	66	1.81E+06	4.55E+07	Very high sediment.
STN10PPB	8/22/2013	15:07	*Thalassiosira visurgis*	Bacillariophyta	16	4.39E+05	1.72E+08	Very high sediment.
STN10PPB	8/22/2013	15:07	*Chlorella* sp.	Chlorophyta	301	8.25E+06	6.75E+07	Very high sediment.
			TOTAL		402	1.10E+07	6.26E+08	
STN10PPC	8/22/2013	15:07	*Actinocyclus* cf. *divisus*	Bacillariophyta	4	6.11E+04	1.77E+09	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Actinoptychus s* sp.	Bacillariophyta	1	1.53E+04	1.31E+08	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Asterionella formosa*	Bacillariophyta	1	1.53E+04	1.14E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Campyloneis* sp.	Bacillariophyta	2	3.06E+04	3.06E+07	Very High sediment. Many broken diatoms.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN10PPC	8/22/2013	15:07	*Cocconeis placentula*	Bacillariophyta	2	3.06E+04	2.12E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Coscinodiscus* sp.	Bacillariophyta	7	1.07E+05	8.39E+09	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Cyclotella meneghiniana*	Bacillariophyta	2	3.06E+04	1.74E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Cyclotella ocellata*	Bacillariophyta	1	1.53E+04	7.20E+06	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Cyclotella striata*	Bacillariophyta	26	3.97E+05	3.16E+08	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Nitzschia inconspicua*	Bacillariophyta	2	3.06E+04	7.33E+05	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Nitzschia punctata*	Bacillariophyta	4	6.11E+04	2.02E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Nitzschia* spp.	Bacillariophyta	8	1.22E+05	3.21E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Odontella aurita*	Bacillariophyta	2	3.06E+04	2.50E+08	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Odontella* spp.	Bacillariophyta	6	9.17E+04	1.42E+09	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Paralia* cf. *sulcata*	Bacillariophyta	12	1.83E+05	8.64E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Rhaphoneis* sp.	Bacillariophyta	3	4.58E+04	1.88E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Rhizosolenia* sp.	Bacillariophyta	4	6.11E+04	5.96E+08	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Thalassionema* sp.	Bacillariophyta	7	1.07E+05	7.70E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	cf. *Thalassiosira* sp.	Bacillariophyta	161	2.46E+06	2.09E+08	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Thalassiosira visurgis*	Bacillariophyta	7	1.07E+05	4.20E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	cf. *Chlorella* sp.	Chlorophyta	177	2.70E+06	3.82E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Chroomonas* sp.	Cryptophyta	2	3.06E+04	2.70E+07	Very High sediment. Many broken diatoms.
STN10PPC	8/22/2013	15:07	*Rhodomonas* sp.	Cryptophyta	2	3.06E+04	6.66E+06	Very High sediment. Many broken diatoms.
			TOTAL		443	6.77E+06	1.35E+10	
STN11PPA	8/24/2013	13:39	*Amphora* sp.	Bacillariophyta	4	2.67E+04	1.28E+07	High sediment.
STN11PPA	8/24/2013	13:39	cf. *Hemidiscus cuneiformis*	Bacillariophyta	1	6.68E+03	2.46E+06	High sediment.
STN11PPA	8/24/2013	13:39	*Leptocylindrus danicus*	Bacillariophyta	1	6.68E+03	5.04E+07	High sediment.
STN11PPA	8/24/2013	13:39	*Nitzschia granulata*	Bacillariophyta	4	2.67E+04	7.22E+06	High sediment.
STN11PPA	8/24/2013	13:39	*Nitzschia laevis*	Bacillariophyta	1	6.68E+03	2.94E+06	High sediment.
STN11PPA	8/24/2013	13:39	*Nitzschia* sp.	Bacillariophyta	1	6.68E+03	2.34E+05	High sediment.
STN11PPA	8/24/2013	13:39	*Rhizosolenia* sp.	Bacillariophyta	1	6.68E+03	3.19E+07	High sediment.
STN11PPA	8/24/2013	13:39	cf. *Thalassiosira* sp.	Bacillariophyta	225	1.50E+06	1.70E+08	High sediment.
STN11PPA	8/24/2013	13:39	*Thalassiosira visurgis*	Bacillariophyta	2	1.34E+04	7.62E+06	High sediment.
STN11PPA	8/24/2013	13:39	cf. *Chlorella* spp.	Chlorophyta	121	8.09E+05	9.15E+07	High sediment.
STN11PPA	8/24/2013	13:39	*Rhodomonas* spp.	Cryptophyta	47	3.14E+05	6.84E+07	High sediment.
STN11PPA	8/24/2013	13:39	*Gymnodinium* sp.	Pyrrophyta	6	4.01E+04	1.30E+08	High sediment.
			TOTAL		414	2.77E+06	5.75E+08	
STN11PPB	8/24/2013	13:39	*Asterionella formosa*	Bacillariophyta	1	7.64E+03	3.07E+06	High sediment.
STN11PPB	8/24/2013	13:39	*Asterionellopsis glacialis*	Bacillariophyta	39	2.98E+05	8.94E+07	High sediment.
STN11PPB	8/24/2013	13:39	*Campyloneis* sp.	Bacillariophyta	4	3.06E+04	1.03E+07	High sediment.
STN11PPB	8/24/2013	13:39	*Chaetoceros* sp.	Bacillariophyta	4	3.06E+04	1.74E+07	High sediment.
STN11PPB	8/24/2013	13:39	*Cocconeis* sp.	Bacillariophyta	1	7.64E+03	3.17E+06	High sediment.
STN11PPB	8/24/2013	13:39	*Cyclotella ocellata*	Bacillariophyta	14	1.07E+05	4.20E+07	High sediment.
STN11PPB	8/24/2013	13:39	*Cyclotella striata*	Bacillariophyta	2	1.53E+04	9.83E+07	High sediment.
STN11PPB	8/24/2013	13:39	*Fragilariopsis kerguelensis*	Bacillariophyta	32	2.44E+05	4.84E+07	High sediment.
STN11PPB	8/24/2013	13:39	cf. *Hemidiscus cuneiformis*	Bacillariophyta	1	7.64E+03	1.32E+06	High sediment.
STN11PPB	8/24/2013	13:39	*Nitzschia* sp.	Bacillariophyta	2	1.53E+04	2.20E+06	High sediment.
STN11PPB	8/24/2013	13:39	*Odontella aurita*	Bacillariophyta	2	1.53E+04	8.40E+06	High sediment.
STN11PPB	8/24/2013	13:39	cf. *Thalassiosira* sp.	Bacillariophyta	255	1.95E+06	1.15E+08	High sediment.
STN11PPB	8/24/2013	13:39	*Chlorella* sp.	Chlorophyta	65	4.97E+05	7.02E+06	High sediment.
STN11PPB	8/24/2013	13:39	*Rhodomonas* sp.	Cryptophyta	9	6.88E+04	7.13E+06	High sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN11PPB	8/24/2013	13:39	*Gymnodinium discoidale*	Pyrrophyta	1	7.64E+03	1.92E+06	High sediment.
			TOTAL		432	3.30E+06	4.55E+08	
STN11PPC	8/24/2013	13:39	*Asterionellopsis glacialis*	Bacillariophyta	4	2.14E+04	6.42E+06	High sediment.
STN11PPC	8/24/2013	13:39	*Cyclotella striata*	Bacillariophyta	6	3.21E+04	5.16E+07	High sediment.
STN11PPC	8/24/2013	13:39	cf. *Delphineis* sp.	Bacillariophyta	4	2.14E+04	9.07E+06	High sediment.
STN11PPC	8/24/2013	13:39	*Odontella aurita*	Bacillariophyta	1	5.35E+03	1.56E+07	High sediment.
STN11PPC	8/24/2013	13:39	*Pseudo-nitzschia* sp.	Bacillariophyta	23	1.23E+05	5.31E+07	High sediment.
STN11PPC	8/24/2013	13:39	*Thalassionema nitzschioides*	Bacillariophyta	18	9.63E+04	1.16E+07	High sediment.
STN11PPC	8/24/2013	13:39	cf. *Thalassiosira* sp.	Bacillariophyta	220	1.18E+06	1.33E+08	High sediment.
STN11PPC	8/24/2013	13:39	*Thalassiosira visurgis*	Bacillariophyta	7	3.74E+04	2.13E+07	High sediment.
STN11PPC	8/24/2013	13:39	*Chlorella* spp.	Chlorophyta	95	5.08E+05	1.70E+07	High sediment.
STN11PPC	8/24/2013	13:39	*Cryptomonas ovata*	Cryptophyta	1	5.35E+03	1.41E+06	High sediment.
STN11PPC	8/24/2013	13:39	*Rhodomonas* spp.	Cryptophyta	16	8.56E+04	2.54E+07	High sediment.
STN11PPC	8/24/2013	13:39	*Aphanocapsa* sp.	Cyanobacteria	150	8.02E+05	4.20E+05	High sediment.
STN11PPC	8/24/2013	13:39	cf. *Gymnodinium discoidale*	Pyrrophyta	2	1.07E+04	4.70E+06	High sediment.
STN11PPC	8/24/2013	13:39	*Gymnodinium* sp.	Pyrrophyta	1	5.35E+03	1.30E+07	High sediment.
			TOTAL		548	2.93E+06	3.64E+08	
STN12PPA	8/24/2013	10:09	*Actinoptychus* cf. *adriaticus*	Bacillariophyta	1	2.14E+04	1.81E+09	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Bacillaria paxillifer*	Bacillariophyta	24	5.13E+05	3.10E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Cerataulina* sp.	Bacillariophyta	2	4.28E+04	4.39E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Ceratoneis closterium*	Bacillariophyta	1	2.14E+04	1.52E+07	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Cocconeis* sp.	Bacillariophyta	2	4.28E+04	4.44E+06	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Coscinodiscus* sp.	Bacillariophyta	1	2.14E+04	6.06E+09	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Cyclotella striata*	Bacillariophyta	8	1.71E+05	2.06E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	cf. *Delphineis* sp.	Bacillariophyta	7	1.50E+05	4.92E+07	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Fragilariopsis kerguelensis*	Bacillariophyta	83	1.78E+06	3.51E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	cf. *Goniothecium* sp.	Bacillariophyta	1	2.14E+04	4.28E+06	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Nitzschia* spp.	Bacillariophyta	4	8.56E+04	3.39E+07	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Odontella aurita*	Bacillariophyta	3	6.42E+04	4.54E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Paralia* cf. *sulcata*	Bacillariophyta	5	1.07E+05	6.10E+07	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Planothidium oestrupii*	Bacillariophyta	2	4.28E+04	6.05E+06	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Pseudostaurosira brevistriata*	Bacillariophyta	1	2.14E+04	1.97E+06	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Thalassionema* sp.	Bacillariophyta	16	3.42E+05	1.14E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Thalassiosira eccentrica*	Bacillariophyta	7	1.50E+05	8.54E+07	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	cf. *Thalassiosira* sp.	Bacillariophyta	257	5.50E+06	4.66E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Thalassiosira* sp.	Bacillariophyta	5	1.07E+05	5.29E+08	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Chlorella* sp.	Chlorophyta	32	6.84E+05	4.48E+07	High sediment. Many broken diatoms.
STN12PPA	8/24/2013	10:09	*Rhodomonas* sp.	Cryptophyta	1	2.14E+04	1.81E+06	High sediment. Many broken diatoms.
			TOTAL		463	9.90E+06	1.11E+10	
STN12PPB	8/24/2013	10:09	*Actinocyclus* cf. *divisus*	Bacillariophyta	2	3.06E+04	2.46E+08	High sediment.
STN12PPB	8/24/2013	10:09	*Chaetoceros* cf. *peruvianus*	Bacillariophyta	2	3.06E+04	6.76E+07	High sediment.
STN12PPB	8/24/2013	10:09	*Cyclotella striata*	Bacillariophyta	6	9.17E+04	2.49E+08	High sediment.
STN12PPB	8/24/2013	10:09	*Delphineis* sp.	Bacillariophyta	5	7.64E+04	1.87E+07	High sediment.
STN12PPB	8/24/2013	10:09	cf. *Rhaphoneis* sp.	Bacillariophyta	1	1.53E+04	1.15E+07	High sediment.
STN12PPB	8/24/2013	10:09	*Rhizosolenia* sp.	Bacillariophyta	4	6.11E+04	7.68E+08	High sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN12PPB	8/24/2013	10:09	cf. *Staurosirella* sp.	Bacillariophyta	6	9.17E+04	5.04E+06	High sediment.
STN12PPB	8/24/2013	10:09	cf. *Thalassionema* sp.	Bacillariophyta	4	6.11E+04	5.78E+07	High sediment.
STN12PPB	8/24/2013	10:09	*Thalassionema* sp.	Bacillariophyta	50	7.64E+05	1.47E+08	High sediment.
STN12PPB	8/24/2013	10:09	cf. *Thalassiosira* sp.	Bacillariophyta	216	3.30E+06	1.30E+08	High sediment.
STN12PPB	8/24/2013	10:09	*Thalassiosira visurgis*	Bacillariophyta	27	4.13E+05	3.29E+08	High sediment.
STN12PPB	8/24/2013	10:09	*Chlorella* sp.	Chlorophyta	84	1.28E+06	1.05E+07	High sediment.
			TOTAL		407	6.22E+06	2.04E+09	
STN12PPC	8/24/2013	10:09	*Chaetoceros* sp.	Bacillariophyta	6	8.02E+04	2.02E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Cyclotella striata*	Bacillariophyta	8	1.07E+05	4.89E+08	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	cf. *Delphineis* sp.	Bacillariophyta	1	1.34E+04	2.21E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Fragilariopsis* sp.	Bacillariophyta	38	5.08E+05	3.83E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Odontella aurita*	Bacillariophyta	2	2.67E+04	5.91E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	cf. *Staurosirella* sp.	Bacillariophyta	1	1.34E+04	2.94E+05	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Thalassionema nitzschioides*	Bacillariophyta	13	1.74E+05	5.84E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Thalassiosira baltica*	Bacillariophyta	7	9.36E+04	4.66E+08	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	cf. *Thalassiosira* sp.	Bacillariophyta	270	3.61E+06	4.08E+08	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Thalassiosira visurgis*	Bacillariophyta	10	1.34E+05	2.15E+08	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Chlorella* spp.	Chlorophyta	70	9.36E+05	3.14E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	*Rhodomonas* sp.	Cryptophyta	8	1.07E+05	2.33E+07	High sediment. Many broken diatoms.
STN12PPC	8/24/2013	10:09	cf. *Gymnodinium discoidale*	Pyrrophyta	4	5.35E+04	7.56E+06	High sediment. Many broken diatoms.
			TOTAL		438	5.86E+06	1.84E+09	
STN13PPA	8/21/2013	12:50	*Achnanthidium* sp.	Bacillariophyta	6	8.02E+04	3.02E+07	High sediment.
STN13PPA	8/21/2013	12:50	*Asterionellopsis glacialis*	Bacillariophyta	15	2.01E+05	6.02E+07	High sediment.
STN13PPA	8/21/2013	12:50	cf. *Campyloneis* sp.	Bacillariophyta	2	2.67E+04	2.12E+07	High sediment.
STN13PPA	8/21/2013	12:50	*Cerataulina* sp.	Bacillariophyta	1	1.34E+04	1.18E+08	High sediment.
STN13PPA	8/21/2013	12:50	*Chaetoceros* sp.	Bacillariophyta	1	1.34E+04	4.04E+06	High sediment.
STN13PPA	8/21/2013	12:50	*Cyclotella striata*	Bacillariophyta	2	2.67E+04	5.56E+07	High sediment.
STN13PPA	8/21/2013	12:50	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	82	1.10E+06	1.08E+08	High sediment.
STN13PPA	8/21/2013	12:50	cf. *Hemidiscus cuneiformis*	Bacillariophyta	4	5.35E+04	9.10E+06	High sediment.
STN13PPA	8/21/2013	12:50	*Navicula* spp.	Bacillariophyta	4	5.35E+04	8.82E+06	High sediment.
STN13PPA	8/21/2013	12:50	*Nitzschia* spp.	Bacillariophyta	2	2.67E+04	1.93E+06	High sediment.
STN13PPA	8/21/2013	12:50	*Odontella* sp.	Bacillariophyta	2	2.67E+04	5.71E+07	High sediment.
STN13PPA	8/21/2013	12:50	*Paralia* cf. *sulcata*	Bacillariophyta	4	5.35E+04	4.07E+07	High sediment.
STN13PPA	8/21/2013	12:50	*Thalassionema* sp.	Bacillariophyta	6	8.02E+04	1.73E+08	High sediment.
STN13PPA	8/21/2013	12:50	*Thalassiosira eccentrica*	Bacillariophyta	2	2.67E+04	6.10E+07	High sediment.
STN13PPA	8/21/2013	12:50	*Thalassiosira* sp.	Bacillariophyta	188	2.51E+06	6.32E+07	High sediment.
STN13PPA	8/21/2013	12:50	*Thalassiosira visurgis*	Bacillariophyta	25	3.34E+05	1.77E+08	High sediment.
STN13PPA	8/21/2013	12:50	*Chlorella* sp.	Chlorophyta	62	8.29E+05	6.78E+06	High sediment.
STN13PPA	8/21/2013	12:50	cf. *Ochromonas* sp.	Chrysophyta	4	5.35E+04	2.80E+06	High sediment.
			TOTAL		412	5.51E+06	1.00E+09	
STN13PPB	8/21/2013	12:50	*Asterionellopsis glacialis*	Bacillariophyta	5	1.53E+05	4.58E+07	High sediment.
STN13PPB	8/21/2013	12:50	*Chaetoceros* sp.	Bacillariophyta	1	3.06E+04	5.76E+06	High sediment.
STN13PPB	8/21/2013	12:50	*Cocconeis* sp.	Bacillariophyta	1	3.06E+04	2.22E+07	High sediment.
STN13PPB	8/21/2013	12:50	*Coscinodiscus* sp.	Bacillariophyta	1	3.06E+04	1.94E+09	High sediment.
STN13PPB	8/21/2013	12:50	*Cyclotella striata*	Bacillariophyta	1	3.06E+04	1.73E+07	High sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN13PPB	8/21/2013	12:50	*Delphineis* sp.	Bacillariophyta	21	6.42E+05	4.13E+08	High sediment.
STN13PPB	8/21/2013	12:50	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	114	3.48E+06	1.15E+09	High sediment.
STN13PPB	8/21/2013	12:50	cf. *Hemidiscus cuneiformis*	Bacillariophyta	1	3.06E+04	5.57E+06	High sediment.
STN13PPB	8/21/2013	12:50	*Odontella aurita*	Bacillariophyta	2	6.11E+04	2.49E+08	High sediment.
STN13PPB	8/21/2013	12:50	*Rhaphoneis* sp.	Bacillariophyta	1	3.06E+04	1.86E+07	High sediment.
STN13PPB	8/21/2013	12:50	*Rhizosolenia* sp.	Bacillariophyta	1	3.06E+04	4.20E+08	High sediment.
STN13PPB	8/21/2013	12:50	cf. *Staurosirella* sp.	Bacillariophyta	1	3.06E+04	4.80E+05	High sediment.
STN13PPB	8/21/2013	12:50	*Thalassionema nitzschioides*	Bacillariophyta	4	1.22E+05	1.54E+08	High sediment.
STN13PPB	8/21/2013	12:50	*Thalassionema* sp.	Bacillariophyta	8	2.44E+05	2.79E+07	High sediment.
STN13PPB	8/21/2013	12:50	*Thalassiosira eccentrica*	Bacillariophyta	2	6.11E+04	3.46E+08	High sediment.
STN13PPB	8/21/2013	12:50	cf. *Thalassiosira* sp.	Bacillariophyta	234	7.15E+06	6.07E+08	High sediment.
STN13PPB	8/21/2013	12:50	*Thalassiosira* cf. *visurgis*	Bacillariophyta	10	3.06E+05	2.82E+08	High sediment.
STN13PPB	8/21/2013	12:50	cf. *Triceratium* sp.	Bacillariophyta	1	3.06E+04	4.53E+07	High sediment.
STN13PPB	8/21/2013	12:50	*Chlorella* sp.	Chlorophyta	13	3.97E+05	2.60E+07	High sediment.
			TOTAL		422	1.29E+07	5.77E+09	
STN13PPC	8/21/2013	12:50	*Actinocyclus* sp.	Bacillariophyta	1	3.06E+04	1.62E+10	High sediment.
STN13PPC	8/21/2013	12:50	*Aulacoseira* sp.	Bacillariophyta	1	3.06E+04	1.12E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Ceratoneis closterium*	Bacillariophyta	2	6.11E+04	1.47E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Chaetoceros* sp.	Bacillariophyta	7	2.14E+05	5.54E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Cyclotella striata*	Bacillariophyta	2	6.11E+04	9.83E+07	High sediment.
STN13PPC	8/21/2013	12:50	cf. *Cymatosira lorenziana*	Bacillariophyta	4	1.22E+05	3.48E+07	High sediment.
STN13PPC	8/21/2013	12:50	cf. *Delphineis* sp.	Bacillariophyta	5	1.53E+05	4.61E+07	High sediment.
STN13PPC	8/21/2013	12:50	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	70	2.14E+06	4.20E+08	High sediment.
STN13PPC	8/21/2013	12:50	cf. *Hemidiscus cuneiformis*	Bacillariophyta	1	3.06E+04	7.55E+06	High sediment.
STN13PPC	8/21/2013	12:50	*Navicula* sp.	Bacillariophyta	1	3.06E+04	9.17E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Nitzschia* spp.	Bacillariophyta	9	2.75E+05	2.68E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Odontella aurita*	Bacillariophyta	2	6.11E+04	1.18E+08	High sediment.
STN13PPC	8/21/2013	12:50	*Rhizosolenia* sp.	Bacillariophyta	2	6.11E+04	2.75E+08	High sediment.
STN13PPC	8/21/2013	12:50	*Thalassionema nitzschioides*	Bacillariophyta	5	1.53E+05	4.03E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Thalassionema* sp.	Bacillariophyta	9	2.75E+05	6.60E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Thalassiosira eccentrica*	Bacillariophyta	2	6.11E+04	7.37E+07	High sediment.
STN13PPC	8/21/2013	12:50	cf. *Thalassiosira* sp.	Bacillariophyta	235	7.18E+06	1.02E+08	High sediment.
STN13PPC	8/21/2013	12:50	*Thalassiosira visurgis*	Bacillariophyta	16	4.89E+05	3.76E+08	High sediment.
STN13PPC	8/21/2013	12:50	*Chlorella* sp.	Chlorophyta	30	9.17E+05	1.30E+07	High sediment.
STN13PPC	8/21/2013	12:50	*Gymnodinium discoidale*	Pyrrophyta	1	3.06E+04	1.60E+07	High sediment.
			TOTAL		405	1.24E+07	1.81E+10	
STN14PPA	8/24/2013	12:40	*Chaetoceros* sp.	Bacillariophyta	4	3.89E+04	7.82E+06	High sediment.
STN14PPA	8/24/2013	12:40	*Cyclotella striata*	Bacillariophyta	4	3.89E+04	1.78E+08	High sediment.
STN14PPA	8/24/2013	12:40	cf. *Delphineis* sp.	Bacillariophyta	4	3.89E+04	1.95E+07	High sediment.
STN14PPA	8/24/2013	12:40	*Fragilariopsis* sp.	Bacillariophyta	26	2.53E+05	1.19E+07	High sediment.
STN14PPA	8/24/2013	12:40	*Nitzschia laevis*	Bacillariophyta	1	9.72E+03	8.75E+05	High sediment.
STN14PPA	8/24/2013	12:40	*Pseudo-nitzschia* sp.	Bacillariophyta	12	1.17E+05	3.01E+07	High sediment.
STN14PPA	8/24/2013	12:40	*Skeletonema* sp.	Bacillariophyta	4	3.89E+04	2.69E+07	High sediment.
STN14PPA	8/24/2013	12:40	*Thalassionema nitzschioides*	Bacillariophyta	7	6.81E+04	1.91E+06	High sediment.
STN14PPA	8/24/2013	12:40	cf. *Thalassiosira* sp.	Bacillariophyta	186	1.81E+06	2.05E+08	High sediment.
STN14PPA	8/24/2013	12:40	*Thalassiosira visurgis*	Bacillariophyta	8	7.78E+04	1.59E+08	High sediment.
STN14PPA	8/24/2013	12:40	*Chlorella* spp.	Chlorophyta	137	1.33E+06	8.72E+07	High sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN14PPA	8/24/2013	12:40	*Rhodomonas* spp.	Cryptophyta	15	1.46E+05	4.33E+07	High sediment.
STN14PPA	8/24/2013	12:40	cf. *Gymnodinium discoidale*	Pyrrophyta	1	9.72E+03	1.10E+06	High sediment.
STN14PPA	8/24/2013	12:40	*Gymnodinium* sp.	Pyrrophyta	1	9.72E+03	2.48E+07	High sediment.
			TOTAL		410	3.99E+06	7.97E+08	
STN14PPB	8/24/2013	12:40	cf. *Amphiprora* sp.	Bacillariophyta	1	1.94E+04	1.33E+08	High sediment.
STN14PPB	8/24/2013	12:40	*Asterionellopsis glacialis*	Bacillariophyta	5	9.72E+04	1.87E+07	High sediment.
STN14PPB	8/24/2013	12:40	*Chaetoceros* sp.	Bacillariophyta	2	3.89E+04	7.33E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Cyclotella striata*	Bacillariophyta	6	1.17E+05	3.17E+08	High sediment.
STN14PPB	8/24/2013	12:40	cf. *Delphineis* sp.	Bacillariophyta	2	3.89E+04	6.05E+06	High sediment.
STN14PPB	8/24/2013	12:40	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	77	1.50E+06	2.47E+08	High sediment.
STN14PPB	8/24/2013	12:40	*Nitzschia* sp.	Bacillariophyta	2	3.89E+04	5.64E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Odontella aurita*	Bacillariophyta	2	3.89E+04	4.84E+07	High sediment.
STN14PPB	8/24/2013	12:40	*Paralia* cf. *sulcata*	Bacillariophyta	2	3.89E+04	9.77E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Rhopalodia* sp.	Bacillariophyta	2	3.89E+04	5.45E+06	High sediment.
STN14PPB	8/24/2013	12:40	cf. *Staurosirella* sp.	Bacillariophyta	1	1.94E+04	1.01E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Thalassionema nitzschioides*	Bacillariophyta	3	5.83E+04	8.31E+07	High sediment.
STN14PPB	8/24/2013	12:40	*Thalassionema* sp.	Bacillariophyta	4	7.78E+04	8.87E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Thalassiosira eccentrica*	Bacillariophyta	3	5.83E+04	1.00E+09	High sediment.
STN14PPB	8/24/2013	12:40	cf. *Thalassiosira* sp.	Bacillariophyta	229	4.45E+06	3.78E+08	High sediment.
STN14PPB	8/24/2013	12:40	*Thalassiosira visurgis*	Bacillariophyta	21	4.08E+05	2.71E+08	High sediment.
STN14PPB	8/24/2013	12:40	*Tryblionella constricta*	Bacillariophyta	1	1.94E+04	1.36E+07	High sediment.
STN14PPB	8/24/2013	12:40	*Chlorella* sp.	Chlorophyta	42	8.17E+05	2.74E+07	High sediment.
STN14PPB	8/24/2013	12:40	*Rhodomonas* sp.	Cryptophyta	1	1.94E+04	3.58E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Gymnodinium discoidale*	Pyrrophyta	5	9.72E+04	6.11E+06	High sediment.
STN14PPB	8/24/2013	12:40	*Gymnodinium* sp.	Pyrrophyta	2	3.89E+04	1.51E+08	High sediment.
			TOTAL		413	8.03E+06	2.74E+09	
STN14PPC	8/24/2013	12:40	*Achnanthes* sp.	Bacillariophyta	2	1.34E+04	1.39E+06	High sediment.
STN14PPC	8/24/2013	12:40	*Actinocyclus* cf. *divisus*	Bacillariophyta	4	2.67E+04	4.84E+08	High sediment.
STN14PPC	8/24/2013	12:40	cf. *Campyloneis* sp.	Bacillariophyta	4	2.67E+04	2.62E+07	High sediment.
STN14PPC	8/24/2013	12:40	*Cyclotella striata*	Bacillariophyta	1	6.68E+03	1.14E+07	High sediment.
STN14PPC	8/24/2013	12:40	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	22	1.47E+05	1.94E+07	High sediment.
STN14PPC	8/24/2013	12:40	*Odontella* sp.	Bacillariophyta	1	6.68E+03	8.27E+07	High sediment.
STN14PPC	8/24/2013	12:40	cf. *Rhaphoneis* sp.	Bacillariophyta	4	2.67E+04	7.62E+06	High sediment.
STN14PPC	8/24/2013	12:40	*Thalassionema* sp.	Bacillariophyta	19	1.27E+05	5.14E+07	High sediment.
STN14PPC	8/24/2013	12:40	cf. *Thalassiosira* sp.	Bacillariophyta	208	1.26E+06	3.16E+07	High sediment.
STN14PPC	8/24/2013	12:40	*Thalassiosira visurgis*	Bacillariophyta	8	5.35E+04	3.05E+07	High sediment.
STN14PPC	8/24/2013	12:40	*Chlorella* sp.	Chlorophyta	118	7.35E+05	6.02E+06	High sediment.
STN14PPC	8/24/2013	12:40	cf. *Ochromonas* sp.	Chrysophyta	8	5.35E+04	3.15E+06	High sediment.
STN14PPC	8/24/2013	12:40	*Ceratium hirundinella*	Pyrrophyta	2	1.34E+04	2.41E+08	High sediment.
			TOTAL		401	2.49E+06	9.96E+08	
STN15PPA	8/27/2013	10:40	*Cerataulina* sp.	Bacillariophyta	1	1.19E+04	1.10E+07	Moderate sediment.
STN15PPA	8/27/2013	10:40	*Cyclotella striata*	Bacillariophyta	1	1.19E+04	2.16E+07	Moderate sediment.
STN15PPA	8/27/2013	10:40	cf. *Cymatosira lorenziana*	Bacillariophyta	1	1.19E+04	8.66E+06	Moderate sediment.
STN15PPA	8/27/2013	10:40	cf. *Delphineis* sp.	Bacillariophyta	4	4.75E+04	1.10E+07	Moderate sediment.
STN15PPA	8/27/2013	10:40	*Fragilariopsis* sp.	Bacillariophyta	31	3.68E+05	2.78E+07	Moderate sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN15PPA	8/27/2013	10:40	*Navicula* sp.	Bacillariophyta	2	2.38E+04	9.74E+06	Moderate sediment.
STN15PPA	8/27/2013	10:40	*Thalassionema nitzschioides*	Bacillariophyta	1	1.19E+04	1.50E+06	Moderate sediment.
STN15PPA	8/27/2013	10:40	cf. *Thalassiosira* sp.	Bacillariophyta	314	3.73E+06	4.22E+08	Moderate sediment.
STN15PPA	8/27/2013	10:40	*Thalassiosira visurgis*	Bacillariophyta	5	5.94E+04	5.52E+07	Moderate sediment.
STN15PPA	8/27/2013	10:40	*Chlorella* spp.	Chlorophyta	58	6.89E+05	7.79E+07	Moderate sediment.
STN15PPA	8/27/2013	10:40	*Rhodomonas* sp.	Cryptophyta	1	1.19E+04	2.59E+06	Moderate sediment.
STN15PPA	8/27/2013	10:40	cf. *Gymnodinium discoidale*	Pyrrophyta	4	4.75E+04	1.10E+07	Moderate sediment.
			TOTAL		423	5.03E+06	6.60E+08	
STN15PPB	8/27/2013	10:40	*Campyloneis* sp.	Bacillariophyta	2	2.14E+04	2.66E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Ceratoneis closterium*	Bacillariophyta	1	1.07E+04	1.03E+06	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Chaetoceros* sp.	Bacillariophyta	4	4.28E+04	6.72E+06	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Cyclotella striata*	Bacillariophyta	4	4.28E+04	8.89E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	cf. *Delphineis* sp.	Bacillariophyta	2	2.14E+04	3.33E+06	Moderate sediment.
STN15PPB	8/27/2013	10:40	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	13	1.39E+05	3.11E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Fragilariopsis* sp.	Bacillariophyta	6	6.42E+04	6.05E+06	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Navicula* sp.	Bacillariophyta	2	2.14E+04	1.75E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Nitzschia* sp.	Bacillariophyta	1	1.07E+04	8.82E+05	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Rhaphoneis* sp.	Bacillariophyta	1	1.07E+04	3.71E+06	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Skeletonema* sp.	Bacillariophyta	22	2.35E+05	6.01E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Thalassionema nitzschioides*	Bacillariophyta	6	6.42E+04	1.72E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	cf. *Thalassiosira* sp.	Bacillariophyta	277	2.96E+06	1.75E+08	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Thalassiosira visurgis*	Bacillariophyta	24	2.57E+05	3.50E+08	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Chlorella* sp.	Chlorophyta	51	5.45E+05	1.83E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	cf. *Ochromonas* sp.	Chrysophyta	4	4.28E+04	2.24E+06	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Rhodomonas* sp.	Cryptophyta	2	2.14E+04	1.15E+07	Moderate sediment.
STN15PPB	8/27/2013	10:40	*Gymnodinium discoidale*	Pyrrophyta	4	4.28E+04	3.36E+06	Moderate sediment.
			TOTAL		426	4.56E+06	8.23E+08	
STN15PPC	8/27/2013	10:40	*Asterionellopsis glacialis*	Bacillariophyta	22	2.61E+05	2.38E+08	Moderate sediment.
STN15PPC	8/27/2013	10:40	cf. *Delphineis* sp.	Bacillariophyta	9	1.07E+05	3.45E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	*Fragilariopsis* sp.	Bacillariophyta	29	3.45E+05	6.17E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	*Rhizosolenia* sp.	Bacillariophyta	4	4.75E+04	8.47E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	*Thalassionema nitzschioides*	Bacillariophyta	12	1.43E+05	4.96E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	cf. *Thalassiosira* sp.	Bacillariophyta	236	2.80E+06	3.17E+08	Moderate sediment.
STN15PPC	8/27/2013	10:40	*Chlamydomonas* sp.	Chlorophyta	10	1.19E+05	2.09E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	*Chlorella* spp.	Chlorophyta	67	7.96E+05	2.67E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	*Rhodomonas* sp.	Cryptophyta	12	1.43E+05	4.23E+07	Moderate sediment.
STN15PPC	8/27/2013	10:40	cf. *Gymnodinium discoidale*	Pyrrophyta	4	4.75E+04	8.71E+06	Moderate sediment.
			TOTAL		405	4.81E+06	8.84E+08	
STN16PPA	8/26/2013	13:29	*Ceratoneis closterium*	Bacillariophyta	1	1.07E+04	2.17E+06	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Chaetoceros* sp.	Bacillariophyta	1	1.07E+04	1.26E+06	Moderate sediment.
STN16PPA	8/26/2013	13:29	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	27	2.89E+05	1.09E+08	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Fragilariopsis* sp.	Bacillariophyta	4	4.28E+04	4.03E+06	Moderate sediment.
STN16PPA	8/26/2013	13:29	cf. *Hemidiscus cuneiformis*	Bacillariophyta	4	4.28E+04	7.53E+06	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Navicula* sp.	Bacillariophyta	6	6.42E+04	4.54E+07	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Paralia* cf. *sulcata*	Bacillariophyta	24	2.57E+05	2.04E+08	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Pleurosigma salinarum*	Bacillariophyta	2	2.14E+04	1.55E+08	Moderate sediment.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN16PPA	8/26/2013	13:29	*Thalassiosira eccentrica*	Bacillariophyta	7	7.49E+04	5.29E+08	Moderate sediment.
STN16PPA	8/26/2013	13:29	cf. *Thalassiosira* sp.	Bacillariophyta	282	3.02E+06	1.78E+08	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Thalassiosira visurgis*	Bacillariophyta	20	2.14E+05	1.02E+08	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Chlorella* sp.	Chlorophyta	24	2.57E+05	8.60E+06	Moderate sediment.
STN16PPA	8/26/2013	13:29	cf. *Ochromonas* sp.	Chrysophyta	12	1.28E+05	3.76E+06	Moderate sediment.
STN16PPA	8/26/2013	13:29	*Gymnodinium* sp.	Pyrrophyta	4	4.28E+04	9.66E+07	Moderate sediment.
			TOTAL		418	4.47E+06	1.45E+09	
STN16PPB	8/26/2013	13:29	*Achnanthes* sp.	Bacillariophyta	2	1.53E+04	1.58E+06	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Asterionellopsis glacialis*	Bacillariophyta	8	6.11E+04	3.50E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	cf. *Campyloneis* sp.	Bacillariophyta	2	1.53E+04	3.11E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Ceratoneis closterium*	Bacillariophyta	2	1.53E+04	2.90E+05	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Cyclotella striata*	Bacillariophyta	2	1.53E+04	4.15E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Fragilariopsis* cf. *kerguelensis*	Bacillariophyta	20	1.53E+05	1.73E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	cf. *Hemidiscus cuneiformis*	Bacillariophyta	4	3.06E+04	4.71E+06	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Odontella* sp.	Bacillariophyta	2	1.53E+04	3.73E+08	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Thalassionema* sp.	Bacillariophyta	14	1.07E+05	2.02E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Thalassiosira eccentrica*	Bacillariophyta	2	1.53E+04	7.37E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	cf. *Thalassiosira* sp.	Bacillariophyta	295	2.25E+06	5.66E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Thalassiosira visurgis*	Bacillariophyta	7	5.35E+04	2.52E+07	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Chlorella* sp.	Chlorophyta	27	2.06E+05	1.69E+06	Moderate sediment.
STN16PPB	8/26/2013	13:29	cf. *Ochromonas* sp.	Chrysophyta	12	9.17E+04	5.40E+06	Moderate sediment.
STN16PPB	8/26/2013	13:29	*Peridinium* sp.	Pyrrophyta	2	1.53E+04	3.88E+07	Moderate sediment.
			TOTAL		401	3.06E+06	7.26E+08	
STN16PPC	8/26/2013	13:29	*Chaetoceros* sp.	Bacillariophyta	4	3.29E+04	1.88E+07	Moderate sediment.
STN16PPC	8/26/2013	13:29	*Cyclotella striata*	Bacillariophyta	8	6.58E+04	8.11E+07	Moderate sediment.
STN16PPC	8/26/2013	13:29	*Thalassionema nitzschioides*	Bacillariophyta	12	9.87E+04	1.90E+07	Moderate sediment.
STN16PPC	8/26/2013	13:29	cf. *Thalassiosira* sp.	Bacillariophyta	307	2.53E+06	2.86E+08	Moderate sediment.
STN16PPC	8/26/2013	13:29	*Thalassiosira visurgis*	Bacillariophyta	6	4.94E+04	4.59E+07	Moderate sediment.
STN16PPC	8/26/2013	13:29	*Chlorella* spp.	Chlorophyta	49	4.03E+05	2.64E+07	Moderate sediment.
STN16PPC	8/26/2013	13:29	*Rhodomonas* sp.	Cryptophyta	15	1.23E+05	3.66E+07	Moderate sediment.
STN16PPC	8/26/2013	13:29	cf. *Gymnodinium discoidale*	Pyrrophyta	7	5.76E+04	1.76E+07	Moderate sediment.
			TOTAL		408	3.36E+06	5.31E+08	
STN17PPA	8/26/2013	11:07	*Aulacoseira* sp.	Bacillariophyta	1	3.06E+04	1.38E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Campyloneis* sp.	Bacillariophyta	1	3.06E+04	1.84E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Ceratoneis closterium*	Bacillariophyta	1	3.06E+04	6.19E+06	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Coscinodiscus* sp.	Bacillariophyta	1	3.06E+04	3.93E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Cyclotella striata*	Bacillariophyta	2	6.11E+04	1.86E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	cf. *Cymatosira lorenziana*	Bacillariophyta	3	9.17E+04	5.23E+06	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Delphineis* sp.	Bacillariophyta	2	6.11E+04	2.69E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	cf. *Fragilariopsis kerguelensis*	Bacillariophyta	35	1.07E+06	2.52E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Navicula* sp.	Bacillariophyta	1	3.06E+04	2.16E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Nitzschia granulata*	Bacillariophyta	1	3.06E+04	1.10E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Nitzschia* sp.	Bacillariophyta	4	1.22E+05	2.93E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Odontella aurita*	Bacillariophyta	5	1.53E+05	9.72E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Paralia* cf. *sulcata*	Bacillariophyta	4	1.22E+05	9.29E+07	High sediment. Many broken diatoms.

Table B2-18: Farim Project - Wet Season Phytoplankton Data

STATION	SAMPLE DATE	SAMPLE TIME	GENUS	DIVISION	TALLY REP 1	DENSITY (cells/L) REP 1	TOTAL BV um^3/L	NOTES
STN17PPA	8/26/2013	11:07	*Pseudo-nitzschia* sp.	Bacillariophyta	9	2.75E+05	4.21E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Thalassionema nitzschioides*	Bacillariophyta	3	9.17E+04	1.09E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Thalassionema* sp.	Bacillariophyta	10	3.06E+05	4.58E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Thalassiosira eccentrica*	Bacillariophyta	5	1.53E+05	1.18E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	cf. *Thalassiosira* sp.	Bacillariophyta	252	7.70E+06	4.54E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Thalassiosira visurgis*	Bacillariophyta	13	3.97E+05	1.35E+08	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Chlorella* sp.	Chlorophyta	43	1.31E+06	4.40E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	cf. *Ochromonas* sp.	Chrysophyta	15	4.58E+05	1.34E+07	High sediment. Many broken diatoms.
STN17PPA	8/26/2013	11:07	*Gymnodinium discoidale*	Pyrrophyta	1	3.06E+04	1.13E+07	High sediment. Many broken diatoms.
			TOTAL		412	1.26E+07	3.38E+09	
STN17PPB	8/26/2013	11:07	cf. *Delphineis* sp.	Bacillariophyta	6	9.87E+04	1.40E+07	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Diploneis* sp.	Bacillariophyta	1	1.65E+04	2.65E+07	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Fragilariopsis* sp.	Bacillariophyta	39	6.42E+05	4.23E+07	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	cf. *Hemidiscus cuneiformis*	Bacillariophyta	3	4.94E+04	2.17E+07	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Nitzschia granulata*	Bacillariophyta	2	3.29E+04	2.89E+07	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Odontella aurita*	Bacillariophyta	2	3.29E+04	1.64E+08	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Paralia* cf. *sulcata*	Bacillariophyta	4	6.58E+04	1.19E+08	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	cf. *Staurosirella* sp.	Bacillariophyta	1	1.65E+04	4.91E+05	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Thalassionema nitzschioides*	Bacillariophyta	22	3.62E+05	2.39E+07	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	cf. *Thalassiosira* sp.	Bacillariophyta	275	4.52E+06	5.12E+08	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Thalassiosira visurgis*	Bacillariophyta	4	6.58E+04	1.49E+08	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Chlamydomonas* sp.	Chlorophyta	3	4.94E+04	4.65E+06	High sediment. Many broken diatoms.
STN17PPB	8/26/2013	11:07	*Chlorella* spp.	Chlorophyta	59	9.71E+05	6.35E+07	High sediment. Many broken diatoms.
			TOTAL		421	6.93E+06	1.17E+09	
STN17PPC	8/26/2013	11:07	*Achnanthes* sp.	Bacillariophyta	4	8.56E+04	1.21E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Cerataulina* sp.	Bacillariophyta	1	2.14E+04	2.41E+08	High sediment.
STN17PPC	8/26/2013	11:07	*Chaetoceros* sp.	Bacillariophyta	12	2.57E+05	8.06E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Cyclotella striata*	Bacillariophyta	9	1.93E+05	4.00E+08	High sediment.
STN17PPC	8/26/2013	11:07	*Fragilariopsis* cf. *kerguelensis*	Bacillariophyta	80	1.71E+06	1.33E+08	High sediment.
STN17PPC	8/26/2013	11:07	cf. *Hemidiscus cuneiformis*	Bacillariophyta	2	4.28E+04	2.66E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Navicula* spp.	Bacillariophyta	2	4.28E+04	4.19E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Odontella* sp.	Bacillariophyta	1	2.14E+04	2.63E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Paralia* cf. *sulcata*	Bacillariophyta	7	1.50E+05	7.11E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Thalassionema nitzschioides*	Bacillariophyta	6	1.28E+05	4.04E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Thalassionema* sp.	Bacillariophyta	8	1.71E+05	1.64E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Thalassiosira eccentrica*	Bacillariophyta	1	2.14E+04	5.81E+07	High sediment.
STN17PPC	8/26/2013	11:07	cf. *Thalassiosira* sp.	Bacillariophyta	173	3.70E+06	9.30E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Thalassiosira visurgis*	Bacillariophyta	9	1.93E+05	5.49E+07	High sediment.
STN17PPC	8/26/2013	11:07	*Chlorella* sp.	Chlorophyta	79	1.69E+06	1.38E+07	High sediment.
STN17PPC	8/26/2013	11:07	cf. *Ochromonas* sp.	Chrysophyta	6	1.28E+05	7.56E+06	High sediment.
			TOTAL		400	8.56E+06	1.32E+09	

APPENDIX F3

Zooplankton Data (Dry Season and Wet Season)

January 2014
Report No. 13514950200.550/B.0

Table C1-1: Farim Project -- Dry Season -- Station 1 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN1	14-May-2013	Acartia	sp.	Copepoda	2.93	30	207.11	349	4.0	0.42	7	2.949	2.651	7.818
		Acartia	sp.	Copepoda	2.77	30	195.80	280	4.0	0.36	10	3.575	2.651	9.478
		Acartia	sp.	Copepoda	3.2	30	226.20	258	3.0	0.38	1	0.380	3.503	1.332
		bivalvia	veliger	Bivalvia	2.93	30	207.11	349	4.0	0.42	90	37.915	0.067	2.533
		bivalvia	veliger larvae	Bivalvia	2.77	30	195.80	280	4.0	0.36	36	12.870	0.022	0.280
		bivalvia	veliger larvae	Bivalvia	3.2	30	226.20	258	3.0	0.38	66	25.093	0.019	0.483
		calanoid	copepodid	Copepoda	2.93	30	207.11	349	4.0	0.42	14	5.898	1.158	6.832
		calanoid	copepodid	Copepoda	2.77	30	195.80	280	4.0	0.36	16	5.720	0.817	4.671
		calanoid	copepodid	Copepoda	3.2	30	226.20	258	3.0	0.38	34	12.927	1.936	25.025
		cyclopoid	copepodid	Copepoda	2.93	30	207.11	349	4.0	0.42	13	5.477	0.373	2.041
		cyclopoid	copepodid	Copepoda	2.77	30	195.80	280	4.0	0.36	12	4.290	0.296	1.272
		cyclopoid	copepodid	Copepoda	3.2	30	226.20	258	3.0	0.38	15	5.703	0.153	0.875
		gastropod	larvae	Bivalvia	2.93	30	207.11	349	4.0	0.42	64	26.962	0.185	4.991
		gastropod	larvae	Bivalvia	2.77	30	195.80	280	4.0	0.36	70	25.026	0.240	5.997
		gastropod	larvae	Bivalvia	3.2	30	226.20	258	3.0	0.38	54	20.531	0.133	2.738
		Halicyclops	sp.	Copepoda	2.93	30	207.11	349	4.0	0.42	3	1.264	1.446	1.827
		Halicyclops	sp.	Copepoda	3.2	30	226.20	258	3.0	0.38	1	0.380	0.785	0.298
		Keratella	tropica	Rotifera	2.93	30	207.11	349	4.0	0.42	7	2.949	0.038	0.113
		Keratella	tropica	Rotifera	2.77	30	195.80	280	4.0	0.36	7	2.503	0.029	0.074
		Keratella	tropica	Rotifera	3.2	30	226.20	258	3.0	0.38	5	1.901	0.022	0.042
		nauplii		Copepoda	2.93	30	207.11	349	4.0	0.42	74	31.174	0.063	1.950
		nauplii		Copepoda	2.77	30	195.80	280	4.0	0.36	83	29.673	0.057	1.700
		nauplii		Copepoda	3.2	30	226.20	258	3.0	0.38	53	20.151	0.033	0.657
		Synchaeta	bicornis	Rotifera	2.93	30	207.11	349	4.0	0.42	2	0.843	0.034	0.029
		Synchaeta	bicornis	Rotifera	2.77	30	195.80	280	4.0	0.36	1	0.358	0.034	0.012
		Trichocerca	pussilla	Rotifera	3.2	30	226.20	258	3.0	0.38	1	0.380	0.000	0.000

Notes: High algae and detritus.
(µg d.w./L) = micrograms dry weight per litre

Table C1-2: Farim Project -- Dry Season -- Station 2 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN2	16-May-2013	Acartia	sp.	Copepoda	4.22	30	298.29	248	3.0	0.28	25	6.928	3.194	22.128
		Acartia	sp.	Copepoda	4.94	30	349.19	204	3.0	0.19	53	10.321	3.076	31.752
		Acartia	sp.	Copepoda	4.19	30	296.17	138	3.0	0.16	126	19.570	2.173	42.516
		bivalvia	veliger larvae	Bivalvia	4.22	30	298.29	248	3.0	0.28	49	13.579	0.247	3.355
		bivalvia	veliger larvae	Bivalvia	4.94	30	349.19	204	3.0	0.19	31	6.037	0.063	0.380
		bivalvia	veliger larvae	Bivalvia	4.19	30	296.17	138	3.0	0.16	31	4.815	0.069	0.334
		calanoid	copepodid	Copepoda	4.22	30	298.29	248	3.0	0.28	34	9.422	2.495	23.508
		calanoid	copepodid	Copepoda	4.94	30	349.19	204	3.0	0.19	32	6.232	2.312	14.405
		calanoid	copepodid	Copepoda	4.19	30	296.17	138	3.0	0.16	100	15.531	2.133	33.128
		cyclopoid	copepodid	Copepoda	4.22	30	298.29	248	3.0	0.28	6	1.663	0.550	0.915
		cyclopoid	copepodid	Copepoda	4.94	30	349.19	204	3.0	0.19	11	2.142	0.711	1.523
		cyclopoid	copepodid	Copepoda	4.19	30	296.17	138	3.0	0.16	7	1.087	0.895	0.973
		gastropod	larvae	Bivalvia	4.22	30	298.29	248	3.0	0.28	34	9.422	0.329	3.101
		gastropod	larvae	Bivalvia	4.94	30	349.19	204	3.0	0.19	48	9.347	0.278	2.600
		gastropod	larvae	Bivalvia	4.19	30	296.17	138	3.0	0.16	56	8.698	0.426	3.704
		Halicyclops	sp.	Copepoda	4.22	30	298.29	248	3.0	0.28	3	0.831	1.081	0.898
		Halicyclops	sp.	Copepoda	4.94	30	349.19	204	3.0	0.19	5	0.974	1.016	0.989
		Halicyclops	sp.	Copepoda	4.19	30	296.17	138	3.0	0.16	2	0.311	1.702	0.529
		Keratella	tropica	Rotifera	4.22	30	298.29	248	3.0	0.28	4	1.109	0.029	0.033
		nauplii		Copepoda	4.22	30	298.29	248	3.0	0.28	47	13.025	0.066	0.865
		nauplii		Copepoda	4.94	30	349.19	204	3.0	0.19	40	7.789	0.065	0.508
		nauplii		Copepoda	4.19	30	296.17	138	3.0	0.16	48	7.455	0.095	0.708
		Synchaeta	bicornis	Rotifera	4.22	30	298.29	248	3.0	0.28	1	0.277	0.028	0.008
		Synchaeta	bicornis	Rotifera	4.19	30	296.17	138	3.0	0.16	1	0.155	0.049	0.008
		Testudinella	sp.	Rotifera	4.22	30	298.29	248	3.0	0.28	1	0.277	0.008	0.002

Notes: High algae and detritus.
(µg d.w./L) = micrograms dry weight per litre

Table C1-3: Farim Project -- Dry Season -- Station 3 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN3	15-May-2013	Acartia	sp.	Copepoda	4.76	30	336.47	309	6.0	0.15	8	1.224	1.264	1.548
		Acartia	sp.	Copepoda	4.76	30	336.47	237	4.0	0.18	6	1.057	2.920	3.085
		Acartia	sp.	Copepoda	4.86	30	343.53	128	2.0	0.19	13	2.422	1.991	4.822
		bivalvia	veliger larvae	Bivalvia	4.76	30	336.47	309	6.0	0.15	85	13.010	0.081	1.051
		bivalvia	veliger larvae	Bivalvia	4.76	30	336.47	237	4.0	0.18	55	9.685	0.031	0.305
		bivalvia	veliger larvae	Bivalvia	4.86	30	343.53	128	2.0	0.19	43	8.011	0.076	0.608
		calanoid	copepodid	Copepoda	4.76	30	336.47	309	6.0	0.15	64	9.796	1.655	16.212
		calanoid	copepodid	Copepoda	4.76	30	336.47	237	4.0	0.18	41	7.220	1.189	8.583
		calanoid	copepodid	Copepoda	4.86	30	343.53	128	2.0	0.19	71	13.227	1.687	22.308
		cyclopoid	copepodid	Copepoda	4.76	30	336.47	309	6.0	0.15	5	0.765	0.258	0.197
		cyclopoid	copepodid	Copepoda	4.76	30	336.47	237	4.0	0.18	3	0.528	0.510	0.269
		cyclopoid	copepodid	Copepoda	4.86	30	343.53	128	2.0	0.19	2	0.373	0.339	0.126
		gastropod	larvae	Bivalvia	4.76	30	336.47	309	6.0	0.15	52	7.959	0.405	3.223
		gastropod	larvae	Bivalvia	4.76	30	336.47	237	4.0	0.18	36	6.339	0.124	0.789
		gastropod	larvae	Bivalvia	4.86	30	343.53	128	2.0	0.19	41	7.638	0.276	2.109
		Halicyclops	sp.	Copepoda	4.76	30	336.47	309	6.0	0.15	3	0.459	1.613	0.741
		Halicyclops	sp.	Copepoda	4.76	30	336.47	237	4.0	0.18	1	0.176	1.987	0.350
		nauplii		Copepoda	4.76	30	336.47	309	6.0	0.15	50	7.653	0.088	0.671
		nauplii		Copepoda	4.76	30	336.47	237	4.0	0.18	57	10.037	0.085	0.858
		nauplii		Copepoda	4.86	30	343.53	128	2.0	0.19	58	10.805	0.075	0.814
		Sabellariidae	trochophore larvae	Polychaeta	4.86	30	343.53	128	2.0	0.19	58	10.805	0.002	0.022
		Synchaeta	spp.	Rotifera	4.76	30	336.47	237	4.0	0.18	1	0.176	0.034	0.006
		Upogebia	zoea	Decapoda	4.76	30	336.47	237	4.0	0.18	1	0.176	0.038	0.007

(µg d.w./L) = micrograms dry weight per litre

Table C1-4: Farim Project -- Dry Season -- Station 4 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN4	15-May-2013	Acartia	sp.	Copepoda	5.56	30	393.01	196	2.0	0.25	3	0.748	3.204	2.396
		Acartia	sp.	Copepoda	5.54	30	391.60	142	3.0	0.12	1	0.121	1.222	0.148
		bivalvia	veliger larvae	Bivalvia	6.75	30	477.13	256	2.0	0.27	60	16.096	0.144	2.317
		bivalvia	veliger larvae	Bivalvia	5.56	30	393.01	196	2.0	0.25	33	8.229	0.063	0.518
		bivalvia	veliger larvae	Bivalvia	5.54	30	391.60	142	3.0	0.12	37	4.472	0.065	0.289
		Brachyura	zoea	Decapoda	5.54	30	391.60	142	3.0	0.12	1	0.121	0.007	0.001
		calanoid	copepodid	Copepoda	6.75	30	477.13	256	2.0	0.27	54	14.487	2.069	29.967
		calanoid	copepodid	Copepoda	5.56	30	393.01	196	2.0	0.25	52	12.966	1.421	18.426
		calanoid	copepodid	Copepoda	5.54	30	391.60	142	3.0	0.12	72	8.703	1.560	13.575
		Caridea	zoea	Decapoda	5.54	30	391.60	142	3.0	0.12	1	0.121	0.029	0.004
		cyclopoid	copepodid	Copepoda	6.75	30	477.13	256	2.0	0.27	2	0.537	0.095	0.051
		cyclopoid	copepodid	Copepoda	5.56	30	393.01	196	2.0	0.25	2	0.499	0.637	0.318
		gastropod	larvae	Bivalvia	6.75	30	477.13	256	2.0	0.27	58	15.560	0.062	0.965
		gastropod	larvae	Bivalvia	5.56	30	393.01	196	2.0	0.25	66	16.457	0.304	5.006
		gastropod	larvae	Bivalvia	5.54	30	391.60	142	3.0	0.12	79	9.549	0.477	4.555
		Halicyclops	sp.	Copepoda	5.54	30	391.60	142	3.0	0.12	1	0.121	1.446	0.175
		Keratella	tropica	Rotifera	6.75	30	477.13	256	2.0	0.27	2	0.537	0.029	0.016
		nauplii		Copepoda	6.75	30	477.13	256	2.0	0.27	47	12.609	0.073	0.924
		nauplii		Copepoda	5.56	30	393.01	196	2.0	0.25	42	10.473	0.089	0.932
		Sabellariidae	trochophore larvae	Polychaeta	6.75	30	477.13	256	2.0	0.27	1	0.268	0.002	0.000
		Sabellariidae	trochophore larvae	Polychaeta	5.56	30	393.01	196	2.0	0.25	3	0.748	0.004	0.003
		Sabellariidae	trochophore larvae	Polychaeta	5.54	30	391.60	142	3.0	0.12	2	0.242	0.002	0.001
		Synchaeta	spp.	Rotifera	6.75	30	477.13	256	2.0	0.27	1	0.268	0.034	0.009

Notes: High algae and detritus.
(µg d.w./L) = micrograms dry weight per litre

Table C1-5: Farim Project -- Dry Season -- Station 5 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN5	16-May-2013	Acartia	sp.	Copepoda	4.35	30	307.48	108	3.0	0.12	1	0.117	2.159	0.253
		Acartia	sp.	Copepoda	6.1	30	431.18	130	2.0	0.15	26	3.919	1.156	4.529
		bivalvia	veliger larvae	Bivalvia	4.35	30	307.48	108	3.0	0.12	108	12.645	0.061	0.772
		bivalvia	veliger larvae	Bivalvia	4.89	30	345.65	174	2.0	0.25	57	14.347	0.055	0.789
		bivalvia	veliger larvae	Bivalvia	6.1	30	431.18	130	2.0	0.15	43	6.482	0.102	0.660
		calanoid	copepodid	Copepoda	4.35	30	307.48	108	3.0	0.12	84	9.835	1.850	18.191
		calanoid	copepodid	Copepoda	4.89	30	345.65	174	2.0	0.25	61	15.353	1.880	28.858
		calanoid	copepodid	Copepoda	6.1	30	431.18	130	2.0	0.15	169	25.476	1.413	36.001
		cyclopoid	copepodid	Copepoda	4.35	30	307.48	108	3.0	0.12	3	0.351	0.310	0.109
		cyclopoid	copepodid	Copepoda	6.1	30	431.18	130	2.0	0.15	3	0.452	0.510	0.231
		gastropod	larvae	Bivalvia	4.35	30	307.48	108	3.0	0.12	169	19.786	0.198	3.922
		gastropod	larvae	Bivalvia	4.89	30	345.65	174	2.0	0.25	85	21.394	0.155	3.319
		gastropod	larvae	Bivalvia	6.1	30	431.18	130	2.0	0.15	57	8.593	0.137	1.177
		Halicyclops	sp.	Copepoda	4.35	30	307.48	108	3.0	0.12	1	0.117	0.472	0.055
		nauplii		Copepoda	4.35	30	307.48	108	3.0	0.12	102	11.942	0.073	0.875
		nauplii		Copepoda	4.89	30	345.65	174	2.0	0.25	37	9.313	0.083	0.776
		Sabellariidae	trochophore larvae	Polychaeta	4.35	30	307.48	108	3.0	0.12	3	0.351	0.002	0.001
		Sabellariidae	trochophore larvae	Polychaeta	4.89	30	345.65	174	2.0	0.25	2	0.503	0.002	0.001
		Sabellariidae	metatrochophore larvae	Polychaeta	6.1	30	431.18	130	2.0	0.15	1	0.151	0.005	0.001
		Sabellariidae	trochophore larvae	Polychaeta	6.1	30	431.18	130	2.0	0.15	3	0.452	0.002	0.001
		Synchaeta	bicornis	Rotifera	4.35	30	307.48	108	3.0	0.12	2	0.234	0.041	0.010
		Upogebia	zoea	Decapoda	6.1	30	431.18	130	2.0	0.15	1	0.151	0.048	0.007

(µg d.w./L) = micrograms dry weight per litre

Table C1-6: Farim Project -- Dry Season -- Station 6 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN6	16-May-2013	Acartia	sp.	Copepoda	4.35	30	307.48	108	3.0	0.12	1	0.117	2.159	0.253
		Acartia	sp.	Copepoda	6.1	30	431.18	130	2.0	0.15	26	3.919	1.156	4.529
		bivalvia	veliger larvae	Bivalvia	4.35	30	307.48	108	3.0	0.12	108	12.645	0.061	0.772
		bivalvia	veliger larvae	Bivalvia	4.89	30	345.65	174	2.0	0.25	57	14.347	0.055	0.789
		bivalvia	veliger larvae	Bivalvia	6.1	30	431.18	130	2.0	0.15	43	6.482	0.102	0.660
		calanoid	copepodid	Copepoda	4.35	30	307.48	108	3.0	0.12	84	9.835	1.850	18.191
		calanoid	copepodid	Copepoda	4.89	30	345.65	174	2.0	0.25	61	15.353	1.880	28.858
		calanoid	copepodid	Copepoda	6.1	30	431.18	130	2.0	0.15	169	25.476	1.413	36.001
		cyclopoid	copepodid	Copepoda	4.35	30	307.48	108	3.0	0.12	3	0.351	0.310	0.109
		cyclopoid	copepodid	Copepoda	6.1	30	431.18	130	2.0	0.15	3	0.452	0.510	0.231
		gastropod	larvae	Bivalvia	4.35	30	307.48	108	3.0	0.12	169	19.786	0.198	3.922
		gastropod	larvae	Bivalvia	4.89	30	345.65	174	2.0	0.25	85	21.394	0.155	3.319
		gastropod	larvae	Bivalvia	6.1	30	431.18	130	2.0	0.15	57	8.593	0.137	1.177
		Halicyclops	sp.	Copepoda	4.35	30	307.48	108	3.0	0.12	1	0.117	0.472	0.055
		nauplii		Copepoda	4.35	30	307.48	108	3.0	0.12	102	11.942	0.073	0.875
		nauplii		Copepoda	4.89	30	345.65	174	2.0	0.25	37	9.313	0.083	0.776
		Sabellariidae	trochophore larvae	Polychaeta	4.35	30	307.48	108	3.0	0.12	3	0.351	0.002	0.001
		Sabellariidae	trochophore larvae	Polychaeta	4.89	30	345.65	174	2.0	0.25	2	0.503	0.002	0.001
		Sabellariidae	metatrochophore larvae	Polychaeta	6.1	30	431.18	130	2.0	0.15	1	0.151	0.005	0.001
		Sabellariidae	trochophore larvae	Polychaeta	6.1	30	431.18	130	2.0	0.15	3	0.452	0.002	0.001
		Synchaeta	bicornis	Rotifera	4.35	30	307.48	108	3.0	0.12	2	0.234	0.041	0.010
		Upogebia	zoea	Decapoda	6.1	30	431.18	130	2.0	0.15	1	0.151	0.048	0.007

(µg d.w./L) = micrograms dry weight per litre

Table C1-7: Farim Project -- Dry Season -- Station 7 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN7	17-May-2013	Acartia	sp.	Copepoda	3.28	30	231.85	158	3.0	0.23	3	0.681	2.651	1.807
		Acartia	sp.	Copepoda	5.43	30	383.82	168	5.0	0.09	1	0.088	1.064	0.093
		Ascidian	tadpole larvae	Polychaeta	4.38	30	309.60	232	4.0	0.19	1	0.187	0.006	0.001
		bivalvia	veliger larvae	Bivalvia	4.38	30	309.60	232	4.0	0.19	1	0.187	0.022	0.004
		bivalvia	veliger larvae	Bivalvia	5.43	30	383.82	168	5.0	0.09	12	1.050	0.157	0.165
		Brachyura	zoea	Decapoda	5.43	30	383.82	168	5.0	0.09	2	0.175	0.071	0.012
		calanoid	copepodid	Copepoda	4.38	30	309.60	232	4.0	0.19	34	6.369	1.164	7.413
		calanoid	copepodid	Copepoda	3.28	30	231.85	158	3.0	0.23	29	6.588	2.524	16.629
		calanoid	copepodid	Copepoda	5.43	30	383.82	168	5.0	0.09	53	4.640	1.526	7.078
		cyclopoid	copepodid	Copepoda	5.43	30	383.82	168	5.0	0.09	1	0.088	0.472	0.041
		gastropod	larvae	Bivalvia	4.38	30	309.60	232	4.0	0.19	22	4.121	0.056	0.231
		gastropod	larvae	Bivalvia	3.28	30	231.85	158	3.0	0.23	49	11.131	0.124	1.382
		gastropod	larvae	Bivalvia	5.43	30	383.82	168	5.0	0.09	26	2.276	0.290	0.660
		Halicyclops	sp.	Copepoda	5.43	30	383.82	168	5.0	0.09	3	0.263	1.367	0.359
		Mysidae	immature	Mysida	5.43	30	383.82	168	5.0	0.09	1	0.088	91.891	8.044
		nauplii		Copepoda	4.38	30	309.60	232	4.0	0.19	64	11.989	0.083	0.989
		nauplii		Copepoda	3.28	30	231.85	158	3.0	0.23	31	7.042	0.053	0.375
		nauplii		Copepoda	5.43	30	383.82	168	5.0	0.09	27	2.364	0.080	0.188
		Oikopleura	sp.	Tunicata	3.28	30	231.85	158	3.0	0.23	3	0.681	0.001	0.000
		Oikopleura	sp.	Tunicata	5.43	30	383.82	168	5.0	0.09	10	0.875	0.004	0.004
		Oithona	sp.	Copepoda	5.43	30	383.82	168	5.0	0.09	2	0.175	1.027	0.180
		Palaemonetes	zoea	Decapoda	5.43	30	383.82	168	5.0	0.09	1	0.088	1.319	0.115
		Paracalanus	parvus	Copepoda	3.28	30	231.85	158	3.0	0.23	7	1.590	1.027	1.633
		Paracalanus	parvus	Copepoda	5.43	30	383.82	168	5.0	0.09	3	0.263	0.755	0.198
		Sabellariidae	trochophore larvae	Polychaeta	4.38	30	309.60	232	4.0	0.19	80	14.987	0.001	0.018
		Sabellariidae	trochophore larvae	Polychaeta	3.28	30	231.85	158	3.0	0.23	124	28.168	0.001	0.030
		Sabellariidae	trochophore larvae	Polychaeta	5.43	30	383.82	168	5.0	0.09	75	6.565	0.002	0.010

Notes: High algae and detritus.
(µg d.w./L) = micrograms dry weight per litre

Table C1-8: Farim Project -- Dry Season -- Station 8 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN8	18-May-2013	ostracod		Ostracoda	3.36	30	237.50	198	18.0	0.05	1	0.046	0.563	0.026
		calanoid	copepodid	Copepoda	3.36	30	237.50	198	18.0	0.05	15	0.695	0.856	0.594
		cyclopoid	copepodid	Copepoda	3.36	30	237.50	198	18.0	0.05	2	0.093	0.108	0.010
		Halicyclops	sp.	Copepoda	3.36	30	237.50	198	18.0	0.05	5	0.232	0.895	0.207
		Paracalanus	parvus	Copepoda	3.36	30	237.50	198	18.0	0.05	2	0.093	1.531	0.142
		nauplii		Copepoda	3.36	30	237.50	198	18.0	0.05	51	2.362	0.052	0.124
		bivalvia	veliger larvae	Bivalvia	3.36	30	237.50	198	18.0	0.05	1	0.046	0.056	0.003
		gastropod	larvae	Bivalvia	3.36	30	237.50	198	18.0	0.05	2	0.093	0.186	0.017
		Brachyura	zoea	Decapoda	3.36	30	237.50	198	18.0	0.05	1	0.046	0.012	0.001
		Anthomedusae		Hydrozoa	3.36	30	237.50	198	18.0	0.05	1	0.046	1.123	0.052
		Ascidian	tadpole larvae	Polychaeta	3.36	30	237.50	198	18.0	0.05	1	0.046	0.002	0.000
		Sabellariidae	trochophore larvae	Polychaeta	3.36	30	237.50	198	18.0	0.05	105	4.863	0.007	0.035
		Chaetognatha			3.36	30	237.50	198	18.0	0.05	5	0.232	0.285	0.066
		Oikopleura	sp.	Tunicata	3.36	30	237.50	198	18.0	0.05	10	0.463	0.015	0.007
		calanoid	copepodid	Copepoda	3.22	30	227.61	250	20.0	0.05	20	1.098	1.112	1.222
		cyclopoid	copepodid	Copepoda	3.22	30	227.61	250	20.0	0.05	1	0.055	0.073	0.004
		Paracalanus	parvus	Copepoda	3.22	30	227.61	250	20.0	0.05	1	0.055	0.818	0.045
		nauplii		Copepoda	3.22	30	227.61	250	20.0	0.05	56	3.075	0.050	0.154
		gastropod	larvae	Bivalvia	3.22	30	227.61	250	20.0	0.05	12	0.659	0.103	0.068
		Sabellariidae	trochophore larvae	Polychaeta	3.22	30	227.61	250	20.0	0.05	112	6.151	0.002	0.010
		Chaetognatha			3.22	30	227.61	250	20.0	0.05	1	0.055	0.030	0.002
		Oikopleura	sp.	Tunicata	3.22	30	227.61	250	20.0	0.05	15	0.824	0.000	0.000
		calanoid	copepodid	Copepoda	2.5	30	176.72	168	16.0	0.06	10	0.594	1.561	0.928
		Halicyclops	sp.	Copepoda	2.5	30	176.72	168	16.0	0.06	2	0.119	1.987	0.236
		Paracalanus	parvus	Copepoda	2.5	30	176.72	168	16.0	0.06	4	0.238	1.142	0.271
		nauplii		Copepoda	2.5	30	176.72	168	16.0	0.06	18	1.070	0.034	0.037
		Anthomedusae		Hydrozoa	2.5	30	176.72	168	16.0	0.06	2	0.119	1.189	0.141
		Sabellariidae	trochophore larvae	Polychaeta	2.5	30	176.72	168	16.0	0.06	136	8.081	0.001	0.011
		Chaetognatha			2.5	30	176.72	168	16.0	0.06	6	0.357	0.116	0.041
		Oikopleura	sp.	Tunicata	2.5	30	176.72	168	16.0	0.06	24	1.426	0.007	0.010

(µg d.w./L) = micrograms dry weight per litre

Table C1-9: Farim Project -- Dry Season -- Station 9 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN9	25-May-2013	Ascidian	tadpole larvae	Polychaeta	1.53	30	108.15	216	20.0	0.10	4	0.399	0.003	0.001
		Balnus	nauplii	Cirripedia	1.53	30	108.15	216	20.0	0.10	12	1.198	0.247	0.296
		Balnus	nauplii	Cirripedia	1.07	30	75.63	92	12.0	0.10	8	0.811	0.140	0.114
		Brachyura	zoea	Decapoda	0.94	30	66.44	149	22.0	0.10	29	2.956	2.006	5.929
		calanoid	copepodid	Copepoda	1.53	30	108.15	216	20.0	0.10	15	1.498	2.658	3.982
		calanoid	copepodid	Copepoda	1.07	30	75.63	92	12.0	0.10	29	2.940	1.241	3.647
		calanoid	copepodid	Copepoda	0.94	30	66.44	149	22.0	0.10	19	1.937	1.735	3.359
		Callianassa	zoea	Decapoda	1.07	30	75.63	92	12.0	0.10	1	0.101	2.582	0.262
		Chaetognatha			0.94	30	66.44	149	22.0	0.10	29	2.956	0.102	0.302
		cyclopoid	copepodid	Copepoda	1.53	30	108.15	216	20.0	0.10	41	4.094	0.445	1.820
		cyclopoid	copepodid	Copepoda	0.94	30	66.44	149	22.0	0.10	86	8.766	0.853	7.478
		Euterpina	acutifrons	Copepoda	1.07	30	75.63	92	12.0	0.10	28	2.838	0.902	2.560
		Euterpina	acutifrons	Copepoda	0.94	30	66.44	149	22.0	0.10	86	8.766	1.339	11.740
		Halicyclops	sp.	Copepoda	1.53	30	108.15	216	20.0	0.10	29	2.896	0.999	2.894
		Halicyclops	sp.	Copepoda	0.94	30	66.44	149	22.0	0.10	10	1.019	2.654	2.705
		harpacticoid		Copepoda	1.07	30	75.63	92	12.0	0.10	84	8.515	0.102	0.871
		Ichthyoplankton		Chordata	0.94	30	66.44	149	22.0	0.10	1	0.102		
		nauplii		Copepoda	1.53	30	108.15	216	20.0	0.10	100	9.986	0.073	0.728
		nauplii		Copepoda	1.07	30	75.63	92	12.0	0.10	69	6.994	0.073	0.508
		Oithona	sp.	Copepoda	1.07	30	75.63	92	12.0	0.10	1	0.101	0.793	0.080
		Oithona	sp.	Copepoda	0.94	30	66.44	149	22.0	0.10	10	1.019	0.996	1.015
		Paracalanus	parvus	Copepoda	1.07	30	75.63	92	12.0	0.10	9	0.912	2.398	2.187
		Sabellariidae	trochophore larvae	Polychaeta	0.94	30	66.44	149	22.0	0.10	10	1.019	0.002	0.002
		Synchaeta	spp.	Rotifera	1.07	30	75.63	92	12.0	0.10	1	0.101	0.122	0.012

Notes: High algae and detritus.
(µg d.w./L) = micrograms dry weight per litre

Table C1-10: Farim Project -- Dry Season -- Station 10 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 10	25-May-2013	Balnus	nauplii	Cirripedia	2.18	30	154.10	138	15.0	0.06	1	0.060	0.263	0.016
		Bipinnaria	larvae	Bivalvia	2.18	30	154.10	138	15.0	0.06	1	0.060	25.232	1.506
		bivalvia	veliger larvae	Bivalvia	2.02	30	142.79	224	12.0	0.13	1	0.131	0.028	0.004
		calanoid	copepodid	Copepoda	2.02	30	142.79	224	12.0	0.13	19	2.484	1.197	2.974
		calanoid	copepodid	Copepoda	2.18	30	154.10	138	15.0	0.06	45	2.687	0.781	2.098
		calanoid	copepodid	Copepoda	3.44	30	243.16	135	13.0	0.04	75	3.203	1.388	4.446
		Chaetognatha			2.02	30	142.79	224	12.0	0.13	1	0.131	0.588	0.077
		cyclopoid	copepodid	Copepoda	2.02	30	142.79	224	12.0	0.13	25	3.268	0.174	0.568
		cyclopoid	copepodid	Copepoda	2.18	30	154.10	138	15.0	0.06	34	2.030	0.482	0.978
		cyclopoid	copepodid	Copepoda	3.44	30	243.16	135	13.0	0.04	71	3.032	0.963	2.920
		Eucalanus	sp.	Copepoda	2.18	30	154.10	138	15.0	0.06	1	0.060	2.046	0.122
		Eucalanus	sp.	Copepoda	3.44	30	243.16	135	13.0	0.04	2	0.085	3.819	0.326
		Euchlanis	sp.	Rotifera	2.18	30	154.10	138	15.0	0.06	1	0.060	7.319	0.437
		Euterpina	acutifrons	Copepoda	2.02	30	142.79	224	12.0	0.13	3	0.392	1.644	0.645
		Euterpina	acutifrons	Copepoda	3.44	30	243.16	135	13.0	0.04	16	0.683	1.246	0.851
		Halicyclops	sp.	Copepoda	3.44	30	243.16	135	13.0	0.04	6	0.256	1.367	0.350
		harpacticoid		Copepoda	2.02	30	142.79	224	12.0	0.13	24	3.138	0.174	0.547
		harpacticoid		Copepoda	2.18	30	154.10	138	15.0	0.06	24	1.433	0.944	1.353
		nauplii		Copepoda	2.02	30	142.79	224	12.0	0.13	119	15.557	0.050	0.773
		nauplii		Copepoda	2.18	30	154.10	138	15.0	0.06	60	3.582	0.052	0.188
		nauplii		Copepoda	3.44	30	243.16	135	13.0	0.04	26	1.110	0.061	0.068
		Oithona	sp.	Copepoda	2.02	30	142.79	224	12.0	0.13	10	1.307	1.382	1.807
		Oithona	sp.	Copepoda	2.18	30	154.10	138	15.0	0.06	15	0.896	0.850	0.761
		Oithona	sp.	Copepoda	3.44	30	243.16	135	13.0	0.04	17	0.726	1.042	0.757
		Paracalanus	parvus	Copepoda	2.02	30	142.79	224	12.0	0.13	6	0.784	0.786	0.616
		Paracalanus	parvus	Copepoda	2.18	30	154.10	138	15.0	0.06	44	2.627	1.339	3.517
		Paracalanus	parvus	Copepoda	3.44	30	243.16	135	13.0	0.04	40	1.708	0.819	1.400
		Sabellariidae	trochophore larvae	Polychaeta	3.44	30	243.16	135	13.0	0.04	3	0.128	0.002	0.000

(µg d.w./L) = micrograms dry weight per litre

Table C1-11: Farim Project -- Dry Season -- Station 11 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 11	19-May-2013	Balnus	nauplii	Cirripedia	4.03	30	284.86	192	5.0	0.13	2	0.270	0.067	0.018
		Balnus	nauplii	Cirripedia	2.63	30	185.90	120	5.0	0.13	2	0.258	0.407	0.105
		bivalvia	veliger larvae	Bivalvia	4.03	30	284.86	192	5.0	0.13	8	1.078	0.045	0.049
		bivalvia	veliger larvae	Bivalvia	2.63	30	185.90	120	5.0	0.13	5	0.645	0.117	0.075
		Brachyura	zoea	Decapoda	4.03	30	284.86	192	5.0	0.13	1	0.135	0.024	0.003
		calanoid	copepodid	Copepoda	4.03	30	284.86	192	5.0	0.13	127	17.120	0.969	16.596
		calanoid	copepodid	Copepoda	2.63	30	185.90	120	5.0	0.13	115	14.846	1.840	27.312
		Callianassa	zoea	Decapoda	2.63	30	185.90	120	5.0	0.13	1	0.129	0.388	0.050
		Caridea	zoea	Decapoda	4.03	30	284.86	192	5.0	0.13	5	0.674	9.234	6.224
		Chaetognatha			2.63	30	185.90	120	5.0	0.13	5	0.645	1.893	1.222
		cyclopoid	copepodid	Copepoda	4.03	30	284.86	192	5.0	0.13	51	6.875	0.594	4.087
		cyclopoid	copepodid	Copepoda	2.63	30	185.90	120	5.0	0.13	53	6.842	1.346	9.213
		Eucalanus	sp.	Copepoda	2.63	30	185.90	120	5.0	0.13	2	0.258	4.773	1.232
		Euterpina	acutifrons	Copepoda	4.03	30	284.86	192	5.0	0.13	21	2.831	1.430	4.047
		Euterpina	acutifrons	Copepoda	3.22	30	227.61	136	119.0	0.01	133	0.668	1.308	0.873
		Euterpina	acutifrons	Copepoda	2.63	30	185.90	120	5.0	0.13	47	6.068	1.305	7.916
		gastropod	larvae	Bivalvia	4.03	30	284.86	192	5.0	0.13	11	1.483	0.295	0.438
		gastropod	larvae	Bivalvia	3.22	30	227.61	136	119.0	0.01	1	0.005	1.414	0.007
		gastropod	larvae	Bivalvia	2.63	30	185.90	120	5.0	0.13	9	1.162	1.303	1.514
		harpacticoid		Copepoda	3.22	30	227.61	136	119.0	0.01	49	0.246	0.135	0.033
		Ichthyoplankton		Chordata	2.63	30	185.90	120	5.0	0.13	1	0.129		
		Liriope	sp.	Hydrozoa	2.63	30	185.90	120	5.0	0.13	2	0.258	0.854	0.220
		nauplii		Copepoda	4.03	30	284.86	192	5.0	0.13	104	14.019	0.051	0.720
		nauplii		Copepoda	3.22	30	227.61	136	119.0	0.01	15	0.075	0.059	0.004
		nauplii		Copepoda	2.63	30	185.90	120	5.0	0.13	51	6.584	0.086	0.566
		Oithona	sp.	Copepoda	4.03	30	284.86	192	5.0	0.13	9	1.213	1.485	1.802
		Oithona	sp.	Copepoda	2.63	30	185.90	120	5.0	0.13	11	1.420	1.057	1.502
		Paracalanus	parvus	Copepoda	2.63	30	185.90	120	5.0	0.13	38	4.906	0.843	4.138
		Sabellariidae	trochophore larvae	Polychaeta	4.03	30	284.86	192	5.0	0.13	13	1.752	0.002	0.004
		Sabellariidae	metatrochophore larvae	Polychaeta	3.22	30	227.61	136	119.0	0.01	1	0.005	0.005	0.000
		Sabellariidae	metatrochophore larvae	Polychaeta	2.63	30	185.90	120	5.0	0.13	3	0.387	0.003	0.001
		Sabellariidae	trochophore larvae	Polychaeta	2.63	30	185.90	120	5.0	0.13	8	1.033	0.001	0.001
		Tortanus	sp.	Copepoda	4.03	30	284.86	192	5.0	0.13	1	0.135	9.715	1.310

(µg d.w./L) = micrograms dry weight per litre

Table C1-12: Farim Project -- Dry Season -- Station 12 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 12	20-May-2013	calanoid	copepodid	Copepoda	3.47	30	245.28	182	6.0	0.12	47	5.812	0.971	5.643
		cyclopoid	copepodid	Copepoda	3.47	30	245.28	182	6.0	0.12	26	3.215	0.472	1.516
		Euterpina	acutifrons	Copepoda	3.47	30	245.28	182	6.0	0.12	7	0.866	1.758	1.522
		harpacticoid		Copepoda	3.47	30	245.28	182	6.0	0.12	15	1.855	0.267	0.495
		Oithona	sp.	Copepoda	3.47	30	245.28	182	6.0	0.12	18	2.226	1.315	2.926
		Paracalanus	parvus	Copepoda	3.47	30	245.28	182	6.0	0.12	24	2.968	1.064	3.159
		nauplii		Copepoda	3.47	30	245.28	182	6.0	0.12	36	4.452	0.018	0.079
		unidentified	rotifer	Rotifera	3.47	30	245.28	182	6.0	0.12	1	0.124	0.010	0.001
		Bipinnaria	larvae	Bivalvia	3.47	30	245.28	182	6.0	0.12	1	0.124	3.842	0.475
		bivalvia	veliger larvae	Bivalvia	3.47	30	245.28	182	6.0	0.12	18	2.226	0.017	0.037
		gastropod	larvae	Bivalvia	3.47	30	245.28	182	6.0	0.12	6	0.742	1.099	0.816
		Sabellariidae	trochophore larvae	Polychaeta	3.47	30	245.28	182	6.0	0.12	12	1.484	0.001	0.001
		calanoid	copepodid	Copepoda	2.61	30	184.49	139	5.0	0.15	65	9.795	0.613	6.001
		cyclopoid	copepodid	Copepoda	2.61	30	184.49	139	5.0	0.15	13	1.959	0.140	0.275
		Euterpina	acutifrons	Copepoda	2.61	30	184.49	139	5.0	0.15	18	2.712	0.790	2.143
		harpacticoid		Copepoda	2.61	30	184.49	139	5.0	0.15	27	4.069	0.070	0.287
		Oithona	sp.	Copepoda	2.61	30	184.49	139	5.0	0.15	7	1.055	1.216	1.282
		Paracalanus	parvus	Copepoda	2.61	30	184.49	139	5.0	0.15	23	3.466	0.797	2.763
		nauplii		Copepoda	2.61	30	184.49	139	5.0	0.15	30	4.521	0.057	0.256
		Synchaeta	spp.	Rotifera	2.61	30	184.49	139	5.0	0.15	1	0.151	0.080	0.012
		bivalvia	veliger larvae	Bivalvia	2.61	30	184.49	139	5.0	0.15	3	0.452	0.036	0.016
		gastropod	larvae	Bivalvia	2.61	30	184.49	139	5.0	0.15	5	0.753	1.532	1.154
		Anthomedusae		Hydrozoa	2.61	30	184.49	139	5.0	0.15	1	0.151	1.108	0.167
		Sabellariidae	metatrochophore larvae	Polychaeta	2.61	30	184.49	139	5.0	0.15	1	0.151	0.007	0.001
		Sabellariidae	trochophore larvae	Polychaeta	2.61	30	184.49	139	5.0	0.15	6	0.904	0.001	0.001
		calanoid	copepodid	Copepoda	3.41	30	241.04	124	4.0	0.13	52	6.688	1.539	10.294
		cyclopoid	copepodid	Copepoda	3.41	30	241.04	124	4.0	0.13	57	7.331	0.735	5.388
		Euterpina	acutifrons	Copepoda	3.41	30	241.04	124	4.0	0.13	43	5.530	1.307	7.227
		Oithona	sp.	Copepoda	3.41	30	241.04	124	4.0	0.13	15	1.929	0.937	1.808
		Paracalanus	parvus	Copepoda	3.41	30	241.04	124	4.0	0.13	13	1.672	0.710	1.187
		nauplii		Copepoda	3.41	30	241.04	124	4.0	0.13	42	5.402	0.063	0.341
		bivalvia	veliger larvae	Bivalvia	3.41	30	241.04	124	4.0	0.13	10	1.286	0.160	0.206
		Sabellariidae	trochophore larvae	Polychaeta	3.41	30	241.04	124	4.0	0.13	5	0.643	0.001	0.001
		Chaetognatha			3.41	30	241.04	124	4.0	0.13	2	0.257	0.052	0.013

(µg d.w./L) = micrograms dry weight per litre

Table C1-13: Farim Project -- Dry Season -- Station 13 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 13	22-May-2013	Balnus	nauplii	Cirripedia	3.74	30	264.37	184	4.0	0.17	1	0.174	0.407	0.071
		Bipinnaria	larvae	Bivalvia	3.74	30	264.37	184	4.0	0.17	14	2.436	1.350	3.290
		Bipinnaria	larvae	Bivalvia	3.65	30	258.00	152	4.0	0.15	3	0.442	1.591	0.703
		bivalvia	veliger larvae	Bivalvia	3.74	30	264.37	184	4.0	0.17	12	2.088	0.076	0.160
		bivalvia	veliger larvae	Bivalvia	3.65	30	258.00	152	4.0	0.15	6	0.884	0.045	0.040
		bivalvia	veliger larvae	Bivalvia	2.45	30	173.18	228	12.0	0.11	2	0.219	1.198	0.263
		Brachyura	zoea	Decapoda	3.74	30	264.37	184	4.0	0.17	1	0.174	0.052	0.009
		calanoid	copepodid	Copepoda	3.74	30	264.37	184	4.0	0.17	30	5.220	0.746	3.893
		calanoid	copepodid	Copepoda	3.65	30	258.00	152	4.0	0.15	23	3.388	0.533	1.806
		calanoid	copepodid	Copepoda	2.45	30	173.18	228	12.0	0.11	58	6.363	0.614	3.906
		Chaetognatha			3.74	30	264.37	184	4.0	0.17	6	1.044	1.146	1.197
		Chaetognatha			3.65	30	258.00	152	4.0	0.15	2	0.295	13.954	4.110
		Chaetognatha			2.45	30	173.18	228	12.0	0.11	7	0.768	2.697	2.071
		Cunina	sp.	Hydrozoa	2.45	30	173.18	228	12.0	0.11	1	0.110	0.639	0.070
		cyclopoid	copepodid	Copepoda	3.74	30	264.37	184	4.0	0.17	34	5.916	0.194	1.146
		cyclopoid	copepodid	Copepoda	3.65	30	258.00	152	4.0	0.15	22	3.240	0.155	0.504
		cyclopoid	copepodid	Copepoda	2.45	30	173.18	228	12.0	0.11	40	4.388	0.326	1.432
		Cypridina		Ostracoda	3.74	30	264.37	184	4.0	0.17	1	0.174	9.799	1.705
		Cypris	larvae	Cirripedia	3.74	30	264.37	184	4.0	0.17	1	0.174	0.920	0.160
		Eucalanus	sp.	Copepoda	2.45	30	173.18	228	12.0	0.11	5	0.549	2.651	1.454
		Euterpina	acutifrons	Copepoda	3.74	30	264.37	184	4.0	0.17	4	0.696	2.005	1.395
		Euterpina	acutifrons	Copepoda	3.65	30	258.00	152	4.0	0.15	3	0.442	1.433	0.633
		Euterpina	acutifrons	Copepoda	2.45	30	173.18	228	12.0	0.11	10	1.097	2.151	2.360
		gastropod	larvae	Bivalvia	3.65	30	258.00	152	4.0	0.15	1	0.147	0.117	0.017
		gastropod	larvae	Bivalvia	2.45	30	173.18	228	12.0	0.11	1	0.110	1.007	0.110
		Halicyclops	sp.	Copepoda	3.74	30	264.37	184	4.0	0.17	1	0.174	2.778	0.483
		harpacticoid		Copepoda	3.74	30	264.37	184	4.0	0.17	3	0.522	0.565	0.295
		harpacticoid		Copepoda	3.65	30	258.00	152	4.0	0.15	4	0.589	0.040	0.024
		nauplii		Copepoda	3.74	30	264.37	184	4.0	0.17	123	21.402	0.028	0.593
		nauplii		Copepoda	3.65	30	258.00	152	4.0	0.15	106	15.612	0.049	0.767
		nauplii		Copepoda	2.45	30	173.18	228	12.0	0.11	35	3.840	0.030	0.116
		Oikopleura	sp.	Tunicata	3.74	30	264.37	184	4.0	0.17	4	0.696	0.002	0.001
		Oikopleura	sp.	Tunicata	3.65	30	258.00	152	4.0	0.15	4	0.589	0.001	0.000
		Oikopleura	sp.	Tunicata	2.45	30	173.18	228	12.0	0.11	20	2.194	0.007	0.016
		Oithona	sp.	Copepoda	3.74	30	264.37	184	4.0	0.17	2	0.348	1.451	0.505
		Oithona	sp.	Copepoda	3.65	30	258.00	152	4.0	0.15	7	1.031	0.907	0.935
		Ophiuroidea	larvae	Ophiuroidea	3.74	30	264.37	184	4.0	0.17	2	0.348	0.263	0.092
		Ophiuroidea	larvae	Ophiuroidea	3.65	30	258.00	152	4.0	0.15	3	0.442	0.044	0.020
		ostracod		Ostracoda	2.45	30	173.18	228	12.0	0.11	2	0.219	9.799	2.150
		Paracalanus	parvus	Copepoda	3.74	30	264.37	184	4.0	0.17	1	0.174	1.627	0.283
		Paracalanus	parvus	Copepoda	3.65	30	258.00	152	4.0	0.15	5	0.736	1.222	0.900
		Paracalanus	parvus	Copepoda	2.45	30	173.18	228	12.0	0.11	9	0.987	2.046	2.020
		Polychaete	larvae	Polychaeta	3.74	30	264.37	184	4.0	0.17	4	0.696	0.005	0.003
		Porcellanidae	zoea	Decapoda	3.65	30	258.00	152	4.0	0.15	2	0.295	0.388	0.114
		Sabellariidae	trochophore larvae	Polychaeta	3.74	30	264.37	184	4.0	0.17	6	1.044	0.002	0.002
		Sabellariidae	metatrochophore larvae	Polychaeta	3.65	30	258.00	152	4.0	0.15	4	0.589	0.023	0.013
		Sabellariidae	trochophore larvae	Polychaeta	3.65	30	258.00	152	4.0	0.15	11	1.620	0.002	0.003
		Sabellariidae	trochophore larvae	Polychaeta	2.45	30	173.18	228	12.0	0.11	27	2.962	0.003	0.008
		Synchaeta	spp.	Rotifera	3.74	30	264.37	184	4.0	0.17	38	6.612	0.095	0.625
		Synchaeta	spp.	Rotifera	3.65	30	258.00	152	4.0	0.15	30	4.419	0.132	0.583
		Synchaeta	spp.	Rotifera	2.45	30	173.18	228	12.0	0.11	16	1.755	0.101	0.178
		Trichocerca	pussilla	Rotifera	3.74	30	264.37	184	4.0	0.17	1	0.174	0.000	0.000
		Trichocerca	sp.	Rotifera	3.65	30	258.00	152	4.0	0.15	1	0.147	0.051	0.008

(µg d.w./L) = micrograms dry weight per litre

Table C1-14: Farim Project -- Dry Season -- Station 14 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN15ZP-A	28-May-13	calanoid	copepodid	Copepoda	7.18	30	507.53	234	4.0	0.12	23	2.651	0.313	0.829
STN15ZP-A	28-May-13	cyclopoid	copepodid	Copepoda	7.18	30	507.53	234	4.0	0.12	47	5.417	0.067	0.362
STN15ZP-A	28-May-13	Euterpina	acutifrons	Copepoda	7.18	30	507.53	234	4.0	0.12	5	0.576	0.727	0.419
STN15ZP-A	28-May-13	Oithona	sp.	Copepoda	7.18	30	507.53	234	4.0	0.12	2	0.231	0.461	0.106
STN15ZP-A	28-May-13	Paracalanus	parvus	Copepoda	7.18	30	507.53	234	4.0	0.12	1	0.115	1.064	0.123
STN15ZP-A	28-May-13	nauplii		Copepoda	7.18	30	507.53	234	4.0	0.12	96	11.065	0.033	0.366
STN15ZP-A	28-May-13	Synchaeta	spp.	Rotifera	7.18	30	507.53	234	4.0	0.12	16	1.844	0.087	0.160
STN15ZP-A	28-May-13	bivalvia	veliger larvae	Bivalvia	7.18	30	507.53	234	4.0	0.12	20	2.305	0.042	0.097
STN15ZP-A	28-May-13	Brachyura	zoea	Decapoda	7.18	30	507.53	234	4.0	0.12	2	0.231	0.240	0.055
STN15ZP-A	28-May-13	Ophiuroidea	larvae	Ophiuroidea	7.18	30	507.53	234	4.0	0.12	1	0.115	0.095	0.011
STN15ZP-A	28-May-13	Sabellariidae	trochophore larvae	Polychaeta	7.18	30	507.53	234	4.0	0.12	15	1.729	0.002	0.004
STN15ZP-B	23-May-13	calanoid	copepodid	Copepoda	5.89	30	416.34	134	3.0	0.11	18	1.931	0.486	0.939
STN15ZP-B	23-May-13	cyclopoid	copepodid	Copepoda	5.89	30	416.34	134	3.0	0.11	46	4.935	0.151	0.746
STN15ZP-B	23-May-13	Euterpina	acutifrons	Copepoda	5.89	30	416.34	134	3.0	0.11	4	0.429	1.433	0.615
STN15ZP-B	23-May-13	harpacticoid		Copepoda	5.89	30	416.34	134	3.0	0.11	3	0.322	0.122	0.039
STN15ZP-B	23-May-13	Oithona	sp.	Copepoda	5.89	30	416.34	134	3.0	0.11	3	0.322	1.184	0.381
STN15ZP-B	23-May-13	Paracalanus	parvus	Copepoda	5.89	30	416.34	134	3.0	0.11	4	0.429	1.439	0.617
STN15ZP-B	23-May-13	nauplii		Copepoda	5.89	30	416.34	134	3.0	0.11	110	11.801	0.058	0.681
STN15ZP-B	23-May-13	Euchlanis	sp.	Rotifera	5.89	30	416.34	134	3.0	0.11	3	0.322	0.017	0.006
STN15ZP-B	23-May-13	Synchaeta	spp.	Rotifera	5.89	30	416.34	134	3.0	0.11	6	0.644	0.022	0.014
STN15ZP-B	23-May-13	Trichocerca	sp.	Rotifera	5.89	30	416.34	134	3.0	0.11	1	0.107	0.038	0.004
STN15ZP-B	23-May-13	Bipinnaria	larvae	Bivalvia	5.89	30	416.34	134	3.0	0.11	2	0.215	4.742	1.018
STN15ZP-B	23-May-13	bivalvia	veliger larvae	Bivalvia	5.89	30	416.34	134	3.0	0.11	13	1.395	0.129	0.180
STN15ZP-B	23-May-13	gastropod	larvae	Bivalvia	5.89	30	416.34	134	3.0	0.11	1	0.107	0.359	0.039
STN15ZP-B	23-May-13	Balnus	nauplii	Cirripedia	5.89	30	416.34	134	3.0	0.11	1	0.107	0.212	0.023
STN15ZP-B	23-May-13	Brachyura	zoea	Decapoda	5.89	30	416.34	134	3.0	0.11	8	0.858	0.016	0.014
STN15ZP-B	23-May-13	Ophiuroidea	larvae	Ophiuroidea	5.89	30	416.34	134	3.0	0.11	3	0.322	0.044	0.014
STN15ZP-B	23-May-13	Sabellariidae	trochophore larvae	Polychaeta	5.89	30	416.34	134	3.0	0.11	4	0.429	0.001	0.001
STN15ZP-B	23-May-13	Chaetognatha			5.89	30	416.34	134	3.0	0.11	1	0.107	0.998	0.107
STN15ZP-B	23-May-13	Oikopleura	sp.	Tunicata	5.89	30	416.34	134	3.0	0.11	2	0.215	0.001	0.000
STN15ZP-C	23-May-13	calanoid	copepodid	Copepoda	4.41	30	311.73	143	7.0	0.07	50	3.277	0.834	2.734
STN15ZP-C	23-May-13	cyclopoid	copepodid	Copepoda	4.41	30	311.73	143	7.0	0.07	44	2.883	0.240	0.692
STN15ZP-C	23-May-13	Euterpina	acutifrons	Copepoda	4.41	30	311.73	143	7.0	0.07	8	0.524	2.278	1.194
STN15ZP-C	23-May-13	Halicyclops	sp.	Copepoda	4.41	30	311.73	143	7.0	0.07	11	0.721	3.039	2.191
STN15ZP-C	23-May-13	Oithona	sp.	Copepoda	4.41	30	311.73	143	7.0	0.07	6	0.393	1.057	0.416
STN15ZP-C	23-May-13	Paracalanus	parvus	Copepoda	4.41	30	311.73	143	7.0	0.07	19	1.245	1.886	2.349
STN15ZP-C	23-May-13	nauplii		Copepoda	4.41	30	311.73	143	7.0	0.07	22	1.442	0.054	0.078
STN15ZP-C	23-May-13	Synchaeta	spp.	Rotifera	4.41	30	311.73	143	7.0	0.07	1	0.066	0.069	0.005
STN15ZP-C	23-May-13	bivalvia	veliger larvae	Bivalvia	4.41	30	311.73	143	7.0	0.07	12	0.786	0.077	0.061

(µg d.w./L) = micrograms dry weight per litre

Table C1-15: Farim Project -- Dry Season -- Station 15 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 15	23-May-2013	Balnus	nauplii	Cirripedia	5.89	30	416.34	134	3.0	0.11	1	0.107	0.212	0.023
		Bipinnaria	larvae	Bivalvia	5.89	30	416.34	134	3.0	0.11	2	0.215	4.742	1.018
		bivalvia	veliger larvae	Bivalvia	7.18	30	507.53	234	4.0	0.12	20	2.305	0.042	0.097
		bivalvia	veliger larvae	Bivalvia	5.89	30	416.34	134	3.0	0.11	13	1.395	0.129	0.180
		bivalvia	veliger larvae	Bivalvia	4.41	30	311.73	143	7.0	0.07	12	0.786	0.077	0.061
		Brachyura	zoea	Decapoda	7.18	30	507.53	234	4.0	0.12	2	0.231	0.240	0.055
		Brachyura	zoea	Decapoda	5.89	30	416.34	134	3.0	0.11	8	0.858	0.016	0.014
		calanoid	copepodid	Copepoda	7.18	30	507.53	234	4.0	0.12	23	2.651	0.313	0.829
		calanoid	copepodid	Copepoda	5.89	30	416.34	134	3.0	0.11	18	1.931	0.486	0.939
		calanoid	copepodid	Copepoda	4.41	30	311.73	143	7.0	0.07	50	3.277	0.834	2.734
		Chaetognatha			5.89	30	416.34	134	3.0	0.11	1	0.107	0.998	0.107
		cyclopoid	copepodid	Copepoda	7.18	30	507.53	234	4.0	0.12	47	5.417	0.067	0.362
		cyclopoid	copepodid	Copepoda	5.89	30	416.34	134	3.0	0.11	46	4.935	0.151	0.746
		cyclopoid	copepodid	Copepoda	4.41	30	311.73	143	7.0	0.07	44	2.883	0.240	0.692
		Euchlanis	sp.	Rotifera	5.89	30	416.34	134	3.0	0.11	3	0.322	0.017	0.006
		Euterpina	acutifrons	Copepoda	7.18	30	507.53	234	4.0	0.12	5	0.576	0.727	0.419
		Euterpina	acutifrons	Copepoda	5.89	30	416.34	134	3.0	0.11	4	0.429	1.433	0.615
		Euterpina	acutifrons	Copepoda	4.41	30	311.73	143	7.0	0.07	8	0.524	2.278	1.194
		gastropod	larvae	Bivalvia	5.89	30	416.34	134	3.0	0.11	1	0.107	0.359	0.039
		Halicyclops	sp.	Copepoda	4.41	30	311.73	143	7.0	0.07	11	0.721	3.039	2.191
		harpacticoid		Copepoda	5.89	30	416.34	134	3.0	0.11	3	0.322	0.122	0.039
		nauplii		Copepoda	7.18	30	507.53	234	4.0	0.12	96	11.065	0.033	0.366
		nauplii		Copepoda	5.89	30	416.34	134	3.0	0.11	110	11.801	0.058	0.681
		nauplii		Copepoda	4.41	30	311.73	143	7.0	0.07	22	1.442	0.054	0.078
		Oikopleura	sp.	Tunicata	5.89	30	416.34	134	3.0	0.11	2	0.215	0.001	0.000
		Oithona	sp.	Copepoda	7.18	30	507.53	234	4.0	0.12	2	0.231	0.461	0.106
		Oithona	sp.	Copepoda	5.89	30	416.34	134	3.0	0.11	3	0.322	1.184	0.381
		Oithona	sp.	Copepoda	4.41	30	311.73	143	7.0	0.07	6	0.393	1.057	0.416
		Ophiuroidea	larvae	Ophiuroidea	7.18	30	507.53	234	4.0	0.12	1	0.115	0.095	0.011
		Ophiuroidea	larvae	Ophiuroidea	5.89	30	416.34	134	3.0	0.11	3	0.322	0.044	0.014
		Paracalanus	parvus	Copepoda	7.18	30	507.53	234	4.0	0.12	1	0.115	1.064	0.123
		Paracalanus	parvus	Copepoda	5.89	30	416.34	134	3.0	0.11	4	0.429	1.439	0.617
		Paracalanus	parvus	Copepoda	4.41	30	311.73	143	7.0	0.07	19	1.245	1.886	2.349
		Sabellariidae	trochophore larvae	Polychaeta	7.18	30	507.53	234	4.0	0.12	15	1.729	0.002	0.004
		Sabellariidae	trochophore larvae	Polychaeta	5.89	30	416.34	134	3.0	0.11	4	0.429	0.001	0.001
		Synchaeta	spp.	Rotifera	7.18	30	507.53	234	4.0	0.12	16	1.844	0.087	0.160
		Synchaeta	spp.	Rotifera	5.89	30	416.34	134	3.0	0.11	6	0.644	0.022	0.014
		Synchaeta	spp.	Rotifera	4.41	30	311.73	143	7.0	0.07	1	0.066	0.069	0.005
		Trichocerca	sp.	Rotifera	5.89	30	416.34	134	3.0	0.11	1	0.107	0.038	0.004

(µg d.w./L) = micrograms dry weight per litre

Table C1-16: Farim Project -- Dry Season -- Station 16 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 16	23-May-2013	bivalvia	veliger larvae	Bivalvia	4.57	30	323.04	226	8.0	0.09	10	0.875	0.036	0.032
		bivalvia	veliger larvae	Bivalvia	3.95	30	279.21	125	3.0	0.15	14	2.089	0.041	0.085
		bivalvia	veliger larvae	Bivalvia	4.97	30	351.31	190	13.0	0.04	3	0.125	0.068	0.009
		Brachyura	zoea	Decapoda	3.95	30	279.21	125	3.0	0.15	2	0.298	0.048	0.014
		Brachyura	zoea	Decapoda	4.97	30	351.31	190	13.0	0.04	6	0.250	0.284	0.071
		calanoid	copepodid	Copepoda	4.57	30	323.04	226	8.0	0.09	38	3.323	0.487	1.619
		calanoid	copepodid	Copepoda	3.95	30	279.21	125	3.0	0.15	20	2.985	0.782	2.335
		calanoid	copepodid	Copepoda	4.97	30	351.31	190	13.0	0.04	55	2.288	0.983	2.249
		Chaetognatha			4.57	30	323.04	226	8.0	0.09	4	0.350	1.217	0.426
		Chaetognatha			3.95	30	279.21	125	3.0	0.15	1	0.149	4.372	0.652
		Chaetognatha			4.97	30	351.31	190	13.0	0.04	17	0.707	0.984	0.696
		Coullana	canadensis	Copepoda	4.97	30	351.31	190	13.0	0.04	2	0.083	2.278	0.190
		cyclopoid	copepodid	Copepoda	4.57	30	323.04	226	8.0	0.09	49	4.285	0.075	0.319
		cyclopoid	copepodid	Copepoda	3.95	30	279.21	125	3.0	0.15	41	6.118	0.133	0.816
		cyclopoid	copepodid	Copepoda	4.97	30	351.31	190	13.0	0.04	40	1.664	0.565	0.941
		Cypridina		Ostracoda	4.57	30	323.04	226	8.0	0.09	1	0.087	13.368	1.169
		Cypris	larvae	Cirripedia	4.97	30	351.31	190	13.0	0.04	3	0.125	9.352	1.167
		Eucalanus	sp.	Copepoda	4.97	30	351.31	190	13.0	0.04	2	0.083	3.819	0.318
		Euterpina	acutifrons	Copepoda	4.57	30	323.04	226	8.0	0.09	2	0.175	3.464	0.606
		Euterpina	acutifrons	Copepoda	3.95	30	279.21	125	3.0	0.15	11	1.642	1.158	1.901
		Euterpina	acutifrons	Copepoda	4.97	30	351.31	190	13.0	0.04	16	0.666	2.832	1.885
		gastropod	larvae	Bivalvia	3.95	30	279.21	125	3.0	0.15	2	0.298	1.414	0.422
		gastropod	larvae	Gastropoda	4.97	30	351.31	190	13.0	0.04	3	0.125	0.359	0.045
		Halicyclops	sp.	Copepoda	4.57	30	323.04	226	8.0	0.09	6	0.525	0.895	0.470
		Halicyclops	sp.	Copepoda	4.97	30	351.31	190	13.0	0.04	14	0.582	2.594	1.511
		harpacticoid		Copepoda	3.95	30	279.21	125	3.0	0.15	7	1.045	0.083	0.087
		Keratella	cochlearis	Rotifera	3.95	30	279.21	125	3.0	0.15	2	0.298	0.012	0.003
		nauplii		Copepoda	4.57	30	323.04	226	8.0	0.09	112	9.795	0.033	0.326
		nauplii		Copepoda	3.95	30	279.21	125	3.0	0.15	90	13.431	0.059	0.787
		nauplii		Copepoda	4.97	30	351.31	190	13.0	0.04	16	0.666	0.038	0.025
		Obelia	sp.	Hydrozoa	4.97	30	351.31	190	13.0	0.04	4	0.166	1.254	0.209
		Oikopleura	sp.	Tunicata	3.95	30	279.21	125	3.0	0.15	1	0.149	0.000	0.000
		Oithona	sp.	Copepoda	4.57	30	323.04	226	8.0	0.09	2	0.175	0.606	0.106
		Oithona	sp.	Copepoda	3.95	30	279.21	125	3.0	0.15	6	0.895	1.382	1.237
		Oithona	sp.	Copepoda	4.97	30	351.31	190	13.0	0.04	6	0.250	0.996	0.249
		Ophiuroidea	larvae	Ophiuroidea	4.57	30	323.04	226	8.0	0.09	1	0.087	0.051	0.004
		Paracalanus	parvus	Copepoda	3.95	30	279.21	125	3.0	0.15	3	0.448	1.579	0.707
		Paracalanus	parvus	Copepoda	4.97	30	351.31	190	13.0	0.04	3	0.125	1.727	0.215
		Porcellanidae	zoea	Decapoda	3.95	30	279.21	125	3.0	0.15	1	0.149	1.649	0.246
		Sabellariidae	trochophore larvae	Polychaeta	4.57	30	323.04	226	8.0	0.09	6	0.525	0.002	0.001
		Sabellariidae	metatrochophore larvae	Polychaeta	3.95	30	279.21	125	3.0	0.15	3	0.448	0.006	0.003
		Sabellariidae	trochophore larvae	Polychaeta	3.95	30	279.21	125	3.0	0.15	6	0.895	0.002	0.002
		Sabellariidae	trochophore larvae	Polychaeta	4.97	30	351.31	190	13.0	0.04	18	0.749	0.003	0.002
		Synchaeta	spp.	Rotifera	4.57	30	323.04	226	8.0	0.09	45	3.935	0.086	0.338
		Synchaeta	spp.	Rotifera	3.95	30	279.21	125	3.0	0.15	40	5.969	0.067	0.397
		Synchaeta	spp.	Rotifera	4.97	30	351.31	190	13.0	0.04	6	0.250	0.093	0.023
		Trichocerca	sp.	Rotifera	3.95	30	279.21	125	3.0	0.15	1	0.149	0.070	0.010
		Tropocyclops	prasinus	Copepoda	4.97	30	351.31	190	13.0	0.04	3	0.125	3.370	0.421

(µg d.w./L) = micrograms dry weight per litre

Table C1-17: Farim Project -- Dry Season -- Station 17 Summary of Zooplankton Taxonomic Data

Site Name	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Diameter (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	# Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 17	24-May-2013	calanoid	copepodid	Copepoda	4.94	30	349.19	190	2.0	0.27	58	15.779	1.120	17.667
		cyclopoid	copepodid	Copepoda	4.94	30	349.19	190	2.0	0.27	32	8.706	0.582	5.069
		Euterpina	acutifrons	Copepoda	4.94	30	349.19	190	2.0	0.27	4	1.088	2.578	2.806
		harpacticoid		Copepoda	4.94	30	349.19	190	2.0	0.27	13	3.537	0.207	0.733
		Oithona	sp.	Copepoda	4.94	30	349.19	190	2.0	0.27	10	2.721	1.168	3.177
		Paracalanus	parvus	Copepoda	4.94	30	349.19	190	2.0	0.27	6	1.632	1.727	2.818
		nauplii		Copepoda	4.94	30	349.19	190	2.0	0.27	75	20.404	0.063	1.295
		Synchaeta	spp.	Rotifera	4.94	30	349.19	190	2.0	0.27	3	0.816	0.034	0.028
		bivalvia	veliger larvae	Bivalvia	4.94	30	349.19	190	2.0	0.27	8	2.176	0.056	0.122
		Porcellanidae	zoea	Decapoda	4.94	30	349.19	190	2.0	0.27	1	0.272	1.422	0.387
		Anthomedusae		Hydrozoa	4.94	30	349.19	190	2.0	0.27	1	0.272	1.087	0.296
		Sabellariidae	metatrochophore larvae	Polychaeta	4.94	30	349.19	190	2.0	0.27	2	0.544	0.005	0.003
		Sabellariidae	trochophore larvae	Polychaeta	4.94	30	349.19	190	2.0	0.27	5	1.360	0.002	0.002
		Chaetognatha			4.94	30	349.19	190	2.0	0.27	1	0.272	6.368	1.732
		calanoid	copepodid	Copepoda	3.79	30	267.90	124	2.0	0.23	49	11.340	0.698	7.915
		cyclopoid	copepodid	Copepoda	3.79	30	267.90	124	2.0	0.23	17	3.934	0.419	1.649
		Euterpina	acutifrons	Copepoda	3.79	30	267.90	124	2.0	0.23	8	1.851	1.433	2.653
		harpacticoid		Copepoda	3.79	30	267.90	124	2.0	0.23	18	4.166	0.125	0.523
		Oithona	sp.	Copepoda	3.79	30	267.90	124	2.0	0.23	10	2.314	0.762	1.763
		Paracalanus	parvus	Copepoda	3.79	30	267.90	124	2.0	0.23	10	2.314	1.778	4.114
		nauplii		Copepoda	3.79	30	267.90	124	2.0	0.23	68	15.737	0.069	1.081
		Synchaeta	spp.	Rotifera	3.79	30	267.90	124	2.0	0.23	3	0.694	0.107	0.074
		bivalvia	veliger larvae	Bivalvia	3.79	30	267.90	124	2.0	0.23	10	2.314	0.028	0.066
		Balnus	nauplii	Cirripedia	3.79	30	267.90	124	2.0	0.23	1	0.231	0.167	0.039
		Anthomedusae		Hydrozoa	3.79	30	267.90	124	2.0	0.23	1	0.231	1.168	0.270
		Ophiuroidea	larvae	Ophiuroidea	3.79	30	267.90	124	2.0	0.23	1	0.231	0.038	0.009
		Sabellariidae	metatrochophore larvae	Polychaeta	3.79	30	267.90	124	2.0	0.23	2	0.463	0.012	0.006
		Oikopleura	sp.	Tunicata	3.79	30	267.90	124	2.0	0.23	1	0.231	0.001	0.000
		Lingula	larvae	Brachiopoda	3.79	30	267.90	124	2.0	0.23	1	0.231	0.404	0.093
		calanoid	copepodid	Copepoda	5.13	30	362.62	126	3.0	0.12	108	12.509	0.691	8.650
		cyclopoid	copepodid	Copepoda	5.13	30	362.62	126	3.0	0.12	45	5.212	0.065	0.337
		Euterpina	acutifrons	Copepoda	5.13	30	362.62	126	3.0	0.12	13	1.506	2.612	3.932
		Halicyclops	sp.	Copepoda	5.13	30	362.62	126	3.0	0.12	1	0.116	2.907	0.337
		Oithona	sp.	Copepoda	5.13	30	362.62	126	3.0	0.12	8	0.927	1.057	0.980
		Paracalanus	parvus	Copepoda	5.13	30	362.62	126	3.0	0.12	17	1.969	1.485	2.924
		nauplii		Copepoda	5.13	30	362.62	126	3.0	0.12	50	5.791	0.057	0.328
		Bipinnaria	larvae	Bivalvia	5.13	30	362.62	126	3.0	0.12	2	0.232	0.406	0.094
		bivalvia	veliger larvae	Bivalvia	5.13	30	362.62	126	3.0	0.12	21	2.432	0.616	1.498
		Balnus	nauplii	Cirripedia	5.13	30	362.62	126	3.0	0.12	2	0.232	0.263	0.061
		Sabellariidae	metatrochophore larvae	Polychaeta	5.13	30	362.62	126	3.0	0.12	6	0.695	0.008	0.005

(µg d.w./L) = micrograms dry weight per litre

Table C2-1: Farim Project - Wet Season Station 1 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 1	15-Aug-13	*Acartia*	sp.	Copepoda	2.61	15.00	184.49046	68.0	1.00	0.36858	10.000	3.686	2.102	7.748
		Acartia	sp.	Copepoda	1.56	15.00	110.27016	90.0	0.50	1.63235	6.000	9.794	3.277	32.096
		Acartia	sp.	Copepoda	1.26	15.00	89.06436	95.0	0.20	5.33322	2.000	10.666	3.277	34.954
		bivalvia	*veliger larvae*	Bivalvia	2.61	15.00	184.49046	68.0	1.00	0.36858	375.000	138.219	0.031	4.257
		bivalvia	*veliger larvae*	Bivalvia	1.56	15.00	110.27016	90.0	0.50	1.63235	126.000	205.677	0.019	3.858
		bivalvia	*veliger larvae*	Bivalvia	1.26	15.00	89.06436	95.0	0.20	5.33322	73.000	389.325	0.026	10.097
		calanoid	*copepodid*	Copepoda	2.61	15.00	184.49046	68.0	1.00	0.36858	12.000	4.423	2.386	10.554
		calanoid	*copepodid*	Copepoda	1.56	15.00	110.27016	90.0	0.50	1.63235	2.000	3.265	1.111	3.627
		calanoid	*copepodid*	Copepoda	1.26	15.00	89.06436	95.0	0.20	5.33322	2.000	10.666	0.872	9.305
		gastropod	*larvae*	Bivalvia	2.61	15.00	184.49046	68.0	1.00	0.36858	154.000	56.762	0.139	7.881
		gastropod	*larvae*	Bivalvia	1.56	15.00	110.27016	90.0	0.50	1.63235	72.000	117.530	0.198	23.307
		gastropod	*larvae*	Bivalvia	1.26	15.00	89.06436	95.0	0.20	5.33322	36.000	191.996	0.154	29.535
		nauplii		Copepoda	2.61	15.00	184.49046	68.0	1.00	0.36858	110.000	40.544	0.115	4.669
		nauplii		Copepoda	1.56	15.00	110.27016	90.0	0.50	1.63235	76.000	124.059	0.057	7.127
		nauplii		Copepoda	1.26	15.00	89.06436	95.0	0.20	5.33322	28.000	149.330	0.072	10.757
		Sabellariidae	*trochophore larvae*	Polychaeta	1.56	15.00	110.27016	90.0	0.50	1.63235	17.000	27.750	0.001	0.034
		Sabellariidae	*trochophore larvae*	Polychaeta	1.26	15.00	89.06436	95.0	0.20	5.33322	11.000	58.665	0.001	0.034
		Synchaeta	*bicornis*	Rotifera	2.61	15.00	184.49046	68.0	1.00	0.36858	5.000	1.843	0.080	0.148
		Synchaeta	*bicornis*	Rotifera	1.56	15.00	110.27016	90.0	0.50	1.63235	15.000	24.485	0.050	1.220
		Synchaeta	spp.	Rotifera	1.56	15.00	110.27016	90.0	0.50	1.63235	8.000	13.059	0.022	0.288
		Synchaeta	*bicornis*	Rotifera	1.26	15.00	89.06436	95.0	0.20	5.33322	2.000	10.666	0.041	0.439
		Trichocerca	*marina*	Rotifera	2.61	15.00	184.49046	68.0	1.00	0.36858	185.000	68.188	0.020	1.338
		Trichocerca	*marina*	Rotifera	1.56	15.00	110.27016	90.0	0.50	1.63235	460.000	750.883	0.015	11.505
		Trichocerca	*marina*	Rotifera	1.26	15.00	89.06436	95.0	0.20	5.33322	101.000	538.655	0.015	7.916
		Trochophore	*larvae*	Polychaeta	2.61	15.00	184.49046	68.0	1.00	0.36858	25.000	9.215	0.002	0.019

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-2: Farim Project - Wet Season Station 2 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 2	15-Aug-13	*Acartia*	sp.	Copepoda	4.62	15.00	326.56932	101.0	0.30	1.03092	2.000	2.062	2.159	4.453
		Acartia	sp.	Copepoda	7.01	15.00	495.50886	85.0	0.20	0.8577	1.000	0.858	3.204	2.748
		Acartia	sp.	Copepoda	5.08	15.00	359.08488	86.0	0.20	1.19749	2.000	2.395	2.651	6.349
		Anthomedusae		Hydrozoa	7.01	15.00	495.50886	85.0	0.20	0.8577	1.000	0.858	1.145	0.982
		bivalvia	*veliger larvae*	Bivalvia	4.62	15.00	326.56932	101.0	0.30	1.03092	17.000	17.526	0.059	1.040
		bivalvia	*veliger larvae*	Bivalvia	7.01	15.00	495.50886	85.0	0.20	0.8577	15.000	12.866	0.029	0.374
		bivalvia	*veliger larvae*	Bivalvia	5.08	15.00	359.08488	86.0	0.20	1.19749	15.000	17.962	0.048	0.869
		calanoid	*copepodid*	Copepoda	4.62	15.00	326.56932	101.0	0.30	1.03092	2.000	2.062	2.354	4.853
		calanoid	*copepodid*	Copepoda	7.01	15.00	495.50886	85.0	0.20	0.8577	7.000	6.004	1.328	7.973
		calanoid	*copepodid*	Copepoda	5.08	15.00	359.08488	86.0	0.20	1.19749	11.000	13.172	0.969	12.763
		cyclopoid	*copepodid*	Copepoda	4.62	15.00	326.56932	101.0	0.30	1.03092	1.000	1.031	1.367	1.409
		cyclopoid	*copepodid*	Copepoda	5.08	15.00	359.08488	86.0	0.20	1.19749	3.000	3.592	0.122	0.440
		gastropod	*larvae*	Bivalvia	4.62	15.00	326.56932	101.0	0.30	1.03092	23.000	23.711	0.513	12.169
		gastropod	*larvae*	Bivalvia	7.01	15.00	495.50886	85.0	0.20	0.8577	22.000	18.869	0.247	4.654
		gastropod	*larvae*	Bivalvia	5.08	15.00	359.08488	86.0	0.20	1.19749	22.000	26.345	0.266	7.016
		Halicyclops	sp.	Copepoda	7.01	15.00	495.50886	85.0	0.20	0.8577	1.000	0.858	1.016	0.872
		nauplii		Copepoda	4.62	15.00	326.56932	101.0	0.30	1.03092	21.000	21.649	0.127	2.743
		nauplii		Copepoda	7.01	15.00	495.50886	85.0	0.20	0.8577	27.000	23.158	0.155	3.591
		nauplii		Copepoda	5.08	15.00	359.08488	86.0	0.20	1.19749	24.000	28.740	0.073	2.108
		Sabellariidae	*trochophore larvae*	Polychaeta	4.62	15.00	326.56932	101.0	0.30	1.03092	59.000	60.824	0.003	0.199
		Sabellariidae	*trochophore larvae*	Polychaeta	7.01	15.00	495.50886	85.0	0.20	0.8577	69.000	59.182	0.002	0.092
		Sabellariidae	*trochophore larvae*	Polychaeta	5.08	15.00	359.08488	86.0	0.20	1.19749	69.000	82.627	0.001	0.094
		Synchaeta	*bicornis*	Rotifera	4.62	15.00	326.56932	101.0	0.30	1.03092	1.000	1.031	0.093	0.096
		Synchaeta	spp.	Rotifera	4.62	15.00	326.56932	101.0	0.30	1.03092	1.000	1.031	0.059	0.060
		Trichocerca	*marina*	Rotifera	4.62	15.00	326.56932	101.0	0.30	1.03092	143.000	147.421	0.019	2.728
		Trichocerca	*marina*	Rotifera	7.01	15.00	495.50886	85.0	0.20	0.8577	141.000	120.936	0.011	1.322
		Trichocerca	*marina*	Rotifera	5.08	15.00	359.08488	86.0	0.20	1.19749	139.000	166.451	0.013	2.138

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-3: Farim Project - Wet Season Station 3 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 3	17-Aug-13	*Acartia*	sp.	Copepoda	2.71	15.00	191.55906	41.0	0.10	2.14033	8.000	17.123	2.277	38.985
		Acartia	sp.	Copepoda	4.57	15.00	323.03502	43.0	0.20	0.66556	5.000	3.328	3.277	10.905
		bivalvia	*veliger larvae*	Bivalvia	2.71	15.00	191.55906	41.0	0.10	2.14033	24.000	51.368	0.046	2.379
		bivalvia	*veliger larvae*	Bivalvia	3.41	15.00	241.03926	39.0	0.20	0.809	53.000	42.877	0.029	1.257
		bivalvia	*veliger larvae*	Bivalvia	4.57	15.00	323.03502	43.0	0.20	0.66556	41.000	27.288	0.042	1.147
		calanoid	*copepodid*	Copepoda	2.71	15.00	191.55906	41.0	0.10	2.14033	15.000	32.105	2.138	68.626
		calanoid	*copepodid*	Copepoda	3.41	15.00	241.03926	39.0	0.20	0.809	29.000	23.461	1.977	46.378
		calanoid	*copepodid*	Copepoda	4.57	15.00	323.03502	43.0	0.20	0.66556	24.000	15.974	1.472	23.512
		gastropod	*larvae*	Bivalvia	2.71	15.00	191.55906	41.0	0.10	2.14033	5.000	10.702	0.137	1.469
		gastropod	*larvae*	Bivalvia	3.41	15.00	241.03926	39.0	0.20	0.809	34.000	27.506	0.217	5.969
		gastropod	*larvae*	Bivalvia	4.57	15.00	323.03502	43.0	0.20	0.66556	22.000	14.642	0.059	0.861
		nauplii		Copepoda	2.71	15.00	191.55906	41.0	0.10	2.14033	97.000	207.612	0.098	20.403
		nauplii		Copepoda	3.41	15.00	241.03926	39.0	0.20	0.809	90.000	72.810	0.113	8.237
		nauplii		Copepoda	4.57	15.00	323.03502	43.0	0.20	0.66556	51.000	33.944	0.065	2.213
		Sabellariidae	*trochophore larvae*	Polychaeta	2.71	15.00	191.55906	41.0	0.10	2.14033	32.000	68.491	0.001	0.093
		Sabellariidae	*trochophore larvae*	Polychaeta	3.41	15.00	241.03926	39.0	0.20	0.809	72.000	58.248	0.002	0.124
		Sabellariidae	*trochophore larvae*	Polychaeta	4.57	15.00	323.03502	43.0	0.20	0.66556	59.000	39.268	0.001	0.046
		Trichocerca	*marina*	Rotifera	2.71	15.00	191.55906	41.0	0.10	2.14033	23.000	49.228	0.015	0.749
		Trichocerca	*marina*	Rotifera	3.41	15.00	241.03926	39.0	0.20	0.809	5.000	4.045	0.017	0.069

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-4: Farim Project - Wet Season Station 4 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 4	17-Aug-13	*Acartia*	sp.	Copepoda	5.24	15.00	370.39464	79.0	0.30	0.71095	6.000	4.266	3.204	13.666
		Acartia	sp.	Copepoda	2.47	15.00	174.59442	78.0	1.20	0.37229	13.000	4.840	2.820	13.649
		Acartia	sp.	Copepoda	4.75	15.00	335.7585	82.0	0.60	0.40704	11.000	4.477	2.220	9.938
		Anthomedusae		Hydrozoa	2.47	15.00	174.59442	78.0	1.20	0.37229	1.000	0.372	1.145	0.426
		bivalvia	*veliger larvae*	Bivalvia	5.24	15.00	370.39464	79.0	0.30	0.71095	13.000	9.242	0.034	0.311
		bivalvia	*veliger larvae*	Bivalvia	2.47	15.00	174.59442	78.0	1.20	0.37229	12.000	4.467	0.017	0.077
		bivalvia	*veliger larvae*	Bivalvia	4.75	15.00	335.7585	82.0	0.60	0.40704	10.000	4.070	0.028	0.116
		calanoid	*copepodid*	Copepoda	5.24	15.00	370.39464	79.0	0.30	0.71095	28.000	19.907	1.557	31.002
		calanoid	*copepodid*	Copepoda	2.47	15.00	174.59442	78.0	1.20	0.37229	46.000	17.125	1.299	22.244
		calanoid	*copepodid*	Copepoda	4.75	15.00	335.7585	82.0	0.60	0.40704	34.000	13.839	1.342	18.569
		gastropod	*larvae*	Bivalvia	5.24	15.00	370.39464	79.0	0.30	0.71095	19.000	13.508	0.121	1.639
		gastropod	*larvae*	Bivalvia	2.47	15.00	174.59442	78.0	1.20	0.37229	11.000	4.095	0.156	0.640
		gastropod	*larvae*	Bivalvia	4.75	15.00	335.7585	82.0	0.60	0.40704	24.000	9.769	0.067	0.651
		nauplii		Copepoda	5.24	15.00	370.39464	79.0	0.30	0.71095	56.000	39.813	0.075	2.981
		nauplii		Copepoda	2.47	15.00	174.59442	78.0	1.20	0.37229	41.000	15.264	0.076	1.163
		nauplii		Copepoda	4.75	15.00	335.7585	82.0	0.60	0.40704	39.000	15.875	0.061	0.975
		Planula	*larvae*	Hydrozoa	2.47	15.00	174.59442	78.0	1.20	0.37229	1.000	0.372	1.254	0.467
		Sabellariidae	*trochophore larvae*	Polychaeta	5.24	15.00	370.39464	79.0	0.30	0.71095	91.000	64.697	0.001	0.088
		Sabellariidae	*trochophore larvae*	Polychaeta	2.47	15.00	174.59442	78.0	1.20	0.37229	108.000	40.207	0.001	0.050
		Sabellariidae	*trochophore larvae*	Polychaeta	4.75	15.00	335.7585	82.0	0.60	0.40704	100.000	40.704	0.002	0.080
		Trichocerca	*marina*	Rotifera	5.24	15.00	370.39464	79.0	0.30	0.71095	1.000	0.711	0.021	0.015

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-5: Farim Project - Wet Season Station 5 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 5	16-Aug-13	*Acartia*	sp.	Copepoda	6.02	15.00	425.52972	58.0	0.50	0.2726	15.000	4.089	1.443	5.899
		Acartia	sp.	Copepoda	6.4	15.00	452.3904	56.0	1.00	0.12379	27.000	3.342	2.989	9.991
		Acartia	sp.	Copepoda	8.4	15.00	593.7624	59.0	1.00	0.09937	18.000	1.789	1.441	2.576
		Anthomedusae		Hydrozoa	6.4	15.00	452.3904	56.0	1.00	0.12379	1.000	0.124	1.423	0.176
		bivalvia	*veliger larvae*	Bivalvia	8.4	15.00	593.7624	59.0	1.00	0.09937	11.000	1.093	0.039	0.043
		calanoid	*copepodid*	Copepoda	6.02	15.00	425.52972	58.0	0.50	0.2726	14.000	3.816	1.544	5.891
		calanoid	*copepodid*	Copepoda	6.4	15.00	452.3904	56.0	1.00	0.12379	30.000	3.714	2.296	8.526
		calanoid	*copepodid*	Copepoda	8.4	15.00	593.7624	59.0	1.00	0.09937	34.000	3.378	1.377	4.652
		cyclopoid	*copepodid*	Copepoda	8.4	15.00	593.7624	59.0	1.00	0.09937	2.000	0.199	0.435	0.087
		gastropod	*larvae*	Bivalvia	6.02	15.00	425.52972	58.0	0.50	0.2726	2.000	0.545	0.280	0.153
		gastropod	*larvae*	Bivalvia	6.4	15.00	452.3904	56.0	1.00	0.12379	8.000	0.990	0.137	0.136
		gastropod	*larvae*	Bivalvia	8.4	15.00	593.7624	59.0	1.00	0.09937	6.000	0.596	0.214	0.128
		Metatrochophore	*larvae*	Polychaeta	6.4	15.00	452.3904	56.0	1.00	0.12379	1.000	0.124	0.013	0.002
		nauplii		Copepoda	6.02	15.00	425.52972	58.0	0.50	0.2726	35.000	9.541	0.084	0.798
		nauplii		Copepoda	6.4	15.00	452.3904	56.0	1.00	0.12379	47.000	5.818	0.106	0.617
		nauplii		Copepoda	8.4	15.00	593.7624	59.0	1.00	0.09937	53.000	5.266	0.057	0.298
		Oithona	sp.	Copepoda	6.4	15.00	452.3904	56.0	1.00	0.12379	1.000	0.124	0.849	0.105
		Oithona	sp.	Copepoda	8.4	15.00	593.7624	59.0	1.00	0.09937	2.000	0.199	0.966	0.192
		Pseudodiaptomus	*hessei*	Copepoda	6.02	15.00	425.52972	58.0	0.50	0.2726	1.000	0.273	1.264	0.345
		Sabellariidae	*trochophore larvae*	Polychaeta	6.02	15.00	425.52972	58.0	0.50	0.2726	134.000	36.529	0.002	0.083
		Sabellariidae	*trochophore larvae*	Polychaeta	6.4	15.00	452.3904	56.0	1.00	0.12379	166.000	20.549	0.001	0.021
		Sabellariidae	*trochophore larvae*	Polychaeta	8.4	15.00	593.7624	59.0	1.00	0.09937	195.000	19.376	0.002	0.041
		Trichocerca	*marina*	Rotifera	6.02	15.00	425.52972	58.0	0.50	0.2726	3.000	0.818	0.026	0.022
		Trichocerca	*marina*	Rotifera	8.4	15.00	593.7624	59.0	1.00	0.09937	1.000	0.099	0.033	0.003

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-6: Farim Project - Wet Season Station 6 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 6	16-Aug-13	*Acartia*	sp.	Copepoda	6.1	15.00	431.1846	44.0	1.00	0.10204	33.000	3.367	2.856	9.616
		Acartia	sp.	Copepoda	5.21	15.00	368.27406	59.0	1.00	0.16021	14.000	2.243	3.204	7.186
		Acartia	sp.	Copepoda	5	15.00	353.43	46.0	1.00	0.13015	23.000	2.994	1.189	3.559
		bivalvia	*veliger larvae*	Bivalvia	6.1	15.00	431.1846	44.0	1.00	0.10204	21.000	2.143	0.038	0.082
		bivalvia	*veliger larvae*	Bivalvia	5.21	15.00	368.27406	59.0	1.00	0.16021	2.000	0.320	0.036	0.012
		bivalvia	*veliger larvae*	Bivalvia	5	15.00	353.43	46.0	1.00	0.13015	11.000	1.432	0.050	0.071
		Brachyura	*zoea*	Decapoda	5	15.00	353.43	46.0	1.00	0.13015	1.000	0.130	0.012	0.002
		calanoid	*copepodid*	Copepoda	6.1	15.00	431.1846	44.0	1.00	0.10204	49.000	5.000	0.926	4.631
		calanoid	*copepodid*	Copepoda	5.21	15.00	368.27406	59.0	1.00	0.16021	30.000	4.806	1.050	5.046
		calanoid	*copepodid*	Copepoda	5	15.00	353.43	46.0	1.00	0.13015	46.000	5.987	1.350	8.084
		cyclopoid	*copepodid*	Copepoda	5.21	15.00	368.27406	59.0	1.00	0.16021	5.000	0.801	0.258	0.206
		cyclopoid	*copepodid*	Copepoda	5	15.00	353.43	46.0	1.00	0.13015	3.000	0.390	0.895	0.350
		gastropod	*larvae*	Bivalvia	6.1	15.00	431.1846	44.0	1.00	0.10204	48.000	4.898	0.134	0.655
		gastropod	*larvae*	Bivalvia	5.21	15.00	368.27406	59.0	1.00	0.16021	7.000	1.121	0.137	0.154
		gastropod	*larvae*	Bivalvia	5	15.00	353.43	46.0	1.00	0.13015	22.000	2.863	0.392	1.121
		Metatrochophore	*larvae*	Polychaeta	5.21	15.00	368.27406	59.0	1.00	0.16021	1.000	0.160	0.002	0.000
		nauplii		Copepoda	6.1	15.00	431.1846	44.0	1.00	0.10204	127.000	12.960	0.103	1.339
		nauplii		Copepoda	5.21	15.00	368.27406	59.0	1.00	0.16021	61.000	9.773	0.102	1.001
		nauplii		Copepoda	5	15.00	353.43	46.0	1.00	0.13015	71.000	9.241	0.075	0.691
		Oithona	sp.	Copepoda	5.21	15.00	368.27406	59.0	1.00	0.16021	3.000	0.481	1.152	0.553
		Sabellariidae	*trochophore larvae*	Polychaeta	6.1	15.00	431.1846	44.0	1.00	0.10204	170.000	17.348	0.001	0.020
		Sabellariidae	*trochophore larvae*	Polychaeta	5.21	15.00	368.27406	59.0	1.00	0.16021	141.000	22.589	0.001	0.019
		Sabellariidae	*trochophore larvae*	Polychaeta	5	15.00	353.43	46.0	1.00	0.13015	109.000	14.187	0.002	0.033
		Trichocerca	*marina*	Rotifera	5.21	15.00	368.27406	59.0	1.00	0.16021	1.000	0.160	0.059	0.009

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-7: Farim Project - Wet Season Station 7 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 7	19-Aug-13	*Acartia*	sp.	Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	19.000	0.218	1.611	0.351
		bivalvia	*veliger larvae*	Bivalvia	3.25	15.00	229.7295	92.0	5.50	0.07281	3.000	0.218	0.068	0.015
		Brachyura	*zoea*	Decapoda	4.94	15.00	349.18884	132.0	33.00	0.01146	6.000	0.069	0.029	0.002
		Brachyura	*zoea*	Decapoda	4.03	15.00	284.86458	112.0	6.00	0.06553	1.000	0.066	0.016	0.001
		calanoid	*copepodid*	Copepoda	3.25	15.00	229.7295	92.0	5.50	0.07281	35.000	2.548	1.744	4.446
		calanoid	*copepodid*	Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	40.000	0.458	0.688	0.315
		calanoid	*copepodid*	Copepoda	4.03	15.00	284.86458	112.0	6.00	0.06553	40.000	2.621	0.603	1.580
		Coullana	*canadensis*	Copepoda	4.03	15.00	284.86458	112.0	6.00	0.06553	1.000	0.066	0.518	0.034
		cyclopoid	*copepodid*	Copepoda	3.25	15.00	229.7295	92.0	5.50	0.07281	4.000	0.291	0.733	0.214
		cyclopoid	*copepodid*	Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	2.000	0.023	0.785	0.018
		cyclopoid	*copepodid*	Copepoda	4.03	15.00	284.86458	112.0	6.00	0.06553	1.000	0.066	0.108	0.007
		gastropod	*larvae*	Bivalvia	3.25	15.00	229.7295	92.0	5.50	0.07281	11.000	0.801	0.325	0.260
		gastropod	*larvae*	Bivalvia	4.03	15.00	284.86458	112.0	6.00	0.06553	8.000	0.524	0.117	0.061
		Halicyclops	sp.	Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	6.000	0.069	1.528	0.105
		nauplii		Copepoda	3.25	15.00	229.7295	92.0	5.50	0.07281	29.000	2.112	0.082	0.173
		nauplii		Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	9.000	0.103	0.032	0.003
		nauplii		Copepoda	4.03	15.00	284.86458	112.0	6.00	0.06553	42.000	2.752	0.056	0.155
		Oikopleura	sp.	Tunicata	3.25	15.00	229.7295	92.0	5.50	0.07281	13.000	0.947	0.004	0.004
		Oikopleura	sp.	Tunicata	4.94	15.00	349.18884	132.0	33.00	0.01146	13.000	0.149	0.000	0.000
		Oikopleura	sp.	Tunicata	4.03	15.00	284.86458	112.0	6.00	0.06553	6.000	0.393	0.000	0.000
		Oithona	sp.	Copepoda	3.25	15.00	229.7295	92.0	5.50	0.07281	2.000	0.146	0.966	0.141
		Oithona	sp.	Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	1.000	0.011	1.315	0.015
		ostracod		Ostracoda	4.94	15.00	349.18884	132.0	33.00	0.01146	2.000	0.023	0.453	0.010
		Paracalanus	*parvus*	Copepoda	3.25	15.00	229.7295	92.0	5.50	0.07281	11.000	0.801	1.812	1.452
		Paracalanus	*parvus*	Copepoda	4.94	15.00	349.18884	132.0	33.00	0.01146	1.000	0.011	1.676	0.019
		Paracalanus	*parvus*	Copepoda	4.03	15.00	284.86458	112.0	6.00	0.06553	5.000	0.328	1.676	0.549
		Sabellariidae	*trochophore larvae*	Polychaeta	3.25	15.00	229.7295	92.0	5.50	0.07281	99.000	7.208	0.003	0.020
		Sabellariidae	*trochophore larvae*	Polychaeta	4.94	15.00	349.18884	132.0	33.00	0.01146	101.000	1.157	0.001	0.001
		Sabellariidae	*trochophore larvae*	Polychaeta	4.03	15.00	284.86458	112.0	6.00	0.06553	114.000	7.470	0.001	0.008

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-8: Farim Project - Wet Season Station 8 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 8	19-Aug-13	*Acartia*	sp.	Copepoda	3.55	15.00	250.9353	77.0	4.00	0.07671	4.000	0.307	0.990	0.304
		Acartia	sp.	Copepoda	4.43	15.00	313.13898	98.0	4.00	0.07824	8.000	0.626	2.523	1.579
		Anthomedusae		Hydrozoa	4.43	15.00	313.13898	98.0	4.00	0.07824	1.000	0.078	1.108	0.087
		Bipinnaria	*larvae*	Bivalvia	3.55	15.00	250.9353	77.0	4.00	0.07671	2.000	0.153	0.454	0.070
		bivalvia	*veliger larvae*	Bivalvia	4.73	15.00	334.34478	140.0	12.00	0.03489	1.000	0.035	0.186	0.006
		Brachyura	*zoea*	Decapoda	4.73	15.00	334.34478	140.0	12.00	0.03489	1.000	0.035	0.032	0.001
		Brachyura	*zoea*	Decapoda	3.55	15.00	250.9353	77.0	4.00	0.07671	12.000	0.921	0.061	0.056
		calanoid	*copepodid*	Copepoda	3.55	15.00	250.9353	77.0	4.00	0.07671	4.000	0.307	1.759	0.540
		calanoid	*copepodid*	Copepoda	4.43	15.00	313.13898	98.0	4.00	0.07824	7.000	0.548	0.798	0.437
		cyclopoid	*copepodid*	Copepoda	4.73	15.00	334.34478	140.0	12.00	0.03489	4.000	0.140	0.895	0.125
		cyclopoid	*copepodid*	Copepoda	3.55	15.00	250.9353	77.0	4.00	0.07671	2.000	0.153	0.895	0.137
		cyclopoid	*copepodid*	Copepoda	4.43	15.00	313.13898	98.0	4.00	0.07824	4.000	0.313	0.435	0.136
		gastropod	*larvae*	Bivalvia	4.43	15.00	313.13898	98.0	4.00	0.07824	1.000	0.078	0.045	0.004
		Halicyclops	sp.	Copepoda	4.73	15.00	334.34478	140.0	12.00	0.03489	1.000	0.035	0.369	0.013
		nauplii		Copepoda	4.73	15.00	334.34478	140.0	12.00	0.03489	3.000	0.105	0.105	0.011
		nauplii		Copepoda	3.55	15.00	250.9353	77.0	4.00	0.07671	18.000	1.381	0.061	0.085
		nauplii		Copepoda	4.43	15.00	313.13898	98.0	4.00	0.07824	12.000	0.939	0.096	0.090
		Oikopleura	sp.	Tunicata	4.73	15.00	334.34478	140.0	12.00	0.03489	19.000	0.663	0.001	0.001
		Oikopleura	sp.	Tunicata	3.55	15.00	250.9353	77.0	4.00	0.07671	30.000	2.301	0.002	0.006
		Oikopleura	sp.	Tunicata	4.43	15.00	313.13898	98.0	4.00	0.07824	31.000	2.425	0.004	0.009
		Oithona	sp.	Copepoda	4.43	15.00	313.13898	98.0	4.00	0.07824	1.000	0.078	1.281	0.100
		Paracalanus	*parvus*	Copepoda	4.73	15.00	334.34478	140.0	12.00	0.03489	4.000	0.140	1.829	0.255
		Paracalanus	*parvus*	Copepoda	4.43	15.00	313.13898	98.0	4.00	0.07824	1.000	0.078	2.046	0.160
		Pseudodiaptomus	*serricaudatus*	Copepoda	3.55	15.00	250.9353	77.0	4.00	0.07671	1.000	0.077	1.990	0.153
		Sabellariidae	*trochophore larvae*	Polychaeta	4.73	15.00	334.34478	140.0	12.00	0.03489	182.000	6.351	0.001	0.009
		Sabellariidae	*trochophore larvae*	Polychaeta	3.55	15.00	250.9353	77.0	4.00	0.07671	133.000	10.203	0.002	0.021
		Sabellariidae	*trochophore larvae*	Polychaeta	4.43	15.00	313.13898	98.0	4.00	0.07824	201.000	15.726	0.001	0.021

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-9: Farim Project - Wet Season Station 9 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 9	22-Aug-13	*Bipinnaria*	*larvae*	Bivalvia	1.5	15.00	106.029	142.0	9.00	0.14881	4.000	0.595	1.077	0.641
		bivalvia	*veliger larvae*	Bivalvia	1.83	15.00	129.35538	110.0	18.00	0.04724	2.000	0.094	0.045	0.004
		Brachyura	*zoea*	Decapoda	1.5	15.00	106.029	142.0	9.00	0.14881	47.000	6.994	0.019	0.134
		Brachyura	*zoea*	Decapoda	1.83	15.00	129.35538	110.0	18.00	0.04724	1.000	0.047	0.045	0.002
		calanoid	*copepodid*	Copepoda	1.5	15.00	106.029	142.0	9.00	0.14881	21.000	3.125	1.810	5.658
		calanoid	*copepodid*	Copepoda	1.83	15.00	129.35538	110.0	18.00	0.04724	54.000	2.551	1.111	2.834
		calanoid	*copepodid*	Copepoda	1.8	15.00	127.2348	110.0	6.00	0.14409	67.000	9.654	1.679	16.208
		cyclopoid	*copepodid*	Copepoda	1.5	15.00	106.029	142.0	9.00	0.14881	9.000	1.339	1.081	1.447
		cyclopoid	*copepodid*	Copepoda	1.8	15.00	127.2348	110.0	6.00	0.14409	50.000	7.205	0.674	4.858
		Euterpina	*acutifrons*	Copepoda	1.5	15.00	106.029	142.0	9.00	0.14881	91.000	13.541	0.661	8.953
		Euterpina	*acutifrons*	Copepoda	1.83	15.00	129.35538	110.0	18.00	0.04724	65.000	3.071	0.234	0.718
		Euterpina	*acutifrons*	Copepoda	1.8	15.00	127.2348	110.0	6.00	0.14409	9.000	1.297	0.996	1.291
		nauplii		Copepoda	1.5	15.00	106.029	142.0	9.00	0.14881	28.000	4.167	0.096	0.400
		nauplii		Copepoda	1.83	15.00	129.35538	110.0	18.00	0.04724	24.000	1.134	0.051	0.058
		nauplii		Copepoda	1.8	15.00	127.2348	110.0	6.00	0.14409	62.000	8.934	0.092	0.826
		Oithona	sp.	Copepoda	1.8	15.00	127.2348	110.0	6.00	0.14409	6.000	0.865	0.849	0.734
		Paracalanus	*parvus*	Copepoda	1.83	15.00	129.35538	110.0	18.00	0.04724	55.000	2.598	0.755	1.961
		Paracalanus	*parvus*	Copepoda	1.8	15.00	127.2348	110.0	6.00	0.14409	5.000	0.720	1.027	0.740
		Sabellariidae	*trochophore larvae*	Polychaeta	1.8	15.00	127.2348	110.0	6.00	0.14409	7.000	1.009	0.002	0.002
		Upogebia	*zoea*	Decapoda	1.5	15.00	106.029	142.0	9.00	0.14881	1.000	0.149	0.141	0.021

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-10: Farim Project - Wet Season Station 10 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 10	22-Aug-13	*Balanus*	*nauplii*	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	7.000	0.117	0.095	0.011
		Balanus	*nauplii*	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	12.000	0.336	0.082	0.028
		Balanus	*nauplii*	Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	10.000	0.273	0.085	0.023
		Brachyura	*zoea*	Decapoda	2.96	15.00	209.23056	140.0	40.00	0.01673	40.000	0.669	0.035	0.023
		Brachyura	*zoea*	Decapoda	3.41	15.00	241.03926	81.0	12.00	0.028	20.000	0.560	0.072	0.041
		Brachyura	*zoea*	Decapoda	2.36	15.00	166.81896	91.0	20.00	0.02728	6.000	0.164	0.071	0.012
		calanoid	*copepodid*	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	15.000	0.251	1.123	0.282
		calanoid	*copepodid*	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	38.000	1.064	1.307	1.391
		calanoid	*copepodid*	Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	54.000	1.473	0.774	1.140
		Caridea	*zoea*	Decapoda	2.96	15.00	209.23056	140.0	40.00	0.01673	1.000	0.017	0.026	0.000
		Chaetognatha			2.96	15.00	209.23056	140.0	40.00	0.01673	12.000	0.201	66.028	13.254
		Chaetognatha			3.41	15.00	241.03926	81.0	12.00	0.028	1.000	0.028	0.645	0.018
		Coullana	*canadensis*	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	2.000	0.056	0.616	0.034
		cyclopoid	*copepodid*	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	8.000	0.134	0.401	0.054
		cyclopoid	*copepodid*	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	22.000	0.616	0.444	0.273
		cyclopoid	*copepodid*	Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	20.000	0.546	0.420	0.229
		Euterpina	*acutifrons*	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	23.000	0.385	2.236	0.860
		Euterpina	*acutifrons*	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	7.000	0.196	1.243	0.244
		Euterpina	*acutifrons*	Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	11.000	0.300	0.231	0.069
		Halicyclops	sp.	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	1.000	0.017	3.316	0.055
		Halicyclops	sp.	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	5.000	0.140	1.446	0.202
		Hemicyclops	sp.	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	2.000	0.056	0.733	0.041
		Labidocera	sp.	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	1.000	0.017	13.704	0.229
		Metatrochophore	*larvae*	Polychaeta	2.96	15.00	209.23056	140.0	40.00	0.01673	1.000	0.017	0.005	0.000
		Metatrochophore	*larvae*	Polychaeta	3.41	15.00	241.03926	81.0	12.00	0.028	12.000	0.336	0.012	0.004
		Metatrochophore	*larvae*	Polychaeta	2.36	15.00	166.81896	91.0	20.00	0.02728	11.000	0.300	0.010	0.003
		Microsetella	sp.	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	2.000	0.056	0.518	0.029
		nauplii		Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	28.000	0.784	0.085	0.067
		nauplii		Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	19.000	0.518	0.106	0.055
		Oikopleura	sp.	Tunicata	2.96	15.00	209.23056	140.0	40.00	0.01673	31.000	0.519	0.002	0.001
		Oikopleura	sp.	Tunicata	3.41	15.00	241.03926	81.0	12.00	0.028	19.000	0.532	0.005	0.003
		Oikopleura	sp.	Tunicata	2.36	15.00	166.81896	91.0	20.00	0.02728	24.000	0.655	0.004	0.003
		Oithona	sp.	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	20.000	0.335	1.282	0.429
		Oithona	sp.	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	4.000	0.112	0.966	0.108
		Oithona	sp.	Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	15.000	0.409	1.298	0.531
		Ophiuroidea	*larvae*	Ophiuroidea	2.96	15.00	209.23056	140.0	40.00	0.01673	16.000	0.268	0.485	0.130
		Ophiuroidea	*larvae*	Ophiuroidea	2.36	15.00	166.81896	91.0	20.00	0.02728	1.000	0.027	0.095	0.003
		Paracalanus	*parvus*	Copepoda	2.96	15.00	209.23056	140.0	40.00	0.01673	27.000	0.452	1.570	0.709
		Paracalanus	*parvus*	Copepoda	3.41	15.00	241.03926	81.0	12.00	0.028	17.000	0.476	1.252	0.596
		Paracalanus	*parvus*	Copepoda	2.36	15.00	166.81896	91.0	20.00	0.02728	23.000	0.627	1.396	0.875
		Sabellariidae	*trochophore larvae*	Polychaeta	2.96	15.00	209.23056	140.0	40.00	0.01673	15.000	0.251	0.002	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	3.41	15.00	241.03926	81.0	12.00	0.028	16.000	0.448	0.002	0.001
		Sabellariidae	*trochophore larvae*	Polychaeta	2.36	15.00	166.81896	91.0	20.00	0.02728	25.000	0.682	0.002	0.001

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-11: Farim Project - Wet Season Station 11 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 11	24-Aug-13	*Balanus*	*nauplii*	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	1.000	0.178	0.105	0.019
		bivalvia	*veliger larvae*	Bivalvia	5.27	15.00	372.51522	99.0	2.00	0.13288	1.000	0.133	0.117	0.016
		Brachyura	*zoea*	Decapoda	4.33	15.00	306.07038	70.0	1.00	0.22871	10.000	2.287	0.095	0.216
		Brachyura	*zoea*	Decapoda	5.27	15.00	372.51522	99.0	2.00	0.13288	10.000	1.329	0.071	0.094
		Brachyura	*zoea*	Decapoda	4.46	15.00	315.25956	112.0	2.00	0.17763	3.000	0.533	0.026	0.014
		calanoid	*copepodid*	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	39.000	8.920	1.464	13.062
		calanoid	*copepodid*	Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	45.000	5.980	1.043	6.238
		calanoid	*copepodid*	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	38.000	6.750	1.073	7.242
		Centropages	*furcatus*	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	1.000	0.229	5.768	1.319
		Centropages	*furcatus*	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	1.000	0.178	5.891	1.046
		Chaetognatha			4.33	15.00	306.07038	70.0	1.00	0.22871	6.000	1.372	0.808	1.109
		Chaetognatha			5.27	15.00	372.51522	99.0	2.00	0.13288	7.000	0.930	8.360	7.776
		Chaetognatha			4.46	15.00	315.25956	112.0	2.00	0.17763	1.000	0.178	5.662	1.006
		cyclopoid	*copepodid*	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	47.000	10.749	0.600	6.449
		cyclopoid	*copepodid*	Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	60.000	7.973	0.364	2.906
		cyclopoid	*copepodid*	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	51.000	9.059	0.378	3.428
		Eucalanus	sp.	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	1.000	0.229	2.046	0.468
		Euterpina	*acutifrons*	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	7.000	1.601	1.243	1.990
		Euterpina	*acutifrons*	Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	37.000	4.917	0.673	3.307
		Euterpina	*acutifrons*	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	30.000	5.329	1.474	7.856
		gastropod	*larvae*	Bivalvia	4.46	15.00	315.25956	112.0	2.00	0.17763	1.000	0.178	0.186	0.033
		Halicyclops	sp.	Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	1.000	0.133	1.613	0.214
		Halicyclops	sp.	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	1.000	0.178	2.089	0.371
		Labidocera	sp.	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	1.000	0.229	1.727	0.395
		Metatrochophore	*larvae*	Polychaeta	4.33	15.00	306.07038	70.0	1.00	0.22871	3.000	0.686	0.013	0.009
		Metatrochophore	*larvae*	Polychaeta	5.27	15.00	372.51522	99.0	2.00	0.13288	1.000	0.133	0.003	0.000
		Metatrochophore	*larvae*	Polychaeta	4.46	15.00	315.25956	112.0	2.00	0.17763	4.000	0.711	0.007	0.005
		nauplii		Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	57.000	13.036	0.105	1.370
		nauplii		Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	78.000	10.365	0.062	0.645
		nauplii		Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	46.000	8.171	0.101	0.824
		Oikopleura	sp.	Tunicata	5.27	15.00	372.51522	99.0	2.00	0.13288	1.000	0.133	0.002	0.000
		Oikopleura	sp.	Tunicata	4.46	15.00	315.25956	112.0	2.00	0.17763	3.000	0.533	0.005	0.003
		Oithona	sp.	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	18.000	4.117	0.937	3.855
		Oithona	sp.	Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	18.000	2.392	1.298	3.105
		Oithona	sp.	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	17.000	3.020	1.365	4.123
		Ophiuroidea	*larvae*	Ophiuroidea	4.33	15.00	306.07038	70.0	1.00	0.22871	1.000	0.229	0.341	0.078
		Ophiuroidea	*larvae*	Ophiuroidea	5.27	15.00	372.51522	99.0	2.00	0.13288	2.000	0.266	0.128	0.034
		Ophiuroidea	*larvae*	Ophiuroidea	4.46	15.00	315.25956	112.0	2.00	0.17763	1.000	0.178	0.140	0.025
		ostracod		Ostracoda	5.27	15.00	372.51522	99.0	2.00	0.13288	6.000	0.797	0.920	0.733
		Paracalanus	*parvus*	Copepoda	4.33	15.00	306.07038	70.0	1.00	0.22871	2.000	0.457	2.218	1.014
		Paracalanus	*parvus*	Copepoda	5.27	15.00	372.51522	99.0	2.00	0.13288	5.000	0.664	1.627	1.081
		Paracalanus	*parvus*	Copepoda	4.46	15.00	315.25956	112.0	2.00	0.17763	6.000	1.066	1.439	1.533
		Porcellanidae	*zoea*	Decapoda	5.27	15.00	372.51522	99.0	2.00	0.13288	1.000	0.133	3.230	0.429
		Sabellariidae	*trochophore larvae*	Polychaeta	4.33	15.00	306.07038	70.0	1.00	0.22871	4.000	0.915	0.002	0.002
		Sabellariidae	*trochophore larvae*	Polychaeta	4.46	15.00	315.25956	112.0	2.00	0.17763	2.000	0.355	0.001	0.000

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-12: Farim Project - Wet Season Station 12 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 12	24-Aug-13	*Anthomedusae*		Hydrozoa	4.35	15.00	307.4841	103.0	6.00	0.05583	1.000	0.056	1.127	0.063
		Anthomedusae		Hydrozoa	4.49	15.00	317.38014	107.0	4.00	0.08428	1.000	0.084	1.123	0.095
		Balanus	*nauplii*	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	2.000	0.220	0.085	0.019
		Balanus	*nauplii*	Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	1.000	0.056	0.105	0.006
		Balanus	*nauplii*	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	1.000	0.084	0.095	0.008
		bivalvia	*veliger larvae*	Bivalvia	4.97	15.00	351.30942	116.0	3.00	0.11006	1.000	0.110	0.028	0.003
		Brachyura	*zoea*	Decapoda	4.49	15.00	317.38014	107.0	4.00	0.08428	3.000	0.253	0.022	0.006
		calanoid	*copepodid*	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	38.000	4.182	1.245	5.206
		calanoid	*copepodid*	Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	48.000	2.680	1.168	3.130
		calanoid	*copepodid*	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	40.000	3.371	1.414	4.767
		Chaetognatha			4.97	15.00	351.30942	116.0	3.00	0.11006	2.000	0.220	0.794	0.175
		Chaetognatha			4.49	15.00	317.38014	107.0	4.00	0.08428	1.000	0.084	69.721	5.876
		cyclopoid	*copepodid*	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	102.000	11.227	0.505	5.664
		cyclopoid	*copepodid*	Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	35.000	1.954	0.230	0.450
		cyclopoid	*copepodid*	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	39.000	3.287	0.302	0.992
		Eucalanus	sp.	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	8.000	0.881	8.554	7.532
		Eucalanus	sp.	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	4.000	0.337	8.424	2.840
		Euterpina	*acutifrons*	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	11.000	1.211	0.456	0.553
		Euterpina	*acutifrons*	Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	44.000	2.456	0.159	0.391
		Euterpina	*acutifrons*	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	45.000	3.793	0.764	2.896
		gastropod	*larvae*	Bivalvia	4.97	15.00	351.30942	116.0	3.00	0.11006	2.000	0.220	0.117	0.026
		Halicyclops	sp.	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	2.000	0.220	0.733	0.161
		Halicyclops	sp.	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	1.000	0.084	1.613	0.136
		Metatrochophore	*larvae*	Polychaeta	4.97	15.00	351.30942	116.0	3.00	0.11006	1.000	0.110	0.017	0.002
		nauplii		Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	59.000	6.494	0.082	0.535
		nauplii		Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	45.000	2.512	0.093	0.233
		nauplii		Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	23.000	1.939	0.054	0.104
		Oikopleura	sp.	Tunicata	4.97	15.00	351.30942	116.0	3.00	0.11006	1.000	0.110	0.001	0.000
		Oikopleura	sp.	Tunicata	4.35	15.00	307.4841	103.0	6.00	0.05583	5.000	0.279	0.001	0.000
		Oikopleura	sp.	Tunicata	4.49	15.00	317.38014	107.0	4.00	0.08428	1.000	0.084	0.000	0.000
		Oithona	sp.	Copepoda	4.97	15.00	351.30942	116.0	3.00	0.11006	12.000	1.321	0.937	1.237
		Oithona	sp.	Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	21.000	1.172	1.260	1.477
		Oithona	sp.	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	23.000	1.939	1.260	2.442
		ostracod		Ostracoda	4.35	15.00	307.4841	103.0	6.00	0.05583	1.000	0.056	0.359	0.020
		Paracalanus	*parvus*	Copepoda	4.35	15.00	307.4841	103.0	6.00	0.05583	11.000	0.614	1.109	0.681
		Paracalanus	*parvus*	Copepoda	4.49	15.00	317.38014	107.0	4.00	0.08428	17.000	1.433	1.508	2.161
		Porcellanidae	*zoea*	Decapoda	4.97	15.00	351.30942	116.0	3.00	0.11006	1.000	0.110	1.532	0.169
		Sabellariidae	*trochophore larvae*	Polychaeta	4.97	15.00	351.30942	116.0	3.00	0.11006	1.000	0.110	0.002	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	4.35	15.00	307.4841	103.0	6.00	0.05583	1.000	0.056	0.001	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	4.49	15.00	317.38014	107.0	4.00	0.08428	4.000	0.337	0.002	0.001
		Unidentifiable	*larvae*		4.49	15.00	317.38014	107.0	4.00	0.08428	1.000	0.084	0.327	0.028

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-13: Farim Project - Wet Season Station 13 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 13	21-Aug-13	*Bipinnaria*	*larvae*	Bivalvia	2.71	15.00	191.55906	98.0	5.00	0.10232	2.000	0.205	45.099	9.229
		bivalvia	*veliger larvae*	Bivalvia	2.71	15.00	191.55906	98.0	5.00	0.10232	4.000	0.409	0.137	0.056
		Brachyura	*megalopa*	Decapoda	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	0.813	0.049
		Brachyura	*zoea*	Decapoda	3.31	15.00	233.97066	112.0	8.00	0.05984	3.000	0.180	0.024	0.004
		calanoid	*copepodid*	Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	59.000	3.977	1.356	5.392
		calanoid	*copepodid*	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	56.000	3.351	0.909	3.046
		calanoid	*copepodid*	Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	51.000	5.218	1.067	5.568
		Chaetognatha			4.03	15.00	284.86458	96.0	5.00	0.0674	4.000	0.270	8.360	2.254
		Chaetognatha			3.31	15.00	233.97066	112.0	8.00	0.05984	4.000	0.239	0.907	0.217
		Chaetognatha			2.71	15.00	191.55906	98.0	5.00	0.10232	6.000	0.614	1.164	0.714
		cyclopoid	*copepodid*	Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	79.000	5.325	0.650	3.462
		cyclopoid	*copepodid*	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	35.000	2.094	0.225	0.471
		cyclopoid	*copepodid*	Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	18.000	1.842	0.867	1.597
		Eucalanus	sp.	Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	11.000	0.741	9.652	7.156
		Eucalanus	sp.	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	9.778	0.585
		Euterpina	*acutifrons*	Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	41.000	2.763	0.699	1.931
		Euterpina	*acutifrons*	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	53.000	3.171	0.809	2.564
		Euterpina	*acutifrons*	Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	39.000	3.990	1.021	4.073
		gastropod	*larvae*	Bivalvia	2.71	15.00	191.55906	98.0	5.00	0.10232	2.000	0.205	0.762	0.156
		Halicyclops	sp.	Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	2.000	0.135	0.733	0.099
		Halicyclops	sp.	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	0.592	0.035
		nauplii		Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	70.000	4.718	0.094	0.441
		nauplii		Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	10.000	0.598	0.167	0.100
		nauplii		Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	29.000	2.967	0.066	0.196
		Nephropidae	*zoea*	Decapoda	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	0.038	0.002
		Oikopleura	sp.	Tunicata	3.31	15.00	233.97066	112.0	8.00	0.05984	5.000	0.299	0.001	0.000
		Oikopleura	sp.	Tunicata	2.71	15.00	191.55906	98.0	5.00	0.10232	5.000	0.512	0.004	0.002
		Oithona	sp.	Copepoda	4.03	15.00	284.86458	96.0	5.00	0.0674	15.000	1.011	1.073	1.085
		Oithona	sp.	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	10.000	0.598	1.281	0.767
		Oithona	sp.	Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	18.000	1.842	0.996	1.835
		Ophiuroidea	*larvae*	Ophiuroidea	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	0.140	0.008
		Paracalanus	*parvus*	Copepoda	3.31	15.00	233.97066	112.0	8.00	0.05984	20.000	1.197	1.317	1.576
		Paracalanus	*parvus*	Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	25.000	2.558	4.541	11.614
		Sabellariidae	*trochophore larvae*	Polychaeta	4.03	15.00	284.86458	96.0	5.00	0.0674	1.000	0.067	0.002	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	0.001	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	2.71	15.00	191.55906	98.0	5.00	0.10232	2.000	0.205	0.002	0.000
		Temora	sp.	Copepoda	2.71	15.00	191.55906	98.0	5.00	0.10232	3.000	0.307	5.289	1.623
		Unidentifiable	*veliger larvae*	Bivalvia	4.03	15.00	284.86458	96.0	5.00	0.0674	3.000	0.202	0.838	0.169
		Unidentifiable	*veliger larvae*	Bivalvia	3.31	15.00	233.97066	112.0	8.00	0.05984	1.000	0.060	1.099	0.066
		Unidentifiable	*larvae*	Bivalvia	2.71	15.00	191.55906	98.0	5.00	0.10232	3.000	0.307	0.907	0.278

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-14: Farim Project - Wet Season Station 14 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 14	24-Aug-13	*Balanus*	*nauplii*	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	15.000	1.356	0.090	0.122
		Balanus	*nauplii*	Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	1.000	0.076	0.095	0.007
		bivalvia	*veliger larvae*	Bivalvia	3.6	15.00	254.4696	138.0	6.00	0.09038	1.000	0.090	0.186	0.017
		Brachyura	*zoea*	Decapoda	3.6	15.00	254.4696	138.0	6.00	0.09038	45.000	4.067	0.038	0.156
		Brachyura	*zoea*	Decapoda	3.9	15.00	275.6754	126.0	6.00	0.07618	21.000	1.600	0.044	0.070
		Brachyura	*megalopa*	Decapoda	3.71	15.00	262.24506	76.0	4.00	0.07245	2.000	0.145	0.369	0.053
		Brachyura	*zoea*	Decapoda	3.71	15.00	262.24506	76.0	4.00	0.07245	45.000	3.260	0.034	0.111
		calanoid	*copepodid*	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	33.000	2.983	1.251	3.731
		calanoid	*copepodid*	Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	56.000	4.266	0.787	3.358
		calanoid	*copepodid*	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	85.000	6.158	1.292	7.955
		Chaetognatha			3.6	15.00	254.4696	138.0	6.00	0.09038	9.000	0.813	22.381	18.206
		cyclopoid	*copepodid*	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	32.000	2.892	0.272	0.786
		cyclopoid	*copepodid*	Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	44.000	3.352	0.386	1.295
		cyclopoid	*copepodid*	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	47.000	3.405	0.962	3.277
		Euterpina	*acutifrons*	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	31.000	2.802	1.093	3.063
		Euterpina	*acutifrons*	Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	32.000	2.438	1.010	2.462
		Euterpina	*acutifrons*	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	13.000	0.942	0.913	0.860
		gastropod	*larvae*	Bivalvia	3.6	15.00	254.4696	138.0	6.00	0.09038	1.000	0.090	0.117	0.011
		gastropod	*larvae*	Bivalvia	3.9	15.00	275.6754	126.0	6.00	0.07618	5.000	0.381	0.186	0.071
		Halicyclops	sp.	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	1.000	0.090	2.089	0.189
		Halicyclops	sp.	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	12.000	0.869	2.163	1.881
		harpacticoid		Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	3.000	0.217	2.424	0.527
		nauplii		Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	33.000	2.983	0.311	0.928
		nauplii		Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	39.000	2.971	0.192	0.571
		nauplii		Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	56.000	4.057	0.085	0.343
		Oikopleura	sp.	Tunicata	3.6	15.00	254.4696	138.0	6.00	0.09038	1.000	0.090	0.002	0.000
		Oikopleura	sp.	Tunicata	3.9	15.00	275.6754	126.0	6.00	0.07618	1.000	0.076	0.001	0.000
		Oikopleura	sp.	Tunicata	3.71	15.00	262.24506	76.0	4.00	0.07245	3.000	0.217	0.001	0.000
		Oithona	sp.	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	17.000	1.537	1.232	1.894
		Oithona	sp.	Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	29.000	2.209	1.349	2.980
		Oithona	sp.	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	20.000	1.449	0.937	1.357
		Ophiuroidea	*larvae*	Ophiuroidea	3.6	15.00	254.4696	138.0	6.00	0.09038	1.000	0.090	0.095	0.009
		Paracalanus	*parvus*	Copepoda	3.6	15.00	254.4696	138.0	6.00	0.09038	10.000	0.904	1.306	1.181
		Paracalanus	*parvus*	Copepoda	3.9	15.00	275.6754	126.0	6.00	0.07618	9.000	0.686	1.439	0.986
		Paracalanus	*parvus*	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	16.000	1.159	2.434	2.822
		Sabellariidae	*trochophore larvae*	Polychaeta	3.6	15.00	254.4696	138.0	6.00	0.09038	12.000	1.085	0.001	0.001
		Sabellariidae	*trochophore larvae*	Polychaeta	3.9	15.00	275.6754	126.0	6.00	0.07618	1.000	0.076	0.002	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	3.71	15.00	262.24506	76.0	4.00	0.07245	15.000	1.087	0.002	0.002
		Temora	sp.	Copepoda	3.71	15.00	262.24506	76.0	4.00	0.07245	4.000	0.290	8.481	2.458

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-15: Farim Project - Wet Season Station 15 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 15	27-Aug-13	*Balanus*	*nauplii*	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	3.000	0.518	0.167	0.087
		bivalvia	*veliger larvae*	Bivalvia	8.65	15.00	611.4339	138.0	2.00	0.11285	1.000	0.113	0.137	0.015
		Brachyura	*zoea*	Decapoda	8.76	15.00	619.20936	107.0	1.00	0.1728	2.000	0.346	0.132	0.046
		Brachyura	*zoea*	Decapoda	9.22	15.00	651.72492	118.0	1.00	0.18106	7.000	1.267	0.001	0.001
		Brachyura	*zoea*	Decapoda	8.65	15.00	611.4339	138.0	2.00	0.11285	18.000	2.031	0.084	0.171
		calanoid	*copepodid*	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	61.000	10.541	0.754	7.948
		calanoid	*copepodid*	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	50.000	9.053	1.326	12.001
		calanoid	*copepodid*	Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	81.000	9.141	0.470	4.292
		Caridea	*zoea*	Decapoda	8.65	15.00	611.4339	138.0	2.00	0.11285	2.000	0.226	0.333	0.075
		Centropages	*furcatus*	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	2.000	0.362	15.916	5.763
		Chaetognatha			8.76	15.00	619.20936	107.0	1.00	0.1728	1.000	0.173	24.323	4.203
		Chaetognatha			8.65	15.00	611.4339	138.0	2.00	0.11285	5.000	0.564	0.536	0.302
		cyclopoid	*copepodid*	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	60.000	10.368	0.342	3.545
		cyclopoid	*copepodid*	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	60.000	10.863	0.604	6.566
		cyclopoid	*copepodid*	Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	60.000	6.771	0.162	1.100
		Eucalanus	sp.	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	3.000	0.543	7.070	3.840
		Euterpina	*acutifrons*	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	24.000	4.147	0.583	2.418
		Euterpina	*acutifrons*	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	19.000	3.440	0.941	3.239
		Euterpina	*acutifrons*	Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	32.000	3.611	0.801	2.893
		gastropod	*larvae*	Bivalvia	8.76	15.00	619.20936	107.0	1.00	0.1728	1.000	0.173	0.506	0.087
		gastropod	*larvae*	Bivalvia	8.65	15.00	611.4339	138.0	2.00	0.11285	1.000	0.113	0.280	0.032
		Halicyclops	sp.	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	1.000	0.181	1.016	0.184
		Hemicyclops	sp.	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	1.000	0.173	0.435	0.075
		Labidocera	sp.	Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	2.000	0.226	15.872	3.582
		Lingula	*larvae*	Brachiopoda	8.76	15.00	619.20936	107.0	1.00	0.1728	1.000	0.173	0.045	0.008
		Metatrochophore	*larvae*	Polychaeta	8.76	15.00	619.20936	107.0	1.00	0.1728	2.000	0.346	0.003	0.001
		Metatrochophore	*larvae*	Polychaeta	8.65	15.00	611.4339	138.0	2.00	0.11285	2.000	0.226	0.006	0.001
		nauplii		Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	48.000	8.294	0.160	1.329
		nauplii		Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	57.000	10.320	0.071	0.728
		nauplii		Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	49.000	5.530	0.106	0.588
		Oikopleura	sp.	Tunicata	8.76	15.00	619.20936	107.0	1.00	0.1728	3.000	0.518	0.001	0.000
		Oikopleura	sp.	Tunicata	9.22	15.00	651.72492	118.0	1.00	0.18106	2.000	0.362	0.005	0.002
		Oikopleura	sp.	Tunicata	8.65	15.00	611.4339	138.0	2.00	0.11285	2.000	0.226	0.000	0.000
		Oithona	sp.	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	6.000	1.037	1.382	1.433
		Oithona	sp.	Copepoda	9.22	15.00	651.72492	118.0	1.00	0.18106	16.000	2.897	0.922	2.671
		Oithona	sp.	Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	19.000	2.144	1.281	2.748
		ostracod		Ostracoda	8.76	15.00	619.20936	107.0	1.00	0.1728	2.000	0.346	5.342	1.846
		Paracalanus	*parvus*	Copepoda	8.76	15.00	619.20936	107.0	1.00	0.1728	1.000	0.173	2.651	0.458
		Paracalanus	*parvus*	Copepoda	8.65	15.00	611.4339	138.0	2.00	0.11285	6.000	0.677	1.394	0.944
		Porcellanidae	*zoea*	Decapoda	9.22	15.00	651.72492	118.0	1.00	0.18106	1.000	0.181	0.369	0.067
		Porcellanidae	*zoea*	Decapoda	8.65	15.00	611.4339	138.0	2.00	0.11285	1.000	0.113	7.550	0.852
		Sabellariidae	*trochophore larvae*	Polychaeta	8.76	15.00	619.20936	107.0	1.00	0.1728	1.000	0.173	0.002	0.000
		Sabellariidae	*trochophore larvae*	Polychaeta	9.22	15.00	651.72492	118.0	1.00	0.18106	3.000	0.543	0.002	0.001
		Sabellariidae	*trochophore larvae*	Polychaeta	8.65	15.00	611.4339	138.0	2.00	0.11285	1.000	0.113	0.002	0.000
		Synchaeta	spp.	Rotifera	8.76	15.00	619.20936	107.0	1.00	0.1728	2.000	0.346	0.028	0.010

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-16: Farim Project - Wet Season Station 16 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 16	26-Aug-13	*Annelida*	*larvae*	Polychaeta	2.93	15.00	207.10998	69.0	2.00	0.16658	2.000	0.333	0.058	0.019
		bivalvia	*veliger larvae*	Bivalvia	2.93	15.00	207.10998	63.0	1.00	0.30419	1.000	0.304	0.137	0.042
		Brachyura	*zoea*	Decapoda	2.93	15.00	207.10998	69.0	2.00	0.16658	10.000	1.666	0.001	0.002
		Brachyura	*zoea*	Decapoda	3.17	15.00	224.07462	92.0	2.00	0.20529	5.000	1.026	0.071	0.073
		Brachyura	*zoea*	Decapoda	2.93	15.00	207.10998	63.0	1.00	0.30419	4.000	1.217	0.003	0.004
		calanoid	*copepodid*	Copepoda	2.93	15.00	207.10998	69.0	2.00	0.16658	92.000	15.325	1.362	20.870
		calanoid	*copepodid*	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	54.000	11.086	0.934	10.351
		calanoid	*copepodid*	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	43.000	13.080	1.263	16.518
		Centropages	*furcatus*	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	1.000	0.304	17.817	5.420
		Chaetognatha			2.93	15.00	207.10998	69.0	2.00	0.16658	7.000	1.166	1.550	1.808
		Chaetognatha			3.17	15.00	224.07462	92.0	2.00	0.20529	1.000	0.205	0.068	0.014
		Chaetognatha			2.93	15.00	207.10998	63.0	1.00	0.30419	2.000	0.608	3.410	2.074
		cyclopoid	*copepodid*	Copepoda	2.93	15.00	207.10998	69.0	2.00	0.16658	49.000	8.162	0.566	4.617
		cyclopoid	*copepodid*	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	23.000	4.722	0.162	0.764
		cyclopoid	*copepodid*	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	36.000	10.951	0.664	7.272
		Eucalanus	sp.	Copepoda	2.93	15.00	207.10998	69.0	2.00	0.16658	4.000	0.666	5.855	3.901
		Eucalanus	sp.	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	1.000	0.205	8.951	1.838
		Eucalanus	sp.	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	1.000	0.304	8.424	2.562
		Euterpina	*acutifrons*	Copepoda	2.93	15.00	207.10998	69.0	2.00	0.16658	54.000	8.995	0.918	8.258
		Euterpina	*acutifrons*	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	39.000	8.006	0.217	1.734
		Euterpina	*acutifrons*	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	20.000	6.084	0.941	5.728
		gastropod	*larvae*	Bivalvia	3.17	15.00	224.07462	92.0	2.00	0.20529	2.000	0.411	0.214	0.088
		gastropod	*larvae*	Bivalvia	2.93	15.00	207.10998	63.0	1.00	0.30419	1.000	0.304	0.214	0.065
		Halicyclops	sp.	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	2.000	0.608	1.793	1.091
		Hemicyclops	sp.	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	3.000	0.616	1.218	0.750
		Lingula	*larvae*	Brachiopoda	3.17	15.00	224.07462	92.0	2.00	0.20529	3.000	0.616	0.036	0.022
		Lingula	*larvae*	Brachiopoda	2.93	15.00	207.10998	63.0	1.00	0.30419	5.000	1.521	0.280	0.426
		Metatrochophore	*larvae*	Polychaeta	3.17	15.00	224.07462	92.0	2.00	0.20529	1.000	0.205	0.004	0.001
		nauplii		Copepoda	2.93	15.00	207.10998	69.0	2.00	0.16658	58.000	9.662	0.091	0.883
		nauplii		Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	75.000	15.397	0.191	2.938
		nauplii		Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	65.000	19.772	0.090	1.771
		Oikopleura	sp.	Tunicata	2.93	15.00	207.10998	69.0	2.00	0.16658	9.000	1.499	0.010	0.016
		Oikopleura	sp.	Tunicata	3.17	15.00	224.07462	92.0	2.00	0.20529	7.000	1.437	0.001	0.002
		Oikopleura	sp.	Tunicata	2.93	15.00	207.10998	63.0	1.00	0.30419	6.000	1.825	0.010	0.019
		Oithona	sp.	Copepoda	2.93	15.00	207.10998	69.0	2.00	0.16658	31.000	5.164	0.956	4.939
		Oithona	sp.	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	17.000	3.490	1.101	3.843
		Oithona	sp.	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	19.000	5.780	0.951	5.498
		Ophiuroidea	*larvae*	Ophiuroidea	2.93	15.00	207.10998	69.0	2.00	0.16658	2.000	0.333	0.095	0.032
		Ophiuroidea	*larvae*	Ophiuroidea	3.17	15.00	224.07462	92.0	2.00	0.20529	9.000	1.848	0.105	0.194
		Ophiuroidea	*larvae*	Ophiuroidea	2.93	15.00	207.10998	63.0	1.00	0.30419	2.000	0.608	0.095	0.058
		ostracod		Ostracoda	3.17	15.00	224.07462	92.0	2.00	0.20529	1.000	0.205	0.280	0.057
		Paracalanus	*parvus*	Copepoda	3.17	15.00	224.07462	92.0	2.00	0.20529	5.000	1.026	1.350	1.385
		Paracalanus	*parvus*	Copepoda	2.93	15.00	207.10998	63.0	1.00	0.30419	2.000	0.608	2.460	1.496
		Polychaeta	*larvae*	Polychaeta	2.93	15.00	207.10998	69.0	2.00	0.16658	1.000	0.167	0.011	0.002
		Sabellariidae	*trochophore larvae*	Polychaeta	2.93	15.00	207.10998	69.0	2.00	0.16658	3.000	0.500	0.002	0.001
		Sabellariidae	*trochophore larvae*	Polychaeta	3.17	15.00	224.07462	92.0	2.00	0.20529	3.000	0.616	0.002	0.001

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-17: Farim Project - Wet Season Station 17 Summary of Zooplankton Taxonomic Data

Sample ID	Date	Genus	Species or Lifestage	Division	Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L	Biomass Factor	Species Biomass (µg d.w./L)
STN 17	26-Aug-13	*calanoid*	*copepodid*	Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	40.000	3.562	1.388	4.946
		cyclopoid	*copepodid*	Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	35.000	3.117	0.455	1.418
		Euterpina	*acutifrons*	Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	55.000	4.898	1.195	5.853
		Halicyclops	sp.	Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	3.000	0.267	1.613	0.431
		Oithona	sp.	Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	27.000	2.404	0.956	2.300
		Paracalanus	*parvus*	Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	7.000	0.623	1.627	1.014
		nauplii		Copepoda	5.56	15.00	393.01416	210.0	6.00	0.08906	46.000	4.097	0.070	0.285
		Gammarus	sp.	Amphipoda	5.56	15.00	393.01416	210.0	6.00	0.08906	1.000	0.089	0.000	0.000
		Oikopleura	sp.	Tunicata	5.56	15.00	393.01416	210.0	6.00	0.08906	4.000	0.356	0.045	0.016
		ostracod		Ostracoda	5.05	15.00	356.9643	220.0	4.00	0.15408	1.000	0.154	1.532	0.236
		calanoid	*copepodid*	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	20.000	3.082	1.351	4.164
		cyclopoid	*copepodid*	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	21.000	3.236	0.303	0.981
		Euterpina	*acutifrons*	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	57.000	8.782	0.433	3.802
		Halicyclops	sp.	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	2.000	0.308	0.684	0.211
		Hemicyclops	sp.	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	1.000	0.154	1.291	0.199
		Oithona	sp.	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	23.000	3.544	1.270	4.502
		Paracalanus	*parvus*	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	7.000	1.079	1.350	1.456
		nauplii		Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	37.000	5.701	0.114	0.648
		Bipinnaria	*larvae*	Bivalvia	5.05	15.00	356.9643	220.0	4.00	0.15408	1.000	0.154	13.203	2.034
		Balanus	*nauplii*	Copepoda	5.05	15.00	356.9643	220.0	4.00	0.15408	1.000	0.154	0.116	0.018
		Brachyura	*zoea*	Decapoda	5.05	15.00	356.9643	220.0	4.00	0.15408	20.000	3.082	0.110	0.340
		Metatrochophore	*larvae*	Polychaeta	5.05	15.00	356.9643	220.0	4.00	0.15408	1.000	0.154	0.012	0.002
		Sabellariidae	*trochophore larvae*	Polychaeta	5.05	15.00	356.9643	220.0	4.00	0.15408	8.000	1.233	0.002	0.003
		Chaetognatha			5.05	15.00	356.9643	220.0	4.00	0.15408	5.000	0.770	5.157	3.973
		calanoid	*copepodid*	Copepoda	4.6	15.00	325.1556	132.0	3.00	0.13532	57.000	7.713	1.107	8.535
		cyclopoid	*copepodid*	Copepoda	4.6	15.00	325.1556	132.0	3.00	0.13532	54.000	7.307	0.716	5.228
		Euterpina	*acutifrons*	Copepoda	4.6	15.00	325.1556	132.0	3.00	0.13532	39.000	5.277	1.230	6.491
		Oithona	sp.	Copepoda	4.6	15.00	325.1556	132.0	3.00	0.13532	17.000	2.300	0.981	2.257
		nauplii		Copepoda	4.6	15.00	325.1556	132.0	3.00	0.13532	33.000	4.466	0.085	0.380
		gastropod	*larvae*	Bivalvia	4.6	15.00	325.1556	132.0	3.00	0.13532	3.000	0.406	0.214	0.087
		Brachyura	*zoea*	Decapoda	4.6	15.00	325.1556	132.0	3.00	0.13532	7.000	0.947	0.108	0.103
		Sabellariidae	*trochophore larvae*	Polychaeta	4.6	15.00	325.1556	132.0	3.00	0.13532	3.000	0.406	0.002	0.001
		Oikopleura	sp.	Tunicata	4.6	15.00	325.1556	132.0	3.00	0.13532	4.000	0.541	0.006	0.003

Note: µg d.w./L = micrograms dry weight per litre.

Table C2-18: Farim Project - Wet Season Ichthyoplankton Data

Sample ID	Date	Time		Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L
STN1ZP-A	15-Aug-2013	11:29	Ichthyoplankton	2.61	15	184.49	68	68	0.01	1	0.005
STN1ZP-B	15-Aug-2013	11:35	Ichthyoplankton	1.56	15	110.27	90	90	0.01	0	0.000
STN1ZP-C	15-Aug-2013	11:40	Ichthyoplankton	1.26	15	89.06	95	95	0.01	6	0.067
STN2ZP-A	15-Aug-2013	14:14	Ichthyoplankton	4.62	15	326.57	101	101	0.00	1	0.003
STN2ZP-B	15-Aug-2013	14:21	Ichthyoplankton	7.01	15	495.51	85	85	0.00	0	0.000
STN2ZP-C	15-Aug-2013	15:09	Ichthyoplankton	5.08	15	359.08	86	86	0.00	5	0.014
STN3ZP-A	17-Aug-2013	12:08	Ichthyoplankton	2.71	15	191.56	41	41	0.01	1	0.005
STN3ZP-B	17-Aug-2013	12:09	Ichthyoplankton	3.41	15	241.04	39	39	0.00	4	0.017
STN3ZP-C	17-Aug-2013	12:12	Ichthyoplankton	4.57	15	323.04	43	43	0.00	0	0.000
STN4ZP-A	17-Aug-2013	9:44	Ichthyoplankton	5.24	15	370.39	79	79	0.00	0	0.000
STN4ZP-B	17-Aug-2013	9:52	Ichthyoplankton	2.47	15	174.59	78	78	0.01	2	0.011
STN4ZP-C	17-Aug-2013	9:58	Ichthyoplankton	4.76	15	336.47	82	82	0.00	0	0.000
STN5ZP-A	16-Aug-2013	13:06	Ichthyoplankton	6.02	15	425.53	58	58	0.00	0	0.000
STN5ZP-B	16-Aug-2013	13:12	Ichthyoplankton	6.40	15	452.39	56	56	0.00	0	0.000
STN5ZP-C	16-Aug-2013	13:17	Ichthyoplankton	6.29	15	444.61	59	59	0.00	3	0.007
STN6ZP-A	16-Aug-2013	10:36	Ichthyoplankton	6.10	15	431.18	44	44	0.00	10	0.023
STN6ZP-B	16-Aug-2013	11:05	Ichthyoplankton	5.21	15	368.27	59	59	0.00	3	0.008
STN6ZP-C	16-Aug-2013	11:11	Ichthyoplankton	5.00	15	353.43	46	46	0.00	4	0.011

Table C2-18: Farim Project - Wet Season Ichthyoplankton Data

Sample ID	Date	Time		Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L
STN7ZP-A	19-Aug-2013	11:31	Ichthyoplankton	3.25	15	229.73	92	95	0.00	2	0.008
STN7ZP-B	19-Aug-2013	11:44	Ichthyoplankton	4.94	15	349.19	132	132	0.00	2	0.006
STN7ZP-C	19-Aug-2013	11:46	Ichthyoplankton	4.03	15	284.86	112	112	0.00	0	0.000
STN8ZP-A	19-Aug-2013	15:00	Ichthyoplankton	4.73	15	334.34	140	140	0.00	0	0.000
STN8ZP-B	19-Aug-2013	15:07	Ichthyoplankton	3.55	15	250.94	77	77	0.00	0	0.000
STN8ZP-C	19-Aug-2013	15:12	Ichthyoplankton	4.43	15	313.14	98	98	0.00	0	0.000
STN9ZP-A	22-Aug-2013	11:52	Ichthyoplankton	1.50	15	106.03	142	142	0.01	0	0.000
STN9ZP-B	22-Aug-2013	12:02	Ichthyoplankton	1.83	15	129.36	110	110	0.01	0	0.000
STN9ZP-C	22-Aug-2013	12:08	Ichthyoplankton	1.80	15	127.23	110	110	0.01	0	0.000
STN10ZP-A	22-Aug-2013	15:10	Ichthyoplankton	2.96	15	209.23	140	140	0.00	0	0.000
STN10ZP-B	22-Aug-2013	15:19	Ichthyoplankton	3.41	15	241.04	81	81	0.00	0	0.000
STN10ZP-C	22-Aug-2013	15:23	Ichthyoplankton	2.36	15	166.82	91	91	0.01	0	0.000
STN11ZP-A	24-Aug-2013	13:31	Ichthyoplankton	4.33	15	306.07	70	70	0.00	0	0.000
STN11ZP-B	24-Aug-2013	13:40	Ichthyoplankton	5.27	15	372.52	99	99	0.00	0	0.000
STN11ZP-C	24-Aug-2013	13:44	Ichthyoplankton	4.46	15	315.26	112	112	0.00	0	0.000

High algae and detritus.

Table C2-18: Farim Project - Wet Season Ichthyoplankton Data

Sample ID	Date	Time		Tow Length (m)	Net Radius (cm)	Tow Volume Filtered (L)	Total Sample Volume (ml)	Aliquot (ml)	Count Factor	#Individuals Counted	# / L
STN12ZP-A	24-Aug-2013	9:48	Ichthyoplankton	4.97	15	351.31	116	116	0.00	3	0.009
STN12ZP-B	24-Aug-2013	9:54	Ichthyoplankton	4.35	15	307.48	103	103	0.00	0	0.000
STN12ZP-C	24-Aug-2013	9:59	Ichthyoplankton	4.49	15	317.38	107	107	0.00	0	0.000
STN13ZP-A	21-Aug-2013	12:30	Ichthyoplankton	4.03	15	284.86	96	96	0.00	0	0.000
STN13ZP-B	21-Aug-2013	12:36	Ichthyoplankton	3.31	15	233.97	112	112	0.00	0	0.000
STN13ZP-C	21-Aug-2013	12:42	Ichthyoplankton	2.71	15	191.56	98	98	0.01	0	0.000
STN14ZP-A	24-Aug-2013	12:24	Ichthyoplankton	3.60	15	254.47	138	138	0.00	1	0.004
STN14ZP-B	24-Aug-2013	12:29	Ichthyoplankton	3.90	15	275.68	126	126	0.00	0	0.000
STN14ZP-C	24-Aug-2013	12:34	Ichthyoplankton	3.71	15	262.25	76	76	0.00	0	0.000
STN15ZP-A	27-Aug-2013	11:13	Ichthyoplankton	8.76	15	619.21	107	107	0.00	5	0.008
STN15ZP-B	27-Aug-2013	11:17	Ichthyoplankton	9.22	15	651.72	118	118	0.00	23	0.035
STN15ZP-C	27-Aug-2013	11:21	Ichthyoplankton	8.65	15	611.43	138	138	0.00	0	0.000
STN16ZP-A	26-Aug-2013	13:41	Ichthyoplankton	2.93	15	207.11	69	69	0.00	2	0.010
STN16ZP-B	26-Aug-2013	13:44	Ichthyoplankton	3.17	15	224.07	92	92	0.00	0	0.000
STN16ZP-C	26-Aug-2013	13:47	Ichthyoplankton	2.93	15	207.11	63	63	0.00	1	0.005
STN17ZP-A	26-Aug-2013	11:15	Ichthyoplankton	5.56	15	393.01	210	210	0.00	0	0.000
STN17ZP-B	26-Aug-2013	11:17	Ichthyoplankton	5.05	15	356.96	220	220	0.00	0	0.000
STN17ZP-C	26-Aug-2013	11:24	Ichthyoplankton	4.60	15	325.16	132	132	0.00	0	0.000

High algae and detritus.

APPENDIX F4

Benthic Invertebrate Data (Dry Season and Wet Season)

January 2014
Report No. 13514950200.550/B.0

water & air RESEARCH, INC.
6821 SW Archer Road
Gainesville, FL 32608
www.waterandair.com

Macroinvertebrate Results

Client: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013
Report Type: Station Indices (Pooled)

Station # Replicates Pooled Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Shannon Diversity Index (H') Base *e*: $H' = [\Sigma (n_i / n) * \ln(n_i / n)]$	1.279	1.972	0.000	2.069	1.741	1.671	1.040	1.732	1.212	1.584	1.677	3.300	2.444	3.554	2.862	2.740	3.284
Pielou's Evenness (J') $J' = H' / H'_{max}$	0.615	0.948	0.000	0.942	0.792	0.672	0.946	0.890	0.552	0.721	0.936	0.779	0.882	0.858	0.842	0.900	0.910
McIntosh's Dominance (M) $M = (n - \sqrt{[\Sigma n_i^2]}) / (n - \sqrt{n})$	0.410	0.864	0.000	0.849	0.615	0.535	0.775	0.732	0.365	0.513	0.813	0.762	0.799	0.837	0.791	0.838	0.864
Margalef's Richness Index (D) $D = (S - 1) / \ln(N)$	2.148	2.919	0.000	3.031	2.114	2.525	1.443	2.216	2.035	2.184	2.276	11.249	4.328	10.675	6.231	5.625	7.961
Number of Taxa	8	8	1	9	9	12	3	7	9	9	6	69	16	63	30	21	37
Number of Genera	8	8	1	9	9	12	3	7	9	9	6	68	16	61	27	20	36

Macroinvertebrate Results
Raw Data Report (Unpooled)

water & air RESEARCH, INC.
6821 SW Archer Road
Gainesville, FL 32608
www.waterandair.com

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	STN1BG A 05/14/13	STN1BG B 05/14/13	STN1BG C 05/14/13	STN2BG A 05/16/13	STN2BG B 05/16/13	STN2BG C 05/16/13
Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	1	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	1	-	1	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

water & air RESEARCH, INC.
6821 SW Archer Road
Gainesville, FL 32608
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Macroinvertebrate Results
Raw Data Report (Unpooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	STN1BG A 05/14/13	STN1BG B 05/14/13	STN1BG C 05/14/13	STN2BG A 05/16/13	STN2BG B 05/16/13	STN2BG C 05/16/13
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Goniadides sp.		-	-	-	-	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	-
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	1	-
Micronephtys sp.		-	-	-	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Namalycastis sp.		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Platynereis sp.		-	-	-	1	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		1	-	-	-	-	-
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	-
Family: Syllidae							
Eusyllis sp.		-	-	-	-	-	-
Plakosyllis sp.		-	-	-	-	-	-

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Syllidae (LPIL)	-	-	-	-	-	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.	-	-	-	-	-	-
Order: Spionida						
Family: Magelonidae						
Magelona sp.	-	-	-	-	-	-
Family: Spionidae						
Minuspio sp.	-	-	-	-	-	-
Polydora sp.	-	-	-	-	-	-
Scolelepis sp.	-	-	-	-	-	-
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	-	-	-	-	-	-
Family: Cirratulidae						
Cirratulidae (LPIL)	-	-	-	-	-	-
Cirriformia sp.	-	-	-	-	-	-
Monticellina sp.	-	-	-	-	-	-
Family: Pectinariidae						
Lagis sp.	-	-	-	-	-	-
Family: Terebellidae						
Eupolymnia sp.	-	-	-	-	-	-
Lanice conchilega	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	-	-	-	-	-	-
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)	8	-	9	2	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)	-	-	-	-	-	-
Tubificoides sp.	-	-	-	-	-	-
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.	-	-	-	-	-	-
Family: Ampeliscidae						
Ampelisca sp.	-	-	-	-	-	-
Family: Aoridae						
Aoridae (LPIL)	1	-	2	-	-	1
Bemlos/Plesiolembos group	-	-	-	-	-	-
Grandidierella sp.	-	-	-	3	-	-
Family: Atylidae						
Nototropis swammerdamei	-	-	-	-	-	-
Family: Bathyporeiidae						
Bathyporeia sp.	-	-	-	-	-	-

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	-	-	-
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	-	-	-
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	-	-	1	-	-
Rhopalophthalmus sp.		-	-	-	-	-	-
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	1	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		1	-	-	-	1	-
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	-	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		1	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	-	-
Macoma sp.		-	-	-	-	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	-	-	-	-
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	✓	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		12	0	14	7	3	1
Total Taxa		5	N/A	5	4	3	1

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Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Goniadides sp.		-	-	-	-	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	-
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys sp.		-	-	-	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Namalycastis sp.		-	-	-	1	-	-
Nereis sp.		-	-	-	-	-	1
Platynereis sp.		-	-	-	-	1	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		-	-	-	1	-	-
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	-
Family: Syllidae							
Eusyllis sp.		-	-	-	-	-	-
Plakosyllis sp.		-	-	-	-	-	-

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Syllidae (LPIL)	-	-	-	-	-	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.	-	-	-	-	-	-
Order: Spionida						
Family: Magelonidae						
Magelona sp.	-	-	-	-	-	-
Family: Spionidae						
Minuspio sp.	-	-	-	-	-	-
Polydora sp.	-	-	-	-	-	-
Scolelepis sp.	-	-	-	-	-	-
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	-	-	-	-	-	-
Family: Cirratulidae						
Cirratulidae (LPIL)	-	-	-	-	-	-
Cirriformia sp.	-	-	-	-	-	-
Monticellina sp.	-	-	-	-	-	-
Family: Pectinariidae						
Lagis sp.	-	-	-	-	-	-
Family: Terebellidae						
Eupolymnia sp.	-	-	-	-	-	-
Lanice conchilega	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	-	-	-	-	-	-
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)	-	2	-	-	2	1
Tubificoid Naididae imm. w/o hair setae (LPIL)	-	-	-	-	-	-
Tubificoides sp.	-	-	-	-	-	-
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.	-	-	-	-	-	-
Family: Ampeliscidae						
Ampelisca sp.	-	-	-	-	-	-
Family: Aoridae						
Aoridae (LPIL)	-	-	-	1	1	1
Bemlos/Plesiolembos group	-	-	-	-	-	-
Grandidierella sp.	-	-	-	-	-	-
Family: Atylidae						
Nototropis swammerdamei	-	-	-	-	-	-
Family: Bathyporeiidae						
Bathyporeia sp.	-	-	-	-	-	-

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	-	-	-
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	-	-	-
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	-	-	-	-	1
Rhopalophthalmus sp.		-	-	-	-	-	-
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	2
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	1	-	-
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	-	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	-	-
Macoma sp.		-	-	-	-	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	-	-	-	-
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		✓	-	✓	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		0	2	0	4	4	6
Total Taxa		N/A	1	N/A	4	3	5

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Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	1	1	-	-
Capitellidae (LPIL)		-	-	-	4	-	-
Decamastus sp.		-	1	4	2	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		4	5	5	1	12	15
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Armandia sp.	-	-	-	-	-	-
Order: Orbiniida						
Family: Orbiniidae						
Orbiniidae (LPIL)	-	-	-	-	-	-
Scoloplos sp.	-	-	-	-	-	-
Family: Paraonidae						
Aricidea catherinae	-	-	-	-	-	-
Aricidea fragilis	-	-	-	-	-	-
Aricidea sp.	-	-	-	-	-	-
Aricidea wassi	-	-	-	-	-	-
Cirrophorus branchiatus	-	-	-	-	-	-
Cirrophorus sp.	-	-	-	-	-	-
Levinsenia sp.	-	-	-	-	-	-
Paradoneis sp.	-	-	-	-	-	-
Paraonidae (LPIL)	-	-	-	-	-	-
Order: Phyllodocida						
Family: Glyceridae						
Glycera africana	-	-	-	-	-	-
Glycera alba	-	-	-	-	-	-
Glycera sp.	-	-	-	-	-	-
Glyceridae (LPIL)	-	-	-	-	-	-
Family: Goniadidae						
Glycinde sp.	-	-	-	-	-	-
Goniada multidentata	-	-	-	-	-	-
Goniadidae (LPIL)	-	-	-	-	-	-
Goniadides sp.	-	-	-	-	-	-
Family: Hesionidae						
Hesione sp.	-	-	-	-	-	-
Hesionidae (LPIL)	-	-	-	-	-	-
Heteropodarke sp.	-	-	-	-	-	-
Podarkeopsis sp.	-	-	-	-	-	-
Family: Nephtyidae						
Aglaophamus sp.	-	-	-	-	-	-
Micronephtys sp.	1	2	-	-	2	2
Micronephtys stammeri	-	-	-	-	-	-
Family: Nereididae						
Namalycastis sp.	-	-	-	-	-	-
Nereis sp.	-	-	-	1	-	-
Platynereis sp.	-	-	-	-	-	-
Family: Pilargidae						
Cabira sp.	-	-	-	-	-	-
Sigambra sp.	2	-	-	1	-	-
Family: Polynoidae						
Polynoidae (LPIL)	-	-	-	-	-	-
Family: Syllidae						
Eusyllis sp.	-	-	-	-	-	-
Plakosyllis sp.	-	-	-	-	-	-

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Syllidae (LPIL)		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		-	-	-	-	-	-
Order: Spionida							
Family: Magelonidae							
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Polydora sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Family: Cirratulidae							
Cirratulidae (LPIL)		-	-	-	-	-	-
Cirriformia sp.		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Pectinariidae							
Lagis sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Lanice conchilega		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		9	3	2	12	8	9
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	-	-
Tubificoides sp.		-	-	-	-	1	1
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		-	-	-	-	-	-
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Bemlos/Plesiolembos group		-	-	-	-	-	-
Grandidierella sp.		-	-	-	-	-	-
Family: Atylidae							
Nototropis swammerdamei		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	-	-	-
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	-	-	-
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	1	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	-	-	-	-	-
Rhopalophthalmus sp.		-	-	-	-	-	2
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		1	1	1	-	3	-
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	-	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		1	-	-	-	-	-
Macoma sp.		-	-	-	-	-	1
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	-	-	-	-
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		18	13	13	22	26	30
Total Taxa		6	6	5	7	5	6

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Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	1	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	2	3	-
Onuphidae (LPIL)		-	-	-	-	1	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Goniadides sp.		-	-	-	-	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	-
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys sp.		-	-	2	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Namalycastis sp.		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Platynereis sp.		-	-	-	-	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		-	-	-	-	1	-
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	-
Family: Syllidae							
Eusyllis sp.		-	-	-	-	-	-
Plakosyllis sp.		-	-	-	-	-	-

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Syllidae (LPIL)		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		-	-	-	-	-	-
Order: Spionida							
Family: Magelonidae							
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Polydora sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Family: Cirratulidae							
Cirratulidae (LPIL)		-	-	-	-	-	-
Cirriformia sp.		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Pectinariidae							
Lagis sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Lanice conchilega		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		-	-	-	-	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	-	-
Tubificoides sp.		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		-	-	-	-	-	-
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	1
Bemlos/Plesiolembos group		-	-	-	-	-	-
Grandidierella sp.		-	-	-	-	-	-
Family: Atylidae							
Nototropis swammerdamei		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	-	-	-
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	-	-	-
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	1	2	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	1	-
Decapoda (LPIL) mysis larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	-	-	-	-	-
Rhopalophthalmus sp.		-	-	-	-	-	-
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	1	-	-	-	-
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / Replicate / Collection Date	STN7BG A 05/17/13	STN7BG B 05/17/13	STN7BG C 05/17/13	STN8BG A 05/18/13	STN8BG B 05/18/13	STN8BG C 05/18/13
Nucula sp.	-	-	-	-	-	-
Order: Ostreoida						
Family: Ostreidae						
Ostreidae (LPIL)	-	-	-	-	-	-
Order: Veneroida						
Family: Cardiidae						
Acanthocardia tuberculata	-	-	-	-	-	-
Cardiidae (LPIL)	-	-	-	-	-	-
Family: Corbulidae						
Caryocorbula sp.	-	-	-	-	-	-
Corbula sp.	-	-	-	-	-	-
Family: Lucinidae						
Lucinidae (LPIL)	-	-	-	-	-	-
Family: Semelidae						
Semelidae (LPIL)	-	-	-	-	-	-
Family: Solecurtidae						
Solecurtidae (LPIL)	-	-	-	-	-	-
Family: Tellinidae						
Angulus sp.	-	-	-	-	-	-
Macoma sp.	-	-	-	2	1	-
Tellinidae (LPIL)	-	-	-	-	-	-
Family: Ungulinidae						
Ungulinidae (LPIL)	-	-	-	-	-	-
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)	-	-	-	-	-	-
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiuridae (LPIL)	-	-	-	-	-	-
Family: Ophiactidae						
Ophiactis plana	-	-	-	-	-	-
Ophiactis sp.	-	-	-	-	-	-
Family: Ophiolepididae						
Ophiolepis paucispina	-	-	-	-	-	-
Order: Ophuridae						
Family: Ophionereididae						
Ophionereididae (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)	-	-	-	-	-	-
Class: Echinoidea						
Order: Unspecified						
Family: Unspecified						

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Sample Method: Petite Ponar
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Taxonomic Classification	Station Replicate Collection Date	STN7BG A 05/17/13	STN7BG B 05/17/13	STN7BG C 05/17/13	STN8BG A 05/18/13	STN8BG B 05/18/13	STN8BG C 05/18/13
Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		✓	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		0	1	3	5	9	1
Total Taxa		N/A	1	2	3	6	1

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Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		1	-	-	1	2	1
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		1	-	-	1	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	1	-	-	-	-
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	1	1	1
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Goniadides sp.		-	-	-	-	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	1
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys sp.		8	7	19	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Namalycastis sp.		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Platynereis sp.		-	-	-	-	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		-	-	-	1	-	1
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	-
Family: Syllidae							
Eusyllis sp.		-	-	-	-	-	-
Plakosyllis sp.		-	-	-	-	-	-

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Syllidae (LPIL)		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		-	-	-	-	-	1
Order: Spionida							
Family: Magelonidae							
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	1	-	-	-	-
Polydora sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Family: Cirratulidae							
Cirratulidae (LPIL)		-	-	-	-	-	-
Cirriformia sp.		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Pectinariidae							
Lagis sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Lanice conchilega		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		-	-	5	-	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	-	-
Tubificoides sp.		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		-	-	-	-	-	-
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	1	-	1
Bemlos/Plesiolembos group		-	-	-	-	-	-
Grandidierella sp.		-	-	-	-	-	-
Family: Atylidae							
Nototropis swammerdamei		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	-	-	-
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	-	-	-
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Sample Method: Petite Ponar
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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	4	2	15
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		1	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		1	-	-	-	-	-
Rhopalophthalmus sp.		-	-	-	-	-	-
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	-	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	-	-
Macoma sp.		1	1	4	-	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	4
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	-	-	-	-
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Taxonomic Classification	Station Replicate Collection Date	STN9BG A 05/25/13	STN9BG B 05/25/13	STN9BG C 05/25/13	STN10BG A 05/25/13	STN10BG B 05/25/13	STN10BG C 05/25/13
Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		13	10	28	9	5	25
Total Taxa		6	4	3	6	3	8

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment
Sample Method: Petite Ponar
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Taxonomic Classification	Station Replicate Collection Date	STN11BG A 05/19/13	STN11BG B 05/19/13	STN11BG C 05/19/13	STN12BG A 05/20/13	STN12BG B 05/20/13	STN12BG C 05/20/13
Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	1	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	1	4	2	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	3	1	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	1	-	-
Maldanidae (LPIL)		-	-	-	-	-	1
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	1	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	2	-
Lumbrineris sp.		-	-	-	1	-	1
Family: Onuphidae							
Diopatra sp.		-	-	-	6	18	9
Onuphidae (LPIL)		-	-	-	-	1	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Taxonomic Classification	Station Replicate Collection Date	STN11BG A 05/19/13	STN11BG B 05/19/13	STN11BG C 05/19/13	STN12BG A 05/20/13	STN12BG B 05/20/13	STN12BG C 05/20/13
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	1	-
Scoloplos sp.		-	-	-	2	2	1
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	1	2
Aricidea sp.		-	-	-	2	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	1	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	2	1	-
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	3	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	3	-	-	-	-
Goniadides sp.		-	-	-	1	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	-
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	3	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys sp.		-	-	-	-	-	-
Micronephtys stammeri		-	-	-	3	2	-
Family: Nereididae							
Namalycastis sp.		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Platynereis sp.		-	-	-	-	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		-	-	-	1	-	-
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	1	-	-
Family: Syllidae							
Eusyllis sp.		-	-	-	1	-	-
Plakosyllis sp.		-	-	-	-	-	-

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Syllidae (LPIL)		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		-	-	-	2	2	-
Order: Spionida							
Family: Magelonidae							
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Polydora sp.		-	-	-	2	-	-
Scolelepis sp.		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	2	2	-
Family: Cirratulidae							
Cirratulidae (LPIL)		-	-	-	-	-	-
Cirriformia sp.		-	-	-	-	2	-
Monticellina sp.		-	-	-	2	1	-
Family: Pectinariidae							
Lagis sp.		-	-	-	7	2	2
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Lanice conchilega		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		-	-	-	-	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	-	-
Tubificoides sp.		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		-	-	-	-	-	-
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	25	28	1
Family: Aoridae							
Aoridae (LPIL)		-	-	-	11	-	1
Bemlos/Plesiolembos group		-	-	-	1	-	-
Grandidierella sp.		-	-	-	-	-	-
Family: Atylidae							
Nototropis swammerdamei		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	1	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	8	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	23	59	4
Family: Ischroceridae							
Ericthonius sp.		-	-	-	1	11	1
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		2	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	1	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	1	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		1	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	1	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	3	12	2
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	18	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	1	-	1
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	1
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	2	1
Family: Majidae							
Majidae (LPIL)		-	-	-	-	1	-
Family: Paguridae							
Paguristes sp.		-	-	-	4	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	1	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	2	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	1	-	1	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	2	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	2	1	1
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	-	-	1	-	-
Rhopalophthalmus sp.		-	-	-	-	-	-
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	2	-
Kalliapseudidae (LPIL)		-	-	-	-	-	1
Family: Metapseudidae							
Calozodion sp.		-	-	-	5	6	-
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	1
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	1	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	2	2
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	1	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	2	4	3
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	2	3	2
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	1
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	-	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	1	1	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	-	-
Macoma sp.		-	-	-	3	2	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		1	-	-	11	-	1
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	1	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	1	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	3	4	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	5	8
Total Organisms		4	3	2	152	222	48
Total Taxa		3	1	2	43	42	23

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Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	1
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	2
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	1	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	2	1
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	2	4
Sabaco sp.		-	-	-	-	-	1
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	1	4	1
Family: Onuphidae							
Diopatra sp.		-	-	-	-	2	3
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		3	2	2	-	-	-

Macroinvertebrate Results
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water & air RESEARCH, INC.
6821 SW Archer Road
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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / Replicate / Collection Date	STN13BG A 05/20/13	STN13BG B 05/20/13	STN13BG C 05/20/13	STN14BG A 05/22/13	STN14BG B 05/22/13	STN14BG C 05/22/13
Armandia sp.	-	-	-	-	-	-
Order: Orbiniida						
Family: Orbiniidae						
Orbiniidae (LPIL)	-	-	-	-	-	-
Scoloplos sp.	-	-	-	-	5	-
Family: Paraonidae						
Aricidea catherinae	-	-	-	-	1	-
Aricidea fragilis	-	-	-	-	1	5
Aricidea sp.	-	-	-	-	-	-
Aricidea wassi	-	-	-	-	-	-
Cirrophorus branchiatus	-	-	-	1	-	-
Cirrophorus sp.	-	-	-	-	-	-
Levinsenia sp.	-	-	-	-	-	-
Paradoneis sp.	-	-	-	-	-	-
Paraonidae (LPIL)	-	-	-	-	-	-
Order: Phyllodocida						
Family: Glyceridae						
Glycera africana	1	-	-	-	1	-
Glycera alba	-	-	-	-	-	2
Glycera sp.	-	-	-	-	-	-
Glyceridae (LPIL)	-	-	-	-	-	-
Family: Goniadidae						
Glycinde sp.	-	-	-	-	-	-
Goniada multidentata	-	-	-	-	-	-
Goniadidae (LPIL)	-	-	-	-	1	2
Goniadides sp.	-	-	-	-	-	-
Family: Hesionidae						
Hesione sp.	-	-	-	-	-	-
Hesionidae (LPIL)	-	-	-	-	-	-
Heteropodarke sp.	-	-	-	-	-	-
Podarkeopsis sp.	-	-	-	1	-	-
Family: Nephtyidae						
Aglaophamus sp.	-	-	-	-	-	-
Micronephtys sp.	-	-	-	-	-	-
Micronephtys stammeri	-	-	-	1	1	-
Family: Nereididae						
Namalycastis sp.	-	-	-	-	-	-
Nereis sp.	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-
Family: Pilargidae						
Cabira sp.	-	-	-	-	-	-
Sigambra sp.	-	-	-	-	-	-
Family: Polynoidae						
Polynoidae (LPIL)	-	-	-	-	-	-
Family: Syllidae						
Eusyllis sp.	-	-	-	-	-	-
Plakosyllis sp.	-	-	-	-	-	-

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Syllidae (LPIL)		-	-	-	-	1	3
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		-	-	-	-	-	1
Order: Spionida							
Family: Magelonidae							
Magelona sp.		1	2	3	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	1
Polydora sp.		-	-	-	-	-	7
Scolelepis sp.		-	-	-	-	-	1
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Family: Cirratulidae							
Cirratulidae (LPIL)		-	-	-	-	-	1
Cirriformia sp.		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	2	-
Family: Pectinariidae							
Lagis sp.		-	-	-	3	5	6
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	1	-
Lanice conchilega		-	-	-	-	-	1
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		-	-	1	-	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	-	-
Tubificoides sp.		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		1	-	-	-	-	-
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	2	10	17
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	2
Bemlos/Plesiolembos group		-	-	-	-	-	-
Grandidierella sp.		-	-	-	-	-	-
Family: Atylidae							
Nototropis swammerdamei		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		1	-	-	-	-	-

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	6	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	-	-	-	-	-
Family: Isaeidae							
Photis sp.		-	-	-	2	10	26
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	2
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	5	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	3
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	-	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	1	-	13
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	2	-	-	-	-
Perioculodes sp.		1	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	2	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	1	7	10
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	2	2	1	1	3
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	1	-	-	2	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	1	2	7
Family: Crangonidae							
Crangonidae (LPIL)		-	-	1	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	4
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	1	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	-	-	2	1
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	4	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	1	-	-	-	-
Rhopalophthalmus sp.		-	-	-	-	-	1
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	1	7
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	1	2	2
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	1
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	1	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	1	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	1	-	-	-	1
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	-	5	-
Order: Myoida							
Family: Myidae							
Sphenia sp.		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	1	-	-
Musculus sp.		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	1	-	3
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	2	3	13
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	1	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	1	4	3
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	2	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	1	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	-	-
Macoma sp.		-	-	-	-	-	1
Tellinidae (LPIL)		-	-	-	-	2	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	3	-	5
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	1	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	-	5	7	11
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	1	-	3	6
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		8	14	10	32	116	185
Total Taxa		6	9	6	21	36	41

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Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		5	1	11	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		2	1	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	1	-	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		1	2	1	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		-	-	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	1	-	-	1
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	1	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Armandia sp.		-	-	-	3	1	3
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	1	-
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	1	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	1	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	2	-	-	-
Glycera sp.		-	1	-	-	1	-
Glyceridae (LPIL)		1	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Goniadides sp.		-	-	-	-	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	-
Hesionidae (LPIL)		1	-	-	-	-	-
Heteropodarke sp.		-	-	-	1	1	-
Podarkeopsis sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys sp.		-	-	-	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Namalycastis sp.		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Platynereis sp.		-	-	-	-	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		-	-	-	-	-	-
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	-
Family: Syllidae							
Eusyllis sp.		-	-	1	-	-	-
Plakosyllis sp.		-	-	-	-	1	-

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Syllidae (LPIL)		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		-	-	1	-	-	-
Order: Spionida							
Family: Magelonidae							
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Polydora sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Family: Cirratulidae							
Cirratulidae (LPIL)		-	-	-	-	-	-
Cirriformia sp.		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Pectinariidae							
Lagis sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Lanice conchilega		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	1
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		-	-	-	-	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	-	-
Tubificoides sp.		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		-	-	-	-	-	-
Family: Ampeliscidae							
Ampelisca sp.		1	-	1	-	-	-
Family: Aoridae							
Aoridae (LPIL)		5	-	-	-	-	-
Bemlos/Plesiolembos group		-	-	-	-	-	-
Grandidierella sp.		-	-	-	-	-	-
Family: Atylidae							
Nototropis swammerdamei		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Family: Caprellidae							
Pseudaeginella sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Haustoriidae							
Haustoriidae (LPIL)		-	6	7	2	2	2
Family: Isaeidae							
Photis sp.		-	-	-	-	-	-
Family: Ischroceridae							
Ericthonius sp.		-	-	-	-	-	-
Family: Ischyroceridae							
Cerapus sp.		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Pardia punctata		-	-	-	-	-	-
Family: Megaluropidae							
Megaluropidae (LPIL)		-	-	2	-	-	-
Family: Melitidae							
Maera sp.		-	-	-	-	-	-
Melitidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Phtisicidae							
Phtisica marina		-	-	-	-	-	-
Family: Pontoporeiidae							
Pontoporeiidae (LPIL)		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		1	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		1	-	-	-	-	-
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Corophiida LPIL		-	-	-	-	-	-
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Cyclaspis sp.		-	-	-	-	-	-
Family: Nannastacidae							
Cumella sp.		-	-	-	-	-	-

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Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	2
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	1	2	-	1	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	1	1	-	-
Decapoda (LPIL) megalopa larva		1	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		1	-	-	-	-	1
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	-	-	-	-	-
Rhopalophthalmus sp.		-	-	-	-	-	-
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Metapseudidae (LPIL)		-	-	-	-	-	-
Tanaidacea (LPIL)		-	-	-	-	-	-
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		-	-	-	-	1	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		-	-	-	-	-	-
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		-	-	-	-	-	-
Marginellidae (LPIL)		-	-	-	-	-	-
Prunum sp.		-	-	-	-	-	-
Family: Muricidae							
Muricidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Neogastropoda (LPIL)		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		4	3	5	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		-	-	1	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	2	-	-	1
Order: Myoida							
Family: Myidae							
Sphenia sp.		1	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		-	-	-	-	-	-
Musculus sp.		1	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							

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Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	1	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		3	1	1	1	1	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	-	-
Macoma sp.		-	-	-	-	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	1	-	-	-
Family: Ophiactidae							
Ophiactis plana		8	-	-	-	-	-
Ophiactis sp.		8	3	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Echinoidea (LPIL)		-	-	1	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	1
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		45	19	41	10	13	12
Total Taxa		17	9	17	7	12	8

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Phylum: Cnidaria				
Class: Anthozoa				
Order: Actiniaria				
Family: Unspecified				
Actiniaria (LPIL)		-	-	-
Phylum: Platyhelminthes				
Class: Turbellaria				
Order: Unspecified				
Family: Unspecified				
Turbellaria (LPIL)		-	-	-
Phylum: Nemertea				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Nemertea (LPIL)		1	1	-
Phylum: Sipuncula				
Class: Phascolosomatidea				
Order: Aspidosiphonida				
Family: Aspidosiphonidae				
Aspidosiphonidae (LPIL)		-	-	-
Phylum: Annelida				
Class: Polychaeta				
Order: Capitellida				
Family: Capitellidae				
Capitella sp.		-	-	-
Capitellidae (LPIL)		-	-	-
Decamastus sp.		-	-	-
Heteromastus filiformis		1	1	-
Mediomastus sp.		2	-	2
Notomastus sp.		-	-	-
Family: Maldanidae				
Euclymene sp.		-	-	-
Maldanidae (LPIL)		-	-	-
Sabaco sp.		-	-	-
Order: Eunicida				
Family: Dorvilleidae				
Dorvilleidae (LPIL)		-	-	-
Protodorvillea sp.		-	-	-
Family: Lumbrineridae				
Augeneria sp.		-	-	-
Lumbrineris sp.		-	1	-
Family: Onuphidae				
Diopatra sp.		-	1	-
Onuphidae (LPIL)		-	-	-
Order: Opheliida				
Family: Opheliidae				
Armandia maculata		-	-	-

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Armandia sp.		1	6	3
Order: Orbiniida				
Family: Orbiniidae				
Orbiniidae (LPIL)		-	-	-
Scoloplos sp.		1	1	4
Family: Paraonidae				
Aricidea catherinae		-	-	-
Aricidea fragilis		-	-	-
Aricidea sp.		-	-	-
Aricidea wassi		-	-	1
Cirrophorus branchiatus		-	-	-
Cirrophorus sp.		-	-	-
Levinsenia sp.		1	-	-
Paradoneis sp.		1	1	-
Paraonidae (LPIL)		-	-	-
Order: Phyllodocida				
Family: Glyceridae				
Glycera africana		-	-	-
Glycera alba		-	-	-
Glycera sp.		-	-	-
Glyceridae (LPIL)		-	-	-
Family: Goniadidae				
Glycinde sp.		-	-	-
Goniada multidentata		1	-	-
Goniadidae (LPIL)		-	-	-
Goniadides sp.		-	-	-
Family: Hesionidae				
Hesione sp.		-	-	-
Hesionidae (LPIL)		-	-	-
Heteropodarke sp.		1	-	-
Podarkeopsis sp.		-	-	-
Family: Nephtyidae				
Aglaophamus sp.		-	-	-
Micronephtys sp.		-	-	-
Micronephtys stammeri		-	-	-
Family: Nereididae				
Namalycastis sp.		-	-	-
Nereis sp.		-	-	-
Platynereis sp.		-	-	-
Family: Pilargidae				
Cabira sp.		1	-	-
Sigambra sp.		-	-	-
Family: Polynoidae				
Polynoidae (LPIL)		1	-	-
Family: Syllidae				
Eusyllis sp.		-	-	-
Plakosyllis sp.		-	-	-

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Syllidae (LPIL)		-	-	-
Order: Sabellida				
Family: Oweniidae				
Galathowenia sp.		-	-	-
Order: Spionida				
Family: Magelonidae				
Magelona sp.		1	2	-
Family: Spionidae				
Minuspio sp.		-	1	-
Polydora sp.		-	-	-
Scolelepis sp.		-	-	-
Order: Terebellida				
Family: Ampharetidae				
Ampharete sp.		-	-	-
Family: Cirratulidae				
Cirratulidae (LPIL)		-	-	-
Cirriformia sp.		-	-	-
Monticellina sp.		-	-	-
Family: Pectinariidae				
Lagis sp.		-	-	-
Family: Terebellidae				
Eupolymnia sp.		-	-	-
Lanice conchilega		-	-	-
Order: Unspecified				
Family: Unspecified				
Polychaeta (LPIL)		-	-	-
Class: Clitellata				
Order: Haplotaxida				
Family: Tubificoid Naididae				
Tubificoid Naididae (LPIL)		-	3	2
Tubificoid Naididae imm. w/o hair setae (LPIL)		1	-	-
Tubificoides sp.		-	-	-
Phylum: Arthropoda				
Class: Malacostraca				
Order: Amphipoda				
Family: Hyperiidae				
Hyperia sp.		-	-	-
Family: Ampeliscidae				
Ampelisca sp.		-	-	-
Family: Aoridae				
Aoridae (LPIL)		-	-	-
Bemlos/Plesiolembos group		-	-	-
Grandidierella sp.		-	-	-
Family: Atylidae				
Nototropis swammerdamei		-	-	2
Family: Bathyporeiidae				
Bathyporeia sp.		-	-	-

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Family: Caprellidae				
Pseudaeginella sp.		-	-	-
Family: Corophiidae				
Cheiriphotis sp		-	-	-
Family: Eriopisidae				
Eriopisella sp.		-	-	-
Family: Haustoriidae				
Haustoriidae (LPIL)		-	-	-
Family: Isaeidae				
Photis sp.		-	-	-
Family: Ischroceridae				
Ericthonius sp.		2	-	-
Family: Ischyroceridae				
Cerapus sp.		-	-	-
Family: Liljeborgiidae				
Idunella sp.		-	-	-
Liljeborgiidae (LPIL)		-	-	-
Family: Lysianassidae				
Pardia punctata		-	-	-
Family: Megaluropidae				
Megaluropidae (LPIL)		-	-	-
Family: Melitidae				
Maera sp.		-	-	-
Melitidae (LPIL)		-	-	-
Family: Oedicerotidae				
Oedicerotidae (LPIL)		-	1	-
Perioculodes sp.		-	-	-
Family: Phoxocephalidae				
Basuto stimpsoni		-	-	-
Family: Phtisicidae				
Phtisica marina		-	-	-
Family: Pontoporeiidae				
Pontoporeiidae (LPIL)		-	-	-
Family: Urothoidae				
Urothoe sp.		-	-	-
Family: Unspecified				
Amphipoda (LPIL)		1	1	-
Class: Malacostraca				
Order: Amphipoda				
Family: Unspecified				
Corophiida LPIL		-	-	-
Class: Malacostraca				
Order: Cumacea				
Family: Bodotriidae				
Cyclaspis sp.		-	4	1
Family: Nannastacidae				
Cumella sp.		2	-	1

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Family: Unspecified				
Cumacea (LPIL)		1	-	-
Order: Decapoda				
Family: Unspecified				
Decapoda (LPIL)		-	-	-
Family: Callianassidae				
Callianassidae (LPIL)		-	-	-
Family: Crangonidae				
Crangonidae (LPIL)		-	-	-
Family: Diogenidae				
Diogenes sp.		-	-	-
Diogenidae (LPIL)		-	-	-
Family: Majidae				
Majidae (LPIL)		-	-	-
Family: Paguridae				
Paguristes sp.		-	-	-
Family: Penaeidae				
Penaeus sp.		-	-	-
Family: Porcellanidae				
Porcellanidae (LPIL)		-	1	-
Family: Upogebiidae				
Upogebia sp.		-	-	-
Family: Unspecified				
Brachyura (LPIL)		-	-	-
Decapoda (LPIL) zoea larva		1	2	1
Decapoda (LPIL) megalopa larva		-	-	-
Decapoda (LPIL) mysis larva		-	-	-
Order: Isopoda				
Family: Anthuridae				
Amakusanthura sp.		-	-	-
Anthuridae (LPIL)		-	-	-
Family: Arcturidae				
Arcturidae (LPIL)		-	-	-
Order: Mysida				
Family: Mysidae				
Gastrosaccus sanctus		-	-	1
Mysidae (LPIL)		-	-	-
Rhopalophthalmus sp.		-	-	-
Order: Tanaidacea				
Family: Apseudidae				
Apseudidae (LPIL)		2	-	-
Family: Kalliapseudidae				
Kalliapseudes sp.		-	-	-
Kalliapseudidae (LPIL)		-	-	-
Family: Metapseudidae				
Calozodion sp.		-	-	-
Family: Unspecified				

Macroinvertebrate Results
Raw Data Report (Unpooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	STN17BG A 05/24/13	STN17BG B 05/24/13	STN17BG C 05/24/13
Metapseudidae (LPIL)		-	-	-
Tanaidacea (LPIL)		-	-	-
Class: Pycnogonida				
Order: Unspecified				
Family: Unspecified				
Pycnogonida (LPIL)		-	-	-
Phylum: Mollusca				
Class: Gastropoda				
Order: Caenogastropoda				
Family: Litiopidae				
Litiopidae (LPIL)		-	-	-
Order: Heterostropha				
Family: Pyramidellidae				
Pyramidellidae (LPIL)		-	-	-
Order: Neogastropoda				
Family: Marginellidae				
Glabella adansoni		-	1	-
Marginellidae (LPIL)		-	1	-
Prunum sp.		-	-	-
Family: Muricidae				
Muricidae (LPIL)		-	-	-
Family: Unspecified				
Neogastropoda (LPIL)		-	-	-
Order: Neotaenioglossa				
Family: Calyptraeidae				
Calyptraea sp.		-	-	-
Family: Cerithiidae				
Cerithium sp.		-	-	-
Order: Nudibranchia				
Family: Unspecified				
Nudibranchia (LPIL)		-	-	-
Order: Unspecified				
Family: Unspecified				
Gastropoda (LPIL)		-	-	-
Class: Bivalvia				
Order: Unspecified				
Family: Unspecified				
Bivalvia (LPIL)		1	1	1
Order: Myoida				
Family: Myidae				
Sphenia sp.		-	-	-
Order: Mytiloida				
Family: Mytilidae				
Lioberus sp.		-	-	-
Musculus sp.		-	-	-
Order: Nuculoida				
Family: Nuculidae				

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Taxonomic Classification	Station Replicate Collection Date	STN17BG A 05/24/13	STN17BG B 05/24/13	STN17BG C 05/24/13
Nucula sp.		-	-	-
Order: Ostreoida				
Family: Ostreidae				
Ostreidae (LPIL)		-	-	-
Order: Veneroida				
Family: Cardiidae				
Acanthocardia tuberculata		-	-	-
Cardiidae (LPIL)		-	2	-
Family: Corbulidae				
Caryocorbula sp.		-	-	-
Corbula sp.		-	-	-
Family: Lucinidae				
Lucinidae (LPIL)		-	-	-
Family: Semelidae				
Semelidae (LPIL)		-	-	-
Family: Solecurtidae				
Solecurtidae (LPIL)		-	-	-
Family: Tellinidae				
Angulus sp.		-	-	-
Macoma sp.		-	-	-
Tellinidae (LPIL)		-	-	-
Family: Ungulinidae				
Ungulinidae (LPIL)		-	-	-
Phylum: Phoronida				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Phoronida (LPIL)		-	-	-
Phylum: Echinodermata				
Class: Ophiuroidea				
Order: Ophiurida				
Family: Amphiuridae				
Amphiuridae (LPIL)		5	5	1
Family: Ophiactidae				
Ophiactis plana		-	-	-
Ophiactis sp.		-	-	-
Family: Ophiolepididae				
Ophiolepis paucispina		-	-	-
Order: Ophuridae				
Family: Ophionereididae				
Ophionereididae (LPIL)		-	-	-
Order: Unspecified				
Family: Unspecified				
Ophiuroidea (LPIL)		1	3	-
Class: Echinoidea				
Order: Unspecified				
Family: Unspecified				

Macroinvertebrate Results
Raw Data Report (Unpooled)

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Taxonomic Classification	Station Replicate Collection Date	STN17BG A 05/24/13	STN17BG B 05/24/13	STN17BG C 05/24/13
Echinoidea (LPIL)		-	-	-
Phylum: Chordata				
Class: Cephalochordata				
Order: Amphioxiformes				
Family: Branchiostomatidae				
Branchiostoma sp.		1	-	-
Phylum: Chaetognatha				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Chaetognatha (LPIL)		1	-	-
No Organisms Present		-	-	-
Phylum: Brachiopoda				
Class: Lingulata				
Order: Lingulida				
Family: Lingulidae				
Lingula sp.		-	-	-
Total Organisms		32	40	20
Total Taxa		24	21	12

Macroinvertebrate Results
Percent Occurrence (Pooled)

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		3.85%	0%	0%	0%	2.27%	1.28%
Capitellidae (LPIL)		0%	0%	0%	0%	0%	5.13%
Decamastus sp.		3.85%	9.09%	0%	0%	11.36%	2.56%
Heteromastus filiformis		0%	0%	0%	0%	0%	0%
Mediomastus sp.		0%	0%	0%	0%	0%	0%
Notomastus sp.		0%	0%	0%	0%	31.82%	35.9%
Family: Maldanidae							
Euclymene sp.		0%	0%	0%	0%	0%	0%
Maldanidae (LPIL)		0%	0%	0%	0%	0%	0%
Sabaco sp.		0%	0%	0%	0%	0%	0%
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		0%	0%	0%	0%	0%	0%
Protodorvillea sp.		0%	0%	0%	0%	0%	0%
Family: Lumbrineridae							
Augeneria sp.		0%	0%	0%	0%	0%	0%
Lumbrineris sp.		0%	0%	0%	0%	0%	0%
Family: Onuphidae							
Diopatra sp.		0%	0%	0%	0%	0%	0%
Onuphidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		0%	0%	0%	0%	0%	0%

Macroinvertebrate Results
Percent Occurrence (Pooled)

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Armandia sp.		0%	0%	0%	0%	0%	0%
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		0%	0%	0%	0%	0%	0%
Scoloplos sp.		0%	0%	0%	0%	0%	0%
Family: Paraonidae							
Aricidea catherinae		0%	0%	0%	0%	0%	0%
Aricidea fragilis		0%	0%	0%	0%	0%	0%
Aricidea sp.		0%	0%	0%	0%	0%	0%
Aricidea wassi		0%	0%	0%	0%	0%	0%
Cirrophorus branchiatus		0%	0%	0%	0%	0%	0%
Cirrophorus sp.		0%	0%	0%	0%	0%	0%
Levinsenia sp.		0%	0%	0%	0%	0%	0%
Paradoneis sp.		0%	0%	0%	0%	0%	0%
Paraonidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		0%	0%	0%	0%	0%	0%
Glycera alba		0%	0%	0%	0%	0%	0%
Glycera sp.		0%	0%	0%	0%	0%	0%
Glyceridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Goniadidae							
Glycinde sp.		0%	0%	0%	0%	0%	0%
Goniada multidentata		0%	0%	0%	0%	0%	0%
Goniadidae (LPIL)		0%	0%	0%	0%	0%	0%
Goniadides sp.		0%	0%	0%	0%	0%	0%
Family: Hesionidae							
Hesione sp.		0%	0%	0%	0%	0%	0%
Hesionidae (LPIL)		0%	0%	0%	0%	0%	0%
Heteropodarke sp.		0%	0%	0%	0%	0%	0%
Podarkeopsis sp.		0%	0%	0%	0%	0%	0%
Family: Nephtyidae							
Aglaophamus sp.		0%	9.09%	0%	0%	0%	0%
Micronephtys sp.		0%	0%	0%	0%	6.82%	5.13%
Micronephtys stammeri		0%	0%	0%	0%	0%	0%
Family: Nereididae							
Namalycastis sp.		0%	0%	0%	7.14%	0%	0%
Nereis sp.		0%	0%	0%	7.14%	0%	1.28%
Platynereis sp.		0%	9.09%	0%	7.14%	0%	0%
Family: Pilargidae							
Cabira sp.		0%	0%	0%	0%	0%	0%
Sigambra sp.		3.85%	0%	0%	7.14%	4.55%	1.28%
Family: Polynoidae							
Polynoidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Syllidae							
Eusyllis sp.		0%	0%	0%	0%	0%	0%
Plakosyllis sp.		0%	0%	0%	0%	0%	0%

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Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Syllidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Sabellida							
Family: Oweniidae							
Galathowenia sp.		0%	0%	0%	0%	0%	0%
Order: Spionida							
Family: Magelonidae							
Magelona sp.		0%	0%	0%	0%	0%	0%
Family: Spionidae							
Minuspio sp.		0%	0%	0%	0%	0%	0%
Polydora sp.		0%	0%	0%	0%	0%	0%
Scolelepis sp.		0%	0%	0%	0%	0%	0%
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		0%	0%	0%	0%	0%	0%
Family: Cirratulidae							
Cirratulidae (LPIL)		0%	0%	0%	0%	0%	0%
Cirriformia sp.		0%	0%	0%	0%	0%	0%
Monticellina sp.		0%	0%	0%	0%	0%	0%
Family: Pectinariidae							
Lagis sp.		0%	0%	0%	0%	0%	0%
Family: Terebellidae							
Eupolymnia sp.		0%	0%	0%	0%	0%	0%
Lanice conchilega		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		0%	0%	0%	0%	0%	0%
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Tubificoid Naididae (LPIL)		65.38%	18.18%	100%	21.43%	31.82%	37.18%
Tubificoid Naididae imm. w/o hair setae (LPIL)		0%	0%	0%	0%	0%	0%
Tubificoides sp.		0%	0%	0%	0%	0%	2.56%
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Hyperia sp.		0%	0%	0%	0%	0%	0%
Family: Ampeliscidae							
Ampelisca sp.		0%	0%	0%	0%	0%	0%
Family: Aoridae							
Aoridae (LPIL)		11.54%	9.09%	0%	21.43%	0%	0%
Bemlos/Plesiolembos group		0%	0%	0%	0%	0%	0%
Grandidierella sp.		0%	27.27%	0%	0%	0%	0%
Family: Atylidae							
Nototropis swammerdamei		0%	0%	0%	0%	0%	0%
Family: Bathyporeiidae							
Bathyporeia sp.		0%	0%	0%	0%	0%	0%

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Taxonomic Classification	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Family: Caprellidae						
Pseudaeginella sp.	0%	0%	0%	0%	0%	0%
Family: Corophiidae						
Cheiriphotis sp	0%	0%	0%	0%	0%	0%
Family: Eriopisidae						
Eriopisella sp.	0%	0%	0%	0%	0%	0%
Family: Haustoriidae						
Haustoriidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Isaeidae						
Photis sp.	0%	0%	0%	0%	0%	0%
Family: Ischroceridae						
Ericthonius sp.	0%	0%	0%	0%	0%	0%
Family: Ischyroceridae						
Cerapus sp.	0%	0%	0%	0%	0%	0%
Family: Liljeborgiidae						
Idunella sp.	0%	0%	0%	0%	0%	0%
Liljeborgiidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Lysianassidae						
Pardia punctata	0%	0%	0%	0%	0%	0%
Family: Megaluropidae						
Megaluropidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Melitidae						
Maera sp.	0%	0%	0%	0%	0%	0%
Melitidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Oedicerotidae						
Oedicerotidae (LPIL)	0%	0%	0%	0%	0%	0%
Perioculodes sp.	0%	0%	0%	0%	0%	0%
Family: Phoxocephalidae						
Basuto stimpsoni	0%	0%	0%	0%	0%	0%
Family: Phtisicidae						
Phtisica marina	0%	0%	0%	0%	0%	0%
Family: Pontoporeiidae						
Pontoporeiidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Urothoidae						
Urothoe sp.	0%	0%	0%	0%	0%	0%
Family: Unspecified						
Amphipoda (LPIL)	0%	0%	0%	0%	0%	0%
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Corophiida LPIL	0%	0%	0%	0%	0%	0%
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Cyclaspis sp.	0%	0%	0%	0%	0%	0%
Family: Nannastacidae						
Cumella sp.	0%	0%	0%	0%	0%	0%

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Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Family: Unspecified							
Cumacea (LPIL)		0%	0%	0%	0%	0%	0%
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		0%	0%	0%	0%	0%	0%
Family: Callianassidae							
Callianassidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Crangonidae							
Crangonidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Diogenidae							
Diogenes sp.		0%	0%	0%	0%	0%	0%
Diogenidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Majidae							
Majidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Paguridae							
Paguristes sp.		0%	0%	0%	0%	0%	0%
Family: Penaeidae							
Penaeus sp.		0%	0%	0%	0%	2.27%	0%
Family: Porcellanidae							
Porcellanidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Upogebiidae							
Upogebia sp.		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Brachyura (LPIL)		0%	0%	0%	0%	0%	0%
Decapoda (LPIL) zoea larva		0%	0%	0%	0%	0%	0%
Decapoda (LPIL) megalopa larva		0%	0%	0%	0%	0%	0%
Decapoda (LPIL) mysis larva		0%	0%	0%	0%	0%	0%
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		0%	0%	0%	0%	0%	0%
Anthuridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Arcturidae							
Arcturidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		0%	0%	0%	0%	0%	0%
Mysidae (LPIL)		0%	9.09%	0%	7.14%	0%	0%
Rhopalophthalmus sp.		0%	0%	0%	0%	0%	2.56%
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Kalliapseudidae							
Kalliapseudes sp.		0%	0%	0%	0%	0%	0%
Kalliapseudidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Metapseudidae							
Calozodion sp.		0%	0%	0%	0%	0%	0%
Family: Unspecified							

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Taxonomic Classification	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Metapseudidae (LPIL)	0%	0%	0%	0%	0%	0%
Tanaidacea (LPIL)	0%	0%	0%	0%	0%	0%
Class: Pycnogonida						
Order: Unspecified						
Family: Unspecified						
Pycnogonida (LPIL)	0%	0%	0%	0%	0%	0%
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Litiopidae						
Litiopidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Heterostropha						
Family: Pyramidellidae						
Pyramidellidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Neogastropoda						
Family: Marginellidae						
Glabella adansoni	0%	0%	0%	0%	0%	0%
Marginellidae (LPIL)	0%	0%	0%	0%	0%	0%
Prunum sp.	0%	0%	0%	0%	0%	0%
Family: Muricidae						
Muricidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Unspecified						
Neogastropoda (LPIL)	0%	0%	0%	0%	0%	0%
Order: Neotaenioglossa						
Family: Calyptraeidae						
Calyptraea sp.	0%	0%	0%	0%	0%	0%
Family: Cerithiidae						
Cerithium sp.	3.85%	0%	0%	14.29%	0%	0%
Order: Nudibranchia						
Family: Unspecified						
Nudibranchia (LPIL)	0%	0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)	0%	0%	0%	0%	0%	0%
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)	3.85%	9.09%	0%	7.14%	6.82%	3.85%
Order: Myoida						
Family: Myidae						
Sphenia sp.	0%	0%	0%	0%	0%	0%
Order: Mytiloida						
Family: Mytilidae						
Lioberus sp.	0%	0%	0%	0%	0%	0%
Musculus sp.	0%	0%	0%	0%	0%	0%
Order: Nuculoida						
Family: Nuculidae						

Macroinvertebrate Results
Percent Occurrence (Pooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13
Nucula sp.		0%	0%	0%	0%	0%	0%
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		0%	0%	0%	0%	0%	0%
Cardiidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Corbulidae							
Caryocorbula sp.		3.85%	0%	0%	0%	0%	0%
Corbula sp.		0%	0%	0%	0%	0%	0%
Family: Lucinidae							
Lucinidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Semelidae							
Semelidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Solecurtidae							
Solecurtidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Tellinidae							
Angulus sp.		0%	0%	0%	0%	2.27%	0%
Macoma sp.		0%	0%	0%	0%	0%	1.28%
Tellinidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Ungulinidae							
Ungulinidae (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Ophiactidae							
Ophiactis plana		0%	0%	0%	0%	0%	0%
Ophiactis sp.		0%	0%	0%	0%	0%	0%
Family: Ophiolepididae							
Ophiolepis paucispina		0%	0%	0%	0%	0%	0%
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		0%	0%	0%	0%	0%	0%
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Echinoidea (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		0%	0%	0%	0%	0%	0%
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		0%	0%	0%	0%	0%	0%
Total Percentage		100.02%	99.99%	100%	99.99%	100%	99.99%
Number of Taxa		8	8	1	9	9	12

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Phylum: Cnidaria						
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)	0%	0%	0%	0%	0%	0%
Phylum: Platyhelminthes						
Class: Turbellaria						
Order: Unspecified						
Family: Unspecified						
Turbellaria (LPIL)	0%	0%	0%	0%	0%	0.24%
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)	0%	0%	1.96%	10.26%	11.11%	1.42%
Phylum: Sipuncula						
Class: Phascolosomatidea						
Order: Aspidosiphonida						
Family: Aspidosiphonidae						
Aspidosiphonidae (LPIL)	0%	0%	0%	0%	0%	0%
Phylum: Annelida						
Class: Polychaeta						
Order: Capitellida						
Family: Capitellidae						
Capitella sp.	0%	0%	0%	0%	0%	0%
Capitellidae (LPIL)	0%	0%	0%	0%	0%	0%
Decamastus sp.	0%	0%	0%	0%	0%	0%
Heteromastus filiformis	0%	0%	1.96%	2.56%	0%	0.95%
Mediomastus sp.	0%	0%	0%	0%	0%	0%
Notomastus sp.	25%	0%	0%	0%	0%	0%
Family: Maldanidae						
Euclymene sp.	0%	0%	0%	0%	0%	0.24%
Maldanidae (LPIL)	0%	0%	0%	0%	0%	0.24%
Sabaco sp.	0%	0%	0%	0%	0%	0%
Order: Eunicida						
Family: Dorvilleidae						
Dorvilleidae (LPIL)	0%	0%	0%	0%	0%	0%
Protodorvillea sp.	0%	0%	0%	0%	0%	0.24%
Family: Lumbrineridae						
Augeneria sp.	0%	0%	0%	0%	0%	0.47%
Lumbrineris sp.	0%	0%	0%	0%	0%	0.47%
Family: Onuphidae						
Diopatra sp.	0%	33.33%	1.96%	0%	0%	7.82%
Onuphidae (LPIL)	0%	6.67%	0%	0%	0%	0.24%
Order: Opheliida						
Family: Opheliidae						
Armandia maculata	0%	0%	0%	0%	0%	0%

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13
Armandia sp.		0%	0%	0%	0%	0%	0%
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		0%	0%	0%	0%	0%	0.24%
Scoloplos sp.		0%	0%	0%	0%	0%	1.18%
Family: Paraonidae							
Aricidea catherinae		0%	0%	0%	0%	0%	0%
Aricidea fragilis		0%	0%	0%	0%	0%	0.71%
Aricidea sp.		0%	0%	0%	0%	0%	0.47%
Aricidea wassi		0%	0%	0%	0%	0%	0%
Cirrophorus branchiatus		0%	0%	0%	0%	0%	0%
Cirrophorus sp.		0%	0%	0%	0%	0%	0%
Levinsenia sp.		0%	0%	0%	0%	0%	0%
Paradoneis sp.		0%	0%	0%	0%	0%	0%
Paraonidae (LPIL)		0%	0%	0%	0%	0%	0.24%
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		0%	0%	0%	0%	0%	0%
Glycera alba		0%	0%	0%	0%	0%	0%
Glycera sp.		0%	0%	0%	7.69%	0%	0.71%
Glyceridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Goniadidae							
Glycinde sp.		0%	0%	0%	0%	0%	0.71%
Goniada multidentata		0%	0%	0%	0%	0%	0%
Goniadidae (LPIL)		0%	0%	0%	0%	33.33%	0%
Goniadides sp.		0%	0%	0%	0%	0%	0.24%
Family: Hesionidae							
Hesione sp.		0%	0%	0%	2.56%	0%	0%
Hesionidae (LPIL)		0%	0%	0%	0%	0%	0%
Heteropodarke sp.		0%	0%	0%	0%	0%	0%
Podarkeopsis sp.		0%	0%	0%	0%	0%	0.71%
Family: Nephtyidae							
Aglaophamus sp.		0%	0%	0%	0%	0%	0%
Micronephtys sp.		50%	0%	66.67%	0%	0%	0%
Micronephtys stammeri		0%	0%	0%	0%	0%	1.18%
Family: Nereididae							
Namalycastis sp.		0%	0%	0%	0%	0%	0%
Nereis sp.		0%	0%	0%	0%	0%	0%
Platynereis sp.		0%	0%	0%	0%	0%	0%
Family: Pilargidae							
Cabira sp.		0%	0%	0%	0%	0%	0%
Sigambra sp.		0%	6.67%	0%	5.13%	0%	0.24%
Family: Polynoidae							
Polynoidae (LPIL)		0%	0%	0%	0%	0%	0.24%
Family: Syllidae							
Eusyllis sp.		0%	0%	0%	0%	0%	0.24%
Plakosyllis sp.		0%	0%	0%	0%	0%	0%

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Syllidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.	0%	0%	0%	2.56%	0%	0.95%
Order: Spionida						
Family: Magelonidae						
Magelona sp.	0%	0%	0%	0%	0%	0%
Family: Spionidae						
Minuspio sp.	0%	0%	1.96%	0%	0%	0%
Polydora sp.	0%	0%	0%	0%	0%	0.47%
Scolelepis sp.	0%	0%	0%	0%	0%	0%
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	0%	0%	0%	0%	0%	0.95%
Family: Cirratulidae						
Cirratulidae (LPIL)	0%	0%	0%	0%	0%	0%
Cirriformia sp.	0%	0%	0%	0%	0%	0.47%
Monticellina sp.	0%	0%	0%	0%	0%	0.71%
Family: Pectinariidae						
Lagis sp.	0%	0%	0%	0%	0%	2.61%
Family: Terebellidae						
Eupolymnia sp.	0%	0%	0%	0%	0%	0%
Lanice conchilega	0%	0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	0%	0%	0%	0%	0%	0%
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)	0%	0%	9.8%	0%	0%	0%
Tubificoid Naididae imm. w/o hair setae (LPIL)	0%	0%	0%	0%	0%	0%
Tubificoides sp.	0%	0%	0%	0%	0%	0%
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.	0%	0%	0%	0%	0%	0%
Family: Ampeliscidae						
Ampelisca sp.	0%	0%	0%	0%	0%	12.8%
Family: Aoridae						
Aoridae (LPIL)	0%	6.67%	0%	5.13%	0%	2.84%
Bemlos/Plesiolembos group	0%	0%	0%	0%	0%	0.24%
Grandidierella sp.	0%	0%	0%	0%	0%	0%
Family: Atylidae						
Nototropis swammerdamei	0%	0%	0%	0%	0%	0%
Family: Bathyporeiidae						
Bathyporeia sp.	0%	0%	0%	0%	0%	0%

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Sample Method: Petite Ponar
Report Date: 10/09/2013

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Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Family: Caprellidae						
Pseudaeginella sp.	0%	0%	0%	0%	0%	0.24%
Family: Corophiidae						
Cheiriphotis sp	0%	0%	0%	0%	0%	1.9%
Family: Eriopisidae						
Eriopisella sp.	0%	0%	0%	0%	0%	0%
Family: Haustoriidae						
Haustoriidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Isaeidae						
Photis sp.	0%	0%	0%	0%	0%	20.38%
Family: Ischroceridae						
Ericthonius sp.	0%	0%	0%	0%	0%	3.08%
Family: Ischyroceridae						
Cerapus sp.	0%	0%	0%	0%	0%	0%
Family: Liljeborgiidae						
Idunella sp.	0%	0%	0%	0%	22.22%	0%
Liljeborgiidae (LPIL)	0%	0%	0%	0%	0%	0.24%
Family: Lysianassidae						
Pardia punctata	0%	0%	0%	0%	0%	0%
Family: Megaluropidae						
Megaluropidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Melitidae						
Maera sp.	0%	0%	0%	0%	0%	0.24%
Melitidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Oedicerotidae						
Oedicerotidae (LPIL)	0%	0%	0%	0%	0%	0%
Perioculodes sp.	0%	0%	0%	0%	0%	0%
Family: Phoxocephalidae						
Basuto stimpsoni	0%	0%	0%	0%	11.11%	0%
Family: Phtisicidae						
Phtisica marina	0%	0%	0%	0%	0%	0.24%
Family: Pontoporeiidae						
Pontoporeiidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Urothoidae						
Urothoe sp.	0%	0%	0%	0%	0%	0%
Family: Unspecified						
Amphipoda (LPIL)	0%	0%	0%	0%	0%	4.03%
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Corophiida LPIL	0%	0%	0%	0%	0%	4.27%
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Cyclaspis sp.	0%	0%	0%	0%	0%	0.47%
Family: Nannastacidae						
Cumella sp.	0%	0%	0%	0%	0%	0%

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Sample Group: Rio Cacheu Benthic Assessment

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Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Family: Unspecified						
Cumacea (LPIL)	0%	0%	0%	0%	0%	0%
Order: Decapoda						
Family: Unspecified						
Decapoda (LPIL)	0%	0%	0%	0%	0%	0%
Family: Callianassidae						
Callianassidae (LPIL)	0%	0%	0%	53.85%	0%	0.24%
Family: Crangonidae						
Crangonidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Diogenidae						
Diogenes sp.	0%	0%	0%	0%	0%	0%
Diogenidae (LPIL)	0%	0%	0%	0%	0%	0.71%
Family: Majidae						
Majidae (LPIL)	0%	0%	0%	0%	0%	0.24%
Family: Paguridae						
Paguristes sp.	0%	0%	0%	0%	0%	0.95%
Family: Penaeidae						
Penaeus sp.	0%	0%	0%	0%	0%	0%
Family: Porcellanidae						
Porcellanidae (LPIL)	0%	0%	0%	0%	0%	0.24%
Family: Upogebiidae						
Upogebia sp.	0%	20%	0%	0%	0%	0%
Family: Unspecified						
Brachyura (LPIL)	0%	0%	0%	0%	0%	0.47%
Decapoda (LPIL) zoea larva	0%	0%	0%	0%	0%	0%
Decapoda (LPIL) megalopa larva	0%	6.67%	0%	0%	0%	0%
Decapoda (LPIL) mysis larva	0%	0%	1.96%	0%	11.11%	0.24%
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.	0%	0%	0%	0%	0%	0.47%
Anthuridae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Arcturidae						
Arcturidae (LPIL)	0%	0%	0%	0%	0%	0.95%
Order: Mysida						
Family: Mysidae						
Gastrosaccus sanctus	0%	0%	0%	0%	0%	0%
Mysidae (LPIL)	0%	0%	1.96%	0%	0%	0.24%
Rhopalophthalmus sp.	0%	0%	0%	0%	0%	0%
Order: Tanaidacea						
Family: Apseudidae						
Apseudidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Kalliapseudidae						
Kalliapseudes sp.	0%	0%	0%	0%	0%	0.47%
Kalliapseudidae (LPIL)	0%	0%	0%	0%	0%	0.24%
Family: Metapseudidae						
Calozodion sp.	0%	0%	0%	0%	0%	2.61%
Family: Unspecified						

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Metapseudidae (LPIL)		0%	0%	0%	0%	0%	0.24%
Tanaidacea (LPIL)		0%	0%	0%	0%	0%	0%
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Pycnogonida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Litiopidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Heterostropha							
Family: Pyramidellidae							
Pyramidellidae (LPIL)		0%	0%	0%	0%	0%	0.24%
Order: Neogastropoda							
Family: Marginellidae							
Glabella adansoni		0%	0%	0%	0%	0%	0%
Marginellidae (LPIL)		0%	0%	0%	0%	0%	0%
Prunum sp.		0%	0%	0%	0%	0%	0%
Family: Muricidae							
Muricidae (LPIL)		0%	0%	0%	0%	0%	0.95%
Family: Unspecified							
Neogastropoda (LPIL)		0%	0%	0%	0%	0%	0.24%
Order: Neotaenioglossa							
Family: Calyptraeidae							
Calyptraea sp.		0%	0%	0%	0%	0%	2.13%
Family: Cerithiidae							
Cerithium sp.		0%	0%	0%	0%	0%	0%
Order: Nudibranchia							
Family: Unspecified							
Nudibranchia (LPIL)		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		0%	0%	0%	0%	0%	0%
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		25%	0%	0%	0%	0%	1.66%
Order: Myoida							
Family: Myidae							
Sphenia sp.		0%	0%	0%	0%	0%	0%
Order: Mytiloida							
Family: Mytilidae							
Lioberus sp.		0%	0%	0%	0%	0%	0%
Musculus sp.		0%	0%	0%	0%	0%	0%
Order: Nuculoida							
Family: Nuculidae							

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Macroinvertebrate Results
Percent Occurrence (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Nucula sp.	0%	0%	0%	0%	0%	0.24%
Order: Ostreoida						
Family: Ostreidae						
Ostreidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Veneroida						
Family: Cardiidae						
Acanthocardia tuberculata	0%	0%	0%	0%	0%	0%
Cardiidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Corbulidae						
Caryocorbula sp.	0%	0%	0%	0%	0%	0%
Corbula sp.	0%	0%	0%	0%	0%	0%
Family: Lucinidae						
Lucinidae (LPIL)	0%	0%	0%	0%	0%	0.47%
Family: Semelidae						
Semelidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Solecurtidae						
Solecurtidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Tellinidae						
Angulus sp.	0%	0%	0%	0%	0%	0%
Macoma sp.	0%	20%	11.76%	0%	0%	1.18%
Tellinidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Ungulinidae						
Ungulinidae (LPIL)	0%	0%	0%	0%	0%	0%
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)	0%	0%	0%	10.26%	0%	0%
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiuridae (LPIL)	0%	0%	0%	0%	11.11%	2.84%
Family: Ophiactidae						
Ophiactis plana	0%	0%	0%	0%	0%	0%
Ophiactis sp.	0%	0%	0%	0%	0%	0%
Family: Ophiolepididae						
Ophiolepis paucispina	0%	0%	0%	0%	0%	0.24%
Order: Ophuridae						
Family: Ophionereididae						
Ophionereididae (LPIL)	0%	0%	0%	0%	0%	0.24%
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)	0%	0%	0%	0%	0%	1.66%
Class: Echinoidea						
Order: Unspecified						
Family: Unspecified						

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Macroinvertebrate Results
Percent Occurrence (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Echinoidea (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		0%	0%	0%	0%	0%	0%
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		0%	0%	0%	0%	0%	3.08%
Total Percentage		100%	100.01%	99.99%	100%	99.99%	100.05%
Number of Taxa		3	7	9	9	6	69

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Phylum: Cnidaria						
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)		0%	0%	16.19%	0%	0%
Phylum: Platyhelminthes						
Class: Turbellaria						
Order: Unspecified						
Family: Unspecified						
Turbellaria (LPIL)		0%	0.3%	2.86%	0%	0%
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)		0%	0.6%	0%	2.86%	2.17%
Phylum: Sipuncula						
Class: Phascolosomatidea						
Order: Aspidosiphonida						
Family: Aspidosiphonidae						
Aspidosiphonidae (LPIL)		0%	0%	3.81%	0%	0%
Phylum: Annelida						
Class: Polychaeta						
Order: Capitellida						
Family: Capitellidae						
Capitella sp.		3.13%	0%	0%	0%	0%
Capitellidae (LPIL)		0%	0%	0%	0%	0%
Decamastus sp.		0%	0%	0%	0%	0%
Heteromastus filiformis		0%	0.9%	0%	0%	2.17%
Mediomastus sp.		0%	0%	0.95%	2.86%	4.35%
Notomastus sp.		0%	0%	0%	0%	0%
Family: Maldanidae						
Euclymene sp.		0%	0%	0%	0%	0%
Maldanidae (LPIL)		0%	1.8%	0%	0%	0%
Sabaco sp.		0%	0.3%	0%	0%	0%
Order: Eunicida						
Family: Dorvilleidae						
Dorvilleidae (LPIL)		0%	0%	0%	2.86%	0%
Protodorvillea sp.		0%	0%	0%	0%	0%
Family: Lumbrineridae						
Augeneria sp.		0%	0%	0%	0%	0%
Lumbrineris sp.		0%	1.8%	0%	0%	1.09%
Family: Onuphidae						
Diopatra sp.		0%	1.5%	0%	0%	1.09%
Onuphidae (LPIL)		0%	0%	0%	0%	0%
Order: Opheliida						
Family: Opheliidae						
Armandia maculata		21.88%	0%	0%	0%	0%

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Armandia sp.		0%	0%	0%	20%	10.87%
Order: Orbiniida						
Family: Orbiniidae						
Orbiniidae (LPIL)		0%	0%	0%	0%	0%
Scoloplos sp.		0%	1.5%	0%	2.86%	6.52%
Family: Paraonidae						
Aricidea catherinae		0%	0.3%	0%	0%	0%
Aricidea fragilis		0%	1.8%	0%	0%	0%
Aricidea sp.		0%	0%	0%	0%	0%
Aricidea wassi		0%	0%	0%	0%	1.09%
Cirrophorus branchiatus		0%	0.3%	0%	0%	0%
Cirrophorus sp.		0%	0%	0%	2.86%	0%
Levinsenia sp.		0%	0%	0%	0%	1.09%
Paradoneis sp.		0%	0%	0%	0%	2.17%
Paraonidae (LPIL)		0%	0%	0%	2.86%	0%
Order: Phyllodocida						
Family: Glyceridae						
Glycera africana		3.13%	0.3%	0%	0%	0%
Glycera alba		0%	0.6%	1.9%	0%	0%
Glycera sp.		0%	0%	0.95%	2.86%	0%
Glyceridae (LPIL)		0%	0%	0.95%	0%	0%
Family: Goniadidae						
Glycinde sp.		0%	0%	0%	0%	0%
Goniada multidentata		0%	0%	0%	0%	1.09%
Goniadidae (LPIL)		0%	0.9%	0%	0%	0%
Goniadides sp.		0%	0%	0%	0%	0%
Family: Hesionidae						
Hesione sp.		0%	0%	0%	0%	0%
Hesionidae (LPIL)		0%	0%	0.95%	0%	0%
Heteropodarke sp.		0%	0%	0%	5.71%	1.09%
Podarkeopsis sp.		0%	0.3%	0%	0%	0%
Family: Nephtyidae						
Aglaophamus sp.		0%	0%	0%	0%	0%
Micronephtys sp.		0%	0%	0%	0%	0%
Micronephtys stammeri		0%	0.6%	0%	0%	0%
Family: Nereididae						
Namalycastis sp.		0%	0%	0%	0%	0%
Nereis sp.		0%	0%	0%	0%	0%
Platynereis sp.		0%	0%	0%	0%	0%
Family: Pilargidae						
Cabira sp.		0%	0%	0%	0%	1.09%
Sigambra sp.		0%	0%	0%	0%	0%
Family: Polynoidae						
Polynoidae (LPIL)		0%	0%	0%	0%	1.09%
Family: Syllidae						
Eusyllis sp.		0%	0%	0.95%	0%	0%
Plakosyllis sp.		0%	0%	0%	2.86%	0%

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Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Syllidae (LPIL)		0%	1.2%	0%	0%	0%
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.		0%	0.3%	0.95%	0%	0%
Order: Spionida						
Family: Magelonidae						
Magelona sp.		18.75%	0%	0%	0%	3.26%
Family: Spionidae						
Minuspio sp.		0%	0.3%	0%	0%	1.09%
Polydora sp.		0%	2.1%	0%	0%	0%
Scolelepis sp.		0%	0.3%	0%	0%	0%
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.		0%	0%	0%	0%	0%
Family: Cirratulidae						
Cirratulidae (LPIL)		0%	0.3%	0%	0%	0%
Cirriformia sp.		0%	0%	0%	0%	0%
Monticellina sp.		0%	0.6%	0%	0%	0%
Family: Pectinariidae						
Lagis sp.		0%	4.2%	0%	0%	0%
Family: Terebellidae						
Eupolymnia sp.		0%	0.3%	0%	0%	0%
Lanice conchilega		0%	0.3%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)		0%	0%	0%	2.86%	0%
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)		3.13%	0%	0%	0%	5.43%
Tubificoid Naididae imm. w/o hair setae (LPIL)		0%	0%	0%	0%	1.09%
Tubificoides sp.		0%	0%	0%	0%	0%
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.		3.13%	0%	0%	0%	0%
Family: Ampeliscidae						
Ampelisca sp.		0%	8.71%	1.9%	0%	0%
Family: Aoridae						
Aoridae (LPIL)		0%	0.6%	4.76%	0%	0%
Bemlos/Plesiolembos group		0%	0%	0%	0%	0%
Grandidierella sp.		0%	0%	0%	0%	0%
Family: Atylidae						
Nototropis swammerdamei		0%	0%	0%	0%	2.17%
Family: Bathyporeiidae						
Bathyporeia sp.		3.13%	0%	0%	0%	0%

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Family: Caprellidae						
Pseudaeginella sp.		0%	0%	0%	0%	0%
Family: Corophiidae						
Cheiriphotis sp		0%	0%	0%	0%	0%
Family: Eriopisidae						
Eriopisella sp.		0%	3.6%	0%	0%	0%
Family: Haustoriidae						
Haustoriidae (LPIL)		0%	0%	12.38%	17.14%	0%
Family: Isaeidae						
Photis sp.		0%	11.41%	0%	0%	0%
Family: Ischroceridae						
Ericthonius sp.		0%	0%	0%	0%	2.17%
Family: Ischyroceridae						
Cerapus sp.		0%	0.6%	0%	0%	0%
Family: Liljeborgiidae						
Idunella sp.		0%	1.5%	0%	0%	0%
Liljeborgiidae (LPIL)		0%	0%	0%	0%	0%
Family: Lysianassidae						
Pardia punctata		0%	0.9%	0%	0%	0%
Family: Megaluropidae						
Megaluropidae (LPIL)		0%	0%	1.9%	0%	0%
Family: Melitidae						
Maera sp.		0%	0%	0%	0%	0%
Melitidae (LPIL)		0%	4.2%	0%	0%	0%
Family: Oedicerotidae						
Oedicerotidae (LPIL)		6.25%	0%	0%	0%	1.09%
Perioculodes sp.		3.13%	0%	0%	0%	0%
Family: Phoxocephalidae						
Basuto stimpsoni		0%	0%	0%	0%	0%
Family: Phtisicidae						
Phtisica marina		0%	0%	0%	0%	0%
Family: Pontoporeiidae						
Pontoporeiidae (LPIL)		6.25%	0%	0%	0%	0%
Family: Urothoidae						
Urothoe sp.		0%	0%	0.95%	0%	0%
Family: Unspecified						
Amphipoda (LPIL)		0%	5.41%	0.95%	0%	2.17%
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Corophiida LPIL		0%	0%	0%	0%	0%
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Cyclaspis sp.		12.5%	1.5%	0%	0%	5.43%
Family: Nannastacidae						
Cumella sp.		0%	0%	0%	0%	3.26%

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN13BG	STN14BG	STN15BG	STN16BG	STN17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	05/20/13	05/22/13	05/23/13	05/23/13	05/24/13
Family: Unspecified						
Cumacea (LPIL)		3.13%	0.6%	0%	0%	1.09%
Order: Decapoda						
Family: Unspecified						
Decapoda (LPIL)		0%	0%	0%	5.71%	0%
Family: Callianassidae						
Callianassidae (LPIL)		0%	3%	0%	0%	0%
Family: Crangonidae						
Crangonidae (LPIL)		3.13%	0%	0%	0%	0%
Family: Diogenidae						
Diogenes sp.		0%	1.2%	0%	0%	0%
Diogenidae (LPIL)		0%	0%	0%	0%	0%
Family: Majidae						
Majidae (LPIL)		0%	0%	0%	0%	0%
Family: Paguridae						
Paguristes sp.		0%	0%	0%	0%	0%
Family: Penaeidae						
Penaeus sp.		0%	0%	0%	0%	0%
Family: Porcellanidae						
Porcellanidae (LPIL)		0%	0%	2.86%	2.86%	1.09%
Family: Upogebiidae						
Upogebia sp.		0%	0%	0%	0%	0%
Family: Unspecified						
Brachyura (LPIL)		0%	0.3%	0%	0%	0%
Decapoda (LPIL) zoea larva		0%	0%	0.95%	2.86%	4.35%
Decapoda (LPIL) megalopa larva		0%	0%	0.95%	0%	0%
Decapoda (LPIL) mysis larva		0%	0.9%	0%	0%	0%
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.		0%	0%	0%	0%	0%
Anthuridae (LPIL)		0%	1.2%	0.95%	2.86%	0%
Family: Arcturidae						
Arcturidae (LPIL)		0%	0%	0%	0%	0%
Order: Mysida						
Family: Mysidae						
Gastrosaccus sanctus		0%	0%	0%	0%	1.09%
Mysidae (LPIL)		3.13%	0%	0%	0%	0%
Rhopalophthalmus sp.		0%	0.3%	0%	0%	0%
Order: Tanaidacea						
Family: Apseudidae						
Apseudidae (LPIL)		0%	0%	0%	0%	2.17%
Family: Kalliapseudidae						
Kalliapseudes sp.		0%	0%	0%	0%	0%
Kalliapseudidae (LPIL)		0%	0%	0%	0%	0%
Family: Metapseudidae						
Calozodion sp.		0%	2.4%	0%	0%	0%
Family: Unspecified						

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Sample Method: Petite Ponar
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Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Metapseudidae (LPIL)		0%	0%	0%	0%	0%
Tanaidacea (LPIL)		0%	1.5%	0%	0%	0%
Class: Pycnogonida						
Order: Unspecified						
Family: Unspecified						
Pycnogonida (LPIL)		0%	0%	0%	2.86%	0%
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Litiopidae						
Litiopidae (LPIL)		0%	0.3%	0%	0%	0%
Order: Heterostropha						
Family: Pyramidellidae						
Pyramidellidae (LPIL)		0%	0%	0%	0%	0%
Order: Neogastropoda						
Family: Marginellidae						
Glabella adansoni		0%	0%	0%	0%	1.09%
Marginellidae (LPIL)		0%	0%	0%	0%	1.09%
Prunum sp.		0%	0.3%	0%	0%	0%
Family: Muricidae						
Muricidae (LPIL)		0%	0%	0%	0%	0%
Family: Unspecified						
Neogastropoda (LPIL)		0%	0%	0%	0%	0%
Order: Neotaenioglossa						
Family: Calyptraeidae						
Calyptraea sp.		0%	0.3%	11.43%	0%	0%
Family: Cerithiidae						
Cerithium sp.		0%	0%	0%	0%	0%
Order: Nudibranchia						
Family: Unspecified						
Nudibranchia (LPIL)		0%	0%	0.95%	0%	0%
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)		3.13%	0.3%	0%	0%	0%
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)		0%	1.5%	1.9%	2.86%	3.26%
Order: Myoida						
Family: Myidae						
Sphenia sp.		0%	0%	0.95%	0%	0%
Order: Mytiloida						
Family: Mytilidae						
Lioberus sp.		0%	0.3%	0%	0%	0%
Musculus sp.		0%	0%	0.95%	0%	0%
Order: Nuculoida						
Family: Nuculidae						

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Macroinvertebrate Results
Percent Occurrence (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Nucula sp.		0%	0%	0%	0%	0%
Order: Ostreoida						
Family: Ostreidae						
Ostreidae (LPIL)		0%	1.2%	0%	2.86%	0%
Order: Veneroida						
Family: Cardiidae						
Acanthocardia tuberculata		0%	5.41%	0%	0%	0%
Cardiidae (LPIL)		0%	0%	0%	0%	2.17%
Family: Corbulidae						
Caryocorbula sp.		0%	0%	4.76%	5.71%	0%
Corbula sp.		0%	0.3%	0%	0%	0%
Family: Lucinidae						
Lucinidae (LPIL)		0%	2.4%	0%	0%	0%
Family: Semelidae						
Semelidae (LPIL)		0%	0.6%	0%	0%	0%
Family: Solecurtidae						
Solecurtidae (LPIL)		0%	0.3%	0%	0%	0%
Family: Tellinidae						
Angulus sp.		0%	0%	0%	0%	0%
Macoma sp.		0%	0.3%	0%	0%	0%
Tellinidae (LPIL)		0%	0.6%	0%	0%	0%
Family: Ungulinidae						
Ungulinidae (LPIL)		0%	2.4%	0%	0%	0%
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)		0%	0.3%	0%	0%	0%
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiuridae (LPIL)		0%	6.91%	0.95%	0%	11.96%
Family: Ophiactidae						
Ophiactis plana		0%	0%	7.62%	0%	0%
Ophiactis sp.		0%	0%	10.48%	0%	0%
Family: Ophiolepididae						
Ophiolepis paucispina		0%	0%	0%	0%	0%
Order: Ophuridae						
Family: Ophionereididae						
Ophionereididae (LPIL)		0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)		3.13%	2.7%	0%	0%	4.35%
Class: Echinoidea						
Order: Unspecified						
Family: Unspecified						

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Echinoidea (LPIL)		0%	0%	0.95%	0%	0%
Phylum: Chordata						
Class: Cephalochordata						
Order: Amphioxiformes						
Family: Branchiostomatidae						
Branchiostoma sp.		0%	0%	0%	0%	1.09%
Phylum: Chaetognatha						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Chaetognatha (LPIL)		0%	0%	0%	2.86%	1.09%
Phylum: Brachiopoda						
Class: Lingulata						
Order: Lingulida						
Family: Lingulidae						
Lingula sp.		0%	0%	0%	0%	0%
Total Percentage		100.06%	99.95%	99.95%	100.03%	100.02%
Number of Taxa		16	63	30	21	37

Macroinvertebrate Results
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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Turbellaria (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Aspidosiphonidae (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Capitella sp.		14	-	-	-	14	14
Capitellidae (LPIL)		-	-	-	-	-	57
Decamastus sp.		14	14	-	-	72	29
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	201	402
Family: Maldanidae							
Euclymene sp.		-	-	-	-	-	-
Maldanidae (LPIL)		-	-	-	-	-	-
Sabaco sp.		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Dorvilleidae (LPIL)		-	-	-	-	-	-
Protodorvillea sp.		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris sp.		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Onuphidae (LPIL)		-	-	-	-	-	-
Order: Opheliida							
Family: Opheliidae							
Armandia maculata		-	-	-	-	-	-

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Goniadides sp.		-	-	-	-	-	-
Family: Hesionidae							
Hesione sp.		-	-	-	-	-	-
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	14	-	-	-	-
Micronephtys sp.		-	-	-	-	43	57
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Namalycastis sp.		-	-	-	14	-	-
Nereis sp.		-	-	-	14	-	14
Platynereis sp.		-	14	-	14	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		14	-	-	14	29	14
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	-
Family: Syllidae							
Eusyllis sp.		-	-	-	-	-	-
Plakosyllis sp.		-	-	-	-	-	-

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Report Date: 10/09/2013

Taxonomic Classification	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Syllidae (LPIL)	-	-	-	-	-	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.	-	-	-	-	-	-
Order: Spionida						
Family: Magelonidae						
Magelona sp.	-	-	-	-	-	-
Family: Spionidae						
Minuspio sp.	-	-	-	-	-	-
Polydora sp.	-	-	-	-	-	-
Scolelepis sp.	-	-	-	-	-	-
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	-	-	-	-	-	-
Family: Cirratulidae						
Cirratulidae (LPIL)	-	-	-	-	-	-
Cirriformia sp.	-	-	-	-	-	-
Monticellina sp.	-	-	-	-	-	-
Family: Pectinariidae						
Lagis sp.	-	-	-	-	-	-
Family: Terebellidae						
Eupolymnia sp.	-	-	-	-	-	-
Lanice conchilega	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	-	-	-	-	-	-
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)	244	29	29	43	201	417
Tubificoid Naididae imm. w/o hair setae (LPIL)	-	-	-	-	-	-
Tubificoides sp.	-	-	-	-	-	29
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.	-	-	-	-	-	-
Family: Ampeliscidae						
Ampelisca sp.	-	-	-	-	-	-
Family: Aoridae						
Aoridae (LPIL)	43	14	-	43	-	-
Bemlos/Plesiolembos group	-	-	-	-	-	-
Grandidierella sp.	-	43	-	-	-	-
Family: Atylidae						
Nototropis swammerdamei	-	-	-	-	-	-
Family: Bathyporeiidae						
Bathyporeia sp.	-	-	-	-	-	-

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Family: Caprellidae						
Pseudaeginella sp.	-	-	-	-	-	-
Family: Corophiidae						
Cheiriphotis sp	-	-	-	-	-	-
Family: Eriopisidae						
Eriopisella sp.	-	-	-	-	-	-
Family: Haustoriidae						
Haustoriidae (LPIL)	-	-	-	-	-	-
Family: Isaeidae						
Photis sp.	-	-	-	-	-	-
Family: Ischroceridae						
Ericthonius sp.	-	-	-	-	-	-
Family: Ischyroceridae						
Cerapus sp.	-	-	-	-	-	-
Family: Liljeborgiidae						
Idunella sp.	-	-	-	-	-	-
Liljeborgiidae (LPIL)	-	-	-	-	-	-
Family: Lysianassidae						
Pardia punctata	-	-	-	-	-	-
Family: Megaluropidae						
Megaluropidae (LPIL)	-	-	-	-	-	-
Family: Melitidae						
Maera sp.	-	-	-	-	-	-
Melitidae (LPIL)	-	-	-	-	-	-
Family: Oedicerotidae						
Oedicerotidae (LPIL)	-	-	-	-	-	-
Perioculodes sp.	-	-	-	-	-	-
Family: Phoxocephalidae						
Basuto stimpsoni	-	-	-	-	-	-
Family: Phtisicidae						
Phtisica marina	-	-	-	-	-	-
Family: Pontoporeiidae						
Pontoporeiidae (LPIL)	-	-	-	-	-	-
Family: Urothoidae						
Urothoe sp.	-	-	-	-	-	-
Family: Unspecified						
Amphipoda (LPIL)	-	-	-	-	-	-
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Corophiida LPIL	-	-	-	-	-	-
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Cyclaspis sp.	-	-	-	-	-	-
Family: Nannastacidae						
Cumella sp.	-	-	-	-	-	-

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Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							
Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Crangonidae							
Crangonidae (LPIL)		-	-	-	-	-	-
Family: Diogenidae							
Diogenes sp.		-	-	-	-	-	-
Diogenidae (LPIL)		-	-	-	-	-	-
Family: Majidae							
Majidae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguristes sp.		-	-	-	-	-	-
Family: Penaeidae							
Penaeus sp.		-	-	-	-	14	-
Family: Porcellanidae							
Porcellanidae (LPIL)		-	-	-	-	-	-
Family: Upogebiidae							
Upogebia sp.		-	-	-	-	-	-
Family: Unspecified							
Brachyura (LPIL)		-	-	-	-	-	-
Decapoda (LPIL) zoea larva		-	-	-	-	-	-
Decapoda (LPIL) megalopa larva		-	-	-	-	-	-
Decapoda (LPIL) mysis larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Family: Arcturidae							
Arcturidae (LPIL)		-	-	-	-	-	-
Order: Mysida							
Family: Mysidae							
Gastrosaccus sanctus		-	-	-	-	-	-
Mysidae (LPIL)		-	14	-	14	-	-
Rhopalophthalmus sp.		-	-	-	-	-	29
Order: Tanaidacea							
Family: Apseudidae							
Apseudidae (LPIL)		-	-	-	-	-	-
Family: Kalliapseudidae							
Kalliapseudes sp.		-	-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							

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Taxonomic Classification	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Metapseudidae (LPIL)	-	-	-	-	-	-
Tanaidacea (LPIL)	-	-	-	-	-	-
Class: Pycnogonida						
Order: Unspecified						
Family: Unspecified						
Pycnogonida (LPIL)	-	-	-	-	-	-
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Litiopidae						
Litiopidae (LPIL)	-	-	-	-	-	-
Order: Heterostropha						
Family: Pyramidellidae						
Pyramidellidae (LPIL)	-	-	-	-	-	-
Order: Neogastropoda						
Family: Marginellidae						
Glabella adansoni	-	-	-	-	-	-
Marginellidae (LPIL)	-	-	-	-	-	-
Prunum sp.	-	-	-	-	-	-
Family: Muricidae						
Muricidae (LPIL)	-	-	-	-	-	-
Family: Unspecified						
Neogastropoda (LPIL)	-	-	-	-	-	-
Order: Neotaenioglossa						
Family: Calyptraeidae						
Calyptraea sp.	-	-	-	-	-	-
Family: Cerithiidae						
Cerithium sp.	14	-	-	29	-	-
Order: Nudibranchia						
Family: Unspecified						
Nudibranchia (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)	-	-	-	-	-	-
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)	14	14	-	14	43	43
Order: Myoida						
Family: Myidae						
Sphenia sp.	-	-	-	-	-	-
Order: Mytiloida						
Family: Mytilidae						
Lioberus sp.	-	-	-	-	-	-
Musculus sp.	-	-	-	-	-	-
Order: Nuculoida						
Family: Nuculidae						

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Ostreidae							
Ostreidae (LPIL)		-	-	-	-	-	-
Order: Veneroida							
Family: Cardiidae							
Acanthocardia tuberculata		-	-	-	-	-	-
Cardiidae (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		14	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Family: Semelidae							
Semelidae (LPIL)		-	-	-	-	-	-
Family: Solecurtidae							
Solecurtidae (LPIL)		-	-	-	-	-	-
Family: Tellinidae							
Angulus sp.		-	-	-	-	14	-
Macoma sp.		-	-	-	-	-	14
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Ungulinidae							
Ungulinidae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiuridae (LPIL)		-	-	-	-	-	-
Family: Ophiactidae							
Ophiactis plana		-	-	-	-	-	-
Ophiactis sp.		-	-	-	-	-	-
Family: Ophiolepididae							
Ophiolepis paucispina		-	-	-	-	-	-
Order: Ophuridae							
Family: Ophionereididae							
Ophionereididae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Taxonomic Classification	Station	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/14/13	05/16/13	05/15/13	05/15/13	05/16/13	05/15/13
Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		374	158	29	201	632	1121
Number of Taxa		8	8	1	9	9	12

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Macroinvertebrate Results
Data Per Square Meter (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Phylum: Cnidaria						
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)	-	-	-	-	-	-
Phylum: Platyhelminthes						
Class: Turbellaria						
Order: Unspecified						
Family: Unspecified						
Turbellaria (LPIL)	-	-	-	-	-	14
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)	-	-	14	57	14	86
Phylum: Sipuncula						
Class: Phascolosomatidea						
Order: Aspidosiphonida						
Family: Aspidosiphonidae						
Aspidosiphonidae (LPIL)	-	-	-	-	-	-
Phylum: Annelida						
Class: Polychaeta						
Order: Capitellida						
Family: Capitellidae						
Capitella sp.	-	-	-	-	-	-
Capitellidae (LPIL)	-	-	-	-	-	-
Decamastus sp.	-	-	-	-	-	-
Heteromastus filiformis	-	-	14	14	-	57
Mediomastus sp.	-	-	-	-	-	-
Notomastus sp.	14	-	-	-	-	-
Family: Maldanidae						
Euclymene sp.	-	-	-	-	-	14
Maldanidae (LPIL)	-	-	-	-	-	14
Sabaco sp.	-	-	-	-	-	-
Order: Eunicida						
Family: Dorvilleidae						
Dorvilleidae (LPIL)	-	-	-	-	-	-
Protodorvillea sp.	-	-	-	-	-	14
Family: Lumbrineridae						
Augeneria sp.	-	-	-	-	-	29
Lumbrineris sp.	-	-	-	-	-	29
Family: Onuphidae						
Diopatra sp.	-	72	14	-	-	474
Onuphidae (LPIL)	-	14	-	-	-	14
Order: Opheliida						
Family: Opheliidae						
Armandia maculata	-	-	-	-	-	-

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Orbiniidae (LPIL)		-	-	-	-	-	14
Scoloplos sp.		-	-	-	-	-	72
Family: Paraonidae							
Aricidea catherinae		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	43
Aricidea sp.		-	-	-	-	-	29
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Cirrophorus sp.		-	-	-	-	-	-
Levinsenia sp.		-	-	-	-	-	-
Paradoneis sp.		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	14
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	43	-	43
Glyceridae (LPIL)		-	-	-	-	-	-
Family: Goniadidae							
Glycinde sp.		-	-	-	-	-	43
Goniada multidentata		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	43	-
Goniadides sp.		-	-	-	-	-	14
Family: Hesionidae							
Hesione sp.		-	-	-	14	-	-
Hesionidae (LPIL)		-	-	-	-	-	-
Heteropodarke sp.		-	-	-	-	-	-
Podarkeopsis sp.		-	-	-	-	-	43
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys sp.		29	-	489	-	-	-
Micronephtys stammeri		-	-	-	-	-	72
Family: Nereididae							
Namalycastis sp.		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Platynereis sp.		-	-	-	-	-	-
Family: Pilargidae							
Cabira sp.		-	-	-	-	-	-
Sigambra sp.		-	14	-	29	-	14
Family: Polynoidae							
Polynoidae (LPIL)		-	-	-	-	-	14
Family: Syllidae							
Eusyllis sp.		-	-	-	-	-	14
Plakosyllis sp.		-	-	-	-	-	-

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Syllidae (LPIL)	-	-	-	-	-	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.	-	-	-	14	-	57
Order: Spionida						
Family: Magelonidae						
Magelona sp.	-	-	-	-	-	-
Family: Spionidae						
Minuspio sp.	-	-	14	-	-	-
Polydora sp.	-	-	-	-	-	29
Scolelepis sp.	-	-	-	-	-	-
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	-	-	-	-	-	57
Family: Cirratulidae						
Cirratulidae (LPIL)	-	-	-	-	-	-
Cirriformia sp.	-	-	-	-	-	29
Monticellina sp.	-	-	-	-	-	43
Family: Pectinariidae						
Lagis sp.	-	-	-	-	-	158
Family: Terebellidae						
Eupolymnia sp.	-	-	-	-	-	-
Lanice conchilega	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	-	-	-	-	-	-
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)	-	-	72	-	-	-
Tubificoid Naididae imm. w/o hair setae (LPIL)	-	-	-	-	-	-
Tubificoides sp.	-	-	-	-	-	-
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.	-	-	-	-	-	-
Family: Ampeliscidae						
Ampelisca sp.	-	-	-	-	-	776
Family: Aoridae						
Aoridae (LPIL)	-	14	-	29	-	172
Bemlos/Plesiolembos group	-	-	-	-	-	14
Grandidierella sp.	-	-	-	-	-	-
Family: Atylidae						
Nototropis swammerdamei	-	-	-	-	-	-
Family: Bathyporeiidae						
Bathyporeia sp.	-	-	-	-	-	-

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Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Family: Caprellidae						
Pseudaeginella sp.	-	-	-	-	-	14
Family: Corophiidae						
Cheiriphotis sp	-	-	-	-	-	115
Family: Eriopisidae						
Eriopisella sp.	-	-	-	-	-	-
Family: Haustoriidae						
Haustoriidae (LPIL)	-	-	-	-	-	-
Family: Isaeidae						
Photis sp.	-	-	-	-	-	1236
Family: Ischroceridae						
Ericthonius sp.	-	-	-	-	-	187
Family: Ischyroceridae						
Cerapus sp.	-	-	-	-	-	-
Family: Liljeborgiidae						
Idunella sp.	-	-	-	-	29	-
Liljeborgiidae (LPIL)	-	-	-	-	-	14
Family: Lysianassidae						
Pardia punctata	-	-	-	-	-	-
Family: Megaluropidae						
Megaluropidae (LPIL)	-	-	-	-	-	-
Family: Melitidae						
Maera sp.	-	-	-	-	-	14
Melitidae (LPIL)	-	-	-	-	-	-
Family: Oedicerotidae						
Oedicerotidae (LPIL)	-	-	-	-	-	-
Perioculodes sp.	-	-	-	-	-	-
Family: Phoxocephalidae						
Basuto stimpsoni	-	-	-	-	14	-
Family: Phtisicidae						
Phtisica marina	-	-	-	-	-	14
Family: Pontoporeiidae						
Pontoporeiidae (LPIL)	-	-	-	-	-	-
Family: Urothoidae						
Urothoe sp.	-	-	-	-	-	-
Family: Unspecified						
Amphipoda (LPIL)	-	-	-	-	-	244
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Corophiida LPIL	-	-	-	-	-	259
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Cyclaspis sp.	-	-	-	-	-	29
Family: Nannastacidae						
Cumella sp.	-	-	-	-	-	-

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Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Family: Unspecified						
Cumacea (LPIL)	-	-	-	-	-	-
Order: Decapoda						
Family: Unspecified						
Decapoda (LPIL)	-	-	-	-	-	-
Family: Callianassidae						
Callianassidae (LPIL)	-	-	-	302	-	14
Family: Crangonidae						
Crangonidae (LPIL)	-	-	-	-	-	-
Family: Diogenidae						
Diogenes sp.	-	-	-	-	-	-
Diogenidae (LPIL)	-	-	-	-	-	43
Family: Majidae						
Majidae (LPIL)	-	-	-	-	-	14
Family: Paguridae						
Paguristes sp.	-	-	-	-	-	57
Family: Penaeidae						
Penaeus sp.	-	-	-	-	-	-
Family: Porcellanidae						
Porcellanidae (LPIL)	-	-	-	-	-	14
Family: Upogebiidae						
Upogebia sp.	-	43	-	-	-	-
Family: Unspecified						
Brachyura (LPIL)	-	-	-	-	-	29
Decapoda (LPIL) zoea larva	-	-	-	-	-	-
Decapoda (LPIL) megalopa larva	-	14	-	-	-	-
Decapoda (LPIL) mysis larva	-	-	14	-	14	14
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.	-	-	-	-	-	29
Anthuridae (LPIL)	-	-	-	-	-	-
Family: Arcturidae						
Arcturidae (LPIL)	-	-	-	-	-	57
Order: Mysida						
Family: Mysidae						
Gastrosaccus sanctus	-	-	-	-	-	-
Mysidae (LPIL)	-	-	14	-	-	14
Rhopalophthalmus sp.	-	-	-	-	-	-
Order: Tanaidacea						
Family: Apseudidae						
Apseudidae (LPIL)	-	-	-	-	-	-
Family: Kalliapseudidae						
Kalliapseudes sp.	-	-	-	-	-	29
Kalliapseudidae (LPIL)	-	-	-	-	-	14
Family: Metapseudidae						
Calozodion sp.	-	-	-	-	-	158
Family: Unspecified						

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Metapseudidae (LPIL)	-	-	-	-	-	14
Tanaidacea (LPIL)	-	-	-	-	-	-
Class: Pycnogonida						
Order: Unspecified						
Family: Unspecified						
Pycnogonida (LPIL)	-	-	-	-	-	-
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Litiopidae						
Litiopidae (LPIL)	-	-	-	-	-	-
Order: Heterostropha						
Family: Pyramidellidae						
Pyramidellidae (LPIL)	-	-	-	-	-	14
Order: Neogastropoda						
Family: Marginellidae						
Glabella adansoni	-	-	-	-	-	-
Marginellidae (LPIL)	-	-	-	-	-	-
Prunum sp.	-	-	-	-	-	-
Family: Muricidae						
Muricidae (LPIL)	-	-	-	-	-	57
Family: Unspecified						
Neogastropoda (LPIL)	-	-	-	-	-	14
Order: Neotaenioglossa						
Family: Calyptraeidae						
Calyptraea sp.	-	-	-	-	-	129
Family: Cerithiidae						
Cerithium sp.	-	-	-	-	-	-
Order: Nudibranchia						
Family: Unspecified						
Nudibranchia (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)	-	-	-	-	-	-
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)	14	-	-	-	-	101
Order: Myoida						
Family: Myidae						
Sphenia sp.	-	-	-	-	-	-
Order: Mytiloida						
Family: Mytilidae						
Lioberus sp.	-	-	-	-	-	-
Musculus sp.	-	-	-	-	-	-
Order: Nuculoida						
Family: Nuculidae						

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Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Nucula sp.	-	-	-	-	-	14
Order: Ostreoida						
Family: Ostreidae						
Ostreidae (LPIL)	-	-	-	-	-	-
Order: Veneroida						
Family: Cardiidae						
Acanthocardia tuberculata	-	-	-	-	-	-
Cardiidae (LPIL)	-	-	-	-	-	-
Family: Corbulidae						
Caryocorbula sp.	-	-	-	-	-	-
Corbula sp.	-	-	-	-	-	-
Family: Lucinidae						
Lucinidae (LPIL)	-	-	-	-	-	29
Family: Semelidae						
Semelidae (LPIL)	-	-	-	-	-	-
Family: Solecurtidae						
Solecurtidae (LPIL)	-	-	-	-	-	-
Family: Tellinidae						
Angulus sp.	-	-	-	-	-	-
Macoma sp.	-	43	86	-	-	72
Tellinidae (LPIL)	-	-	-	-	-	-
Family: Ungulinidae						
Ungulinidae (LPIL)	-	-	-	-	-	-
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)	-	-	-	57	-	-
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiuridae (LPIL)	-	-	-	-	14	172
Family: Ophiactidae						
Ophiactis plana	-	-	-	-	-	-
Ophiactis sp.	-	-	-	-	-	-
Family: Ophiolepididae						
Ophiolepis paucispina	-	-	-	-	-	14
Order: Ophuridae						
Family: Ophionereididae						
Ophionereididae (LPIL)	-	-	-	-	-	14
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)	-	-	-	-	-	101
Class: Echinoidea						
Order: Unspecified						
Family: Unspecified						

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Taxonomic Classification	Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13
Echinoidea (LPIL)		-	-	-	-	-	-
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Branchiostoma sp.		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	187
Total Organisms		57	216	733	560	129	6063
Number of Taxa		3	7	9	9	6	69

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Taxonomic Classification	Station	STN13BG	STN14BG	STN15BG	STN16BG	STN17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	05/20/13	05/22/13	05/23/13	05/23/13	05/24/13
Phylum: Cnidaria						
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)		-	-	244	-	-
Phylum: Platyhelminthes						
Class: Turbellaria						
Order: Unspecified						
Family: Unspecified						
Turbellaria (LPIL)		-	14	43	-	-
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)		-	29	-	14	29
Phylum: Sipuncula						
Class: Phascolosomatidea						
Order: Aspidosiphonida						
Family: Aspidosiphonidae						
Aspidosiphonidae (LPIL)		-	-	57	-	-
Phylum: Annelida						
Class: Polychaeta						
Order: Capitellida						
Family: Capitellidae						
Capitella sp.		14	-	-	-	-
Capitellidae (LPIL)		-	-	-	-	-
Decamastus sp.		-	-	-	-	-
Heteromastus filiformis		-	43	-	-	29
Mediomastus sp.		-	-	14	14	57
Notomastus sp.		-	-	-	-	-
Family: Maldanidae						
Euclymene sp.		-	-	-	-	-
Maldanidae (LPIL)		-	86	-	-	-
Sabaco sp.		-	14	-	-	-
Order: Eunicida						
Family: Dorvilleidae						
Dorvilleidae (LPIL)		-	-	-	14	-
Protodorvillea sp.		-	-	-	-	-
Family: Lumbrineridae						
Augeneria sp.		-	-	-	-	-
Lumbrineris sp.		-	86	-	-	14
Family: Onuphidae						
Diopatra sp.		-	72	-	-	14
Onuphidae (LPIL)		-	-	-	-	-
Order: Opheliida						
Family: Opheliidae						
Armandia maculata		101	-	-	-	-

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Macroinvertebrate Results
Data Per Square Meter (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13
Armandia sp.		-	-	-	101	144
Order: Orbiniida						
Family: Orbiniidae						
Orbiniidae (LPIL)		-	-	-	-	-
Scoloplos sp.		-	72	-	14	86
Family: Paraonidae						
Aricidea catherinae		-	14	-	-	-
Aricidea fragilis		-	86	-	-	-
Aricidea sp.		-	-	-	-	-
Aricidea wassi		-	-	-	-	14
Cirrophorus branchiatus		-	14	-	-	-
Cirrophorus sp.		-	-	-	14	-
Levinsenia sp.		-	-	-	-	14
Paradoneis sp.		-	-	-	-	29
Paraonidae (LPIL)		-	-	-	14	-
Order: Phyllodocida						
Family: Glyceridae						
Glycera africana		14	14	-	-	-
Glycera alba		-	29	29	-	-
Glycera sp.		-	-	14	14	-
Glyceridae (LPIL)		-	-	14	-	-
Family: Goniadidae						
Glycinde sp.		-	-	-	-	-
Goniada multidentata		-	-	-	-	14
Goniadidae (LPIL)		-	43	-	-	-
Goniadides sp.		-	-	-	-	-
Family: Hesionidae						
Hesione sp.		-	-	-	-	-
Hesionidae (LPIL)		-	-	14	-	-
Heteropodarke sp.		-	-	-	29	14
Podarkeopsis sp.		-	14	-	-	-
Family: Nephtyidae						
Aglaophamus sp.		-	-	-	-	-
Micronephtys sp.		-	-	-	-	-
Micronephtys stammeri		-	29	-	-	-
Family: Nereididae						
Namalycastis sp.		-	-	-	-	-
Nereis sp.		-	-	-	-	-
Platynereis sp.		-	-	-	-	-
Family: Pilargidae						
Cabira sp.		-	-	-	-	14
Sigambra sp.		-	-	-	-	-
Family: Polynoidae						
Polynoidae (LPIL)		-	-	-	-	14
Family: Syllidae						
Eusyllis sp.		-	-	14	-	-
Plakosyllis sp.		-	-	-	14	-

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Syllidae (LPIL)		-	57	-	-	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia sp.		-	14	14	-	-
Order: Spionida						
Family: Magelonidae						
Magelona sp.		86	-	-	-	43
Family: Spionidae						
Minuspio sp.		-	14	-	-	14
Polydora sp.		-	101	-	-	-
Scolelepis sp.		-	14	-	-	-
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.		-	-	-	-	-
Family: Cirratulidae						
Cirratulidae (LPIL)		-	14	-	-	-
Cirriformia sp.		-	-	-	-	-
Monticellina sp.		-	29	-	-	-
Family: Pectinariidae						
Lagis sp.		-	201	-	-	-
Family: Terebellidae						
Eupolymnia sp.		-	14	-	-	-
Lanice conchilega		-	14	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)		-	-	-	14	-
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Tubificoid Naididae (LPIL)		14	-	-	-	72
Tubificoid Naididae imm. w/o hair setae (LPIL)		-	-	-	-	14
Tubificoides sp.		-	-	-	-	-
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Hyperia sp.		14	-	-	-	-
Family: Ampeliscidae						
Ampelisca sp.		-	417	29	-	-
Family: Aoridae						
Aoridae (LPIL)		-	29	72	-	-
Bemlos/Plesiolembos group		-	-	-	-	-
Grandidierella sp.		-	-	-	-	-
Family: Atylidae						
Nototropis swammerdamei		-	-	-	-	29
Family: Bathyporeiidae						
Bathyporeia sp.		14	-	-	-	-

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Family: Caprellidae						
Pseudaeginella sp.		-	-	-	-	-
Family: Corophiidae						
Cheiriphotis sp		-	-	-	-	-
Family: Eriopisidae						
Eriopisella sp.		-	172	-	-	-
Family: Haustoriidae						
Haustoriidae (LPIL)		-	-	187	86	-
Family: Isaeidae						
Photis sp.		-	546	-	-	-
Family: Ischroceridae						
Ericthonius sp.		-	-	-	-	29
Family: Ischyroceridae						
Cerapus sp.		-	29	-	-	-
Family: Liljeborgiidae						
Idunella sp.		-	72	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-
Family: Lysianassidae						
Pardia punctata		-	43	-	-	-
Family: Megaluropidae						
Megaluropidae (LPIL)		-	-	29	-	-
Family: Melitidae						
Maera sp.		-	-	-	-	-
Melitidae (LPIL)		-	201	-	-	-
Family: Oedicerotidae						
Oedicerotidae (LPIL)		29	-	-	-	14
Perioculodes sp.		14	-	-	-	-
Family: Phoxocephalidae						
Basuto stimpsoni		-	-	-	-	-
Family: Phtisicidae						
Phtisica marina		-	-	-	-	-
Family: Pontoporeiidae						
Pontoporeiidae (LPIL)		29	-	-	-	-
Family: Urothoidae						
Urothoe sp.		-	-	14	-	-
Family: Unspecified						
Amphipoda (LPIL)		-	259	14	-	29
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Corophiida LPIL		-	-	-	-	-
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Cyclaspis sp.		57	72	-	-	72
Family: Nannastacidae						
Cumella sp.		-	-	-	-	43

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	STN13BG	STN14BG	STN15BG	STN16BG	STN17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	05/20/13	05/22/13	05/23/13	05/23/13	05/24/13
Family: Unspecified						
Cumacea (LPIL)		14	29	-	-	14
Order: Decapoda						
Family: Unspecified						
Decapoda (LPIL)		-	-	-	29	-
Family: Callianassidae						
Callianassidae (LPIL)		-	144	-	-	-
Family: Crangonidae						
Crangonidae (LPIL)		14	-	-	-	-
Family: Diogenidae						
Diogenes sp.		-	57	-	-	-
Diogenidae (LPIL)		-	-	-	-	-
Family: Majidae						
Majidae (LPIL)		-	-	-	-	-
Family: Paguridae						
Paguristes sp.		-	-	-	-	-
Family: Penaeidae						
Penaeus sp.		-	-	-	-	-
Family: Porcellanidae						
Porcellanidae (LPIL)		-	-	43	14	14
Family: Upogebiidae						
Upogebia sp.		-	-	-	-	-
Family: Unspecified						
Brachyura (LPIL)		-	14	-	-	-
Decapoda (LPIL) zoea larva		-	-	14	14	57
Decapoda (LPIL) megalopa larva		-	-	14	-	-
Decapoda (LPIL) mysis larva		-	43	-	-	-
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.		-	-	-	-	-
Anthuridae (LPIL)		-	57	14	14	-
Family: Arcturidae						
Arcturidae (LPIL)		-	-	-	-	-
Order: Mysida						
Family: Mysidae						
Gastrosaccus sanctus		-	-	-	-	14
Mysidae (LPIL)		14	-	-	-	-
Rhopalophthalmus sp.		-	14	-	-	-
Order: Tanaidacea						
Family: Apseudidae						
Apseudidae (LPIL)		-	-	-	-	29
Family: Kalliapseudidae						
Kalliapseudes sp.		-	-	-	-	-
Kalliapseudidae (LPIL)		-	-	-	-	-
Family: Metapseudidae						
Calozodion sp.		-	115	-	-	-
Family: Unspecified						

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	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	05/20/13	05/22/13	05/23/13	05/23/13	05/24/13
Metapseudidae (LPIL)		-	-	-	-	-
Tanaidacea (LPIL)		-	72	-	-	-
Class: Pycnogonida						
Order: Unspecified						
Family: Unspecified						
Pycnogonida (LPIL)		-	-	-	14	-
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Litiopidae						
Litiopidae (LPIL)		-	14	-	-	-
Order: Heterostropha						
Family: Pyramidellidae						
Pyramidellidae (LPIL)		-	-	-	-	-
Order: Neogastropoda						
Family: Marginellidae						
Glabella adansoni		-	-	-	-	14
Marginellidae (LPIL)		-	-	-	-	14
Prunum sp.		-	14	-	-	-
Family: Muricidae						
Muricidae (LPIL)		-	-	-	-	-
Family: Unspecified						
Neogastropoda (LPIL)		-	-	-	-	-
Order: Neotaenioglossa						
Family: Calyptraeidae						
Calyptraea sp.		-	14	172	-	-
Family: Cerithiidae						
Cerithium sp.		-	-	-	-	-
Order: Nudibranchia						
Family: Unspecified						
Nudibranchia (LPIL)		-	-	14	-	-
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)		14	14	-	-	-
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)		-	72	29	14	43
Order: Myoida						
Family: Myidae						
Sphenia sp.		-	-	14	-	-
Order: Mytiloida						
Family: Mytilidae						
Lioberus sp.		-	14	-	-	-
Musculus sp.		-	-	14	-	-
Order: Nuculoida						
Family: Nuculidae						

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Nucula sp.		-	-	-	-	-
Order: Ostreoida						
Family: Ostreidae						
Ostreidae (LPIL)		-	57	-	14	-
Order: Veneroida						
Family: Cardiidae						
Acanthocardia tuberculata		-	259	-	-	-
Cardiidae (LPIL)		-	-	-	-	29
Family: Corbulidae						
Caryocorbula sp.		-	-	72	29	-
Corbula sp.		-	14	-	-	-
Family: Lucinidae						
Lucinidae (LPIL)		-	115	-	-	-
Family: Semelidae						
Semelidae (LPIL)		-	29	-	-	-
Family: Solecurtidae						
Solecurtidae (LPIL)		-	14	-	-	-
Family: Tellinidae						
Angulus sp.		-	-	-	-	-
Macoma sp.		-	14	-	-	-
Tellinidae (LPIL)		-	29	-	-	-
Family: Ungulinidae						
Ungulinidae (LPIL)		-	115	-	-	-
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)		-	14	-	-	-
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiuridae (LPIL)		-	330	14	-	158
Family: Ophiactidae						
Ophiactis plana		-	-	115	-	-
Ophiactis sp.		-	-	158	-	-
Family: Ophiolepididae						
Ophiolepis paucispina		-	-	-	-	-
Order: Ophuridae						
Family: Ophionereididae						
Ophionereididae (LPIL)		-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)		14	129	-	-	57
Class: Echinoidea						
Order: Unspecified						
Family: Unspecified						

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Echinoidea (LPIL)		-	-	14	-	-
Phylum: Chordata						
Class: Cephalochordata						
Order: Amphioxiformes						
Family: Branchiostomatidae						
Branchiostoma sp.		-	-	-	-	14
Phylum: Chaetognatha						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Chaetognatha (LPIL)		-	-	-	14	14
Phylum: Brachiopoda						
Class: Lingulata						
Order: Lingulida						
Family: Lingulidae						
Lingula sp.		-	-	-	-	-
Total Organisms		460	4784	1509	503	1322
Number of Taxa		16	63	30	21	37

Macroinvertebrate Results
Summary Table (Pooled)

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Phylum: Cnidaria								
Class: Anthozoa								
Order: Actiniaria								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Phylum: Platyhelminthes								
Class: Turbellaria								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	4
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Nemertea								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%
Phylum: Sipuncula								
Class: Phascolosomatidea								
Order: Aspidosiphonida								
Family: Aspidosiphonidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Annelida								
Class: Polychaeta								
Order: Capitellida								
Family: Capitellidae								
Number of Taxa		2	1	0	0	3	4	1
Number of Organisms per M^2		29	14	0	0	287	503	65
% Organisms (Sample Group)		2.6%	1.3%	0.0%	0.0%	26%	45.5%	N/A
% Organisms (This Station)		7.7%	9.1%	0.0%	0.0%	45.5%	44.9%	8.9%
Family: Maldanidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Eunicida								
Family: Dorvilleidae								

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Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Lumbrineridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	9
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Onuphidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	40
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%
Order: Opheliida								
Family: Opheliidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	20
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%
Order: Orbiniida								
Family: Orbiniidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	15
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Family: Paraonidae								
Number of Taxa		0	0	0	0	0	0	1
Number of Organisms per M^2		0	0	0	0	0	0	17
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
Order: Phyllodocida								
Family: Glyceridae								
Number of Taxa		0	0	0	0	0	0	1
Number of Organisms per M^2		0	0	0	0	0	0	13
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
Family: Goniadidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	9
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%
Family: Hesionidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%

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Macroinvertebrate Results
Summary Table (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
Family: Nephtyidae								
Number of Taxa		0	1	0	0	1	1	0
Number of Organisms per M^2		0	14	0	0	43	57	43
% Organisms (Sample Group)		0.0%	2%	0.0%	0.0%	5.9%	7.8%	N/A
% Organisms (This Station)		0.0%	9.1%	0.0%	0.0%	6.8%	5.1%	8.2%
Family: Nereididae								
Number of Taxa		0	1	0	3	0	1	0
Number of Organisms per M^2		0	14	0	43	0	14	4
% Organisms (Sample Group)		0.0%	20%	0.0%	60%	0.0%	20%	N/A
% Organisms (This Station)		0.0%	9.1%	0.0%	21.4%	0.0%	1.3%	1.9%
Family: Pilargidae								
Number of Taxa		1	0	0	1	1	1	0
Number of Organisms per M^2		14	0	0	14	29	14	8
% Organisms (Sample Group)		10%	0.0%	0.0%	10%	20%	10%	N/A
% Organisms (This Station)		3.8%	0.0%	0.0%	7.1%	4.5%	1.3%	1.8%
Family: Polynoidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Syllidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Sabellida								
Family: Oweniidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Spionida								
Family: Magelonidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
Family: Spionidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	11
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Order: Terebellida								
Family: Ampharetidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Cirratulidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Pectinariidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	21
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Terebellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Class: Clitellata							
Order: Haplotaxida							
Family: Tubificoid Naididae							
Number of Taxa	1	1	1	1	1	2	1
Number of Organisms per M^2	244	29	29	43	201	445	68
% Organisms (Sample Group)	21%	2.5%	2.5%	3.7%	17.3%	38.3%	N/A
% Organisms (This Station)	65.4%	18.2%	100%	21.4%	31.8%	39.7%	17.4%
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Hyperiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Ampeliscidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	72
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
Family: Aoridae							
Number of Taxa	1	2	0	1	0	0	1
Number of Organisms per M^2	43	57	0	43	0	0	28
% Organisms (Sample Group)	9.1%	12.1%	0.0%	9.1%	0.0%	0.0%	N/A
% Organisms (This Station)	11.5%	36.4%	0.0%	21.4%	0.0%	0.0%	5.3%

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
Family: Atylidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Bathyporeiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Caprellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Corophiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Eriopisidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	10
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Haustoriidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%
Family: Isaeidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	105
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%
Family: Ischroceridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	13
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Family: Ischyroceridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Liljeborgiidae							
Number of Taxa	0	0	0	0	0	0	0

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
Family: Lysianassidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Megaluropidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Melitidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	13
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Family: Oedicerotidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
Family: Phoxocephalidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Family: Phtisicidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Pontoporeiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Urothoidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	32
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	14
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
Family: Nannastacidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Decapoda							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	1
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%
Family: Callianassidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	27
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.4%
Family: Crangonidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Diogenidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	6
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Majidae							

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Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Paguridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Penaeidae							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	14	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.3%	0.0%	0.1%
Family: Porcellanidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Upogebiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	1
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%
Order: Isopoda							
Family: Anthuridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Family: Arcturidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Mysida							
Family: Mysidae							
Number of Taxa	0	1	0	1	0	1	0
Number of Organisms per M^2	0	14	0	14	0	29	8
% Organisms (Sample Group)	0.0%	11.1%	0.0%	11.1%	0.0%	22.2%	N/A
% Organisms (This Station)	0.0%	9.1%	0.0%	7.1%	0.0%	2.6%	1.5%
Order: Tanaidacea							

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
Family: Apseudidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Kalliapseudidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Metapseudidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Heterostropha							
Family: Pyramidellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Neogastropoda							
Family: Marginellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
Family: Muricidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Neotaenioglossa								
Family: Calyptraeidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	19
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
Family: Cerithiidae								
Number of Taxa		1	0	0	1	0	0	0
Number of Organisms per M^2		14	0	0	29	0	0	3
% Organisms (Sample Group)		33.3%	0.0%	0.0%	66.7%	0.0%	0.0%	N/A
% Organisms (This Station)		3.8%	0.0%	0.0%	14.3%	0.0%	0.0%	1.1%
Order: Nudibranchia								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Class: Bivalvia								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		1	1	0	1	1	1	1
Number of Organisms per M^2		14	14	0	14	43	43	24
% Organisms (Sample Group)		3.6%	3.6%	0.0%	3.6%	10.7%	10.7%	N/A
% Organisms (This Station)		3.8%	9.1%	0.0%	7.1%	6.8%	3.8%	3.9%
Order: Myoida								
Family: Myidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Mytiloida								

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Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
Family: Mytilidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Nuculoida							
Family: Nuculidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Ostreoida							
Family: Ostreidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	4
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Veneroida							
Family: Cardiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	17
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Corbulidae							
Number of Taxa	1	0	0	0	0	0	0
Number of Organisms per M^2	14	0	0	0	0	0	8
% Organisms (Sample Group)	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Family: Lucinidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	8
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Semelidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Solecurtidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Tellinidae							
Number of Taxa	0	0	0	0	1	1	0
Number of Organisms per M^2	0	0	0	0	14	14	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	5.3%	5.3%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN1BG 3 05/14/13	STN2BG 3 05/16/13	STN3BG 3 05/15/13	STN4BG 3 05/15/13	SNT5BG 3 05/16/13	STN6BG 3 05/15/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.3%	1.3%	2.2%
Family: Ungulinidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	4
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	41
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%
Family: Ophiactidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
Family: Ophiolepididae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Ophuridae							
Family: Ophionereididae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	18
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Chordata								
Class: Cephalochordata								
Order: Amphioxiformes								
Family: Branchiostomatidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Chaetognatha								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Brachiopoda								
Class: Lingulata								
Order: Lingulida								
Family: Lingulidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	11
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Total Taxa		8	8	1	9	9	12	19
Total Organisms per M^2		374	158	29	201	632	1121	1109
% Organisms (Sample Group)		2%	0.8%	0.2%	1.1%	3.4%	5.9%	N/A

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Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Phylum: Cnidaria								
Class: Anthozoa								
Order: Actiniaria								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Phylum: Platyhelminthes								
Class: Turbellaria								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	4
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	20%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%
Phylum: Nemertea								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	1	1	1	1	0
Number of Organisms per M^2		0	0	14	57	14	86	14
% Organisms (Sample Group)		0.0%	0.0%	5.9%	23.5%	5.9%	35.3%	N/A
% Organisms (This Station)		0.0%	0.0%	2%	10.3%	11.1%	1.4%	1.8%
Phylum: Sipuncula								
Class: Phascolosomatidea								
Order: Aspidosiphonida								
Family: Aspidosiphonidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Annelida								
Class: Polychaeta								
Order: Capitellida								
Family: Capitellidae								
Number of Taxa		1	0	1	1	0	1	1
Number of Organisms per M^2		14	0	14	14	0	57	65
% Organisms (Sample Group)		1.3%	0.0%	1.3%	1.3%	0.0%	5.2%	N/A
% Organisms (This Station)		25%	0.0%	2%	2.6%	0.0%	0.9%	8.9%
Family: Maldanidae								
Number of Taxa		0	0	0	0	0	2	0
Number of Organisms per M^2		0	0	0	0	0	29	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	22.2%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.2%
Order: Eunicida								
Family: Dorvilleidae								

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Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%
Family: Lumbrineridae							
Number of Taxa	0	0	0	0	0	2	0
Number of Organisms per M^2	0	0	0	0	0	57	9
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	36.4%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.2%
Family: Onuphidae							
Number of Taxa	0	2	1	0	0	2	0
Number of Organisms per M^2	0	86	14	0	0	489	40
% Organisms (Sample Group)	0.0%	12.8%	2.1%	0.0%	0.0%	72.3%	N/A
% Organisms (This Station)	0.0%	40%	2%	0.0%	0.0%	8.1%	3.1%
Order: Opheliida							
Family: Opheliidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	20
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%
Order: Orbiniida							
Family: Orbiniidae							
Number of Taxa	0	0	0	0	0	2	0
Number of Organisms per M^2	0	0	0	0	0	86	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.7%
Family: Paraonidae							
Number of Taxa	0	0	0	0	0	3	1
Number of Organisms per M^2	0	0	0	0	0	86	17
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	30%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.8%
Order: Phyllodocida							
Family: Glyceridae							
Number of Taxa	0	0	0	1	0	1	1
Number of Organisms per M^2	0	0	0	43	0	43	13
% Organisms (Sample Group)	0.0%	0.0%	0.0%	20%	0.0%	20%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	7.7%	0.0%	0.7%	1.1%
Family: Goniadidae							
Number of Taxa	0	0	0	0	1	2	0
Number of Organisms per M^2	0	0	0	0	43	57	9
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	27.3%	36.4%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	33.3%	0.9%	2.1%
Family: Hesionidae							
Number of Taxa	0	0	0	1	0	1	0
Number of Organisms per M^2	0	0	0	14	0	43	8
% Organisms (Sample Group)	0.0%	0.0%	0.0%	11.1%	0.0%	33.3%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2.6%	0.0%	0.7%	0.7%

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Family: Nephtyidae								
Number of Taxa		1	0	1	0	0	1	0
Number of Organisms per M^2		29	0	489	0	0	72	43
% Organisms (Sample Group)		3.9%	0.0%	66.7%	0.0%	0.0%	9.8%	N/A
% Organisms (This Station)		50%	0.0%	66.7%	0.0%	0.0%	1.2%	8.2%
Family: Nereididae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	4
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%
Family: Pilargidae								
Number of Taxa		0	1	0	1	0	1	0
Number of Organisms per M^2		0	14	0	29	0	14	8
% Organisms (Sample Group)		0.0%	10%	0.0%	20%	0.0%	10%	N/A
% Organisms (This Station)		0.0%	6.7%	0.0%	5.1%	0.0%	0.2%	1.8%
Family: Polynoidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%
Family: Syllidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	14.3%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%
Order: Sabellida								
Family: Oweniidae								
Number of Taxa		0	0	0	1	0	1	0
Number of Organisms per M^2		0	0	0	14	0	57	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	14.3%	0.0%	57.1%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2.6%	0.0%	0.9%	0.3%
Order: Spionida								
Family: Magelonidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
Family: Spionidae								
Number of Taxa		0	0	1	0	0	1	0
Number of Organisms per M^2		0	0	14	0	0	29	11
% Organisms (Sample Group)		0.0%	0.0%	7.7%	0.0%	0.0%	15.4%	N/A
% Organisms (This Station)		0.0%	0.0%	2%	0.0%	0.0%	0.5%	0.4%
Order: Terebellida								
Family: Ampharetidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	57	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A

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% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%
Family: Cirratulidae								
Number of Taxa		0	0	0	0	0	2	0
Number of Organisms per M^2		0	0	0	0	0	72	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	62.5%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.1%
Family: Pectinariidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	158	21
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	44%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	0.4%
Family: Terebellidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Class: Clitellata								
Order: Haplotaxida								
Family: Tubificoid Naididae								
Number of Taxa		0	0	1	0	0	0	1
Number of Organisms per M^2		0	0	72	0	0	0	68
% Organisms (Sample Group)		0.0%	0.0%	6.2%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	9.8%	0.0%	0.0%	0.0%	17.4%
Phylum: Arthropoda								
Class: Malacostraca								
Order: Amphipoda								
Family: Hyperiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Ampeliscidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	776	72
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	63.5%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	12.8%	1.4%
Family: Aoridae								
Number of Taxa		0	1	0	1	0	2	1
Number of Organisms per M^2		0	14	0	29	0	187	28
% Organisms (Sample Group)		0.0%	3%	0.0%	6.1%	0.0%	39.4%	N/A
% Organisms (This Station)		0.0%	6.7%	0.0%	5.1%	0.0%	3.1%	5.3%

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Sample Method: Petite Ponar
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Family: Atylidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Bathyporeiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Caprellidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Family: Corophiidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	115	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.1%
Family: Eriopisidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	10
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Haustoriidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	16
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%
Family: Isaeidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	1236	105
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	69.4%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	20.4%	1.9%
Family: Ischroceridae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	187	13
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	86.7%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	0.3%
Family: Ischyroceridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Liljeborgiidae								
Number of Taxa		0	0	0	0	1	1	0

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Number of Organisms per M^2		0	0	0	0	29	14	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	25%	12.5%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	22.2%	0.2%	1.4%
Family: Lysianassidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Megaluropidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Melitidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	13
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	6.7%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%
Family: Oedicerotidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
Family: Phoxocephalidae								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	14	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	11.1%	0.0%	0.7%
Family: Phtisicidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Family: Pontoporeiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Urothoidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	244	32
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	44.7%	N/A

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% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	4%	0.7%
Class: Malacostraca							
Order: Amphipoda							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	259	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%	0.3%
Class: Malacostraca							
Order: Cumacea							
Family: Bodotriidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	29	14
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	1.2%
Family: Nannastacidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Decapoda							
Family: Unspecified							
Number of Taxa	0	1	1	0	1	2	1
Number of Organisms per M^2	0	14	14	0	14	43	16
% Organisms (Sample Group)	0.0%	5.3%	5.3%	0.0%	5.3%	15.8%	N/A
% Organisms (This Station)	0.0%	6.7%	2%	0.0%	11.1%	0.7%	2.1%
Family: Callianassidae							
Number of Taxa	0	0	0	1	0	1	0
Number of Organisms per M^2	0	0	0	302	0	14	27
% Organisms (Sample Group)	0.0%	0.0%	0.0%	65.6%	0.0%	3.1%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	53.8%	0.0%	0.2%	3.4%
Family: Crangonidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Diogenidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	43	6
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	42.9%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.1%
Family: Majidae							

Macroinvertebrate Results
Summary Table (Pooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Family: Paguridae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	57	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%
Family: Penaeidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Porcellanidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%
Family: Upogebiidae								
Number of Taxa		0	1	0	0	0	0	0
Number of Organisms per M^2		0	43	0	0	0	0	3
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	20%	0.0%	0.0%	0.0%	0.0%	1.2%
Family: Unspecified								
Number of Taxa		0	1	1	0	1	2	1
Number of Organisms per M^2		0	14	14	0	14	43	16
% Organisms (Sample Group)		0.0%	5.3%	5.3%	0.0%	5.3%	15.8%	N/A
% Organisms (This Station)		0.0%	6.7%	2%	0.0%	11.1%	0.7%	2.1%
Order: Isopoda								
Family: Anthuridae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	29	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	25%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.3%
Family: Arcturidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	57	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%
Order: Mysida								
Family: Mysidae								
Number of Taxa		0	0	1	0	0	1	0
Number of Organisms per M^2		0	0	14	0	0	14	8
% Organisms (Sample Group)		0.0%	0.0%	11.1%	0.0%	0.0%	11.1%	N/A
% Organisms (This Station)		0.0%	0.0%	2%	0.0%	0.0%	0.2%	1.5%
Order: Tanaidacea								

Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG	Mean Values
Station	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG	
# of Replicates Pooled	3	3	3	3	3	3	
Collection Date	05/17/13	05/18/13	05/25/13	05/25/13	05/19/13	05/20/13	
Family: Apseudidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Kalliapseudidae							
Number of Taxa	0	0	0	0	0	2	0
Number of Organisms per M^2	0	0	0	0	0	43	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%
Family: Metapseudidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	158	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	57.9%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	0.3%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%
Class: Pycnogonida							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Litiopidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Heterostropha							
Family: Pyramidellidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Order: Neogastropoda							
Family: Marginellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%

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Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Family: Muricidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	57	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Order: Neotaenioglossa								
Family: Calyptraeidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	129	19
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	40.9%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.8%
Family: Cerithiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
Order: Nudibranchia								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Class: Bivalvia								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		1	0	0	0	0	1	1
Number of Organisms per M^2		14	0	0	0	0	101	24
% Organisms (Sample Group)		3.6%	0.0%	0.0%	0.0%	0.0%	25%	N/A
% Organisms (This Station)		25%	0.0%	0.0%	0.0%	0.0%	1.7%	3.9%
Order: Myoida								
Family: Myidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Mytiloida								

Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Family: Mytilidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Nuculoida								
Family: Nuculidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Order: Ostreoida								
Family: Ostreidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	4
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Veneroida								
Family: Cardiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	17
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Corbulidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Family: Lucinidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	29	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	20%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.2%
Family: Semelidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Solecurtidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Tellinidae								
Number of Taxa		0	1	1	0	0	1	0
Number of Organisms per M^2		0	43	86	0	0	72	16
% Organisms (Sample Group)		0.0%	15.8%	31.6%	0.0%	0.0%	26.3%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

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Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
% Organisms (This Station)	0.0%	20%	11.8%	0.0%	0.0%	1.2%	2.2%
Family: Ungulinidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	1	0	0	0
Number of Organisms per M^2	0	0	0	57	0	0	4
% Organisms (Sample Group)	0.0%	0.0%	0.0%	80%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	10.3%	0.0%	0.0%	0.6%
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Number of Taxa	0	0	0	0	1	1	0
Number of Organisms per M^2	0	0	0	0	14	172	41
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	2.1%	25%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	11.1%	2.8%	2.0%
Family: Ophiactidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
Family: Ophiolepididae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Order: Ophuridae							
Family: Ophionereididae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	101	18
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.7%
Class: Echinoidea							
Order: Unspecified							
Family: Unspecified							

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN7BG 3 05/17/13	STN8BG 3 05/18/13	STN9BG 3 05/25/13	STN10BG 3 05/25/13	STN11BG 3 05/19/13	STN12BG 3 05/20/13	Mean Values
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Chordata								
Class: Cephalochordata								
Order: Amphioxiformes								
Family: Branchiostomatidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Chaetognatha								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Brachiopoda								
Class: Lingulata								
Order: Lingulida								
Family: Lingulidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	187	11
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	0.2%
Total Taxa		3	7	9	9	6	69	19
Total Organisms per M^2		57	216	733	560	129	6063	1109
% Organisms (Sample Group)		0.3%	1.1%	3.9%	3%	0.7%	32.2%	N/A

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Macroinvertebrate Results
Summary Table (Pooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13	Mean Values
Phylum: Cnidaria							
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	244	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	16.2%	0.0%	0.0%	1.0%
Phylum: Platyhelminthes							
Class: Turbellaria							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	1	0	0	0
Number of Organisms per M^2		0	14	43	0	0	4
% Organisms (Sample Group)		0.0%	20%	60%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.3%	2.9%	0.0%	0.0%	0.2%
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	0	1	1	0
Number of Organisms per M^2		0	29	0	14	29	14
% Organisms (Sample Group)		0.0%	11.8%	0.0%	5.9%	11.8%	N/A
% Organisms (This Station)		0.0%	0.6%	0.0%	2.9%	2.2%	1.8%
Phylum: Sipuncula							
Class: Phascolosomatidea							
Order: Aspidosiphonida							
Family: Aspidosiphonidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	57	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	3.8%	0.0%	0.0%	0.2%
Phylum: Annelida							
Class: Polychaeta							
Order: Capitellida							
Family: Capitellidae							
Number of Taxa		1	1	1	1	2	1
Number of Organisms per M^2		14	43	14	14	86	65
% Organisms (Sample Group)		1.3%	3.9%	1.3%	1.3%	7.8%	N/A
% Organisms (This Station)		3.1%	0.9%	1%	2.9%	6.5%	8.9%
Family: Maldanidae							
Number of Taxa		0	2	0	0	0	0
Number of Organisms per M^2		0	101	0	0	0	8
% Organisms (Sample Group)		0.0%	77.8%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	2.1%	0.0%	0.0%	0.0%	0.2%
Order: Eunicida							
Family: Dorvilleidae							

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13	Mean Values
Number of Taxa	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	14	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	50%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2.9%	0.0%	0.2%
Family: Lumbrineridae						
Number of Taxa	0	1	0	0	1	0
Number of Organisms per M^2	0	86	0	0	14	9
% Organisms (Sample Group)	0.0%	54.5%	0.0%	0.0%	9.1%	N/A
% Organisms (This Station)	0.0%	1.8%	0.0%	0.0%	1.1%	0.2%
Family: Onuphidae						
Number of Taxa	0	1	0	0	1	0
Number of Organisms per M^2	0	72	0	0	14	40
% Organisms (Sample Group)	0.0%	10.6%	0.0%	0.0%	2.1%	N/A
% Organisms (This Station)	0.0%	1.5%	0.0%	0.0%	1.1%	3.1%
Order: Opheliida						
Family: Opheliidae						
Number of Taxa	1	0	0	1	1	0
Number of Organisms per M^2	101	0	0	101	144	20
% Organisms (Sample Group)	29.2%	0.0%	0.0%	29.2%	41.7%	N/A
% Organisms (This Station)	21.9%	0.0%	0.0%	20%	10.9%	3.1%
Order: Orbiniida						
Family: Orbiniidae						
Number of Taxa	0	1	0	1	1	0
Number of Organisms per M^2	0	72	0	14	86	15
% Organisms (Sample Group)	0.0%	27.8%	0.0%	5.6%	33.3%	N/A
% Organisms (This Station)	0.0%	1.5%	0.0%	2.9%	6.5%	0.7%
Family: Paraonidae						
Number of Taxa	0	3	0	2	3	1
Number of Organisms per M^2	0	115	0	29	57	17
% Organisms (Sample Group)	0.0%	40%	0.0%	10%	20%	N/A
% Organisms (This Station)	0.0%	2.4%	0.0%	5.7%	4.3%	0.8%
Order: Phyllodocida						
Family: Glyceridae						
Number of Taxa	1	2	3	1	0	1
Number of Organisms per M^2	14	43	57	14	0	13
% Organisms (Sample Group)	6.7%	20%	26.7%	6.7%	0.0%	N/A
% Organisms (This Station)	3.1%	0.9%	3.8%	2.9%	0.0%	1.1%
Family: Goniadidae						
Number of Taxa	0	1	0	0	1	0
Number of Organisms per M^2	0	43	0	0	14	9
% Organisms (Sample Group)	0.0%	27.3%	0.0%	0.0%	9.1%	N/A
% Organisms (This Station)	0.0%	0.9%	0.0%	0.0%	1.1%	2.1%
Family: Hesionidae						
Number of Taxa	0	1	1	1	1	0
Number of Organisms per M^2	0	14	14	29	14	8
% Organisms (Sample Group)	0.0%	11.1%	11.1%	22.2%	11.1%	N/A
% Organisms (This Station)	0.0%	0.3%	1%	5.7%	1.1%	0.7%

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Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13	Mean Values
Family: Nephtyidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	29	0	0	0	43
% Organisms (Sample Group)	0.0%	3.9%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.6%	0.0%	0.0%	0.0%	8.2%
Family: Nereididae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	4
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%
Family: Pilargidae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	14	8
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	10%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	1.1%	1.8%
Family: Polynoidae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	14	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	1.1%	0.1%
Family: Syllidae						
Number of Taxa	0	1	1	1	0	0
Number of Organisms per M^2	0	57	14	14	0	6
% Organisms (Sample Group)	0.0%	57.1%	14.3%	14.3%	0.0%	N/A
% Organisms (This Station)	0.0%	1.2%	1%	2.9%	0.0%	0.3%
Order: Sabellida						
Family: Oweniidae						
Number of Taxa	0	1	1	0	0	0
Number of Organisms per M^2	0	14	14	0	0	6
% Organisms (Sample Group)	0.0%	14.3%	14.3%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.3%	1%	0.0%	0.0%	0.3%
Order: Spionida						
Family: Magelonidae						
Number of Taxa	1	0	0	0	1	0
Number of Organisms per M^2	86	0	0	0	43	8
% Organisms (Sample Group)	66.7%	0.0%	0.0%	0.0%	33.3%	N/A
% Organisms (This Station)	18.8%	0.0%	0.0%	0.0%	3.3%	1.3%
Family: Spionidae						
Number of Taxa	0	3	0	0	1	0
Number of Organisms per M^2	0	129	0	0	14	11
% Organisms (Sample Group)	0.0%	69.2%	0.0%	0.0%	7.7%	N/A
% Organisms (This Station)	0.0%	2.7%	0.0%	0.0%	1.1%	0.4%
Order: Terebellida						
Family: Ampharetidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

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% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Cirratulidae						
Number of Taxa	0	2	0	0	0	0
Number of Organisms per M^2	0	43	0	0	0	7
% Organisms (Sample Group)	0.0%	37.5%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.9%	0.0%	0.0%	0.0%	0.1%
Family: Pectinariidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	201	0	0	0	21
% Organisms (Sample Group)	0.0%	56%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	4.2%	0.0%	0.0%	0.0%	0.4%
Family: Terebellidae						
Number of Taxa	0	2	0	0	0	0
Number of Organisms per M^2	0	29	0	0	0	2
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified						
Family: Unspecified						
Number of Taxa	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	14	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2.9%	0.0%	0.2%
Class: Clitellata						
Order: Haplotaxida						
Family: Tubificoid Naididae						
Number of Taxa	1	0	0	0	2	1
Number of Organisms per M^2	14	0	0	0	86	68
% Organisms (Sample Group)	1.2%	0.0%	0.0%	0.0%	7.4%	N/A
% Organisms (This Station)	3.1%	0.0%	0.0%	0.0%	6.5%	17.4%
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Hyperiidae						
Number of Taxa	1	0	0	0	0	0
Number of Organisms per M^2	14	0	0	0	0	1
% Organisms (Sample Group)	100%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	3.1%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Ampeliscidae						
Number of Taxa	0	1	1	0	0	0
Number of Organisms per M^2	0	417	29	0	0	72
% Organisms (Sample Group)	0.0%	34.1%	2.4%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	8.7%	1.9%	0.0%	0.0%	1.4%
Family: Aoridae						
Number of Taxa	0	1	1	0	0	1
Number of Organisms per M^2	0	29	72	0	0	28
% Organisms (Sample Group)	0.0%	6.1%	15.2%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.6%	4.8%	0.0%	0.0%	5.3%

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Family: Atylidae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	29	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.2%	0.1%
Family: Bathyporeiidae						
Number of Taxa	1	0	0	0	0	0
Number of Organisms per M^2	14	0	0	0	0	1
% Organisms (Sample Group)	100%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	3.1%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Caprellidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Corophiidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Eriopisidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	172	0	0	0	10
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	3.6%	0.0%	0.0%	0.0%	0.2%
Family: Haustoriidae						
Number of Taxa	0	0	1	1	0	0
Number of Organisms per M^2	0	0	187	86	0	16
% Organisms (Sample Group)	0.0%	0.0%	68.4%	31.6%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	12.4%	17.1%	0.0%	1.7%
Family: Isaeidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	546	0	0	0	105
% Organisms (Sample Group)	0.0%	30.6%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	11.4%	0.0%	0.0%	0.0%	1.9%
Family: Ischroceridae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	29	13
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	13.3%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.2%	0.3%
Family: Ischyroceridae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	29	0	0	0	2
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
Family: Liljeborgiidae						
Number of Taxa	0	1	0	0	0	0

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13	Mean Values
Number of Organisms per M^2	0	72	0	0	0	7
% Organisms (Sample Group)	0.0%	62.5%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	1.5%	0.0%	0.0%	0.0%	1.4%
Family: Lysianassidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	43	0	0	0	3
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.9%	0.0%	0.0%	0.0%	0.1%
Family: Megaluropidae						
Number of Taxa	0	0	1	0	0	0
Number of Organisms per M^2	0	0	29	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	1.9%	0.0%	0.0%	0.1%
Family: Melitidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	201	0	0	0	13
% Organisms (Sample Group)	0.0%	93.3%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	4.2%	0.0%	0.0%	0.0%	0.3%
Family: Oedicerotidae						
Number of Taxa	2	0	0	0	1	0
Number of Organisms per M^2	43	0	0	0	14	3
% Organisms (Sample Group)	75%	0.0%	0.0%	0.0%	25%	N/A
% Organisms (This Station)	9.4%	0.0%	0.0%	0.0%	1.1%	0.6%
Family: Phoxocephalidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Family: Phtisicidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Pontoporeiidae						
Number of Taxa	1	0	0	0	0	0
Number of Organisms per M^2	29	0	0	0	0	2
% Organisms (Sample Group)	100%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	6.3%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Urothoidae						
Number of Taxa	0	0	1	0	0	0
Number of Organisms per M^2	0	0	14	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	1%	0.0%	0.0%	0.1%
Family: Unspecified						
Number of Taxa	0	1	1	0	1	0
Number of Organisms per M^2	0	259	14	0	29	32
% Organisms (Sample Group)	0.0%	47.4%	2.6%	0.0%	5.3%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment
Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13	Mean Values
% Organisms (This Station)	0.0%	5.4%	1%	0.0%	2.2%	0.7%
Class: Malacostraca						
Order: Amphipoda						
Family: Unspecified						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Class: Malacostraca						
Order: Cumacea						
Family: Bodotriidae						
Number of Taxa	1	1	0	0	1	0
Number of Organisms per M^2	57	72	0	0	72	14
% Organisms (Sample Group)	25%	31.3%	0.0%	0.0%	31.3%	N/A
% Organisms (This Station)	12.5%	1.5%	0.0%	0.0%	5.4%	1.2%
Family: Nannastacidae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	43	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	3.3%	0.2%
Family: Unspecified						
Number of Taxa	1	1	0	0	1	0
Number of Organisms per M^2	14	29	0	0	14	3
% Organisms (Sample Group)	25%	50%	0.0%	0.0%	25%	N/A
% Organisms (This Station)	3.1%	0.6%	0.0%	0.0%	1.1%	0.3%
Order: Decapoda						
Family: Unspecified						
Number of Taxa	0	2	2	2	1	1
Number of Organisms per M^2	0	57	29	43	57	16
% Organisms (Sample Group)	0.0%	21.1%	10.5%	15.8%	21.1%	N/A
% Organisms (This Station)	0.0%	1.2%	1.9%	8.6%	4.3%	2.1%
Family: Callianassidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	144	0	0	0	27
% Organisms (Sample Group)	0.0%	31.3%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	3%	0.0%	0.0%	0.0%	3.4%
Family: Crangonidae						
Number of Taxa	1	0	0	0	0	0
Number of Organisms per M^2	14	0	0	0	0	1
% Organisms (Sample Group)	100%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	3.1%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Diogenidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	57	0	0	0	6
% Organisms (Sample Group)	0.0%	57.1%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	1.2%	0.0%	0.0%	0.0%	0.1%
Family: Majidae						

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Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Paguridae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Penaeidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Porcellanidae						
Number of Taxa	0	0	1	1	1	0
Number of Organisms per M^2	0	0	43	14	14	5
% Organisms (Sample Group)	0.0%	0.0%	50%	16.7%	16.7%	N/A
% Organisms (This Station)	0.0%	0.0%	2.9%	2.9%	1.1%	0.4%
Family: Upogebiidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
Family: Unspecified						
Number of Taxa	0	2	2	2	1	1
Number of Organisms per M^2	0	57	29	43	57	16
% Organisms (Sample Group)	0.0%	21.1%	10.5%	15.8%	21.1%	N/A
% Organisms (This Station)	0.0%	1.2%	1.9%	8.6%	4.3%	2.1%
Order: Isopoda						
Family: Anthuridae						
Number of Taxa	0	1	1	1	0	0
Number of Organisms per M^2	0	57	14	14	0	7
% Organisms (Sample Group)	0.0%	50%	12.5%	12.5%	0.0%	N/A
% Organisms (This Station)	0.0%	1.2%	1%	2.9%	0.0%	0.3%
Family: Arcturidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Mysida						
Family: Mysidae						
Number of Taxa	1	1	0	0	1	0
Number of Organisms per M^2	14	14	0	0	14	8
% Organisms (Sample Group)	11.1%	11.1%	0.0%	0.0%	11.1%	N/A
% Organisms (This Station)	3.1%	0.3%	0.0%	0.0%	1.1%	1.5%
Order: Tanaidacea						

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Family: Apseudidae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	29	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.2%	0.1%
Family: Kalliapseudidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Metapseudidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	115	0	0	0	16
% Organisms (Sample Group)	0.0%	42.1%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	2.4%	0.0%	0.0%	0.0%	0.3%
Family: Unspecified						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	72	0	0	0	5
% Organisms (Sample Group)	0.0%	83.3%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	1.5%	0.0%	0.0%	0.0%	0.1%
Class: Pycnogonida						
Order: Unspecified						
Family: Unspecified						
Number of Taxa	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	14	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2.9%	0.0%	0.2%
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Litiopidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	14	0	0	0	1
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
Order: Heterostropha						
Family: Pyramidellidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Neogastropoda						
Family: Marginellidae						
Number of Taxa	0	1	0	0	2	0
Number of Organisms per M^2	0	14	0	0	29	3
% Organisms (Sample Group)	0.0%	33.3%	0.0%	0.0%	66.7%	N/A
% Organisms (This Station)	0.0%	0.3%	0.0%	0.0%	2.2%	0.1%

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Family: Muricidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Neotaenioglossa							
Family: Calyptraeidae							
Number of Taxa		0	1	1	0	0	0
Number of Organisms per M^2		0	14	172	0	0	19
% Organisms (Sample Group)		0.0%	4.5%	54.5%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.3%	11.4%	0.0%	0.0%	0.8%
Family: Cerithiidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
Order: Nudibranchia							
Family: Unspecified							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1%	0.0%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		1	1	0	0	0	0
Number of Organisms per M^2		14	14	0	0	0	2
% Organisms (Sample Group)		50%	50%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		3.1%	0.3%	0.0%	0.0%	0.0%	0.2%
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	1	1	1	1
Number of Organisms per M^2		0	72	29	14	43	24
% Organisms (Sample Group)		0.0%	17.9%	7.1%	3.6%	10.7%	N/A
% Organisms (This Station)		0.0%	1.5%	1.9%	2.9%	3.3%	3.9%
Order: Myoida							
Family: Myidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1%	0.0%	0.0%	0.1%
Order: Mytiloida							

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Family: Mytilidae						
Number of Taxa	0	1	1	0	0	0
Number of Organisms per M^2	0	14	14	0	0	2
% Organisms (Sample Group)	0.0%	50%	50%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.3%	1%	0.0%	0.0%	0.1%
Order: Nuculoida						
Family: Nuculidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Ostreoida						
Family: Ostreidae						
Number of Taxa	0	1	0	1	0	0
Number of Organisms per M^2	0	57	0	14	0	4
% Organisms (Sample Group)	0.0%	80%	0.0%	20%	0.0%	N/A
% Organisms (This Station)	0.0%	1.2%	0.0%	2.9%	0.0%	0.2%
Order: Veneroida						
Family: Cardiidae						
Number of Taxa	0	1	0	0	1	0
Number of Organisms per M^2	0	259	0	0	29	17
% Organisms (Sample Group)	0.0%	90%	0.0%	0.0%	10%	N/A
% Organisms (This Station)	0.0%	5.4%	0.0%	0.0%	2.2%	0.4%
Family: Corbulidae						
Number of Taxa	0	1	1	1	0	0
Number of Organisms per M^2	0	14	72	29	0	8
% Organisms (Sample Group)	0.0%	11.1%	55.6%	22.2%	0.0%	N/A
% Organisms (This Station)	0.0%	0.3%	4.8%	5.7%	0.0%	0.9%
Family: Lucinidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	115	0	0	0	8
% Organisms (Sample Group)	0.0%	80%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	2.4%	0.0%	0.0%	0.0%	0.2%
Family: Semelidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	29	0	0	0	2
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
Family: Solecurtidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	14	0	0	0	1
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
Family: Tellinidae						
Number of Taxa	0	2	0	0	0	0
Number of Organisms per M^2	0	43	0	0	0	16
% Organisms (Sample Group)	0.0%	15.8%	0.0%	0.0%	0.0%	N/A

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% Organisms (This Station)	0.0%	0.9%	0.0%	0.0%	0.0%	2.2%
Family: Ungulinidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	115	0	0	0	7
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	2.4%	0.0%	0.0%	0.0%	0.1%
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	14	0	0	0	4
% Organisms (Sample Group)	0.0%	20%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.3%	0.0%	0.0%	0.0%	0.6%
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Number of Taxa	0	1	1	0	1	0
Number of Organisms per M^2	0	330	14	0	158	41
% Organisms (Sample Group)	0.0%	47.9%	2.1%	0.0%	22.9%	N/A
% Organisms (This Station)	0.0%	6.9%	1%	0.0%	12%	2.0%
Family: Ophiactidae						
Number of Taxa	0	0	2	0	0	0
Number of Organisms per M^2	0	0	273	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	18.1%	0.0%	0.0%	1.1%
Family: Ophiolepididae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Ophuridae						
Family: Ophionereididae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified						
Family: Unspecified						
Number of Taxa	1	1	0	0	1	0
Number of Organisms per M^2	14	129	0	0	57	18
% Organisms (Sample Group)	4.8%	42.9%	0.0%	0.0%	19%	N/A
% Organisms (This Station)	3.1%	2.7%	0.0%	0.0%	4.3%	0.7%
Class: Echinoidea						
Order: Unspecified						
Family: Unspecified						

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Taxonomic Classification	Station # of Replicates Pooled Collection Date	STN13BG 3 05/20/13	STN14BG 3 05/22/13	STN15BG 3 05/23/13	STN16BG 3 05/23/13	STN17BG 3 05/24/13	Mean Values
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1%	0.0%	0.0%	0.1%
Phylum: Chordata							
Class: Cephalochordata							
Order: Amphioxiformes							
Family: Branchiostomatidae							
Number of Taxa		0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	1.1%	0.1%
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	0	1	1	0
Number of Organisms per M^2		0	0	0	14	14	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	50%	50%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2.9%	1.1%	0.2%
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	11
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Total Taxa		16	63	30	21	37	19
Total Organisms per M^2		460	4784	1509	503	1322	1109
% Organisms (Sample Group)		2.4%	25.4%	8%	2.7%	7%	N/A

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Sample Group: Rio Cacheu Benthic Assessment

Sample Method: Petite Ponar
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	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG	STN13BG	STN14BG	STN15BG	STN16BG	STN17BG
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	05/14/2013	05/16/2013	05/15/2013	05/15/2013	05/16/2013	05/15/2013	05/17/2013	05/18/2013	05/25/2013	05/25/2013	05/19/2013	05/20/2013	05/20/2013	05/22/2013	05/23/2013	05/23/2013	05/24/2013
Actiniaria (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	0	0
Turbellaria (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	14	43	0	0
Nemertea (LPIL)	0	0	0	0	0	0	0	0	14	57	14	57	0	29	0	14	29
Nemertea sp. D (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Aspidosiphonidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0
Capitella sp.	14	0	0	0	14	14	0	0	0	0	0	0	14	0	0	0	0
Capitellidae (LPIL)	0	0	0	0	0	57	0	0	0	0	0	0	0	0	0	0	0
Decamastus sp.	14	14	0	0	72	29	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	14	14	0	57	0	43	0	0	29
Mediomastus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	57
Notomastus sp.	0	0	0	0	201	402	14	0	0	0	0	0	0	0	0	0	0
Euclymene sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Maldanidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	86	0	0	0
Sabaco sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Dorvilleidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Protodorvillea sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Lumbrineris sp.	0	0	0	0	0	0	0	0	0	0	0	57	0	86	0	0	14
Diopatra sp.	0	0	0	0	0	0	0	72	14	0	0	474	0	72	0	0	14
Onuphidae (LPIL)	0	0	0	0	0	0	0	14	0	0	0	14	0	0	0	0	0
Armandia maculata	0	0	0	0	0	0	0	0	0	0	0	0	101	0	0	0	0
Armandia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	144
Orbiniidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Scoloplos sp.	0	0	0	0	0	0	0	0	0	0	0	72	0	72	0	14	86
Aricidea catherinae	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Aricidea fragilis	0	0	0	0	0	0	0	0	0	0	0	43	0	86	0	0	0
Aricidea sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0
Aricidea wassi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Cirrophorus branchiatus	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Cirrophorus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Levinsenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Paradoneis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Paraonidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	14	0
Glycera africana	0	0	0	0	0	0	0	0	0	0	0	0	14	14	0	0	0
Glycera alba	0	0	0	0	0	0	0	0	0	0	0	0	0	29	29	0	0
Glycera sp.	0	0	0	0	0	0	0	0	0	43	0	43	0	0	14	14	0
Glyceridae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Goniada multidentata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Goniadidae (LPIL)	0	0	0	0	0	0	0	0	0	0	43	0	0	43	0	0	0
Goniadides sp.	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0
Hesione sp.	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
Hesionidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Heteropodarke sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	14
Podarkeopsis sp.	0	0	0	0	0	0	0	0	0	0	0	43	0	14	0	0	0
Aglaophamus sp.	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micronephtys sp.	0	0	0	0	43	57	29	0	489	0	0	0	0	0	0	0	0
Micronephtys stammeri	0	0	0	0	0	0	0	0	0	0	0	72	0	29	0	0	0
Namalycastis sp.	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereis sp.	0	0	0	14	0	14	0	0	0	0	0	0	0	0	0	0	0
Platynereis sp.	0	14	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabira sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14

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	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	05/14/2013	05/16/2013	05/15/2013	05/15/2013	05/16/2013	05/15/2013	05/17/2013	05/18/2013	05/25/2013	05/25/2013	05/19/2013	05/20/2013	05/20/2013	05/22/2013	05/23/2013	05/23/2013	05/24/2013
Actiniaria (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	0	0
Sigambra sp.	14	0	0	14	29	14	0	14	0	29	0	14	0	0	0	0	0
Polynoidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	14
Eusyllis sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	14	0	0
Plakosyllis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Syllidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0
Galathowenia sp.	0	0	0	0	0	0	0	0	0	14	0	57	0	14	14	0	0
Magelona sp.	0	0	0	0	0	0	0	0	0	0	0	0	86	0	0	0	43
Minuspio sp.	0	0	0	0	0	0	0	0	14	0	0	0	0	14	0	0	14
Polydora sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	101	0	0	0
Scolelepis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Ampharete sp.	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0
Cirratulidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Cirriformia sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0
Monticellina sp.	0	0	0	0	0	0	0	0	0	0	0	43	0	29	0	0	0
Lagis sp.	0	0	0	0	0	0	0	0	0	0	0	158	0	201	0	0	0
Eupolymnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Lanice conchilega	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Polychaeta (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Tubificoid Naididae (LPIL)	244	29	29	43	201	417	0	0	72	0	0	0	14	0	0	0	72
Tubificoid Naididae imm. w/o hair set	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Tubificoides sp.	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0
Hyperia sp.	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
Ampelisca sp.	0	0	0	0	0	0	0	0	0	0	0	776	0	417	29	0	0
Aoridae (LPIL)	43	57	0	43	0	0	0	14	0	29	0	172	0	29	72	0	0
Bemlos/Plesiolembos group	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Nototropis swammerdamei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Pseudaeginella sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Haustoriidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	43	187	86	0
Isaeidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	374	0	0	0	0	0
Photis sp.	0	0	0	0	0	0	0	0	0	0	0	1236	0	546	0	0	0
Ericthonius sp.	0	0	0	0	0	0	0	0	0	0	0	187	0	0	0	0	29
Cerapus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
Liljeborgiidae (LPIL)	0	0	0	0	0	0	0	0	0	0	14	14	0	0	0	0	0
Megaluropidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0
Maera sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Melitidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	359	0	0	0
Oedicerotidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0	14
Phoxocephalidae (LPIL)	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
Phtisica marina	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Pontoporeiidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0
Amphipoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	244	0	259	14	0	29
Cyclaspis sp.	0	0	0	0	0	0	0	0	0	0	0	29	57	72	0	0	72
Cumella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43
Cumacea (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	14	29	0	0	14
Callianassidae (LPIL)	0	0	0	0	0	0	0	0	0	302	0	14	0	144	0	0	0
Crangonidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
Diogenes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0
Diogenidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0
Majidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0

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	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	05/14/2013	05/16/2013	05/15/2013	05/15/2013	05/16/2013	05/15/2013	05/17/2013	05/18/2013	05/25/2013	05/25/2013	05/19/2013	05/20/2013	05/20/2013	05/22/2013	05/23/2013	05/23/2013	05/24/2013
Actiniaria (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	0	0
Paguristes sp.	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0
Penaeus sp.	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Porcellanidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	43	14	14
Upogebia sp.	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0	0
Brachyura (LPIL)	0	0	0	0	0	0	0	0	0	0	0	29	0	14	0	0	0
Decapoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0
Decapoda (LPIL) zoea larva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	57
Decapoda (LPIL) megalopa larva	0	0	0	0	0	0	0	14	0	0	0	0	0	0	14	0	0
Decapoda (LPIL) mysis larva	0	0	0	0	0	0	0	0	14	0	14	14	0	43	0	0	0
Anthuridae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	29	0	57	14	14	0
Arcturidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0
Gastrosaccus sanctus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Mysidae (LPIL)	0	14	0	14	0	0	0	0	14	0	0	14	14	0	0	0	0
Rhopalophthalmus sp.	0	0	0	0	0	29	0	0	0	0	0	0	0	14	0	0	0
Apseudidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Kalliapseudes sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0
Kalliapseudidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Calozodion sp.	0	0	0	0	0	0	0	0	0	0	0	158	0	115	0	0	0
Metapseudidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Tanaidacea (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	72	0	0	0
Pycnogonida (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Litiopidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Pyramidellidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Glabella adansoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Marginellidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Prunum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Muricidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0
Neogastropoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Calyptraea sp.	0	0	0	0	0	0	0	0	0	0	0	129	0	14	172	0	0
Cerithium sp.	14	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0
Nudibranchia (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Gastropoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	14	14	0	0	0
Sphenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Lioberus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Musculus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Nucula sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Ostreidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	14	0
Acanthocardia tuberculata	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0
Cardiidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Caryocorbula sp.	14	0	0	0	0	0	0	0	0	0	0	0	0	0	72	29	0
Corbula sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Lucinidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	29	0	115	0	0	0
Semelidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
Solecurtidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Angulus sp.	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Macoma sp.	0	0	0	0	0	14	0	43	86	0	0	72	0	14	0	0	0
Tellinidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
Ungulinidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	115	0	0	0
Bivalvia (LPIL)	14	14	0	14	43	43	14	0	0	0	0	101	0	72	29	14	43

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Report Generated: 07/19/2013
Number per Sq. Meter

	STN1BG	STN2BG	STN3BG	STN4BG	SNT5BG	STN6BG	STN7BG	STN8BG	STN9BG	STN10BG	STN11BG	STN12BG	STN13BG	STN14BG	STN15BG	STN16BG	STN17BG
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	05/14/2013	05/16/2013	05/15/2013	05/15/2013	05/16/2013	05/15/2013	05/17/2013	05/18/2013	05/25/2013	05/25/2013	05/19/2013	05/20/2013	05/20/2013	05/22/2013	05/23/2013	05/23/2013	05/24/2013
Actiniaria (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	0	0
Phoronida (LPIL)	0	0	0	0	0	0	0	0	0	57	0	0	0	14	0	0	0
Amphiuridae (LPIL)	0	0	0	0	0	0	0	0	0	0	14	172	0	330	14	0	158
Ophiactis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	158	0	0
Ophiolepis paucispina	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Ophionereididae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Ophiuroidea (LPIL)	0	0	0	0	0	0	0	0	0	0	0	101	14	129	0	0	57
Echinoidea (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Branchiostoma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Chaetognatha (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14
Lingula sp.	0	0	0	0	0	0	0	0	0	0	0	187	0	0	0	0	0

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Macroinvertebrate Results

Client: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013
Report Type: Station Indices (Pooled)

Station	1BG	2BG	3BG	4BG	5BG	6BG	7BG	BG8	9BG	10BG	11BG	12BG	13BG	14BG	15BG	16BG	17BG
# Replicates Pooled	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Shannon Diversity Index (H') Base *e*: $H' = [\Sigma (n_i / n) * \ln(n_i / n)]$	1.609	1.510	2.050	1.401	2.632	1.379	0.271	0.868	1.013	2.253	1.229	3.183	1.792	2.458	3.438	3.391	3.101
Pielou's Evenness (J') $J' = H' / H'_{max}$	0.827	0.776	0.890	0.720	0.818	0.769	0.246	0.790	0.630	0.795	0.632	0.781	1.000	0.596	0.850	0.854	0.865
McIntosh's Dominance (M) $M = (n - \sqrt{[\Sigma n_i^2]}) / (n - \sqrt{n})$	0.644	0.532	0.738	0.495	0.757	0.537	0.072	0.495	0.417	0.667	0.460	0.722	1.000	0.512	0.831	0.826	0.821
Margalef's Richness Index (D) $D = (S - 1) / \ln(N)$	2.003	1.576	2.531	1.662	5.040	1.265	0.572	1.116	1.125	4.111	1.558	10.460	2.791	9.921	9.907	9.805	7.418
Number of Taxa	7	7	10	7	25	6	3	3	5	17	7	59	6	62	57	53	36
Number of Genera	7	7	10	7	24	6	3	3	5	17	7	57	6	60	55	52	31

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Macroinvertebrate Results
Raw Data Report (Unpooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	1BG A 08/15/13	1BG B 08/15/13	1BG C 08/15/13	2BG A 08/15/13	2BG B 08/15/13	2BG C 08/15/13
Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	-	-	-	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	-	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	-	-	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		-	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		2	1	1	3	1	2
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	-
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Order: Opheliida							

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Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		1	-	-	-	1	-
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	-

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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	6	2	-
Nais sp.		-	-	4	-	22	-
Family: Tubificoid Naididae							

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Tubificoid Naididae (LPIL)		1	1	6	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	-	-	-
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	1	-	-	-	-
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		-	-	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	1	2	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	1	1	1	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		-	-	1	-	3	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	-
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	1BG A 08/15/13	1BG B 08/15/13	1BG C 08/15/13	2BG A 08/15/13	2BG B 08/15/13	2BG C 08/15/13
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		4	3	13	11	32	2
Total Taxa		3	3	5	4	7	1

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Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	-	-	-	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	1
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	-	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	1	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	-	-	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		-	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	1
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		3	-	4	2	2	2
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	-
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Order: Opheliida							

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Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		2	-	6	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-	1
Nereis sp.		-	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		2	-	1	1	2	1
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	-

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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	-	-
Family: Tubificoid Naididae							

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Tubificoid Naididae (LPIL)		-	1	3	1	2	1
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	-	-	-
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		-	-	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	1	-	-	15	5
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		1	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	1	-	-	-	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		3	-	2	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		-	-	-	-	-	-
Tellinidae (LPIL)		3	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	-
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	3BG A 08/17/13	3BG B 08/17/13	3BG C 08/17/13	4BG A 08/17/13	4BG B 08/17/13	4BG C 08/17/13
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		14	3	18	4	21	12
Total Taxa		6	3	6	3	4	7

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	5BG A 08/16/13	5BG B 08/16/13	5BG C 08/16/13	6BG A 08/16/13	6BG B 08/16/13	6BG C 08/16/13
Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	1	-	-	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	-	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	-	-	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		5	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		1	2	-	-	-	-
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	1	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	1	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		6	2	-	6	4	1
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	-
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Order: Opheliida							

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Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	3	2	14	5	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-	-
Nereis sp.		3	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	1	-	-	-	-
Sigambra sp.		2	5	7	13	1	3
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	-

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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	-	-
Family: Tubificoid Naididae							

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Tubificoid Naididae (LPIL)		6	2	9	-	-	3
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		1	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	1	-	-	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	-	-	-
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		1	-	-	-	-	-
Cyathura sp.		-	1	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		3	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		-	1	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		1	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		2	-	-	-	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	1	-	-	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	1	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	2	7	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		6	-	13	-	-	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	1	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	1	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		-	-	-	1	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	-
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		15	-	1	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		52	23	42	34	11	7
Total Taxa		13	13	9	4	4	3

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Taxonomic Classification	Station Replicate Collection Date	7BG A 08/19/13	7BG B 08/19/13	7BG C 08/19/13	BG8 A 08/19/13	BG8 B 08/19/13	BG8 C 08/19/13
Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	-	-	-	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	-	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	-	-	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		-	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
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Taxonomic Classification	Station Replicate Collection Date	7BG A 08/19/13	7BG B 08/19/13	7BG C 08/19/13	BG8 A 08/19/13	BG8 B 08/19/13	BG8 C 08/19/13
Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	-	-	-
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	-
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Order: Opheliida							

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Taxonomic Classification	Station Replicate Collection Date	7BG A 08/19/13	7BG B 08/19/13	7BG C 08/19/13	BG8 A 08/19/13	BG8 B 08/19/13	BG8 C 08/19/13
Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		16	15	-	1	1	2
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	1	-
Nereis sp.		-	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		1	-	-	-	-	-
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	-

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Sample Group: Wet Season

Sample Method: Petite Ponar
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Taxonomic Classification	Station Replicate Collection Date	7BG A 08/19/13	7BG B 08/19/13	7BG C 08/19/13	BG8 A 08/19/13	BG8 B 08/19/13	BG8 C 08/19/13
Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	-	-
Family: Tubificoid Naididae							

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Tubificoid Naididae (LPIL)		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	-	-	-
Callianassidae (LPIL)		-	-	-	-	-	-
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		-	-	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	1	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	-	-	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		-	1	-	-	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	-
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	-	-
No Organisms Present		-	-	✓	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		17	16	0	2	2	2
Total Taxa		2	2	N/A	2	2	1

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Taxonomic Classification	Station Replicate Collection Date	9BG A 08/22/13	9BG B 08/22/13	9BG C 08/22/13	10BG A 08/22/13	10BG B 08/22/13	10BG C 08/22/13
Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	-	-	-	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	-	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	-	-	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		-	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	9BG A 08/22/13	9BG B 08/22/13	9BG C 08/22/13	10BG A 08/22/13	10BG B 08/22/13	10BG C 08/22/13
Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	4	1	-
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	1	2	1
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	-
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	-
Order: Opheliida							

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Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	1	1	1
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	2
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	1	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		9	8	1	-	-	-
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Neanthes sp.		-	-	1	-	-	-
Nereididae (LPIL)		-	-	-	-	-	-
Nereis sp.		1	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		-	-	-	1	-	-
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	-

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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	1	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		1	-	-	2	-	-
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	3	-
Family: Tubificoid Naididae							

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Tubificoid Naididae (LPIL)		3	11	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	1	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	1	-
Liljeborgiidae (LPIL)		-	-	-	1	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	2
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	-	-	-
Callianassidae (LPIL)		-	-	-	5	9	5
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		-	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		-	-	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	1	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	-	-	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	1	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		-	-	-	-	-	-
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	-
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	1	-	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		14	19	2	17	21	11
Total Taxa		4	2	2	9	10	5

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Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	-	-	1	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	1	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	2	17	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		-	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	4	2
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	1	1

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Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		1	-	-	-	1	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	1	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	-	-	5	2	2
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	7	1
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	2	5	3
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	5
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	1	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	-	4	7	5
Order: Opheliida							

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	1	1	3
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	1	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	1	-
Glycera alba		-	-	-	-	-	1
Glycera sp.		-	-	-	-	-	2
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	1
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys stammeri		-	-	-	1	2	1
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	1	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		-	-	-	-	-	1
Family: Polynoidae							
Malmgreniella sp.		-	-	-	2	-	1

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	1	2
Pionosyllis sp.		-	-	-	-	1	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	1	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	1
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	3	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	1	-
Spionidae (LPIL)		-	-	-	-	1	1
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	7
Lysippe sp.		-	-	-	1	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	4	2
Cirratulidae (LPIL)		-	-	-	1	-	2
Monticellina sp.		-	-	-	-	1	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	6	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	-	-
Family: Tubificoid Naididae							

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Sample Method: Petite Ponar
Report Date: 10/09/2013

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Tubificoid Naididae (LPIL)		-	-	-	-	2	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	15	60
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	1
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	2	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	1
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	1
Family: Phoxocephalidae							
Basuto stimpsoni		-	1	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	5
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	-	-	-
Callianassidae (LPIL)		-	-	-	-	-	1
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		1	-	-	-	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	1	2
Anthuridae (LPIL)		-	-	-	-	-	-
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		2	1	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	2	15	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	4
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	1
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	1	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	1	1	1
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		1	-	-	1	-	1
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	1
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		-	-	-	1	-	1
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	1
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	2	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	1	1	2
Ophiophragmus sp.		-	-	-	-	1	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	1
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		21	-	-	-	-	-
Phylum: Bryozoa							

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Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	-	2	3
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	3	-
Total Organisms		26	4	17	28	97	131
Total Taxa		5	3	1	17	33	37

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Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	-	-	-	-	-
Demospongiae boring (LPIL)		-	-	-	-	-	-
Demospongiae encrusting (LPIL)		-	-	-	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		-	-	-	-	-	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	-	-
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	-	-
Family: Lovenellidae							
Lovenellidae (LPIL)		-	-	-	-	-	-
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	-
Sertulariidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Leptothecata (LPIL)		-	-	-	-	-	-
Plumulariidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	-	-	-
Hydroidolina (LPIL)		-	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	-	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	-	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	2	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	1	1	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		-	1	-	-	-	14
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		-	-	-	1	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	-	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	3
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	7	-	3
Mediomastus sp.		-	-	-	-	-	2
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	1	2	2
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	1	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	1
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	1
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	1	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	1
Family: Onuphidae							
Diopatra sp.		-	-	-	-	-	2
Order: Opheliida							

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Macroinvertebrate Results
Raw Data Report (Unpooled)

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	13BG A 08/21/13	13BG B 08/21/13	13BG C 08/21/13	14BG A 08/24/13	14BG B 08/24/13	14BG C 08/24/13
Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	10	-	-
Scoloplos acmeceps		-	-	-	-	2	-
Scoloplos sp.		-	-	-	1	-	6
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	1	1	-
Aricidea simplex		-	-	-	-	-	1
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	2	1
Levinsenia gracilis		-	-	-	1	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	1	-	1
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	3
Goniada multidentata		-	-	-	1	-	1
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	1	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	1	-	-
Micronephtys stammeri		-	-	-	1	1	-
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	1	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		-	-	-	-	-	-
Family: Polynoidae							
Malmgreniella sp.		-	-	-	1	-	2

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Sample Method: Petite Ponar
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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	7
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	1
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	2
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	27	-	3
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	2
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	1
Monticellina sp.		-	-	-	-	1	2
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	1
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	-	-
Family: Tubificoid Naididae							

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Tubificoid Naididae (LPIL)		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	1	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	2	-	3
Liljeborgiidae (LPIL)		-	-	-	1	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	4	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		-	-	-	-	2	-
Family: Callianassidae							
Callianassa sp.		-	-	-	3	-	-
Callianassidae (LPIL)		-	-	-	-	-	16
Family: Epialtidae							
Pisinae (LPIL)		-	-	-	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	-	1	-	-	234
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	1	-	1	-	-
Family: Unspecified							
Brachyura zoea larva		-	1	-	1	-	-
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	2
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		1	-	-	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	-	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	1
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	1
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	1	1	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	-
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	4	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	1	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	1	-
Parvilucina sp.		-	-	-	2	-	2
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	2	-	-
Family: Tellinidae							
Macoma sp.		-	-	-	-	2	-
Tellinidae (LPIL)		1	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	1
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	7	-	3
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	4	5	15
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	2	6	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	2	-	1
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		2	3	1	97	29	342
Total Taxa		2	3	1	33	15	35

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Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		4	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		-	1	-	-	-	-
Demospongiae boring (LPIL)		-	-	9	-	-	-
Demospongiae encrusting (LPIL)		3	-	3	-	-	-
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		-	-	-	-	-	-
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		8	-	6	-	1	-
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		-	-	-	-	2	2
Family: Campanulariidae							
Campanulariidae (LPIL)		-	-	-	-	1	-
Family: Lovenellidae							
Lovenellidae (LPIL)		12	3	4	-	-	4
Family: Sertulariidae							
Sertularia sp.		-	-	-	-	-	1
Sertulariidae (LPIL)		-	-	-	1	4	-
Family: Unspecified							
Leptothecata (LPIL)		5	-	5	-	3	-
Plumulariidae (LPIL)		-	-	-	-	1	-
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		-	-	-	3	-	-
Hydroidolina (LPIL)		1	-	-	-	-	-
Hydrozoa (LPIL)		-	-	-	2	-	-
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		-	-	-	-	1	-
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		-	-	-	-	-	-
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		-	-	-	-	-	-

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Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		-	-	-	-	-	-
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		3	15	1	6	-	-
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		5	-	2	-	-	-
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		-	-	2	-	-	-
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		-	-	-	-	-	-
Capitobranchus sp.		-	-	-	-	-	-
Decamastus sp.		-	-	-	-	-	-
Heteromastus filiformis		-	-	-	-	-	-
Mediomastus sp.		-	-	-	-	-	-
Notomastus sp.		-	-	-	-	-	-
Family: Maldanidae							
Maldanidae (LPIL)		-	-	-	-	-	-
Order: Cossurida							
Family: Cossuridae							
Cossura delta		-	-	-	-	-	-
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		-	-	-	-	-	-
Schistomeringos rudolphii		-	-	-	-	-	-
Family: Lumbrineridae							
Augeneria sp.		-	-	-	-	-	-
Lumbrineris meteorana		-	-	-	-	-	-
Scoletoma impatiens		-	-	-	-	-	-
Family: Oenonidae							
Oenonidae (LPIL)		-	-	-	-	-	-
Family: Onuphidae							
Diopatra sp.		-	-	1	-	-	-
Order: Opheliida							

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Family: Opheliidae							
Armandia sp.		-	-	1	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	1	-	-
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	1	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	2
Glycera sp.		-	1	-	1	2	-
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	1	-	-
Goniadella sp.		-	-	-	-	1	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	-	-	-	-
Micronephtys stammeri		4	1	3	1	-	4
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-	-
Nereis sp.		-	-	-	-	-	1
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		-	-	-	-	-	-
Family: Polynoidae							
Malmgreniella sp.		3	1	-	-	2	-

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	1	-
Exogone sp.		-	-	1	-	1	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	1	-	-	-	1
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	1	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	1	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	5	-	-	1	3
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	1	1
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		1	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	-	-	-	-	-
Nais sp.		-	-	-	-	-	-
Family: Tubificoid Naididae							

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

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Tubificoid Naididae (LPIL)		-	-	-	-	-	-
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	1	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	1	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	2	-	-	-	-
Corophiidae (LPIL)		-	2	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	1	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	1	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	1	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	4	-
Liljeborgiidae (LPIL)		-	-	-	1	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	1
Perioculodes sp.		-	1	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	1	-	3	10	10
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	-	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	3	-
Family: Leuconidae							
Leuconidae (LPIL)		-	2	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		1	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Decapoda (LPIL)		3	-	-	-	-	-
Family: Callianassidae							
Callianassa sp.		-	-	-	1	1	-
Callianassidae (LPIL)		-	2	-	-	-	-
Family: Epialtidae							
Pisinae (LPIL)		-	-	1	-	-	-
Family: Paguridae							
Paguridae *zoea larva*		-	1	-	-	-	-
Paguristes sp.		-	-	-	-	-	-
Family: Porcellanidae							
Porcellanidae *zoea larva*		-	-	-	-	-	-
Family: Unspecified							
Brachyura zoea larva		3	1	13	1	-	1
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		-	-	-	-	-	-
Anthuridae (LPIL)		-	-	-	-	-	-
Cyathura sp.		-	-	-	-	-	-
Family: Sphaeromatidae							
Cassidinidea sp.		-	-	-	-	-	-
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		-	2	2	-	-	-
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		-	-	1	-	-	-
Family: Metapseudidae							
Calozodion sp.		-	-	-	-	-	-
Family: Unspecified							
Metapseudidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		-	-	-	-	-	-
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		-	-	-	-	-	-
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		-	-	-	-	-	-
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	1
Order: Heterostropha							

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Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	-	1	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		2	-	1	3	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	1	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		6	-	1	7	2	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	1	-	-	-	-
Crepidula sp.		-	-	-	-	-	-
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Family: Eulimidae							
Melanella sp.		1	2	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	1	-	-	-	-
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		4	-	-	-	1	-
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		1	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	-	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	2	1	1	1
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		27	1	5	-	-	-

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Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	1	1	1	-	1
Corbula sp.		3	4	7	3	5	8
Corbulidae (LPIL)		-	-	-	4	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	1	5	9	-	1
Family: Tellinidae							
Macoma sp.		-	-	-	-	4	-
Tellinidae (LPIL)		-	-	3	-	-	1
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		6	16	3	20	-	5
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		8	3	1	5	12	-
Ophiophragmus sp.		-	-	1	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		1	1	2	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	1	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		2	-	1	1	2	1
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	1	1	1	1	-
No Organisms Present		-	-	-	-	-	-
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	-
Total Organisms		117	77	91	79	72	50
Total Taxa		25	31	32	25	30	20

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Phylum: Porifera				
Class: Demospongiae				
Order: Hadromerida				
Family: Clionidae				
Cliona sp.		-	-	-
Order: Unspecified				
Family: Unspecified				
Demospongiae (LPIL)		-	-	-
Demospongiae boring (LPIL)		-	-	-
Demospongiae encrusting (LPIL)		-	-	-
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Porifera (LPIL)		-	-	-
Phylum: Cnidaria				
Class: Hydrozoa				
Order: Anthoathecata				
Family: Unspecified				
Anthoathecata (LPIL)		-	-	-
Order: Leptothecata				
Family: Aglaopheniidae				
Aglaopheniidae (LPIL)		-	-	-
Family: Campanulariidae				
Campanulariidae (LPIL)		-	-	-
Family: Lovenellidae				
Lovenellidae (LPIL)		3	-	6
Family: Sertulariidae				
Sertularia sp.		-	-	-
Sertulariidae (LPIL)		-	-	-
Family: Unspecified				
Leptothecata (LPIL)		-	-	-
Plumulariidae (LPIL)		-	-	-
Order: Unspecified				
Family: Unspecified				
Hydroida (LPIL)		-	-	-
Hydroidolina (LPIL)		-	-	-
Hydrozoa (LPIL)		-	-	-
Class: Anthozoa				
Order: Actiniaria				
Family: Unspecified				
Actiniaria (LPIL)		-	-	-
Order: Alcyonacea				
Family: Scleraxonia				
Scleraxonia (LPIL)		-	-	-
Order: Pennatulacea				
Family: Kophobelmnidae				
Kophobelemnon sp.		-	-	-

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Order: Scleractinia				
Family: Unspecified				
Scleractinia (LPIL)		-	-	-
Order: Unspecified				
Family: Unspecified				
Anthozoa (LPIL)		-	-	-
Phylum: Nemertea				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Nemertea (LPIL)		1	2	-
Phylum: Sipuncula				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Sipuncula (LPIL)		-	-	-
Phylum: Annelida				
Class: Polychaeta				
Order: Amphinomida				
Family: Amphinomidae				
Amphinomidae (LPIL)		-	-	-
Order: Capitellida				
Family: Capitellidae				
Capitellidae (LPIL)		-	-	-
Capitobranchus sp.		-	-	-
Decamastus sp.		-	-	-
Heteromastus filiformis		3	1	1
Mediomastus sp.		2	4	1
Notomastus sp.		-	-	-
Family: Maldanidae				
Maldanidae (LPIL)		-	-	-
Order: Cossurida				
Family: Cossuridae				
Cossura delta		-	-	-
Order: Eunicida				
Family: Dorvilleidae				
Protodorvillea egena		-	2	-
Schistomeringos rudolphii		-	-	-
Family: Lumbrineridae				
Augeneria sp.		-	-	-
Lumbrineris meteorana		-	-	-
Scoletoma impatiens		-	-	-
Family: Oenonidae				
Oenonidae (LPIL)		-	-	-
Family: Onuphidae				
Diopatra sp.		-	-	-
Order: Opheliida				

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Family: Opheliidae				
Armandia sp.		-	-	6
Order: Orbiniida				
Family: Orbiniidae				
Proscoloplos sp.		-	-	-
Scoloplos acmeceps		-	-	-
Scoloplos sp.		3	10	2
Family: Paraonidae				
Aricidea cerrutii		1	-	-
Aricidea fragilis		-	-	-
Aricidea simplex		-	-	-
Aricidea sp.		1	-	-
Aricidea wassi		-	2	-
Cirrophorus branchiatus		2	1	3
Levinsenia gracilis		-	-	-
Paraonidae (LPIL)		-	1	1
Paraonis fulgens		-	-	-
Order: Phyllodocida				
Family: Glyceridae				
Glycera africana		-	1	-
Glycera alba		1	-	-
Glycera sp.		-	-	2
Family: Goniadidae				
Glycinde kameruniana		-	-	-
Goniada multidentata		-	-	-
Goniada sp.		-	-	-
Goniadella sp.		-	-	-
Goniadidae (LPIL)		-	-	-
Family: Hesionidae				
Gyptis sp.		-	-	-
Kefersteinia sp.		-	-	-
Family: Nephtyidae				
Aglaophamus sp.		-	-	-
Micronephtys stammeri		-	-	1
Family: Nereididae				
Neanthes sp.		-	-	-
Nereididae (LPIL)		-	-	-
Nereis sp.		-	-	-
Family: Phyllodocidae				
Eteone sp.		-	-	-
Family: Pilargidae				
Ancistrosyllis sp.		1	1	-
Cabira sp.		-	-	-
Sigambra bassi		-	-	-
Sigambra sp.		-	-	-
Family: Polynoidae				
Malmgreniella sp.		-	-	-

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Family: Sphaerodoridae				
Ephesiella sp.		-	-	-
Family: Syllidae				
Eusyllis assimilis		-	-	-
Eusyllis sp.		-	-	-
Exogone sp.		-	-	-
Pionosyllis sp.		-	-	-
Sphaerosyllis sp.		-	-	-
Order: Sabellida				
Family: Oweniidae				
Galathowenia oculata		-	-	-
Galathowenia sp.		-	-	-
Family: Sabellariidae				
Sabellaria sp.		-	-	-
Sabellariidae (LPIL)		-	-	-
Order: Spionida				
Family: Chaetopteridae				
Spiochaetopterus sp.		-	-	-
Family: Magelonidae				
Magelona cincta		-	1	-
Magelona sp.		1	-	-
Family: Spionidae				
Minuspio sp.		-	-	-
Scolelepis sp.		-	-	-
Spionidae (LPIL)		-	1	-
Order: Terebellida				
Family: Ampharetidae				
Ampharete sp.		-	-	-
Lysippe sp.		-	-	-
Family: Cirratulidae				
Aphelochaeta marioni		-	-	-
Aphelochaeta sp.		-	-	-
Cirratulidae (LPIL)		-	-	1
Monticellina sp.		-	-	-
Family: Terebellidae				
Eupolymnia sp.		-	-	-
Order: Unspecified				
Family: Unspecified				
Polychaeta (LPIL)		-	-	-
Class: Clitellata				
Order: Haplotaxida				
Family: Enchytraeidae				
Enchytraeidae (LPIL)		-	1	-
Family: Naididae				
Naididae (LPIL)		-	-	-
Nais sp.		-	-	-
Family: Tubificoid Naididae				

Macroinvertebrate Results
Raw Data Report (Unpooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Replicate Collection Date	17BG A 08/26/13	17BG B 08/26/13	17BG C 08/26/13
Tubificoid Naididae (LPIL)		8	6	2
Phylum: Arthropoda				
Class: Malacostraca				
Order: Amphipoda				
Family: Ampeliscidae				
Ampelisca sp.		-	-	-
Family: Aoridae				
Aoridae (LPIL)		-	-	-
Family: Bathyporeiidae				
Bathyporeia sp.		-	-	-
Family: Corophiidae				
Cheiriphotis sp		-	-	-
Corophiidae (LPIL)		-	-	-
Family: Dexaminidae				
Nototropis sp.		-	-	-
Family: Eriopisidae				
Eriopisella sp.		-	-	-
Family: Isaeida				
Isaeidae (LPIL)		-	-	-
Family: Ischyroceridae				
Ischyroceridae (LPIL)		-	-	-
Family: Liljeborgiidae				
Idunella sp.		-	-	1
Liljeborgiidae (LPIL)		1	-	-
Family: Lysianassidae				
Lysianassidae (LPIL)		-	-	-
Family: Oedicerotidae				
Oedicerotidae (LPIL)		-	-	-
Perioculodes sp.		-	-	-
Family: Photidae				
Photidae (LPIL)		-	-	-
Family: Phoxocephalidae				
Basuto stimpsoni		-	-	-
Family: Urothoidae				
Urothoe sp.		-	-	-
Family: Unspecified				
Amphipoda (LPIL)		-	-	-
Order: Cumacea				
Family: Bodotriidae				
Apocuma sp.		-	-	-
Bodotriidae (LPIL)		-	-	-
Family: Leuconidae				
Leuconidae (LPIL)		-	-	-
Family: Unspecified				
Cumacea (LPIL)		-	-	-
Order: Decapoda				
Family: Unspecified				

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Decapoda (LPIL)		-	-	-
Family: Callianassidae				
Callianassa sp.		-	-	-
Callianassidae (LPIL)		-	-	-
Family: Epialtidae				
Pisinae (LPIL)		-	-	-
Family: Paguridae				
Paguridae *zoea larva*		-	-	-
Paguristes sp.		1	-	-
Family: Porcellanidae				
Porcellanidae *zoea larva*		-	-	-
Family: Unspecified				
Brachyura zoea larva		-	-	-
Order: Isopoda				
Family: Anthuridae				
Amakusanthura sp.		-	-	-
Anthuridae (LPIL)		-	-	-
Cyathura sp.		-	-	-
Family: Sphaeromatidae				
Cassidinidea sp.		-	-	-
Order: Mysida				
Family: Unspecified				
Mysidacea (LPIL)		1	1	-
Order: Tanaidacea				
Family: Kalliapseudidae				
Kalliapseudidae (LPIL)		-	-	-
Family: Metapseudidae				
Calozodion sp.		-	-	-
Family: Unspecified				
Metapseudidae (LPIL)		-	-	-
Order: Unspecified				
Family: Unspecified				
Malacostraca (LPIL)		-	-	-
Class: Entognatha				
Order: Collembola				
Family: Unspecified				
Collembola (LPIL)		-	-	-
Class: Insecta				
Order: Diptera				
Family: Unspecified				
Diptera (LPIL)		-	-	-
Phylum: Mollusca				
Class: Gastropoda				
Order: Caenogastropoda				
Family: Eulimidae				
Melanella sp.		-	-	-
Order: Heterostropha				

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Taxonomic Classification	Station Replicate Collection Date	17BG A 08/26/13	17BG B 08/26/13	17BG C 08/26/13
Family: Pyramidellidae				
Pyramidellidae (LPIL)		-	-	-
Order: Littorinimorpha				
Family: Naticidae				
Sinum sp.		-	-	-
Order: Neogastropoda				
Family: Cystiscidae				
Plesiocystiscus sp.		-	-	-
Order: Neotaenioglossa				
Family: Caecidae				
Caecum sp.		-	-	-
Cerithiidae (LPIL)		-	-	-
Family: Calyptraeidae				
Calyptraea sp.		-	-	-
Crepidula sp.		-	-	-
Family: Cerithiidae				
Cerithium sp.		-	-	-
Family: Eulimidae				
Melanella sp.		-	-	-
Family: Hydrobiidae				
Hydrobiidae (LPIL)		-	-	-
Order: Unspecified				
Family: Unspecified				
Gastropoda (LPIL)		-	-	1
Class: Bivalvia				
Order: Unspecified				
Family: Unspecified				
Bivalvia (LPIL)		1	-	-
Order: Arcoida				
Family: Arcidae				
Anadara sp.		-	-	1
Order: Carditoida				
Family: Carditidae				
Pleuromeris sp.		2	-	4
Order: Myoida				
Family: Myidae				
Myidae (LPIL)		-	-	-
Order: Mytiloida				
Family: Mytilidae				
Musculus sp.		-	-	-
Mytilidae (LPIL)		-	-	-
Order: Nuculoida				
Family: Nuculidae				
Nucula sp.		-	-	-
Order: Ostreoida				
Family: Anomiidae				
Anomia sp.		-	-	-

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Order: Veneroida				
Family: Unspecified				
Veneroida (LPIL)		-	-	-
Family: Corbulidae				
Caryocorbula sp.		-	-	1
Corbula sp.		-	-	-
Corbulidae (LPIL)		-	-	-
Family: Lucinidae				
Lucinidae (LPIL)		-	-	-
Parvilucina sp.		-	-	-
Family: Mactridae				
Mactridae (LPIL)		-	-	-
Family: Montecutidae				
Mysella sp.		-	2	-
Family: Tellinidae				
Macoma sp.		-	-	-
Tellinidae (LPIL)		-	-	-
Family: Veneridae				
Veneridae (LPIL)		-	-	-
Phylum: Phoronida				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Phoronida (LPIL)		-	-	-
Phylum: Echinodermata				
Class: Ophiuroidea				
Order: Ophiurida				
Family: Amphiuridae				
Amphiodia/Amphipholis complex		-	-	-
Amphioplus sp.		-	-	-
Amphiura sp.		-	1	-
Amphiuridae (LPIL)		2	1	2
Ophiophragmus sp.		-	-	-
Order: Unspecified				
Family: Unspecified				
Ophiuroidea (LPIL)		-	-	-
Phylum: Platyhelminthes				
Class: Rhabditophora				
Order: Polycladida				
Family: Unspecified				
Polycladida (LPIL)		-	-	-
Phylum: Bryozoa				
Class: Gymnolaemata				
Order: Ctenostomatida				
Family: Unspecified				
Ctenostomatida (LPIL)		-	-	-
Phylum: Bryozoa				

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Taxonomic Classification	Station Replicate Collection Date	17BG A 08/26/13	17BG B 08/26/13	17BG C 08/26/13
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Bryozoa (LPIL)		-	-	-
Phylum: Chaetognatha				
Class: Unspecified				
Order: Unspecified				
Family: Unspecified				
Chaetognatha (LPIL)		-	-	2
No Organisms Present		-	-	-
Phylum: Brachiopoda				
Class: Lingulata				
Order: Lingulida				
Family: Lingulidae				
Lingula sp.		-	-	-
Total Organisms		35	39	38
Total Taxa		18	18	18

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Percent Occurrence (Pooled)

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Taxonomic Classification	1BG	2BG	3BG	4BG	5BG	6BG
Station	1BG	2BG	3BG	4BG	5BG	6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Phylum: Porifera						
Class: Demospongiae						
Order: Hadromerida						
Family: Clionidae						
Cliona sp.	0%	0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Demospongiae (LPIL)	0%	0%	0%	0%	0.85%	0%
Demospongiae boring (LPIL)	0%	0%	0%	0%	0%	0%
Demospongiae encrusting (LPIL)	0%	0%	0%	0%	0%	0%
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Porifera (LPIL)	0%	0%	0%	2.7%	0%	0%
Phylum: Cnidaria						
Class: Hydrozoa						
Order: Anthoathecata						
Family: Unspecified						
Anthoathecata (LPIL)	0%	0%	0%	0%	0%	0%
Order: Leptothecata						
Family: Aglaopheniidae						
Aglaopheniidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Campanulariidae						
Campanulariidae (LPIL)	0%	0%	2.86%	0%	0%	0%
Family: Lovenellidae						
Lovenellidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Sertulariidae						
Sertularia sp.	0%	0%	0%	0%	0%	0%
Sertulariidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Unspecified						
Leptothecata (LPIL)	0%	0%	0%	0%	0%	0%
Plumulariidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Hydroida (LPIL)	0%	0%	0%	0%	0%	0%
Hydroidolina (LPIL)	0%	0%	0%	0%	4.27%	0%
Hydrozoa (LPIL)	0%	0%	0%	0%	0%	0%
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)	0%	0%	0%	0%	0%	0%
Order: Alcyonacea						
Family: Scleraxonia						
Scleraxonia (LPIL)	0%	0%	0%	0%	0%	0%
Order: Pennatulacea						
Family: Kophobelmnidae						
Kophobelemnon sp.	0%	0%	0%	0%	0%	0%

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Order: Scleractinia							
Family: Unspecified							
Scleractinia (LPIL)		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Anthozoa (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Nemertea							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Nemertea (LPIL)		0%	0%	0%	0%	2.56%	0%
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Sipuncula (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Amphinomidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Capitellida							
Family: Capitellidae							
Capitellidae (LPIL)		0%	0%	0%	0%	0.85%	0%
Capitobranchus sp.		0%	0%	0%	0%	0%	0%
Decamastus sp.		0%	0%	0%	2.7%	0.85%	0%
Heteromastus filiformis		0%	0%	0%	0%	0%	0%
Mediomastus sp.		0%	0%	0%	0%	0%	0%
Notomastus sp.		20%	13.33%	20%	16.22%	6.84%	21.15%
Family: Maldanidae							
Maldanidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Cossurida							
Family: Cossuridae							
Cossura delta		0%	0%	0%	0%	0%	0%
Order: Eunicida							
Family: Dorvilleidae							
Protodorvillea egena		0%	0%	0%	0%	0%	0%
Schistomeringos rudolphii		0%	0%	0%	0%	0%	0%
Family: Lumbrineridae							
Augeneria sp.		0%	0%	0%	0%	0%	0%
Lumbrineris meteorana		0%	0%	0%	0%	0%	0%
Scoletoma impatiens		0%	0%	0%	0%	0%	0%
Family: Oenonidae							
Oenonidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Onuphidae							
Diopatra sp.		0%	0%	0%	0%	0%	0%
Order: Opheliida							

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Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Family: Opheliidae							
Armandia sp.		0%	0%	0%	0%	0%	0%
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		0%	0%	0%	0%	0%	0%
Scoloplos acmeceps		0%	0%	0%	0%	0%	0%
Scoloplos sp.		0%	0%	0%	0%	0%	0%
Family: Paraonidae							
Aricidea cerrutii		0%	0%	0%	0%	0%	0%
Aricidea fragilis		0%	0%	0%	0%	0%	0%
Aricidea simplex		0%	0%	0%	0%	0%	0%
Aricidea sp.		0%	0%	0%	0%	0%	0%
Aricidea wassi		0%	0%	0%	0%	0%	0%
Cirrophorus branchiatus		0%	0%	0%	0%	0%	0%
Levinsenia gracilis		0%	0%	0%	0%	0%	0%
Paraonidae (LPIL)		0%	0%	0%	0%	0%	0%
Paraonis fulgens		0%	0%	0%	0%	0%	0%
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		0%	0%	0%	0%	0%	0%
Glycera alba		0%	0%	0%	0%	0%	0%
Glycera sp.		0%	0%	0%	0%	0%	0%
Family: Goniadidae							
Glycinde kameruniana		0%	0%	0%	0%	0%	0%
Goniada multidentata		0%	0%	0%	0%	0%	0%
Goniada sp.		0%	0%	0%	0%	0%	0%
Goniadella sp.		0%	0%	0%	0%	0%	0%
Goniadidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Hesionidae							
Gyptis sp.		0%	0%	0%	0%	0%	0%
Kefersteinia sp.		0%	0%	0%	0%	0%	0%
Family: Nephtyidae							
Aglaophamus sp.		0%	0%	22.86%	0%	4.27%	36.54%
Micronephtys stammeri		0%	0%	0%	0%	0%	0%
Family: Nereididae							
Neanthes sp.		0%	0%	0%	0%	0%	0%
Nereididae (LPIL)		0%	0%	0%	2.7%	0%	0%
Nereis sp.		0%	0%	0%	0%	2.56%	0%
Family: Phyllodocidae							
Eteone sp.		0%	0%	0%	0%	0%	0%
Family: Pilargidae							
Ancistrosyllis sp.		0%	0%	0%	0%	0%	0%
Cabira sp.		0%	0%	0%	0%	0%	0%
Sigambra bassi		0%	0%	0%	0%	0.85%	0%
Sigambra sp.		5%	2.22%	11.43%	10.81%	11.97%	32.69%
Family: Polynoidae							
Malmgreniella sp.		0%	0%	0%	0%	0%	0%

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Family: Sphaerodoridae							
Ephesiella sp.		0%	0%	0%	0%	0%	0%
Family: Syllidae							
Eusyllis assimilis		0%	0%	0%	0%	0%	0%
Eusyllis sp.		0%	0%	0%	0%	0%	0%
Exogone sp.		0%	0%	0%	0%	0%	0%
Pionosyllis sp.		0%	0%	0%	0%	0%	0%
Sphaerosyllis sp.		0%	0%	0%	0%	0%	0%
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		0%	0%	0%	0%	0%	0%
Galathowenia sp.		0%	0%	0%	0%	0%	0%
Family: Sabellariidae							
Sabellaria sp.		0%	0%	0%	0%	0%	0%
Sabellariidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		0%	0%	0%	0%	0%	0%
Family: Magelonidae							
Magelona cincta		0%	0%	0%	0%	0%	0%
Magelona sp.		0%	0%	0%	0%	0%	0%
Family: Spionidae							
Minuspio sp.		0%	0%	0%	0%	0%	0%
Scolelepis sp.		0%	0%	0%	0%	0%	0%
Spionidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		0%	0%	0%	0%	0%	0%
Lysippe sp.		0%	0%	0%	0%	0%	0%
Family: Cirratulidae							
Aphelochaeta marioni		0%	0%	0%	0%	0%	0%
Aphelochaeta sp.		0%	0%	0%	0%	0%	0%
Cirratulidae (LPIL)		0%	0%	0%	0%	0%	0%
Monticellina sp.		0%	0%	0%	0%	0%	0%
Family: Terebellidae							
Eupolymnia sp.		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		0%	0%	0%	0%	0%	0%
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Naididae							
Naididae (LPIL)		0%	17.78%	0%	0%	0%	0%
Nais sp.		20%	48.89%	0%	0%	0%	0%
Family: Tubificoid Naididae							

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Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Tubificoid Naididae (LPIL)		40%	0%	11.43%	10.81%	14.53%	5.77%
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		0%	0%	0%	0%	0%	0%
Family: Aoridae							
Aoridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Bathyporeiidae							
Bathyporeia sp.		0%	0%	0%	0%	0%	0%
Family: Corophiidae							
Cheiriphotis sp		0%	0%	0%	0%	0%	0%
Corophiidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Dexaminidae							
Nototropis sp.		0%	0%	0%	0%	0%	0%
Family: Eriopisidae							
Eriopisella sp.		0%	0%	0%	0%	0%	0%
Family: Isaeida							
Isaeidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Ischyroceridae							
Ischyroceridae (LPIL)		0%	0%	0%	0%	0.85%	0%
Family: Liljeborgiidae							
Idunella sp.		0%	0%	0%	0%	0%	0%
Liljeborgiidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Lysianassidae							
Lysianassidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Oedicerotidae							
Oedicerotidae (LPIL)		0%	0%	0%	0%	0%	0%
Perioculodes sp.		0%	0%	0%	0%	0%	0%
Family: Photidae							
Photidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Phoxocephalidae							
Basuto stimpsoni		0%	0%	0%	0%	0%	0%
Family: Urothoidae							
Urothoe sp.		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Amphipoda (LPIL)		0%	0%	0%	0%	0.85%	0%
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		0%	0%	0%	0%	0%	0%
Bodotriidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Leuconidae							
Leuconidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Cumacea (LPIL)		0%	0%	0%	0%	0%	0%
Order: Decapoda							
Family: Unspecified							

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Macroinvertebrate Results
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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station Number of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13
Decapoda (LPIL)		0%	0%	0%	0%	0%	0%
Family: Callianassidae							
Callianassa sp.		0%	0%	0%	0%	0%	0%
Callianassidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Epialtidae							
Pisinae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Paguridae							
Paguridae *zoea larva*		0%	0%	0%	0%	0%	0%
Paguristes sp.		0%	0%	0%	0%	0%	0%
Family: Porcellanidae							
Porcellanidae *zoea larva*		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Brachyura zoea larva		0%	0%	0%	0%	0%	0%
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		0%	0%	0%	0%	0%	0%
Anthuridae (LPIL)		5%	0%	0%	0%	0.85%	0%
Cyathura sp.		0%	0%	0%	0%	0.85%	0%
Family: Sphaeromatidae							
Cassidinidea sp.		0%	0%	0%	0%	2.56%	0%
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		0%	0%	0%	0%	0.85%	0%
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Metapseudidae							
Calozodion sp.		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Metapseudidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		0%	0%	0%	0%	0%	0%
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		0%	0%	0%	0%	0%	0%
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		0%	0%	0%	0%	0.85%	0%
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		0%	0%	0%	0%	0%	0%
Order: Heterostropha							

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Family: Pyramidellidae							
Pyramidellidae (LPIL)		0%	0%	0%	0%	1.71%	0%
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		0%	0%	0%	0%	0%	0%
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		0%	0%	0%	0%	0%	0%
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		0%	0%	0%	0%	0%	0%
Cerithiidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Calyptraeidae							
Calyptraea sp.		0%	0%	0%	0%	0%	0%
Crepidula sp.		0%	0%	0%	0%	0%	0%
Family: Cerithiidae							
Cerithium sp.		0%	6.67%	2.86%	54.05%	0.85%	0%
Family: Eulimidae							
Melanella sp.		0%	0%	0%	0%	0%	0%
Family: Hydrobiidae							
Hydrobiidae (LPIL)		0%	0%	0%	0%	0.85%	0%
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		0%	0%	2.86%	0%	7.69%	0%
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		5%	4.44%	2.86%	0%	16.24%	0%
Order: Arcoida							
Family: Arcidae							
Anadara sp.		0%	0%	0%	0%	0%	0%
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		0%	0%	0%	0%	0%	0%
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		0%	0%	14.29%	0%	0.85%	0%
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		0%	0%	0%	0%	0%	0%
Mytilidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		0%	0%	0%	0%	0%	0%
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		0%	0%	0%	0%	0%	0%

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		0%	0%	0%	0%	0%	0%
Family: Corbulidae							
Caryocorbula sp.		0%	0%	0%	0%	0%	0%
Corbula sp.		0%	0%	0%	0%	0%	0%
Corbulidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Lucinidae							
Lucinidae (LPIL)		0%	0%	0%	0%	0%	0%
Parvilucina sp.		0%	0%	0%	0%	0%	0%
Family: Mactridae							
Mactridae (LPIL)		0%	0%	0%	0%	0%	1.92%
Family: Montecutidae							
Mysella sp.		0%	0%	0%	0%	0%	0%
Family: Tellinidae							
Macoma sp.		5%	6.67%	0%	0%	0%	1.92%
Tellinidae (LPIL)		0%	0%	8.57%	0%	0%	0%
Family: Veneridae							
Veneridae (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		0%	0%	0%	0%	0%	0%
Amphioplus sp.		0%	0%	0%	0%	0%	0%
Amphiura sp.		0%	0%	0%	0%	0%	0%
Amphiuridae (LPIL)		0%	0%	0%	0%	0%	0%
Ophiophragmus sp.		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Bryozoa							

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		0%	0%	0%	0%	13.68%	0%
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		0%	0%	0%	0%	0%	0%
Total Percentage		100%	100%	100.02%	99.99%	99.93%	99.99%
Number of Taxa		7	7	10	7	25	6

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Report Date: 10/09/2013

Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Cliona sp.		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Demospongiae (LPIL)		0%	0%	0%	0%	0%	0.39%
Demospongiae boring (LPIL)		0%	0%	0%	0%	0%	0%
Demospongiae encrusting (LPIL)		0%	0%	0%	0%	0%	0%
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Porifera (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Anthoathecata (LPIL)		0%	0%	0%	0%	0%	0.39%
Order: Leptothecata							
Family: Aglaopheniidae							
Aglaopheniidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Campanulariidae							
Campanulariidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Lovenellidae							
Lovenellidae (LPIL)		0%	0%	0%	0%	40.43%	0%
Family: Sertulariidae							
Sertularia sp.		0%	0%	0%	0%	0%	0%
Sertulariidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Leptothecata (LPIL)		0%	0%	0%	0%	0%	0%
Plumulariidae (LPIL)		0%	0%	0%	0%	0%	0%
Order: Unspecified							
Family: Unspecified							
Hydroida (LPIL)		0%	0%	0%	0%	0%	0%
Hydroidolina (LPIL)		0%	0%	0%	0%	0%	0%
Hydrozoa (LPIL)		0%	0%	0%	0%	0%	0%
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Actiniaria (LPIL)		0%	0%	0%	0%	0%	0%
Order: Alcyonacea							
Family: Scleraxonia							
Scleraxonia (LPIL)		0%	0%	0%	0%	0%	2.34%
Order: Pennatulacea							
Family: Kophobelmnidae							
Kophobelemnon sp.		0%	0%	0%	0%	0%	0.78%

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	7BG	BG8	9BG	10BG	11BG	12BG
Station	7BG	BG8	9BG	10BG	11BG	12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Order: Scleractinia						
Family: Unspecified						
Scleractinia (LPIL)	0%	0%	0%	0%	2.13%	0.39%
Order: Unspecified						
Family: Unspecified						
Anthozoa (LPIL)	0%	0%	0%	0%	0%	0.39%
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)	0%	0%	0%	10.2%	0%	3.52%
Phylum: Sipuncula						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Sipuncula (LPIL)	0%	0%	0%	0%	0%	0%
Phylum: Annelida						
Class: Polychaeta						
Order: Amphinomida						
Family: Amphinomidae						
Amphinomidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Capitellida						
Family: Capitellidae						
Capitellidae (LPIL)	0%	0%	0%	0%	0%	3.13%
Capitobranchus sp.	0%	0%	0%	0%	0%	0%
Decamastus sp.	0%	0%	0%	0%	0%	0%
Heteromastus filiformis	0%	0%	0%	8.16%	0%	3.91%
Mediomastus sp.	0%	0%	0%	0%	0%	0%
Notomastus sp.	0%	0%	0%	0%	0%	0%
Family: Maldanidae						
Maldanidae (LPIL)	0%	0%	0%	0%	0%	1.95%
Order: Cossurida						
Family: Cossuridae						
Cossura delta	0%	0%	0%	0%	0%	0%
Order: Eunicida						
Family: Dorvilleidae						
Protodorvillea egena	0%	0%	0%	0%	0%	0%
Schistomeringos rudolphii	0%	0%	0%	0%	0%	0%
Family: Lumbrineridae						
Augeneria sp.	0%	0%	0%	0%	0%	0%
Lumbrineris meteorana	0%	0%	0%	0%	0%	0.39%
Scoletoma impatiens	0%	0%	0%	0%	0%	0%
Family: Oenonidae						
Oenonidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Onuphidae						
Diopatra sp.	0%	0%	0%	0%	0%	6.25%
Order: Opheliida						

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Report Date: 10/09/2013

Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Family: Opheliidae							
Armandia sp.		0%	0%	0%	0%	0%	0%
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		0%	0%	0%	0%	0%	0%
Scoloplos acmeceps		0%	0%	0%	0%	0%	0%
Scoloplos sp.		0%	0%	0%	6.12%	0%	1.95%
Family: Paraonidae							
Aricidea cerrutii		0%	0%	0%	0%	0%	0%
Aricidea fragilis		0%	0%	0%	0%	0%	0.39%
Aricidea simplex		0%	0%	0%	0%	0%	0%
Aricidea sp.		0%	0%	0%	0%	0%	0%
Aricidea wassi		0%	0%	0%	0%	0%	0%
Cirrophorus branchiatus		0%	0%	0%	0%	0%	0%
Levinsenia gracilis		0%	0%	0%	0%	0%	0%
Paraonidae (LPIL)		0%	0%	0%	0%	0%	0%
Paraonis fulgens		0%	0%	0%	0%	0%	0%
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		0%	0%	0%	0%	0%	0.39%
Glycera alba		0%	0%	0%	0%	0%	0.39%
Glycera sp.		0%	0%	0%	4.08%	0%	0.78%
Family: Goniadidae							
Glycinde kameruniana		0%	0%	0%	0%	0%	0%
Goniada multidentata		0%	0%	0%	0%	0%	0%
Goniada sp.		0%	0%	0%	0%	0%	0%
Goniadella sp.		0%	0%	0%	0%	0%	0%
Goniadidae (LPIL)		0%	0%	0%	2.04%	0%	0%
Family: Hesionidae							
Gyptis sp.		0%	0%	0%	0%	0%	0%
Kefersteinia sp.		0%	0%	0%	0%	0%	0.39%
Family: Nephtyidae							
Aglaophamus sp.		93.94%	66.67%	51.43%	0%	0%	0%
Micronephtys stammeri		0%	0%	0%	0%	0%	1.56%
Family: Nereididae							
Neanthes sp.		0%	0%	2.86%	0%	0%	0%
Nereididae (LPIL)		0%	16.67%	0%	0%	0%	0%
Nereis sp.		0%	0%	2.86%	0%	0%	0%
Family: Phyllodocidae							
Eteone sp.		0%	0%	0%	0%	0%	0.39%
Family: Pilargidae							
Ancistrosyllis sp.		0%	0%	0%	0%	0%	0%
Cabira sp.		0%	0%	0%	0%	0%	0%
Sigambra bassi		0%	0%	0%	0%	0%	0%
Sigambra sp.		3.03%	0%	0%	2.04%	0%	0.39%
Family: Polynoidae							
Malmgreniella sp.		0%	0%	0%	0%	0%	1.17%

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Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Family: Sphaerodoridae						
Ephesiella sp.	0%	0%	0%	0%	0%	0%
Family: Syllidae						
Eusyllis assimilis	0%	0%	0%	0%	0%	0%
Eusyllis sp.	0%	0%	0%	0%	0%	0%
Exogone sp.	0%	0%	0%	0%	0%	1.17%
Pionosyllis sp.	0%	0%	0%	0%	0%	0.39%
Sphaerosyllis sp.	0%	0%	0%	0%	0%	0%
Order: Sabellida						
Family: Oweniidae						
Galathowenia oculata	0%	0%	0%	0%	0%	0.39%
Galathowenia sp.	0%	0%	0%	0%	0%	0%
Family: Sabellariidae						
Sabellaria sp.	0%	0%	0%	0%	0%	0%
Sabellariidae (LPIL)	0%	0%	0%	0%	0%	0.39%
Order: Spionida						
Family: Chaetopteridae						
Spiochaetopterus sp.	0%	0%	0%	2.04%	0%	0%
Family: Magelonidae						
Magelona cincta	0%	0%	0%	0%	0%	1.17%
Magelona sp.	0%	0%	0%	0%	0%	0%
Family: Spionidae						
Minuspio sp.	0%	0%	2.86%	4.08%	0%	0%
Scolelepis sp.	0%	0%	0%	0%	0%	0.39%
Spionidae (LPIL)	0%	0%	0%	0%	0%	0.78%
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	0%	0%	0%	0%	0%	2.73%
Lysippe sp.	0%	0%	0%	0%	0%	0.39%
Family: Cirratulidae						
Aphelochaeta marioni	0%	0%	0%	0%	0%	0%
Aphelochaeta sp.	0%	0%	0%	0%	0%	2.34%
Cirratulidae (LPIL)	0%	0%	0%	0%	0%	1.17%
Monticellina sp.	0%	0%	0%	0%	0%	0.39%
Family: Terebellidae						
Eupolymnia sp.	0%	0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	0%	0%	0%	0%	0%	2.34%
Class: Clitellata						
Order: Haplotaxida						
Family: Enchytraeidae						
Enchytraeidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Naididae						
Naididae (LPIL)	0%	0%	0%	0%	0%	0%
Nais sp.	0%	0%	0%	6.12%	0%	0%
Family: Tubificoid Naididae						

Macroinvertebrate Results
Percent Occurrence (Pooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Tubificoid Naididae (LPIL)		0%	0%	40%	0%	0%	0.78%
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		0%	0%	0%	0%	0%	29.3%
Family: Aoridae							
Aoridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Bathyporeiidae							
Bathyporeia sp.		0%	0%	0%	0%	0%	0%
Family: Corophiidae							
Cheiriphotis sp		0%	0%	0%	0%	0%	0%
Corophiidae (LPIL)		0%	0%	0%	0%	0%	0.39%
Family: Dexaminidae							
Nototropis sp.		0%	0%	0%	0%	0%	0%
Family: Eriopisidae							
Eriopisella sp.		0%	0%	0%	0%	0%	0.78%
Family: Isaeida							
Isaeidae (LPIL)		0%	0%	0%	2.04%	0%	0%
Family: Ischyroceridae							
Ischyroceridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Liljeborgiidae							
Idunella sp.		0%	0%	0%	2.04%	0%	0%
Liljeborgiidae (LPIL)		0%	0%	0%	2.04%	0%	0%
Family: Lysianassidae							
Lysianassidae (LPIL)		0%	0%	0%	0%	0%	0.39%
Family: Oedicerotidae							
Oedicerotidae (LPIL)		0%	0%	0%	0%	0%	0%
Perioculodes sp.		0%	0%	0%	0%	0%	0%
Family: Photidae							
Photidae (LPIL)		0%	0%	0%	0%	0%	0.39%
Family: Phoxocephalidae							
Basuto stimpsoni		0%	0%	0%	0%	2.13%	0%
Family: Urothoidae							
Urothoe sp.		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Amphipoda (LPIL)		0%	0%	0%	4.08%	0%	1.95%
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		0%	0%	0%	0%	0%	0%
Bodotriidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Leuconidae							
Leuconidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Cumacea (LPIL)		0%	0%	0%	0%	0%	0%
Order: Decapoda							
Family: Unspecified							

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Decapoda (LPIL)		0%	0%	0%	0%	0%	0%
Family: Callianassidae							
Callianassa sp.		0%	0%	0%	0%	0%	0%
Callianassidae (LPIL)		0%	0%	0%	38.78%	0%	0.39%
Family: Epialtidae							
Pisinae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Paguridae							
Paguridae *zoea larva*		0%	0%	0%	0%	0%	0%
Paguristes sp.		0%	0%	0%	0%	0%	0%
Family: Porcellanidae							
Porcellanidae *zoea larva*		0%	0%	0%	0%	0%	0%
Family: Unspecified							
Brachyura zoea larva		0%	0%	0%	0%	2.13%	0%
Order: Isopoda							
Family: Anthuridae							
Amakusanthura sp.		0%	0%	0%	0%	0%	1.17%
Anthuridae (LPIL)		0%	0%	0%	0%	0%	0%
Cyathura sp.		0%	0%	0%	0%	0%	0%
Family: Sphaeromatidae							
Cassidinidea sp.		0%	0%	0%	0%	0%	0%
Order: Mysida							
Family: Unspecified							
Mysidacea (LPIL)		0%	0%	0%	0%	6.38%	0%
Order: Tanaidacea							
Family: Kalliapseudidae							
Kalliapseudidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Metapseudidae							
Calozodion sp.		0%	0%	0%	0%	0%	6.64%
Family: Unspecified							
Metapseudidae (LPIL)		0%	0%	0%	0%	0%	1.56%
Order: Unspecified							
Family: Unspecified							
Malacostraca (LPIL)		0%	0%	0%	0%	0%	0.39%
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Collembola (LPIL)		0%	16.67%	0%	0%	0%	0%
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Diptera (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							
Melanella sp.		0%	0%	0%	0%	0%	0%
Order: Heterostropha							

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	7BG	BG8	9BG	10BG	11BG	12BG
Station	7BG	BG8	9BG	10BG	11BG	12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Family: Pyramidellidae						
Pyramidellidae (LPIL)	0%	0%	0%	2.04%	0%	0%
Order: Littorinimorpha						
Family: Naticidae						
Sinum sp.	0%	0%	0%	0%	0%	0%
Order: Neogastropoda						
Family: Cystiscidae						
Plesiocystiscus sp.	0%	0%	0%	0%	0%	0%
Order: Neotaenioglossa						
Family: Caecidae						
Caecum sp.	0%	0%	0%	0%	0%	0%
Cerithiidae (LPIL)	0%	0%	0%	0%	0%	0%
Family: Calyptraeidae						
Calyptraea sp.	0%	0%	0%	0%	0%	0%
Crepidula sp.	0%	0%	0%	0%	0%	0.39%
Family: Cerithiidae						
Cerithium sp.	0%	0%	0%	0%	0%	0%
Family: Eulimidae						
Melanella sp.	0%	0%	0%	0%	0%	0%
Family: Hydrobiidae						
Hydrobiidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)	0%	0%	0%	0%	0%	1.17%
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)	0%	0%	0%	0%	2.13%	0.78%
Order: Arcoida						
Family: Arcidae						
Anadara sp.	0%	0%	0%	0%	0%	0%
Order: Carditoida						
Family: Carditidae						
Pleuromeris sp.	0%	0%	0%	0%	0%	0%
Order: Myoida						
Family: Myidae						
Myidae (LPIL)	0%	0%	0%	0%	0%	0%
Order: Mytiloida						
Family: Mytilidae						
Musculus sp.	0%	0%	0%	0%	0%	0%
Mytilidae (LPIL)	0%	0%	0%	2.04%	0%	0%
Order: Nuculoida						
Family: Nuculidae						
Nucula sp.	0%	0%	0%	0%	0%	0.39%
Order: Ostreoida						
Family: Anomiidae						
Anomia sp.	0%	0%	0%	0%	0%	0%

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Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		0%	0%	0%	0%	0%	0%
Family: Corbulidae							
Caryocorbula sp.		0%	0%	0%	0%	0%	0%
Corbula sp.		0%	0%	0%	0%	0%	0%
Corbulidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Lucinidae							
Lucinidae (LPIL)		0%	0%	0%	0%	0%	0%
Parvilucina sp.		0%	0%	0%	0%	0%	0%
Family: Mactridae							
Mactridae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Montecutidae							
Mysella sp.		0%	0%	0%	0%	0%	0%
Family: Tellinidae							
Macoma sp.		3.03%	0%	0%	0%	0%	0.78%
Tellinidae (LPIL)		0%	0%	0%	0%	0%	0%
Family: Veneridae							
Veneridae (LPIL)		0%	0%	0%	0%	0%	0.39%
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		0%	0%	0%	0%	0%	0%
Amphioplus sp.		0%	0%	0%	0%	0%	0.78%
Amphiura sp.		0%	0%	0%	0%	0%	0%
Amphiuridae (LPIL)		0%	0%	0%	0%	0%	1.56%
Ophiophragmus sp.		0%	0%	0%	0%	0%	0.39%
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		0%	0%	0%	0%	0%	0.39%
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		0%	0%	0%	0%	44.68%	0%
Phylum: Bryozoa							

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		0%	0%	0%	0%	0%	0%
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		0%	0%	0%	2.04%	0%	1.95%
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		0%	0%	0%	0%	0%	1.17%
Total Percentage		100%	100.01%	100.01%	99.98%	100.01%	99.94%
Number of Taxa		3	3	5	17	7	59

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Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Phylum: Porifera						
Class: Demospongiae						
Order: Hadromerida						
Family: Clionidae						
Cliona sp.		0%	0%	1.4%	0%	0%
Order: Unspecified						
Family: Unspecified						
Demospongiae (LPIL)		0%	0%	0.35%	0%	0%
Demospongiae boring (LPIL)		0%	0%	3.16%	0%	0%
Demospongiae encrusting (LPIL)		0%	0%	2.11%	0%	0%
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Porifera (LPIL)		0%	0%	0%	0%	0%
Phylum: Cnidaria						
Class: Hydrozoa						
Order: Anthoathecata						
Family: Unspecified						
Anthoathecata (LPIL)		0%	0%	4.91%	0.5%	0%
Order: Leptothecata						
Family: Aglaopheniidae						
Aglaopheniidae (LPIL)		0%	0%	0%	1.99%	0%
Family: Campanulariidae						
Campanulariidae (LPIL)		0%	0%	0%	0.5%	0%
Family: Lovenellidae						
Lovenellidae (LPIL)		0%	0%	6.67%	1.99%	8.04%
Family: Sertulariidae						
Sertularia sp.		0%	0%	0%	0.5%	0%
Sertulariidae (LPIL)		0%	0%	0%	2.49%	0%
Family: Unspecified						
Leptothecata (LPIL)		0%	0%	3.51%	1.49%	0%
Plumulariidae (LPIL)		0%	0%	0%	0.5%	0%
Order: Unspecified						
Family: Unspecified						
Hydroida (LPIL)		0%	0%	0%	1.49%	0%
Hydroidolina (LPIL)		0%	0%	0.35%	0%	0%
Hydrozoa (LPIL)		0%	0%	0%	1%	0%
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)		0%	0%	0%	0.5%	0%
Order: Alcyonacea						
Family: Scleraxonia						
Scleraxonia (LPIL)		0%	0.43%	0%	0%	0%
Order: Pennatulacea						
Family: Kophobelmnidae						
Kophobelemnon sp.		0%	0%	0%	0%	0%

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	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Order: Scleractinia						
Family: Unspecified						
Scleractinia (LPIL)		0%	0.43%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Anthozoa (LPIL)		0%	0%	0%	0%	0%
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)		16.67%	2.99%	6.67%	2.99%	2.68%
Phylum: Sipuncula						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Sipuncula (LPIL)		0%	0.21%	2.46%	0%	0%
Phylum: Annelida						
Class: Polychaeta						
Order: Amphinomida						
Family: Amphinomidae						
Amphinomidae (LPIL)		0%	0%	0.7%	0%	0%
Order: Capitellida						
Family: Capitellidae						
Capitellidae (LPIL)		0%	0%	0%	0%	0%
Capitobranchus sp.		0%	0.64%	0%	0%	0%
Decamastus sp.		0%	0%	0%	0%	0%
Heteromastus filiformis		0%	2.14%	0%	0%	4.46%
Mediomastus sp.		0%	0.43%	0%	0%	6.25%
Notomastus sp.		0%	0%	0%	0%	0%
Family: Maldanidae						
Maldanidae (LPIL)		0%	1.07%	0%	0%	0%
Order: Cossurida						
Family: Cossuridae						
Cossura delta		0%	0.21%	0%	0%	0%
Order: Eunicida						
Family: Dorvilleidae						
Protodorvillea egena		0%	0%	0%	0%	1.79%
Schistomeringos rudolphii		0%	0.21%	0%	0%	0%
Family: Lumbrineridae						
Augeneria sp.		0%	0.21%	0%	0%	0%
Lumbrineris meteorana		0%	0%	0%	0%	0%
Scoletoma impatiens		0%	0.21%	0%	0%	0%
Family: Oenonidae						
Oenonidae (LPIL)		0%	0.21%	0%	0%	0%
Family: Onuphidae						
Diopatra sp.		0%	0.43%	0.35%	0%	0%
Order: Opheliida						

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	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Family: Opheliidae						
Armandia sp.		0%	0%	0.35%	0%	5.36%
Order: Orbiniida						
Family: Orbiniidae						
Proscoloplos sp.		0%	2.14%	0%	0%	0%
Scoloplos acmeceps		0%	0.43%	0%	0%	0%
Scoloplos sp.		0%	1.5%	0%	0.5%	13.39%
Family: Paraonidae						
Aricidea cerrutii		0%	0%	0%	0%	0.89%
Aricidea fragilis		0%	0.43%	0%	0%	0%
Aricidea simplex		0%	0.21%	0%	0%	0%
Aricidea sp.		0%	0%	0%	0%	0.89%
Aricidea wassi		0%	0%	0%	0%	1.79%
Cirrophorus branchiatus		0%	0.64%	0%	0%	5.36%
Levinsenia gracilis		0%	0.21%	0%	0%	0%
Paraonidae (LPIL)		0%	0%	0%	0%	1.79%
Paraonis fulgens		0%	0%	0.35%	0%	0%
Order: Phyllodocida						
Family: Glyceridae						
Glycera africana		0%	0%	0%	0%	0.89%
Glycera alba		0%	0%	0%	1%	0.89%
Glycera sp.		0%	0.43%	0.35%	1.49%	1.79%
Family: Goniadidae						
Glycinde kameruniana		0%	0.64%	0%	0%	0%
Goniada multidentata		0%	0.43%	0%	0%	0%
Goniada sp.		0%	0%	0%	0.5%	0%
Goniadella sp.		0%	0%	0%	0.5%	0%
Goniadidae (LPIL)		0%	0%	0%	0%	0%
Family: Hesionidae						
Gyptis sp.		0%	0.21%	0%	0%	0%
Kefersteinia sp.		0%	0%	0%	0%	0%
Family: Nephtyidae						
Aglaophamus sp.		0%	0.21%	0%	0%	0%
Micronephtys stammeri		0%	0.43%	2.81%	2.49%	0.89%
Family: Nereididae						
Neanthes sp.		0%	0%	0%	0%	0%
Nereididae (LPIL)		0%	0%	0%	0%	0%
Nereis sp.		0%	0%	0%	0.5%	0%
Family: Phyllodocidae						
Eteone sp.		0%	0%	0%	0%	0%
Family: Pilargidae						
Ancistrosyllis sp.		0%	0%	0%	0%	1.79%
Cabira sp.		0%	0.21%	0%	0%	0%
Sigambra bassi		0%	0%	0%	0%	0%
Sigambra sp.		0%	0%	0%	0%	0%
Family: Polynoidae						
Malmgreniella sp.		0%	0.64%	1.4%	1%	0%

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	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Family: Sphaerodoridae						
Ephesiella sp.		0%	1.5%	0%	0%	0%
Family: Syllidae						
Eusyllis assimilis		0%	0.21%	0%	0%	0%
Eusyllis sp.		0%	0%	0%	0.5%	0%
Exogone sp.		0%	0%	0.35%	0.5%	0%
Pionosyllis sp.		0%	0%	0%	0%	0%
Sphaerosyllis sp.		0%	0%	0.35%	0.5%	0%
Order: Sabellida						
Family: Oweniidae						
Galathowenia oculata		0%	0%	0%	0%	0%
Galathowenia sp.		0%	0%	0%	0.5%	0%
Family: Sabellariidae						
Sabellaria sp.		0%	0%	0%	0.5%	0%
Sabellariidae (LPIL)		0%	0%	0%	0%	0%
Order: Spionida						
Family: Chaetopteridae						
Spiochaetopterus sp.		0%	0%	0%	0%	0%
Family: Magelonidae						
Magelona cincta		0%	0.43%	0%	0%	0.89%
Magelona sp.		0%	0%	0%	0%	0.89%
Family: Spionidae						
Minuspio sp.		0%	6.41%	1.75%	1.99%	0%
Scolelepis sp.		0%	0%	0%	0%	0%
Spionidae (LPIL)		0%	0%	0%	1%	0.89%
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.		0%	0%	0%	0%	0%
Lysippe sp.		0%	0%	0%	0%	0%
Family: Cirratulidae						
Aphelochaeta marioni		0%	0.43%	0%	0%	0%
Aphelochaeta sp.		0%	0%	0%	0%	0%
Cirratulidae (LPIL)		0%	0.21%	0.35%	0%	0.89%
Monticellina sp.		0%	0.64%	0%	0%	0%
Family: Terebellidae						
Eupolymnia sp.		0%	0.21%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)		0%	0%	0%	0%	0%
Class: Clitellata						
Order: Haplotaxida						
Family: Enchytraeidae						
Enchytraeidae (LPIL)		0%	0%	0%	0%	0.89%
Family: Naididae						
Naididae (LPIL)		0%	0%	0%	0%	0%
Nais sp.		0%	0%	0%	0%	0%
Family: Tubificoid Naididae						

Macroinvertebrate Results
Percent Occurrence (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Tubificoid Naididae (LPIL)		0%	0%	0%	0%	14.29%
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Ampeliscidae						
Ampelisca sp.		0%	0.21%	0%	0%	0%
Family: Aoridae						
Aoridae (LPIL)		0%	0%	0.35%	0%	0%
Family: Bathyporeiidae						
Bathyporeia sp.		0%	0%	0.35%	0%	0%
Family: Corophiidae						
Cheiriphotis sp		0%	0%	0.7%	0%	0%
Corophiidae (LPIL)		0%	0%	0.7%	0%	0%
Family: Dexaminidae						
Nototropis sp.		0%	0%	0%	0.5%	0%
Family: Eriopisidae						
Eriopisella sp.		0%	0%	0%	0.5%	0%
Family: Isaeida						
Isaeidae (LPIL)		0%	0%	0%	0%	0%
Family: Ischyroceridae						
Ischyroceridae (LPIL)		0%	0%	0.35%	0%	0%
Family: Liljeborgiidae						
Idunella sp.		0%	1.07%	0%	1.99%	0.89%
Liljeborgiidae (LPIL)		0%	0.21%	0%	0.5%	0.89%
Family: Lysianassidae						
Lysianassidae (LPIL)		0%	0%	0%	0%	0%
Family: Oedicerotidae						
Oedicerotidae (LPIL)		0%	0%	0%	0.5%	0%
Perioculodes sp.		0%	0%	0.35%	0%	0%
Family: Photidae						
Photidae (LPIL)		0%	0%	0%	0%	0%
Family: Phoxocephalidae						
Basuto stimpsoni		0%	0%	0%	0%	0%
Family: Urothoidae						
Urothoe sp.		0%	0%	0.35%	11.44%	0%
Family: Unspecified						
Amphipoda (LPIL)		0%	0%	0%	0%	0%
Order: Cumacea						
Family: Bodotriidae						
Apocuma sp.		0%	0.85%	0%	0%	0%
Bodotriidae (LPIL)		0%	0%	0%	1.49%	0%
Family: Leuconidae						
Leuconidae (LPIL)		0%	0%	0.7%	0%	0%
Family: Unspecified						
Cumacea (LPIL)		0%	0%	0.35%	0%	0%
Order: Decapoda						
Family: Unspecified						

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Decapoda (LPIL)		0%	0.43%	1.05%	0%	0%
Family: Callianassidae						
Callianassa sp.		0%	0.64%	0%	1%	0%
Callianassidae (LPIL)		0%	3.42%	0.7%	0%	0%
Family: Epialtidae						
Pisinae (LPIL)		0%	0%	0.35%	0%	0%
Family: Paguridae						
Paguridae *zoea larva*		16.67%	50%	0.35%	0%	0%
Paguristes sp.		0%	0%	0%	0%	0.89%
Family: Porcellanidae						
Porcellanidae *zoea larva*		16.67%	0.21%	0%	0%	0%
Family: Unspecified						
Brachyura zoea larva		16.67%	0.21%	5.96%	1%	0%
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.		0%	0%	0%	0%	0%
Anthuridae (LPIL)		0%	0.43%	0%	0%	0%
Cyathura sp.		0%	0%	0%	0%	0%
Family: Sphaeromatidae						
Cassidinidea sp.		0%	0%	0%	0%	0%
Order: Mysida						
Family: Unspecified						
Mysidacea (LPIL)		16.67%	0%	1.4%	0%	1.79%
Order: Tanaidacea						
Family: Kalliapseudidae						
Kalliapseudidae (LPIL)		0%	0%	0.35%	0%	0%
Family: Metapseudidae						
Calozodion sp.		0%	0%	0%	0%	0%
Family: Unspecified						
Metapseudidae (LPIL)		0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Malacostraca (LPIL)		0%	0%	0%	0%	0%
Class: Entognatha						
Order: Collembola						
Family: Unspecified						
Collembola (LPIL)		0%	0%	0%	0%	0%
Class: Insecta						
Order: Diptera						
Family: Unspecified						
Diptera (LPIL)		0%	0%	0%	0%	0%
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Eulimidae						
Melanella sp.		0%	0%	0%	0.5%	0%
Order: Heterostropha						

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Family: Pyramidellidae						
Pyramidellidae (LPIL)		0%	0%	0%	0.5%	0%
Order: Littorinimorpha						
Family: Naticidae						
Sinum sp.		0%	0%	1.05%	1.49%	0%
Order: Neogastropoda						
Family: Cystiscidae						
Plesiocystiscus sp.		0%	0%	0.35%	0%	0%
Order: Neotaenioglossa						
Family: Caecidae						
Caecum sp.		0%	0%	2.46%	4.48%	0%
Cerithiidae (LPIL)		0%	0.21%	0%	0%	0%
Family: Calyptraeidae						
Calyptraea sp.		0%	0.21%	0.35%	0%	0%
Crepidula sp.		0%	0%	0%	0%	0%
Family: Cerithiidae						
Cerithium sp.		0%	0%	0%	0%	0%
Family: Eulimidae						
Melanella sp.		0%	0%	1.05%	0%	0%
Family: Hydrobiidae						
Hydrobiidae (LPIL)		0%	0%	0%	0%	0%
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)		0%	0%	0.35%	0%	0.89%
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)		0%	0.43%	1.4%	0.5%	0.89%
Order: Arcoida						
Family: Arcidae						
Anadara sp.		0%	0%	0%	0%	0.89%
Order: Carditoida						
Family: Carditidae						
Pleuromeris sp.		0%	0%	0%	0%	5.36%
Order: Myoida						
Family: Myidae						
Myidae (LPIL)		0%	0%	0%	0%	0%
Order: Mytiloida						
Family: Mytilidae						
Musculus sp.		0%	0%	0.35%	0%	0%
Mytilidae (LPIL)		0%	0%	0%	0%	0%
Order: Nuculoida						
Family: Nuculidae						
Nucula sp.		0%	0%	0.7%	1.49%	0%
Order: Ostreoida						
Family: Anomiidae						
Anomia sp.		0%	0%	11.58%	0%	0%

Macroinvertebrate Results
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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Order: Veneroida						
Family: Unspecified						
Veneroida (LPIL)		0%	0.85%	0%	0%	0%
Family: Corbulidae						
Caryocorbula sp.		0%	0%	0.7%	1%	0.89%
Corbula sp.		0%	0%	4.91%	7.96%	0%
Corbulidae (LPIL)		0%	0.21%	0%	1.99%	0%
Family: Lucinidae						
Lucinidae (LPIL)		0%	0.21%	0%	0%	0%
Parvilucina sp.		0%	0.85%	0%	0%	0%
Family: Mactridae						
Mactridae (LPIL)		0%	0%	0%	0%	0%
Family: Montecutidae						
Mysella sp.		0%	0.43%	2.11%	4.98%	1.79%
Family: Tellinidae						
Macoma sp.		0%	0.43%	0%	1.99%	0%
Tellinidae (LPIL)		16.67%	0%	1.05%	0.5%	0%
Family: Veneridae						
Veneridae (LPIL)		0%	0%	0%	0%	0%
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)		0%	0.21%	0%	0%	0%
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiodia/Amphipholis complex		0%	2.14%	8.77%	12.44%	0%
Amphioplus sp.		0%	0%	0%	0%	0%
Amphiura sp.		0%	0%	0%	0%	0.89%
Amphiuridae (LPIL)		0%	5.13%	4.21%	8.46%	4.46%
Ophiophragmus sp.		0%	0%	0.35%	0%	0%
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)		0%	1.71%	1.4%	0%	0%
Phylum: Platyhelminthes						
Class: Rhabditophora						
Order: Polycladida						
Family: Unspecified						
Polycladida (LPIL)		0%	0%	0%	0.5%	0%
Phylum: Bryozoa						
Class: Gymnolaemata						
Order: Ctenostomatida						
Family: Unspecified						
Ctenostomatida (LPIL)		0%	0%	0%	0%	0%
Phylum: Bryozoa						

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Macroinvertebrate Results
Percent Occurrence (Pooled)

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Bryozoa (LPIL)		0%	0%	1.05%	1.99%	0%
Phylum: Chaetognatha						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Chaetognatha (LPIL)		0%	0.64%	0.7%	1%	1.79%
Phylum: Brachiopoda						
Class: Lingulata						
Order: Lingulida						
Family: Lingulidae						
Lingula sp.		0%	0%	0%	0%	0%
Total Percentage		100.02%	99.96%	99.95%	100.1%	99.99%
Number of Taxa		6	62	57	53	36

Macroinvertebrate Results
Summary Table (Pooled)

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	1BG	2BG	3BG	4BG	5BG	6BG	Mean Values
Station	1BG	2BG	3BG	4BG	5BG	6BG	
# of Replicates Pooled	3	3	3	3	3	3	
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13	
Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	14	0	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.4%
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	1	0	0	0
Number of Organisms per M^2	0	0	0	14	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2.7%	0.0%	0.0%	0.2%
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	14
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Leptothecata							
Family: Aglaopheniidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Campanulariidae							
Number of Taxa	0	0	1	0	0	0	0
Number of Organisms per M^2	0	0	14	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	50%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.2%
Family: Lovenellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	43
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.4%
Family: Sertulariidae							
Number of Taxa	0	0	0	0	0	0	0

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Taxonomic Classification	Station # of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Number of Organisms per M^2		0	0	0	0	0	0	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	12
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	72	0	9
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	45.5%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	4.3%	0.0%	0.4%
Class: Anthozoa								
Order: Actiniaria								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Alcyonacea								
Family: Scleraxonia								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Pennatulacea								
Family: Kophobelmnidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Scleractinia								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Phylum: Nemertea								
Class: Unspecified								

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Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	43	0	51
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	5%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	2.6%	0.0%	2.8%
Phylum: Sipuncula								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Annelida								
Class: Polychaeta								
Order: Amphinomida								
Family: Amphinomidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Capitellida								
Family: Capitellidae								
Number of Taxa		1	1	1	2	3	1	1
Number of Organisms per M^2		57	86	101	101	144	158	79
% Organisms (Sample Group)		4.3%	6.4%	7.4%	7.4%	10.6%	11.7%	N/A
% Organisms (This Station)		20%	13.3%	20%	18.9%	8.5%	21.2%	7.7%
Family: Maldanidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Cossurida								
Family: Cossuridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Eunicida								
Family: Dorvilleidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Lumbrineridae								
Number of Taxa		0	0	0	0	0	0	0

Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Oenonidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Onuphidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	16
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Order: Opheliida							
Family: Opheliidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	6
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Orbiniida							
Family: Orbiniidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	36
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%
Family: Paraonidae							
Number of Taxa	0	0	0	0	0	0	1
Number of Organisms per M^2	0	0	0	0	0	0	18
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
Order: Phyllodocida							
Family: Glyceridae							
Number of Taxa	0	0	0	0	0	0	1
Number of Organisms per M^2	0	0	0	0	0	0	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Family: Goniadidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Hesionidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Nephtyidae							

Macroinvertebrate Results
Summary Table (Pooled)

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Number of Taxa		0	0	1	0	1	1	1
Number of Organisms per M^2		0	0	115	0	72	273	90
% Organisms (Sample Group)		0.0%	0.0%	7.5%	0.0%	4.7%	17.9%	N/A
% Organisms (This Station)		0.0%	0.0%	22.9%	0.0%	4.3%	36.5%	16.7%
Family: Nereididae								
Number of Taxa		0	0	0	1	1	0	0
Number of Organisms per M^2		0	0	0	14	43	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	12.5%	37.5%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2.7%	2.6%	0.0%	1.7%
Family: Phyllodocidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Pilargidae								
Number of Taxa		1	1	1	1	2	1	1
Number of Organisms per M^2		14	14	57	57	216	244	41
% Organisms (Sample Group)		2.1%	2.1%	8.3%	8.3%	31.3%	35.4%	N/A
% Organisms (This Station)		5%	2.2%	11.4%	10.8%	12.8%	32.7%	4.8%
Family: Polynoidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	10
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Sphaerodoridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Syllidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Sabellida								
Family: Oweniidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Sabellariidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Spionida								
Family: Chaetopteridae								

Macroinvertebrate Results
Summary Table (Pooled)

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Magelonidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	6
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Spionidae							
Number of Taxa	0	0	0	0	0	0	1
Number of Organisms per M^2	0	0	0	0	0	0	41
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
Order: Terebellida							
Family: Ampharetidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Cirratulidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	15
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Terebellidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Naididae							
Number of Taxa	1	2	0	0	0	0	0
Number of Organisms per M^2	57	431	0	0	0	0	31
% Organisms (Sample Group)	10.8%	81.1%	0.0%	0.0%	0.0%	0.0%	N/A

Macroinvertebrate Results
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Sample Method: Petite Ponar
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% Organisms (This Station)	20%	66.7%	0.0%	0.0%	0.0%	0.0%	5.5%
Family: Tubificoid Naididae							
Number of Taxa	1	0	1	1	1	1	0
Number of Organisms per M^2	115	0	57	57	244	43	57
% Organisms (Sample Group)	11.8%	0.0%	5.9%	5.9%	25%	4.4%	N/A
% Organisms (This Station)	40%	0.0%	11.4%	10.8%	14.5%	5.8%	8.1%
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	64
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%
Family: Aoridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Bathyporeiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Corophiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	4
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Dexaminidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Eriopisidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Isaeida							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Ischyroceridae							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	14	0	2

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% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	50%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.1%
Family: Liljeborgiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	13
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
Family: Lysianassidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Oedicerotidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Photidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Phoxocephalidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Urothoidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	20
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Family: Unspecified							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	14	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	12.5%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.4%
Order: Cumacea							
Family: Bodotriidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	6
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Leuconidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Decapoda							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	23
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%
Family: Callianassidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	36
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%
Family: Epialtidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Paguridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	200
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%
Family: Porcellanidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	23
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%
Order: Isopoda							
Family: Anthuridae							
Number of Taxa	1	0	0	0	2	0	0
Number of Organisms per M^2	14	0	0	0	29	0	7
% Organisms (Sample Group)	12.5%	0.0%	0.0%	0.0%	25%	0.0%	N/A
% Organisms (This Station)	5%	0.0%	0.0%	0.0%	1.7%	0.0%	0.5%
Family: Sphaeromatidae							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	43	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A

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Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	2.6%	0.0%	0.2%
Order: Mysida								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	14	0	9
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	9.1%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	1.6%
Order: Tanaidacea								
Family: Kalliapseudidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Metapseudidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class: Entognatha								
Order: Collembola								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Class: Insecta								
Order: Diptera								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	14	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.1%
Phylum: Mollusca								
Class: Gastropoda								
Order: Caenogastropoda								
Family: Eulimidae								

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Heterostropha							
Family: Pyramidellidae							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	29	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	50%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.2%
Order: Littorinimorpha							
Family: Naticidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Neogastropoda							
Family: Cystiscidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Neotaenioglossa							
Family: Caecidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	14
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Calyptraeidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Cerithiidae							
Number of Taxa	0	1	1	1	1	0	0
Number of Organisms per M^2	0	43	14	287	14	0	21
% Organisms (Sample Group)	0.0%	12%	4%	80%	4%	0.0%	N/A
% Organisms (This Station)	0.0%	6.7%	2.9%	54.1%	0.9%	0.0%	3.8%
Family: Eulimidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Hydrobiidae							
Number of Taxa	0	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	0	14	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A

Macroinvertebrate Results
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Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	1	0	1	0	0
Number of Organisms per M^2	0	0	14	0	129	0	13
% Organisms (Sample Group)	0.0%	0.0%	6.7%	0.0%	60%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	2.9%	0.0%	7.7%	0.0%	0.8%
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	1	1	1	0	1	0	1
Number of Organisms per M^2	14	29	14	0	273	0	29
% Organisms (Sample Group)	2.9%	5.9%	2.9%	0.0%	55.9%	0.0%	N/A
% Organisms (This Station)	5%	4.4%	2.9%	0.0%	16.2%	0.0%	2.0%
Order: Arcoida							
Family: Arcidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Carditoida							
Family: Carditidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Myoida							
Family: Myidae							
Number of Taxa	0	0	1	0	1	0	0
Number of Organisms per M^2	0	0	72	0	14	0	5
% Organisms (Sample Group)	0.0%	0.0%	83.3%	0.0%	16.7%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	14.3%	0.0%	0.9%	0.0%	0.9%
Order: Mytiloida							
Family: Mytilidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Nuculoida							
Family: Nuculidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Ostreoida							
Family: Anomiidae							
Number of Taxa	0	0	0	0	0	0	0

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Number of Organisms per M^2		0	0	0	0	0	0	28
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Order: Veneroida								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Corbulidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	34
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Family: Lucinidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	4
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Mactridae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.1%
Family: Montecutidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	17
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
Family: Tellinidae								
Number of Taxa		1	1	1	0	0	1	1
Number of Organisms per M^2		14	43	43	0	0	14	19
% Organisms (Sample Group)		4.5%	13.6%	13.6%	0.0%	0.0%	4.5%	N/A
% Organisms (This Station)		5%	6.7%	8.6%	0.0%	0.0%	1.9%	2.7%
Family: Veneridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Phylum: Phoronida								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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Taxonomic Classification	Station # of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Phylum: Echinodermata								
Class: Ophiuroidea								
Order: Ophiurida								
Family: Amphiuridae								
Number of Taxa		0	0	0	0	0	0	1
Number of Organisms per M^2		0	0	0	0	0	0	107
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	11
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Platyhelminthes								
Class: Rhabditophora								
Order: Polycladida								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Phylum: Bryozoa								
Class: Gymnolaemata								
Order: Ctenostomatida								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	18
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%
Phylum: Bryozoa								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	230	0	19
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	69.6%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	13.7%	0.0%	1.0%
Phylum: Chaetognatha								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	13
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
Phylum: Brachiopoda								

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	1BG 3 08/15/13	2BG 3 08/15/13	3BG 3 08/17/13	4BG 3 08/17/13	5BG 3 08/16/13	6BG 3 08/16/13	Mean Values
Class: Lingulata								
Order: Lingulida								
Family: Lingulidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Total Taxa		7	7	10	7	25	6	22
Total Organisms per M^2		287	647	503	532	1681	747	1525
% Organisms (Sample Group)		1.1%	2.5%	1.9%	2.1%	6.5%	2.9%	N/A

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Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
Phylum: Porifera								
Class: Demospongiae								
Order: Hadromerida								
Family: Clionidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	15
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	5.6%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Cnidaria								
Class: Hydrozoa								
Order: Anthoathecata								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%
Order: Leptothecata								
Family: Aglaopheniidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Campanulariidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Lovenellidae								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	273	0	43
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	37.3%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	40.4%	0.0%	3.4%
Family: Sertulariidae								
Number of Taxa		0	0	0	0	0	0	0

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	12
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	9
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Alcyonacea							
Family: Scleraxonia							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	86	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	75%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%	0.2%
Order: Pennatulacea							
Family: Kophobelmnidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	29	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%
Order: Scleractinia							
Family: Unspecified							
Number of Taxa	0	0	0	0	1	1	0
Number of Organisms per M^2	0	0	0	0	14	14	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	25%	25%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.1%	0.4%	0.2%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Phylum: Nemertea							
Class: Unspecified							

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Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	1	0	1	0
Number of Organisms per M^2		0	0	0	72	0	129	51
% Organisms (Sample Group)		0.0%	0.0%	0.0%	8.3%	0.0%	15%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	10.2%	0.0%	3.5%	2.8%
Phylum: Sipuncula								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Annelida								
Class: Polychaeta								
Order: Amphinomida								
Family: Amphinomidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Capitellida								
Family: Capitellidae								
Number of Taxa		0	0	0	1	0	2	1
Number of Organisms per M^2		0	0	0	57	0	259	79
% Organisms (Sample Group)		0.0%	0.0%	0.0%	4.3%	0.0%	19.1%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	8.2%	0.0%	7%	7.7%
Family: Maldanidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	72	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	2%	0.2%
Order: Cossurida								
Family: Cossuridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Eunicida								
Family: Dorvilleidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Lumbrineridae								
Number of Taxa		0	0	0	0	0	1	0

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Taxonomic Classification	Station # of Replicates Pooled Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
Number of Organisms per M^2		0	0	0	0	0	14	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Family: Oenonidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Onuphidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	230	16
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	84.2%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	0.4%
Order: Opheliida								
Family: Opheliidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Orbiniida								
Family: Orbiniidae								
Number of Taxa		0	0	0	1	0	1	0
Number of Organisms per M^2		0	0	0	43	0	72	36
% Organisms (Sample Group)		0.0%	0.0%	0.0%	7%	0.0%	11.6%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	6.1%	0.0%	2%	1.5%
Family: Paraonidae								
Number of Taxa		0	0	0	0	0	1	1
Number of Organisms per M^2		0	0	0	0	0	14	18
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.8%
Order: Phyllodocida								
Family: Glyceridae								
Number of Taxa		0	0	0	1	0	3	1
Number of Organisms per M^2		0	0	0	29	0	57	15
% Organisms (Sample Group)		0.0%	0.0%	0.0%	11.1%	0.0%	22.2%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	4.1%	0.0%	1.6%	0.7%
Family: Goniadidae								
Number of Taxa		0	0	0	1	0	0	0
Number of Organisms per M^2		0	0	0	14	0	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	12.5%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2%	0.0%	0.0%	0.2%
Family: Hesionidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Family: Nephtyidae								

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Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
Number of Taxa		1	1	1	0	0	1	1
Number of Organisms per M^2		445	57	259	0	0	57	90
% Organisms (Sample Group)		29.2%	3.8%	17%	0.0%	0.0%	3.8%	N/A
% Organisms (This Station)		93.9%	66.7%	51.4%	0.0%	0.0%	1.6%	16.7%
Family: Nereididae								
Number of Taxa		0	1	2	0	0	0	0
Number of Organisms per M^2		0	14	29	0	0	0	7
% Organisms (Sample Group)		0.0%	12.5%	25%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	16.7%	5.7%	0.0%	0.0%	0.0%	1.7%
Family: Phyllodocidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Family: Pilargidae								
Number of Taxa		1	0	0	1	0	1	1
Number of Organisms per M^2		14	0	0	14	0	14	41
% Organisms (Sample Group)		2.1%	0.0%	0.0%	2.1%	0.0%	2.1%	N/A
% Organisms (This Station)		3%	0.0%	0.0%	2%	0.0%	0.4%	4.8%
Family: Polynoidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	43	10
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	25%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.2%
Family: Sphaerodoridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Syllidae								
Number of Taxa		0	0	0	0	0	2	0
Number of Organisms per M^2		0	0	0	0	0	57	8
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	40%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.2%
Order: Sabellida								
Family: Oweniidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%
Family: Sabellariidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	50%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%
Order: Spionida								
Family: Chaetopteridae								

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Number of Taxa		0	0	0	1	0	0	0
Number of Organisms per M^2		0	0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2%	0.0%	0.0%	0.1%
Family: Magelonidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	43	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	42.9%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.2%
Family: Spionidae								
Number of Taxa		0	0	1	1	0	2	1
Number of Organisms per M^2		0	0	14	29	0	43	41
% Organisms (Sample Group)		0.0%	0.0%	2.1%	4.2%	0.0%	6.3%	N/A
% Organisms (This Station)		0.0%	0.0%	2.9%	4.1%	0.0%	1.2%	1.2%
Order: Terebellida								
Family: Ampharetidae								
Number of Taxa		0	0	0	0	0	2	0
Number of Organisms per M^2		0	0	0	0	0	115	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	0.2%
Family: Cirratulidae								
Number of Taxa		0	0	0	0	0	3	0
Number of Organisms per M^2		0	0	0	0	0	144	15
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	55.6%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	0.4%
Family: Terebellidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	86	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	2.3%	0.1%
Class: Clitellata								
Order: Haplotaxida								
Family: Enchytraeidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Naididae								
Number of Taxa		0	0	0	1	0	0	0
Number of Organisms per M^2		0	0	0	43	0	0	31
% Organisms (Sample Group)		0.0%	0.0%	0.0%	8.1%	0.0%	0.0%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

water & air RESEARCH, INC.
6821 SW Archer Road
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Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	6.1%	0.0%	0.0%	5.5%
Family: Tubificoid Naididae							
Number of Taxa	0	0	1	0	0	1	0
Number of Organisms per M^2	0	0	201	0	0	29	57
% Organisms (Sample Group)	0.0%	0.0%	20.6%	0.0%	0.0%	2.9%	N/A
% Organisms (This Station)	0.0%	0.0%	40%	0.0%	0.0%	0.8%	8.1%
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	1078	64
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	98.7%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	29.3%	1.7%
Family: Aoridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Bathyporeiidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Corophiidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	4
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	20%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%
Family: Dexaminidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Eriopisidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	29	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	66.7%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.1%
Family: Isaeida							
Number of Taxa	0	0	0	1	0	0	0
Number of Organisms per M^2	0	0	0	14	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2%	0.0%	0.0%	0.1%
Family: Ischyroceridae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	2

Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Liljeborgiidae								
Number of Taxa		0	0	0	2	0	0	0
Number of Organisms per M^2		0	0	0	29	0	0	13
% Organisms (Sample Group)		0.0%	0.0%	0.0%	13.3%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	4.1%	0.0%	0.0%	0.6%
Family: Lysianassidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Family: Oedicerotidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Photidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Family: Phoxocephalidae								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	14	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.1%
Family: Urothoidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	20
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Family: Unspecified								
Number of Taxa		0	0	0	1	0	1	0
Number of Organisms per M^2		0	0	0	29	0	72	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	25%	0.0%	62.5%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	4.1%	0.0%	2%	0.4%
Order: Cumacea								
Family: Bodotriidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	6
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Leuconidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Decapoda								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	14	0	23
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	3.7%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	1.6%
Family: Callianassidae								
Number of Taxa		0	0	0	1	0	1	0
Number of Organisms per M^2		0	0	0	273	0	14	36
% Organisms (Sample Group)		0.0%	0.0%	0.0%	44.2%	0.0%	2.3%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	38.8%	0.0%	0.4%	2.6%
Family: Epialtidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Paguridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	200
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%
Family: Porcellanidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	14	0	23
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	3.7%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	1.6%
Order: Isopoda								
Family: Anthuridae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	43	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	37.5%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.5%
Family: Sphaeromatidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

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Sample Method: Petite Ponar
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Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Mysida								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	43	0	9
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	27.3%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	1.6%
Order: Tanaidacea								
Family: Kalliapseudidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Metapseudidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	244	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.4%
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	57	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.1%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Class: Entognatha								
Order: Collembola								
Family: Unspecified								
Number of Taxa		0	1	0	0	0	0	0
Number of Organisms per M^2		0	14	0	0	0	0	1
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	16.7%	0.0%	0.0%	0.0%	0.0%	1.0%
Class: Insecta								
Order: Diptera								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Mollusca								
Class: Gastropoda								
Order: Caenogastropoda								
Family: Eulimidae								

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Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Heterostropha								
Family: Pyramidellidae								
Number of Taxa		0	0	0	1	0	0	0
Number of Organisms per M^2		0	0	0	14	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	25%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2%	0.0%	0.0%	0.2%
Order: Littorinimorpha								
Family: Naticidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Neogastropoda								
Family: Cystiscidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Neotaenioglossa								
Family: Caecidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Calyptraeidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%
Family: Cerithiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	21
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.8%
Family: Eulimidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Hydrobiidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

Macroinvertebrate Results
Summary Table (Pooled)

water & air RESEARCH, INC.
6821 SW Archer Road
Gainesville, FL 32608
www.waterandair.com

Prepared For: Golder Associates, Inc.
Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	43	13
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	20%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.8%
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Number of Taxa	0	0	0	0	1	1	1
Number of Organisms per M^2	0	0	0	0	14	29	29
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	2.9%	5.9%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	2.1%	0.8%	2.0%
Order: Arcoida							
Family: Arcidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Carditoida							
Family: Carditidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Order: Myoida							
Family: Myidae							
Number of Taxa	0	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Order: Mytiloida							
Family: Mytilidae							
Number of Taxa	0	0	0	1	0	0	0
Number of Organisms per M^2	0	0	0	14	0	0	2
% Organisms (Sample Group)	0.0%	0.0%	0.0%	50%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	2%	0.0%	0.0%	0.1%
Order: Nuculoida							
Family: Nuculidae							
Number of Taxa	0	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	0	14	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.2%
Order: Ostreoida							
Family: Anomiidae							
Number of Taxa	0	0	0	0	0	0	0

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Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	7BG 3 08/19/13	BG8 3 08/19/13	9BG 3 08/22/13	10BG 3 08/22/13	11BG 3 08/24/13	12BG 3 08/24/13	Mean Values
Number of Organisms per M^2		0	0	0	0	0	0	28
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Order: Veneroida								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Corbulidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	34
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Family: Lucinidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	4
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Mactridae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Montecutidae								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	17
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
Family: Tellinidae								
Number of Taxa		1	0	0	0	0	1	1
Number of Organisms per M^2		14	0	0	0	0	29	19
% Organisms (Sample Group)		4.5%	0.0%	0.0%	0.0%	0.0%	9.1%	N/A
% Organisms (This Station)		3%	0.0%	0.0%	0.0%	0.0%	0.8%	2.7%
Family: Veneridae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
Phylum: Phoronida								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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Sample Method: Petite Ponar
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Phylum: Echinodermata								
Class: Ophiuroidea								
Order: Ophiurida								
Family: Amphiuridae								
Number of Taxa		0	0	0	0	0	3	1
Number of Organisms per M^2		0	0	0	0	0	101	107
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	5.5%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	2.9%
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	14	11
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	7.7%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.2%
Phylum: Platyhelminthes								
Class: Rhabditophora								
Order: Polycladida								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Phylum: Bryozoa								
Class: Gymnolaemata								
Order: Ctenostomatida								
Family: Unspecified								
Number of Taxa		0	0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	0	302	0	18
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	44.7%	0.0%	2.6%
Phylum: Bryozoa								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	0	19
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Phylum: Chaetognatha								
Class: Unspecified								
Order: Unspecified								
Family: Unspecified								
Number of Taxa		0	0	0	1	0	1	0
Number of Organisms per M^2		0	0	0	14	0	72	13
% Organisms (Sample Group)		0.0%	0.0%	0.0%	6.7%	0.0%	33.3%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2%	0.0%	2%	0.5%
Phylum: Brachiopoda								

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Class: Lingulata								
Order: Lingulida								
Family: Lingulidae								
Number of Taxa		0	0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	0	43	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.1%
Total Taxa		3	3	5	17	7	59	22
Total Organisms per M^2		474	86	503	704	675	3678	1525
% Organisms (Sample Group)		1.8%	0.3%	1.9%	2.7%	2.6%	14.2%	N/A

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Phylum: Porifera							
Class: Demospongiae							
Order: Hadromerida							
Family: Clionidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	57	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1.4%	0.0%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	3	0	0	0
Number of Organisms per M^2		0	0	230	0	0	15
% Organisms (Sample Group)		0.0%	0.0%	88.9%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	5.6%	0.0%	0.0%	0.4%
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Phylum: Cnidaria							
Class: Hydrozoa							
Order: Anthoathecata							
Family: Unspecified							
Number of Taxa		0	0	1	1	0	0
Number of Organisms per M^2		0	0	201	14	0	14
% Organisms (Sample Group)		0.0%	0.0%	87.5%	6.3%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	4.9%	0.5%	0.0%	0.3%
Order: Leptothecata							
Family: Aglaopheniidae							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	57	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	2%	0.0%	0.1%
Family: Campanulariidae							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	50%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.2%
Family: Lovenellidae							
Number of Taxa		0	0	1	1	1	0
Number of Organisms per M^2		0	0	273	57	129	43
% Organisms (Sample Group)		0.0%	0.0%	37.3%	7.8%	17.6%	N/A
% Organisms (This Station)		0.0%	0.0%	6.7%	2%	8%	3.4%
Family: Sertulariidae							
Number of Taxa		0	0	0	2	0	0

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Number of Organisms per M^2		0	0	0	86	0	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	3%	0.0%	0.2%
Family: Unspecified							
Number of Taxa		0	0	1	2	0	0
Number of Organisms per M^2		0	0	144	57	0	12
% Organisms (Sample Group)		0.0%	0.0%	71.4%	28.6%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	3.5%	2%	0.0%	0.3%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	1	2	0	0
Number of Organisms per M^2		0	0	14	72	0	9
% Organisms (Sample Group)		0.0%	0.0%	9.1%	45.5%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	2.5%	0.0%	0.4%
Class: Anthozoa							
Order: Actiniaria							
Family: Unspecified							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Order: Alcyonacea							
Family: Scleraxonia							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	29	0	0	0	7
% Organisms (Sample Group)		0.0%	25%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.4%	0.0%	0.0%	0.0%	0.2%
Order: Pennatulacea							
Family: Kophobelmnidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Order: Scleractinia							
Family: Unspecified							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	29	0	0	0	3
% Organisms (Sample Group)		0.0%	50%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.4%	0.0%	0.0%	0.0%	0.2%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Phylum: Nemertea							
Class: Unspecified							

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Order: Unspecified							
Family: Unspecified							
Number of Taxa		1	1	1	1	1	0
Number of Organisms per M^2		14	201	273	86	43	51
% Organisms (Sample Group)		1.7%	23.3%	31.7%	10%	5%	N/A
% Organisms (This Station)		16.7%	3%	6.7%	3%	2.7%	2.8%
Phylum: Sipuncula							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	1	0	0	0
Number of Organisms per M^2		0	14	101	0	0	7
% Organisms (Sample Group)		0.0%	12.5%	87.5%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	2.5%	0.0%	0.0%	0.2%
Phylum: Annelida							
Class: Polychaeta							
Order: Amphinomida							
Family: Amphinomidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	29	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.7%	0.0%	0.0%	0.0%
Order: Capitellida							
Family: Capitellidae							
Number of Taxa		0	3	0	0	2	1
Number of Organisms per M^2		0	216	0	0	172	79
% Organisms (Sample Group)		0.0%	16%	0.0%	0.0%	12.8%	N/A
% Organisms (This Station)		0.0%	3.2%	0.0%	0.0%	10.7%	7.7%
Family: Maldanidae							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	72	0	0	0	8
% Organisms (Sample Group)		0.0%	50%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	1.1%	0.0%	0.0%	0.0%	0.2%
Order: Cossurida							
Family: Cossuridae							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	14	0	0	0	1
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Order: Eunicida							
Family: Dorvilleidae							
Number of Taxa		0	1	0	0	1	0
Number of Organisms per M^2		0	14	0	0	29	3
% Organisms (Sample Group)		0.0%	33.3%	0.0%	0.0%	66.7%	N/A
% Organisms (This Station)		0.0%	0.2%	0.0%	0.0%	1.8%	0.1%
Family: Lumbrineridae							
Number of Taxa		0	2	0	0	0	0

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Sample Method: Petite Ponar
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Taxonomic Classification	Station # of Replicates Pooled Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
Number of Organisms per M^2		0	29	0	0	0	3
% Organisms (Sample Group)		0.0%	66.7%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
Family: Oenonidae							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	14	0	0	0	1
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Family: Onuphidae							
Number of Taxa		0	1	1	0	0	0
Number of Organisms per M^2		0	29	14	0	0	16
% Organisms (Sample Group)		0.0%	10.5%	5.3%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.4%	0.4%	0.0%	0.0%	0.4%
Order: Opheliida							
Family: Opheliidae							
Number of Taxa		0	0	1	0	1	0
Number of Organisms per M^2		0	0	14	0	86	6
% Organisms (Sample Group)		0.0%	0.0%	14.3%	0.0%	85.7%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	5.4%	0.3%
Order: Orbiniida							
Family: Orbiniidae							
Number of Taxa		0	3	0	1	1	0
Number of Organisms per M^2		0	273	0	14	216	36
% Organisms (Sample Group)		0.0%	44.2%	0.0%	2.3%	34.9%	N/A
% Organisms (This Station)		0.0%	4.1%	0.0%	0.5%	13.4%	1.5%
Family: Paraonidae							
Number of Taxa		0	4	1	0	5	1
Number of Organisms per M^2		0	101	14	0	172	18
% Organisms (Sample Group)		0.0%	33.3%	4.8%	0.0%	57.1%	N/A
% Organisms (This Station)		0.0%	1.5%	0.4%	0.0%	10.7%	0.8%
Order: Phyllodocida							
Family: Glyceridae							
Number of Taxa		0	1	1	2	3	1
Number of Organisms per M^2		0	29	14	72	57	15
% Organisms (Sample Group)		0.0%	11.1%	5.6%	27.8%	22.2%	N/A
% Organisms (This Station)		0.0%	0.4%	0.4%	2.5%	3.6%	0.7%
Family: Goniadidae							
Number of Taxa		0	2	0	2	0	0
Number of Organisms per M^2		0	72	0	29	0	7
% Organisms (Sample Group)		0.0%	62.5%	0.0%	25%	0.0%	N/A
% Organisms (This Station)		0.0%	1.1%	0.0%	1%	0.0%	0.2%
Family: Hesionidae							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	14	0	0	0	2
% Organisms (Sample Group)		0.0%	50%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Family: Nephtyidae							

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Macroinvertebrate Results
Summary Table (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
Number of Taxa		0	2	1	1	1	1
Number of Organisms per M^2		0	43	115	72	14	90
% Organisms (Sample Group)		0.0%	2.8%	7.5%	4.7%	0.9%	N/A
% Organisms (This Station)		0.0%	0.6%	2.8%	2.5%	0.9%	16.7%
Family: Nereididae							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	12.5%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	1.7%
Family: Phyllodocidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Pilargidae							
Number of Taxa		0	1	0	0	1	1
Number of Organisms per M^2		0	14	0	0	29	41
% Organisms (Sample Group)		0.0%	2.1%	0.0%	0.0%	4.2%	N/A
% Organisms (This Station)		0.0%	0.2%	0.0%	0.0%	1.8%	4.8%
Family: Polynoidae							
Number of Taxa		0	1	1	1	0	0
Number of Organisms per M^2		0	43	57	29	0	10
% Organisms (Sample Group)		0.0%	25%	33.3%	16.7%	0.0%	N/A
% Organisms (This Station)		0.0%	0.6%	1.4%	1%	0.0%	0.2%
Family: Sphaerodoridae							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	101	0	0	0	6
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	1.5%	0.0%	0.0%	0.0%	0.1%
Family: Syllidae							
Number of Taxa		0	1	2	3	0	0
Number of Organisms per M^2		0	14	29	43	0	8
% Organisms (Sample Group)		0.0%	10%	20%	30%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	0.7%	1.5%	0.0%	0.2%
Order: Sabellida							
Family: Oweniidae							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	50%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.1%
Family: Sabellariidae							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	2
% Organisms (Sample Group)		0.0%	0.0%	0.0%	50%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.1%
Order: Spionida							
Family: Chaetopteridae							

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Taxonomic Classification / Station / # of Replicates Pooled / Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Magelonidae						
Number of Taxa	0	1	0	0	2	0
Number of Organisms per M^2	0	29	0	0	29	6
% Organisms (Sample Group)	0.0%	28.6%	0.0%	0.0%	28.6%	N/A
% Organisms (This Station)	0.0%	0.4%	0.0%	0.0%	1.8%	0.2%
Family: Spionidae						
Number of Taxa	0	1	1	2	1	1
Number of Organisms per M^2	0	431	72	86	14	41
% Organisms (Sample Group)	0.0%	62.5%	10.4%	12.5%	2.1%	N/A
% Organisms (This Station)	0.0%	6.4%	1.8%	3%	0.9%	1.2%
Order: Terebellida						
Family: Ampharetidae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	7
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Family: Cirratulidae						
Number of Taxa	0	3	1	0	1	0
Number of Organisms per M^2	0	86	14	0	14	15
% Organisms (Sample Group)	0.0%	33.3%	5.6%	0.0%	5.6%	N/A
% Organisms (This Station)	0.0%	1.3%	0.4%	0.0%	0.9%	0.4%
Family: Terebellidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	14	0	0	0	1
% Organisms (Sample Group)	0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Order: Unspecified						
Family: Unspecified						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	5
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Class: Clitellata						
Order: Haplotaxida						
Family: Enchytraeidae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	14	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%
Family: Naididae						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	31
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A

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% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	5.5%
Family: Tubificoid Naididae						
Number of Taxa	0	0	0	0	1	0
Number of Organisms per M^2	0	0	0	0	230	57
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	23.5%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	14.3%	8.1%
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Ampeliscidae						
Number of Taxa	0	1	0	0	0	0
Number of Organisms per M^2	0	14	0	0	0	64
% Organisms (Sample Group)	0.0%	1.3%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.2%	0.0%	0.0%	0.0%	1.7%
Family: Aoridae						
Number of Taxa	0	0	1	0	0	0
Number of Organisms per M^2	0	0	14	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
Family: Bathyporeiidae						
Number of Taxa	0	0	1	0	0	0
Number of Organisms per M^2	0	0	14	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
Family: Corophiidae						
Number of Taxa	0	0	2	0	0	0
Number of Organisms per M^2	0	0	57	0	0	4
% Organisms (Sample Group)	0.0%	0.0%	80%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	1.4%	0.0%	0.0%	0.1%
Family: Dexaminidae						
Number of Taxa	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	14	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Family: Eriopisidae						
Number of Taxa	0	0	0	1	0	0
Number of Organisms per M^2	0	0	0	14	0	3
% Organisms (Sample Group)	0.0%	0.0%	0.0%	33.3%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.5%	0.0%	0.1%
Family: Isaeida						
Number of Taxa	0	0	0	0	0	0
Number of Organisms per M^2	0	0	0	0	0	1
% Organisms (Sample Group)	0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Ischyroceridae						
Number of Taxa	0	0	1	0	0	0
Number of Organisms per M^2	0	0	14	0	0	2

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% Organisms (Sample Group)		0.0%	0.0%	50%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.0%	0.1%
Family: Liljeborgiidae							
Number of Taxa		0	2	0	2	2	0
Number of Organisms per M^2		0	86	0	72	29	13
% Organisms (Sample Group)		0.0%	40%	0.0%	33.3%	13.3%	N/A
% Organisms (This Station)		0.0%	1.3%	0.0%	2.5%	1.8%	0.6%
Family: Lysianassidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Oedicerotidae							
Number of Taxa		0	0	1	1	0	0
Number of Organisms per M^2		0	0	14	14	0	2
% Organisms (Sample Group)		0.0%	0.0%	50%	50%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.5%	0.0%	0.0%
Family: Photidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Family: Phoxocephalidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Urothoidae							
Number of Taxa		0	0	1	1	0	0
Number of Organisms per M^2		0	0	14	330	0	20
% Organisms (Sample Group)		0.0%	0.0%	4.2%	95.8%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	11.4%	0.0%	0.7%
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	7
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Order: Cumacea							
Family: Bodotriidae							
Number of Taxa		0	1	0	1	0	0
Number of Organisms per M^2		0	57	0	43	0	6
% Organisms (Sample Group)		0.0%	57.1%	0.0%	42.9%	0.0%	N/A
% Organisms (This Station)		0.0%	0.9%	0.0%	1.5%	0.0%	0.1%
Family: Leuconidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	29	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A

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% Organisms (This Station)		0.0%	0.0%	0.7%	0.0%	0.0%	0.0%
Family: Unspecified							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
Order: Decapoda							
Family: Unspecified							
Number of Taxa		1	2	2	1	0	0
Number of Organisms per M^2		14	43	287	29	0	23
% Organisms (Sample Group)		3.7%	11.1%	74.1%	7.4%	0.0%	N/A
% Organisms (This Station)		16.7%	0.6%	7%	1%	0.0%	1.6%
Family: Callianassidae							
Number of Taxa		0	2	1	1	0	0
Number of Organisms per M^2		0	273	29	29	0	36
% Organisms (Sample Group)		0.0%	44.2%	4.7%	4.7%	0.0%	N/A
% Organisms (This Station)		0.0%	4.1%	0.7%	1%	0.0%	2.6%
Family: Epialtidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
Family: Paguridae							
Number of Taxa		1	1	1	0	1	0
Number of Organisms per M^2		14	3362	14	0	14	200
% Organisms (Sample Group)		0.4%	98.7%	0.4%	0.0%	0.4%	N/A
% Organisms (This Station)		16.7%	50%	0.4%	0.0%	0.9%	4.0%
Family: Porcellanidae							
Number of Taxa		1	1	0	0	0	0
Number of Organisms per M^2		14	14	0	0	0	2
% Organisms (Sample Group)		50%	50%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		16.7%	0.2%	0.0%	0.0%	0.0%	1.0%
Family: Unspecified							
Number of Taxa		1	2	2	1	0	0
Number of Organisms per M^2		14	43	287	29	0	23
% Organisms (Sample Group)		3.7%	11.1%	74.1%	7.4%	0.0%	N/A
% Organisms (This Station)		16.7%	0.6%	7%	1%	0.0%	1.6%
Order: Isopoda							
Family: Anthuridae							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	29	0	0	0	7
% Organisms (Sample Group)		0.0%	25%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.4%	0.0%	0.0%	0.0%	0.5%
Family: Sphaeromatidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A

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% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Order: Mysida							
Family: Unspecified							
Number of Taxa		1	0	1	0	1	0
Number of Organisms per M^2		14	0	57	0	29	9
% Organisms (Sample Group)		9.1%	0.0%	36.4%	0.0%	18.2%	N/A
% Organisms (This Station)		16.7%	0.0%	1.4%	0.0%	1.8%	1.6%
Order: Tanaidacea							
Family: Kalliapseudidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
Family: Metapseudidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	14
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class: Entognatha							
Order: Collembola							
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Class: Insecta							
Order: Diptera							
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Phylum: Mollusca							
Class: Gastropoda							
Order: Caenogastropoda							
Family: Eulimidae							

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Macroinvertebrate Results
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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Order: Heterostropha							
Family: Pyramidellidae							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	25%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.2%
Order: Littorinimorpha							
Family: Naticidae							
Number of Taxa		0	0	1	1	0	0
Number of Organisms per M^2		0	0	43	43	0	5
% Organisms (Sample Group)		0.0%	0.0%	50%	50%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1.1%	1.5%	0.0%	0.1%
Order: Neogastropoda							
Family: Cystiscidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
Order: Neotaenioglossa							
Family: Caecidae							
Number of Taxa		0	1	1	1	0	0
Number of Organisms per M^2		0	14	101	129	0	14
% Organisms (Sample Group)		0.0%	5.9%	41.2%	52.9%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	2.5%	4.5%	0.0%	0.4%
Family: Calyptraeidae							
Number of Taxa		0	1	1	0	0	0
Number of Organisms per M^2		0	14	14	0	0	3
% Organisms (Sample Group)		0.0%	33.3%	33.3%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	0.4%	0.0%	0.0%	0.1%
Family: Cerithiidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	21
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	3.8%
Family: Eulimidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	43	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1.1%	0.0%	0.0%	0.1%
Family: Hydrobiidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A

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Taxonomic Classification	Station / # of Replicates Pooled / Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	1	0	1	0
Number of Organisms per M^2		0	0	14	0	14	13
% Organisms (Sample Group)		0.0%	0.0%	6.7%	0.0%	6.7%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.9%	0.8%
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	1	1	1	1
Number of Organisms per M^2		0	29	57	14	14	29
% Organisms (Sample Group)		0.0%	5.9%	11.8%	2.9%	2.9%	N/A
% Organisms (This Station)		0.0%	0.4%	1.4%	0.5%	0.9%	2.0%
Order: Arcoida							
Family: Arcidae							
Number of Taxa		0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	14	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.9%	0.1%
Order: Carditoida							
Family: Carditidae							
Number of Taxa		0	0	0	0	1	0
Number of Organisms per M^2		0	0	0	0	86	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	100%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	5.4%	0.3%
Order: Myoida							
Family: Myidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	5
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Order: Mytiloida							
Family: Mytilidae							
Number of Taxa		0	0	1	0	0	0
Number of Organisms per M^2		0	0	14	0	0	2
% Organisms (Sample Group)		0.0%	0.0%	50%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.4%	0.0%	0.0%	0.1%
Order: Nuculoida							
Family: Nuculidae							
Number of Taxa		0	0	1	1	0	0
Number of Organisms per M^2		0	0	29	43	0	5
% Organisms (Sample Group)		0.0%	0.0%	33.3%	50%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.7%	1.5%	0.0%	0.2%
Order: Ostreoida							
Family: Anomiidae							
Number of Taxa		0	0	1	0	0	0

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Taxonomic Classification	Station # of Replicates Pooled Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
Number of Organisms per M^2		0	0	474	0	0	28
% Organisms (Sample Group)		0.0%	0.0%	100%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	11.6%	0.0%	0.0%	0.7%
Order: Veneroida							
Family: Unspecified							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	57	0	0	0	3
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.9%	0.0%	0.0%	0.0%	0.1%
Family: Corbulidae							
Number of Taxa		0	1	2	3	1	0
Number of Organisms per M^2		0	14	230	316	14	34
% Organisms (Sample Group)		0.0%	2.5%	40%	55%	2.5%	N/A
% Organisms (This Station)		0.0%	0.2%	5.6%	10.9%	0.9%	1.0%
Family: Lucinidae							
Number of Taxa		0	2	0	0	0	0
Number of Organisms per M^2		0	72	0	0	0	4
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	1.1%	0.0%	0.0%	0.0%	0.1%
Family: Mactridae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Family: Montecutidae							
Number of Taxa		0	1	1	1	1	0
Number of Organisms per M^2		0	29	86	144	29	17
% Organisms (Sample Group)		0.0%	10%	30%	50%	10%	N/A
% Organisms (This Station)		0.0%	0.4%	2.1%	5%	1.8%	0.5%
Family: Tellinidae							
Number of Taxa		1	1	1	2	0	1
Number of Organisms per M^2		14	29	43	72	0	19
% Organisms (Sample Group)		4.5%	9.1%	13.6%	22.7%	0.0%	N/A
% Organisms (This Station)		16.7%	0.4%	1.1%	2.5%	0.0%	2.7%
Family: Veneridae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	0	0	0	0
Number of Organisms per M^2		0	14	0	0	0	1
% Organisms (Sample Group)		0.0%	100%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.2%	0.0%	0.0%	0.0%	0.0%

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Macroinvertebrate Results
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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station # of Replicates Pooled Collection Date	13BG 3 08/21/13	14BG 3 08/24/13	15BG 3 08/27/13	16BG 3 08/27/13	17BG 3 08/26/13	Mean Values
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Number of Taxa		0	2	3	2	2	1
Number of Organisms per M^2		0	489	546	603	86	107
% Organisms (Sample Group)		0.0%	26.8%	29.9%	33.1%	4.7%	N/A
% Organisms (This Station)		0.0%	7.3%	13.3%	20.9%	5.4%	2.9%
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	1	0	0	0
Number of Organisms per M^2		0	115	57	0	0	11
% Organisms (Sample Group)		0.0%	61.5%	30.8%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	1.7%	1.4%	0.0%	0.0%	0.2%
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Number of Taxa		0	0	0	1	0	0
Number of Organisms per M^2		0	0	0	14	0	1
% Organisms (Sample Group)		0.0%	0.0%	0.0%	100%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	18
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	2.6%
Phylum: Bryozoa							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	0	1	1	0	0
Number of Organisms per M^2		0	0	43	57	0	19
% Organisms (Sample Group)		0.0%	0.0%	13%	17.4%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	1.1%	2%	0.0%	1.0%
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Number of Taxa		0	1	1	1	1	0
Number of Organisms per M^2		0	43	29	29	29	13
% Organisms (Sample Group)		0.0%	20%	13.3%	13.3%	13.3%	N/A
% Organisms (This Station)		0.0%	0.6%	0.7%	1%	1.8%	0.5%
Phylum: Brachiopoda							

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Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Number of Taxa		0	0	0	0	0	0
Number of Organisms per M^2		0	0	0	0	0	3
% Organisms (Sample Group)		0.0%	0.0%	0.0%	0.0%	0.0%	N/A
% Organisms (This Station)		0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Total Taxa		6	62	57	53	36	22
Total Organisms per M^2		86	6724	4095	2888	1609	1525
% Organisms (Sample Group)		0.3%	25.9%	15.8%	11.1%	6.2%	N/A

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Macroinvertebrate Results
Data Per Square Meter (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	1BG	2BG	3BG	4BG	5BG	6BG
Station	1BG	2BG	3BG	4BG	5BG	6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Phylum: Porifera						
Class: Demospongiae						
Order: Hadromerida						
Family: Clionidae						
Cliona sp.	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Demospongiae (LPIL)	-	-	-	-	14	-
Demospongiae boring (LPIL)	-	-	-	-	-	-
Demospongiae encrusting (LPIL)	-	-	-	-	-	-
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Porifera (LPIL)	-	-	-	14	-	-
Phylum: Cnidaria						
Class: Hydrozoa						
Order: Anthoathecata						
Family: Unspecified						
Anthoathecata (LPIL)	-	-	-	-	-	-
Order: Leptothecata						
Family: Aglaopheniidae						
Aglaopheniidae (LPIL)	-	-	-	-	-	-
Family: Campanulariidae						
Campanulariidae (LPIL)	-	-	14	-	-	-
Family: Lovenellidae						
Lovenellidae (LPIL)	-	-	-	-	-	-
Family: Sertulariidae						
Sertularia sp.	-	-	-	-	-	-
Sertulariidae (LPIL)	-	-	-	-	-	-
Family: Unspecified						
Leptothecata (LPIL)	-	-	-	-	-	-
Plumulariidae (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Hydroida (LPIL)	-	-	-	-	-	-
Hydroidolina (LPIL)	-	-	-	-	72	-
Hydrozoa (LPIL)	-	-	-	-	-	-
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)	-	-	-	-	-	-
Order: Alcyonacea						
Family: Scleraxonia						
Scleraxonia (LPIL)	-	-	-	-	-	-
Order: Pennatulacea						
Family: Kophobelmnidae						
Kophobelemnon sp.	-	-	-	-	-	-

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Taxonomic Classification	1BG	2BG	3BG	4BG	5BG	6BG
Station	1BG	2BG	3BG	4BG	5BG	6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Order: Scleractinia						
Family: Unspecified						
Scleractinia (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Anthozoa (LPIL)	-	-	-	-	-	-
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)	-	-	-	-	43	-
Phylum: Sipuncula						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Sipuncula (LPIL)	-	-	-	-	-	-
Phylum: Annelida						
Class: Polychaeta						
Order: Amphinomida						
Family: Amphinomidae						
Amphinomidae (LPIL)	-	-	-	-	-	-
Order: Capitellida						
Family: Capitellidae						
Capitellidae (LPIL)	-	-	-	-	14	-
Capitobranchus sp.	-	-	-	-	-	-
Decamastus sp.	-	-	-	14	14	-
Heteromastus filiformis	-	-	-	-	-	-
Mediomastus sp.	-	-	-	-	-	-
Notomastus sp.	57	86	101	86	115	158
Family: Maldanidae						
Maldanidae (LPIL)	-	-	-	-	-	-
Order: Cossurida						
Family: Cossuridae						
Cossura delta	-	-	-	-	-	-
Order: Eunicida						
Family: Dorvilleidae						
Protodorvillea egena	-	-	-	-	-	-
Schistomeringos rudolphii	-	-	-	-	-	-
Family: Lumbrineridae						
Augeneria sp.	-	-	-	-	-	-
Lumbrineris meteorana	-	-	-	-	-	-
Scoletoma impatiens	-	-	-	-	-	-
Family: Oenonidae						
Oenonidae (LPIL)	-	-	-	-	-	-
Family: Onuphidae						
Diopatra sp.	-	-	-	-	-	-
Order: Opheliida						

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	-	-	-
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	-
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	-
Glycera alba		-	-	-	-	-	-
Glycera sp.		-	-	-	-	-	-
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	-	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	-
Family: Nephtyidae							
Aglaophamus sp.		-	-	115	-	72	273
Micronephtys stammeri		-	-	-	-	-	-
Family: Nereididae							
Neanthes sp.		-	-	-	-	-	-
Nereididae (LPIL)		-	-	-	14	-	-
Nereis sp.		-	-	-	-	43	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	-
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	14	-
Sigambra sp.		14	14	57	57	201	244
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	-

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Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Family: Sphaerodoridae							
Ephesiella sp.		-	-	-	-	-	-
Family: Syllidae							
Eusyllis assimilis		-	-	-	-	-	-
Eusyllis sp.		-	-	-	-	-	-
Exogone sp.		-	-	-	-	-	-
Pionosyllis sp.		-	-	-	-	-	-
Sphaerosyllis sp.		-	-	-	-	-	-
Order: Sabellida							
Family: Oweniidae							
Galathowenia oculata		-	-	-	-	-	-
Galathowenia sp.		-	-	-	-	-	-
Family: Sabellariidae							
Sabellaria sp.		-	-	-	-	-	-
Sabellariidae (LPIL)		-	-	-	-	-	-
Order: Spionida							
Family: Chaetopteridae							
Spiochaetopterus sp.		-	-	-	-	-	-
Family: Magelonidae							
Magelona cincta		-	-	-	-	-	-
Magelona sp.		-	-	-	-	-	-
Family: Spionidae							
Minuspio sp.		-	-	-	-	-	-
Scolelepis sp.		-	-	-	-	-	-
Spionidae (LPIL)		-	-	-	-	-	-
Order: Terebellida							
Family: Ampharetidae							
Ampharete sp.		-	-	-	-	-	-
Lysippe sp.		-	-	-	-	-	-
Family: Cirratulidae							
Aphelochaeta marioni		-	-	-	-	-	-
Aphelochaeta sp.		-	-	-	-	-	-
Cirratulidae (LPIL)		-	-	-	-	-	-
Monticellina sp.		-	-	-	-	-	-
Family: Terebellidae							
Eupolymnia sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Polychaeta (LPIL)		-	-	-	-	-	-
Class: Clitellata							
Order: Haplotaxida							
Family: Enchytraeidae							
Enchytraeidae (LPIL)		-	-	-	-	-	-
Family: Naididae							
Naididae (LPIL)		-	115	-	-	-	-
Nais sp.		57	316	-	-	-	-
Family: Tubificoid Naididae							

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Sample Group: Wet Season

Sample Method: Petite Ponar
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Taxonomic Classification	Station	1BG	2BG	3BG	4BG	5BG	6BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Tubificoid Naididae (LPIL)		115	-	57	57	244	43
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	-
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	-
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	-
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	-	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	14	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	-	-	-
Liljeborgiidae (LPIL)		-	-	-	-	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	-
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	-
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	-	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	-	14	-
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Station	1BG	2BG	3BG	4BG	5BG	6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Decapoda (LPIL)	-	-	-	-	-	-
Family: Callianassidae						
Callianassa sp.	-	-	-	-	-	-
Callianassidae (LPIL)	-	-	-	-	-	-
Family: Epialtidae						
Pisinae (LPIL)	-	-	-	-	-	-
Family: Paguridae						
Paguridae *zoea larva*	-	-	-	-	-	-
Paguristes sp.	-	-	-	-	-	-
Family: Porcellanidae						
Porcellanidae *zoea larva*	-	-	-	-	-	-
Family: Unspecified						
Brachyura zoea larva	-	-	-	-	-	-
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.	-	-	-	-	-	-
Anthuridae (LPIL)	14	-	-	-	14	-
Cyathura sp.	-	-	-	-	14	-
Family: Sphaeromatidae						
Cassidinidea sp.	-	-	-	-	43	-
Order: Mysida						
Family: Unspecified						
Mysidacea (LPIL)	-	-	-	-	14	-
Order: Tanaidacea						
Family: Kalliapseudidae						
Kalliapseudidae (LPIL)	-	-	-	-	-	-
Family: Metapseudidae						
Calozodion sp.	-	-	-	-	-	-
Family: Unspecified						
Metapseudidae (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Malacostraca (LPIL)	-	-	-	-	-	-
Class: Entognatha						
Order: Collembola						
Family: Unspecified						
Collembola (LPIL)	-	-	-	-	-	-
Class: Insecta						
Order: Diptera						
Family: Unspecified						
Diptera (LPIL)	-	-	-	-	14	-
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Eulimidae						
Melanella sp.	-	-	-	-	-	-
Order: Heterostropha						

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Station	1BG	2BG	3BG	4BG	5BG	6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Family: Pyramidellidae						
Pyramidellidae (LPIL)	-	-	-	-	29	-
Order: Littorinimorpha						
Family: Naticidae						
Sinum sp.	-	-	-	-	-	-
Order: Neogastropoda						
Family: Cystiscidae						
Plesiocystiscus sp.	-	-	-	-	-	-
Order: Neotaenioglossa						
Family: Caecidae						
Caecum sp.	-	-	-	-	-	-
Cerithiidae (LPIL)	-	-	-	-	-	-
Family: Calyptraeidae						
Calyptraea sp.	-	-	-	-	-	-
Crepidula sp.	-	-	-	-	-	-
Family: Cerithiidae						
Cerithium sp.	-	43	14	287	14	-
Family: Eulimidae						
Melanella sp.	-	-	-	-	-	-
Family: Hydrobiidae						
Hydrobiidae (LPIL)	-	-	-	-	14	-
Order: Unspecified						
Family: Unspecified						
Gastropoda (LPIL)	-	-	14	-	129	-
Class: Bivalvia						
Order: Unspecified						
Family: Unspecified						
Bivalvia (LPIL)	14	29	14	-	273	-
Order: Arcoida						
Family: Arcidae						
Anadara sp.	-	-	-	-	-	-
Order: Carditoida						
Family: Carditidae						
Pleuromeris sp.	-	-	-	-	-	-
Order: Myoida						
Family: Myidae						
Myidae (LPIL)	-	-	72	-	14	-
Order: Mytiloida						
Family: Mytilidae						
Musculus sp.	-	-	-	-	-	-
Mytilidae (LPIL)	-	-	-	-	-	-
Order: Nuculoida						
Family: Nuculidae						
Nucula sp.	-	-	-	-	-	-
Order: Ostreoida						
Family: Anomiidae						
Anomia sp.	-	-	-	-	-	-

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	14
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		14	43	-	-	-	14
Tellinidae (LPIL)		-	-	43	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	-
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	-
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	-
Ophiophragmus sp.		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	-
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							

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Station	1BG	2BG	3BG	4BG	5BG	6BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/15/13	08/15/13	08/17/13	08/17/13	08/16/13	08/16/13
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Bryozoa (LPIL)	-	-	-	-	230	-
Phylum: Chaetognatha						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Chaetognatha (LPIL)	-	-	-	-	-	-
Phylum: Brachiopoda						
Class: Lingulata						
Order: Lingulida						
Family: Lingulidae						
Lingula sp.	-	-	-	-	-	-
Total Organisms	287	647	503	532	1681	747
Number of Taxa	7	7	10	7	25	6

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Taxonomic Classification	7BG	BG8	9BG	10BG	11BG	12BG
Station	7BG	BG8	9BG	10BG	11BG	12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Phylum: Porifera						
Class: Demospongiae						
Order: Hadromerida						
Family: Clionidae						
Cliona sp.	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Demospongiae (LPIL)	-	-	-	-	-	14
Demospongiae boring (LPIL)	-	-	-	-	-	-
Demospongiae encrusting (LPIL)	-	-	-	-	-	-
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Porifera (LPIL)	-	-	-	-	-	-
Phylum: Cnidaria						
Class: Hydrozoa						
Order: Anthoathecata						
Family: Unspecified						
Anthoathecata (LPIL)	-	-	-	-	-	14
Order: Leptothecata						
Family: Aglaopheniidae						
Aglaopheniidae (LPIL)	-	-	-	-	-	-
Family: Campanulariidae						
Campanulariidae (LPIL)	-	-	-	-	-	-
Family: Lovenellidae						
Lovenellidae (LPIL)	-	-	-	-	273	-
Family: Sertulariidae						
Sertularia sp.	-	-	-	-	-	-
Sertulariidae (LPIL)	-	-	-	-	-	-
Family: Unspecified						
Leptothecata (LPIL)	-	-	-	-	-	-
Plumulariidae (LPIL)	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Hydroida (LPIL)	-	-	-	-	-	-
Hydroidolina (LPIL)	-	-	-	-	-	-
Hydrozoa (LPIL)	-	-	-	-	-	-
Class: Anthozoa						
Order: Actiniaria						
Family: Unspecified						
Actiniaria (LPIL)	-	-	-	-	-	-
Order: Alcyonacea						
Family: Scleraxonia						
Scleraxonia (LPIL)	-	-	-	-	-	86
Order: Pennatulacea						
Family: Kophobelmnidae						
Kophobelemnon sp.	-	-	-	-	-	29

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Station	7BG	BG8	9BG	10BG	11BG	12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Order: Scleractinia						
Family: Unspecified						
Scleractinia (LPIL)	-	-	-	-	14	14
Order: Unspecified						
Family: Unspecified						
Anthozoa (LPIL)	-	-	-	-	-	14
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)	-	-	-	72	-	129
Phylum: Sipuncula						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Sipuncula (LPIL)	-	-	-	-	-	-
Phylum: Annelida						
Class: Polychaeta						
Order: Amphinomida						
Family: Amphinomidae						
Amphinomidae (LPIL)	-	-	-	-	-	-
Order: Capitellida						
Family: Capitellidae						
Capitellidae (LPIL)	-	-	-	-	-	115
Capitobranchus sp.	-	-	-	-	-	-
Decamastus sp.	-	-	-	-	-	-
Heteromastus filiformis	-	-	-	57	-	144
Mediomastus sp.	-	-	-	-	-	-
Notomastus sp.	-	-	-	-	-	-
Family: Maldanidae						
Maldanidae (LPIL)	-	-	-	-	-	72
Order: Cossurida						
Family: Cossuridae						
Cossura delta	-	-	-	-	-	-
Order: Eunicida						
Family: Dorvilleidae						
Protodorvillea egena	-	-	-	-	-	-
Schistomeringos rudolphii	-	-	-	-	-	-
Family: Lumbrineridae						
Augeneria sp.	-	-	-	-	-	-
Lumbrineris meteorana	-	-	-	-	-	14
Scoletoma impatiens	-	-	-	-	-	-
Family: Oenonidae						
Oenonidae (LPIL)	-	-	-	-	-	-
Family: Onuphidae						
Diopatra sp.	-	-	-	-	-	230
Order: Opheliida						

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Family: Opheliidae							
Armandia sp.		-	-	-	-	-	-
Order: Orbiniida							
Family: Orbiniidae							
Proscoloplos sp.		-	-	-	-	-	-
Scoloplos acmeceps		-	-	-	-	-	-
Scoloplos sp.		-	-	-	43	-	72
Family: Paraonidae							
Aricidea cerrutii		-	-	-	-	-	-
Aricidea fragilis		-	-	-	-	-	14
Aricidea simplex		-	-	-	-	-	-
Aricidea sp.		-	-	-	-	-	-
Aricidea wassi		-	-	-	-	-	-
Cirrophorus branchiatus		-	-	-	-	-	-
Levinsenia gracilis		-	-	-	-	-	-
Paraonidae (LPIL)		-	-	-	-	-	-
Paraonis fulgens		-	-	-	-	-	-
Order: Phyllodocida							
Family: Glyceridae							
Glycera africana		-	-	-	-	-	14
Glycera alba		-	-	-	-	-	14
Glycera sp.		-	-	-	29	-	29
Family: Goniadidae							
Glycinde kameruniana		-	-	-	-	-	-
Goniada multidentata		-	-	-	-	-	-
Goniada sp.		-	-	-	-	-	-
Goniadella sp.		-	-	-	-	-	-
Goniadidae (LPIL)		-	-	-	14	-	-
Family: Hesionidae							
Gyptis sp.		-	-	-	-	-	-
Kefersteinia sp.		-	-	-	-	-	14
Family: Nephtyidae							
Aglaophamus sp.		445	57	259	-	-	-
Micronephtys stammeri		-	-	-	-	-	57
Family: Nereididae							
Neanthes sp.		-	-	14	-	-	-
Nereididae (LPIL)		-	14	-	-	-	-
Nereis sp.		-	-	14	-	-	-
Family: Phyllodocidae							
Eteone sp.		-	-	-	-	-	14
Family: Pilargidae							
Ancistrosyllis sp.		-	-	-	-	-	-
Cabira sp.		-	-	-	-	-	-
Sigambra bassi		-	-	-	-	-	-
Sigambra sp.		14	-	-	14	-	14
Family: Polynoidae							
Malmgreniella sp.		-	-	-	-	-	43

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	7BG	BG8	9BG	10BG	11BG	12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Family: Sphaerodoridae						
Ephesiella sp.	-	-	-	-	-	-
Family: Syllidae						
Eusyllis assimilis	-	-	-	-	-	-
Eusyllis sp.	-	-	-	-	-	-
Exogone sp.	-	-	-	-	-	43
Pionosyllis sp.	-	-	-	-	-	14
Sphaerosyllis sp.	-	-	-	-	-	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia oculata	-	-	-	-	-	14
Galathowenia sp.	-	-	-	-	-	-
Family: Sabellariidae						
Sabellaria sp.	-	-	-	-	-	-
Sabellariidae (LPIL)	-	-	-	-	-	14
Order: Spionida						
Family: Chaetopteridae						
Spiochaetopterus sp.	-	-	-	14	-	-
Family: Magelonidae						
Magelona cincta	-	-	-	-	-	43
Magelona sp.	-	-	-	-	-	-
Family: Spionidae						
Minuspio sp.	-	-	14	29	-	-
Scolelepis sp.	-	-	-	-	-	14
Spionidae (LPIL)	-	-	-	-	-	29
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.	-	-	-	-	-	101
Lysippe sp.	-	-	-	-	-	14
Family: Cirratulidae						
Aphelochaeta marioni	-	-	-	-	-	-
Aphelochaeta sp.	-	-	-	-	-	86
Cirratulidae (LPIL)	-	-	-	-	-	43
Monticellina sp.	-	-	-	-	-	14
Family: Terebellidae						
Eupolymnia sp.	-	-	-	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)	-	-	-	-	-	86
Class: Clitellata						
Order: Haplotaxida						
Family: Enchytraeidae						
Enchytraeidae (LPIL)	-	-	-	-	-	-
Family: Naididae						
Naididae (LPIL)	-	-	-	-	-	-
Nais sp.	-	-	-	43	-	-
Family: Tubificoid Naididae						

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Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Tubificoid Naididae (LPIL)		-	-	201	-	-	29
Phylum: Arthropoda							
Class: Malacostraca							
Order: Amphipoda							
Family: Ampeliscidae							
Ampelisca sp.		-	-	-	-	-	1078
Family: Aoridae							
Aoridae (LPIL)		-	-	-	-	-	-
Family: Bathyporeiidae							
Bathyporeia sp.		-	-	-	-	-	-
Family: Corophiidae							
Cheiriphotis sp		-	-	-	-	-	-
Corophiidae (LPIL)		-	-	-	-	-	14
Family: Dexaminidae							
Nototropis sp.		-	-	-	-	-	-
Family: Eriopisidae							
Eriopisella sp.		-	-	-	-	-	29
Family: Isaeida							
Isaeidae (LPIL)		-	-	-	14	-	-
Family: Ischyroceridae							
Ischyroceridae (LPIL)		-	-	-	-	-	-
Family: Liljeborgiidae							
Idunella sp.		-	-	-	14	-	-
Liljeborgiidae (LPIL)		-	-	-	14	-	-
Family: Lysianassidae							
Lysianassidae (LPIL)		-	-	-	-	-	14
Family: Oedicerotidae							
Oedicerotidae (LPIL)		-	-	-	-	-	-
Perioculodes sp.		-	-	-	-	-	-
Family: Photidae							
Photidae (LPIL)		-	-	-	-	-	14
Family: Phoxocephalidae							
Basuto stimpsoni		-	-	-	-	14	-
Family: Urothoidae							
Urothoe sp.		-	-	-	-	-	-
Family: Unspecified							
Amphipoda (LPIL)		-	-	-	29	-	72
Order: Cumacea							
Family: Bodotriidae							
Apocuma sp.		-	-	-	-	-	-
Bodotriidae (LPIL)		-	-	-	-	-	-
Family: Leuconidae							
Leuconidae (LPIL)		-	-	-	-	-	-
Family: Unspecified							
Cumacea (LPIL)		-	-	-	-	-	-
Order: Decapoda							
Family: Unspecified							

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Sample Group: Wet Season

Sample Method: Petite Ponar
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Taxonomic Classification	7BG	BG8	9BG	10BG	11BG	12BG
Station	7BG	BG8	9BG	10BG	11BG	12BG
Number of Replicates Pooled	3	3	3	3	3	3
Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Decapoda (LPIL)	-	-	-	-	-	-
Family: Callianassidae						
Callianassa sp.	-	-	-	-	-	-
Callianassidae (LPIL)	-	-	-	273	-	14
Family: Epialtidae						
Pisinae (LPIL)	-	-	-	-	-	-
Family: Paguridae						
Paguridae *zoea larva*	-	-	-	-	-	-
Paguristes sp.	-	-	-	-	-	-
Family: Porcellanidae						
Porcellanidae *zoea larva*	-	-	-	-	-	-
Family: Unspecified						
Brachyura zoea larva	-	-	-	-	14	-
Order: Isopoda						
Family: Anthuridae						
Amakusanthura sp.	-	-	-	-	-	43
Anthuridae (LPIL)	-	-	-	-	-	-
Cyathura sp.	-	-	-	-	-	-
Family: Sphaeromatidae						
Cassidinidea sp.	-	-	-	-	-	-
Order: Mysida						
Family: Unspecified						
Mysidacea (LPIL)	-	-	-	-	43	-
Order: Tanaidacea						
Family: Kalliapseudidae						
Kalliapseudidae (LPIL)	-	-	-	-	-	-
Family: Metapseudidae						
Calozodion sp.	-	-	-	-	-	244
Family: Unspecified						
Metapseudidae (LPIL)	-	-	-	-	-	57
Order: Unspecified						
Family: Unspecified						
Malacostraca (LPIL)	-	-	-	-	-	14
Class: Entognatha						
Order: Collembola						
Family: Unspecified						
Collembola (LPIL)	-	14	-	-	-	-
Class: Insecta						
Order: Diptera						
Family: Unspecified						
Diptera (LPIL)	-	-	-	-	-	-
Phylum: Mollusca						
Class: Gastropoda						
Order: Caenogastropoda						
Family: Eulimidae						
Melanella sp.	-	-	-	-	-	-
Order: Heterostropha						

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	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Family: Pyramidellidae							
Pyramidellidae (LPIL)		-	-	-	14	-	-
Order: Littorinimorpha							
Family: Naticidae							
Sinum sp.		-	-	-	-	-	-
Order: Neogastropoda							
Family: Cystiscidae							
Plesiocystiscus sp.		-	-	-	-	-	-
Order: Neotaenioglossa							
Family: Caecidae							
Caecum sp.		-	-	-	-	-	-
Cerithiidae (LPIL)		-	-	-	-	-	-
Family: Calyptraeidae							
Calyptraea sp.		-	-	-	-	-	-
Crepidula sp.		-	-	-	-	-	14
Family: Cerithiidae							
Cerithium sp.		-	-	-	-	-	-
Family: Eulimidae							
Melanella sp.		-	-	-	-	-	-
Family: Hydrobiidae							
Hydrobiidae (LPIL)		-	-	-	-	-	-
Order: Unspecified							
Family: Unspecified							
Gastropoda (LPIL)		-	-	-	-	-	43
Class: Bivalvia							
Order: Unspecified							
Family: Unspecified							
Bivalvia (LPIL)		-	-	-	-	14	29
Order: Arcoida							
Family: Arcidae							
Anadara sp.		-	-	-	-	-	-
Order: Carditoida							
Family: Carditidae							
Pleuromeris sp.		-	-	-	-	-	-
Order: Myoida							
Family: Myidae							
Myidae (LPIL)		-	-	-	-	-	-
Order: Mytiloida							
Family: Mytilidae							
Musculus sp.		-	-	-	-	-	-
Mytilidae (LPIL)		-	-	-	14	-	-
Order: Nuculoida							
Family: Nuculidae							
Nucula sp.		-	-	-	-	-	14
Order: Ostreoida							
Family: Anomiidae							
Anomia sp.		-	-	-	-	-	-

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Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Order: Veneroida							
Family: Unspecified							
Veneroida (LPIL)		-	-	-	-	-	-
Family: Corbulidae							
Caryocorbula sp.		-	-	-	-	-	-
Corbula sp.		-	-	-	-	-	-
Corbulidae (LPIL)		-	-	-	-	-	-
Family: Lucinidae							
Lucinidae (LPIL)		-	-	-	-	-	-
Parvilucina sp.		-	-	-	-	-	-
Family: Mactridae							
Mactridae (LPIL)		-	-	-	-	-	-
Family: Montecutidae							
Mysella sp.		-	-	-	-	-	-
Family: Tellinidae							
Macoma sp.		14	-	-	-	-	29
Tellinidae (LPIL)		-	-	-	-	-	-
Family: Veneridae							
Veneridae (LPIL)		-	-	-	-	-	14
Phylum: Phoronida							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Phoronida (LPIL)		-	-	-	-	-	-
Phylum: Echinodermata							
Class: Ophiuroidea							
Order: Ophiurida							
Family: Amphiuridae							
Amphiodia/Amphipholis complex		-	-	-	-	-	-
Amphioplus sp.		-	-	-	-	-	29
Amphiura sp.		-	-	-	-	-	-
Amphiuridae (LPIL)		-	-	-	-	-	57
Ophiophragmus sp.		-	-	-	-	-	14
Order: Unspecified							
Family: Unspecified							
Ophiuroidea (LPIL)		-	-	-	-	-	14
Phylum: Platyhelminthes							
Class: Rhabditophora							
Order: Polycladida							
Family: Unspecified							
Polycladida (LPIL)		-	-	-	-	-	-
Phylum: Bryozoa							
Class: Gymnolaemata							
Order: Ctenostomatida							
Family: Unspecified							
Ctenostomatida (LPIL)		-	-	-	-	302	-
Phylum: Bryozoa							

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Taxonomic Classification	Station	7BG	BG8	9BG	10BG	11BG	12BG
	Number of Replicates Pooled	3	3	3	3	3	3
	Collection Date	08/19/13	08/19/13	08/22/13	08/22/13	08/24/13	08/24/13
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Bryozoa (LPIL)		-	-	-	-	-	-
Phylum: Chaetognatha							
Class: Unspecified							
Order: Unspecified							
Family: Unspecified							
Chaetognatha (LPIL)		-	-	-	14	-	72
Phylum: Brachiopoda							
Class: Lingulata							
Order: Lingulida							
Family: Lingulidae							
Lingula sp.		-	-	-	-	-	43
Total Organisms		474	86	503	704	675	3678
Number of Taxa		3	3	5	17	7	59

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Taxonomic Classification	13BG	14BG	15BG	16BG	17BG
Station	13BG	14BG	15BG	16BG	17BG
Number of Replicates Pooled	3	3	3	3	3
Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Phylum: Porifera					
Class: Demospongiae					
Order: Hadromerida					
Family: Clionidae					
Cliona sp.	-	-	57	-	-
Order: Unspecified					
Family: Unspecified					
Demospongiae (LPIL)	-	-	14	-	-
Demospongiae boring (LPIL)	-	-	129	-	-
Demospongiae encrusting (LPIL)	-	-	86	-	-
Class: Unspecified					
Order: Unspecified					
Family: Unspecified					
Porifera (LPIL)	-	-	-	-	-
Phylum: Cnidaria					
Class: Hydrozoa					
Order: Anthoathecata					
Family: Unspecified					
Anthoathecata (LPIL)	-	-	201	14	-
Order: Leptothecata					
Family: Aglaopheniidae					
Aglaopheniidae (LPIL)	-	-	-	57	-
Family: Campanulariidae					
Campanulariidae (LPIL)	-	-	-	14	-
Family: Lovenellidae					
Lovenellidae (LPIL)	-	-	273	57	129
Family: Sertulariidae					
Sertularia sp.	-	-	-	14	-
Sertulariidae (LPIL)	-	-	-	72	-
Family: Unspecified					
Leptothecata (LPIL)	-	-	144	43	-
Plumulariidae (LPIL)	-	-	-	14	-
Order: Unspecified					
Family: Unspecified					
Hydroida (LPIL)	-	-	-	43	-
Hydroidolina (LPIL)	-	-	14	-	-
Hydrozoa (LPIL)	-	-	-	29	-
Class: Anthozoa					
Order: Actiniaria					
Family: Unspecified					
Actiniaria (LPIL)	-	-	-	14	-
Order: Alcyonacea					
Family: Scleraxonia					
Scleraxonia (LPIL)	-	29	-	-	-
Order: Pennatulacea					
Family: Kophobelmnidae					
Kophobelemnon sp.	-	-	-	-	-

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Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Order: Scleractinia						
Family: Unspecified						
Scleractinia (LPIL)		-	29	-	-	-
Order: Unspecified						
Family: Unspecified						
Anthozoa (LPIL)		-	-	-	-	-
Phylum: Nemertea						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Nemertea (LPIL)		14	201	273	86	43
Phylum: Sipuncula						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Sipuncula (LPIL)		-	14	101	-	-
Phylum: Annelida						
Class: Polychaeta						
Order: Amphinomida						
Family: Amphinomidae						
Amphinomidae (LPIL)		-	-	29	-	-
Order: Capitellida						
Family: Capitellidae						
Capitellidae (LPIL)		-	-	-	-	-
Capitobranchus sp.		-	43	-	-	-
Decamastus sp.		-	-	-	-	-
Heteromastus filiformis		-	144	-	-	72
Mediomastus sp.		-	29	-	-	101
Notomastus sp.		-	-	-	-	-
Family: Maldanidae						
Maldanidae (LPIL)		-	72	-	-	-
Order: Cossurida						
Family: Cossuridae						
Cossura delta		-	14	-	-	-
Order: Eunicida						
Family: Dorvilleidae						
Protodorvillea egena		-	-	-	-	29
Schistomeringos rudolphii		-	14	-	-	-
Family: Lumbrineridae						
Augeneria sp.		-	14	-	-	-
Lumbrineris meteorana		-	-	-	-	-
Scoletoma impatiens		-	14	-	-	-
Family: Oenonidae						
Oenonidae (LPIL)		-	14	-	-	-
Family: Onuphidae						
Diopatra sp.		-	29	14	-	-
Order: Opheliida						

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	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Family: Opheliidae						
Armandia sp.		-	-	14	-	86
Order: Orbiniida						
Family: Orbiniidae						
Proscoloplos sp.		-	144	-	-	-
Scoloplos acmeceps		-	29	-	-	-
Scoloplos sp.		-	101	-	14	216
Family: Paraonidae						
Aricidea cerrutii		-	-	-	-	14
Aricidea fragilis		-	29	-	-	-
Aricidea simplex		-	14	-	-	-
Aricidea sp.		-	-	-	-	14
Aricidea wassi		-	-	-	-	29
Cirrophorus branchiatus		-	43	-	-	86
Levinsenia gracilis		-	14	-	-	-
Paraonidae (LPIL)		-	-	-	-	29
Paraonis fulgens		-	-	14	-	-
Order: Phyllodocida						
Family: Glyceridae						
Glycera africana		-	-	-	-	14
Glycera alba		-	-	-	29	14
Glycera sp.		-	29	14	43	29
Family: Goniadidae						
Glycinde kameruniana		-	43	-	-	-
Goniada multidentata		-	29	-	-	-
Goniada sp.		-	-	-	14	-
Goniadella sp.		-	-	-	14	-
Goniadidae (LPIL)		-	-	-	-	-
Family: Hesionidae						
Gyptis sp.		-	14	-	-	-
Kefersteinia sp.		-	-	-	-	-
Family: Nephtyidae						
Aglaophamus sp.		-	14	-	-	-
Micronephtys stammeri		-	29	115	72	14
Family: Nereididae						
Neanthes sp.		-	-	-	-	-
Nereididae (LPIL)		-	-	-	-	-
Nereis sp.		-	-	-	14	-
Family: Phyllodocidae						
Eteone sp.		-	-	-	-	-
Family: Pilargidae						
Ancistrosyllis sp.		-	-	-	-	29
Cabira sp.		-	14	-	-	-
Sigambra bassi		-	-	-	-	-
Sigambra sp.		-	-	-	-	-
Family: Polynoidae						
Malmgreniella sp.		-	43	57	29	-

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Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Family: Sphaerodoridae						
Ephesiella sp.		-	101	-	-	-
Family: Syllidae						
Eusyllis assimilis		-	14	-	-	-
Eusyllis sp.		-	-	-	14	-
Exogone sp.		-	-	14	14	-
Pionosyllis sp.		-	-	-	-	-
Sphaerosyllis sp.		-	-	14	14	-
Order: Sabellida						
Family: Oweniidae						
Galathowenia oculata		-	-	-	-	-
Galathowenia sp.		-	-	-	14	-
Family: Sabellariidae						
Sabellaria sp.		-	-	-	14	-
Sabellariidae (LPIL)		-	-	-	-	-
Order: Spionida						
Family: Chaetopteridae						
Spiochaetopterus sp.		-	-	-	-	-
Family: Magelonidae						
Magelona cincta		-	29	-	-	14
Magelona sp.		-	-	-	-	14
Family: Spionidae						
Minuspio sp.		-	431	72	57	-
Scolelepis sp.		-	-	-	-	-
Spionidae (LPIL)		-	-	-	29	14
Order: Terebellida						
Family: Ampharetidae						
Ampharete sp.		-	-	-	-	-
Lysippe sp.		-	-	-	-	-
Family: Cirratulidae						
Aphelochaeta marioni		-	29	-	-	-
Aphelochaeta sp.		-	-	-	-	-
Cirratulidae (LPIL)		-	14	14	-	14
Monticellina sp.		-	43	-	-	-
Family: Terebellidae						
Eupolymnia sp.		-	14	-	-	-
Order: Unspecified						
Family: Unspecified						
Polychaeta (LPIL)		-	-	-	-	-
Class: Clitellata						
Order: Haplotaxida						
Family: Enchytraeidae						
Enchytraeidae (LPIL)		-	-	-	-	14
Family: Naididae						
Naididae (LPIL)		-	-	-	-	-
Nais sp.		-	-	-	-	-
Family: Tubificoid Naididae						

Macroinvertebrate Results
Data Per Square Meter (Pooled)

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Project: Rio Cacheu Benthic Assessment (Wet Season)
Sample Group: Wet Season

Sample Method: Petite Ponar
Report Date: 10/09/2013

Taxonomic Classification	Station	13BG	14BG	15BG	16BG	17BG
	Number of Replicates Pooled	3	3	3	3	3
	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Tubificoid Naididae (LPIL)		-	-	-	-	230
Phylum: Arthropoda						
Class: Malacostraca						
Order: Amphipoda						
Family: Ampeliscidae						
Ampelisca sp.		-	14	-	-	-
Family: Aoridae						
Aoridae (LPIL)		-	-	14	-	-
Family: Bathyporeiidae						
Bathyporeia sp.		-	-	14	-	-
Family: Corophiidae						
Cheiriphotis sp		-	-	29	-	-
Corophiidae (LPIL)		-	-	29	-	-
Family: Dexaminidae						
Nototropis sp.		-	-	-	14	-
Family: Eriopisidae						
Eriopisella sp.		-	-	-	14	-
Family: Isaeida						
Isaeidae (LPIL)		-	-	-	-	-
Family: Ischyroceridae						
Ischyroceridae (LPIL)		-	-	14	-	-
Family: Liljeborgiidae						
Idunella sp.		-	72	-	57	14
Liljeborgiidae (LPIL)		-	14	-	14	14
Family: Lysianassidae						
Lysianassidae (LPIL)		-	-	-	-	-
Family: Oedicerotidae						
Oedicerotidae (LPIL)		-	-	-	14	-
Perioculodes sp.		-	-	14	-	-
Family: Photidae						
Photidae (LPIL)		-	-	-	-	-
Family: Phoxocephalidae						
Basuto stimpsoni		-	-	-	-	-
Family: Urothoidae						
Urothoe sp.		-	-	14	330	-
Family: Unspecified						
Amphipoda (LPIL)		-	-	-	-	-
Order: Cumacea						
Family: Bodotriidae						
Apocuma sp.		-	57	-	-	-
Bodotriidae (LPIL)		-	-	-	43	-
Family: Leuconidae						
Leuconidae (LPIL)		-	-	29	-	-
Family: Unspecified						
Cumacea (LPIL)		-	-	14	-	-
Order: Decapoda						
Family: Unspecified						

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Station	13BG	14BG	15BG	16BG	17BG
Number of Replicates Pooled	3	3	3	3	3
Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Decapoda (LPIL)	-	29	43	-	-
Family: Callianassidae					
Callianassa sp.	-	43	-	29	-
Callianassidae (LPIL)	-	230	29	-	-
Family: Epialtidae					
Pisinae (LPIL)	-	-	14	-	-
Family: Paguridae					
Paguridae *zoea larva*	14	3362	14	-	-
Paguristes sp.	-	-	-	-	14
Family: Porcellanidae					
Porcellanidae *zoea larva*	14	14	-	-	-
Family: Unspecified					
Brachyura zoea larva	14	14	244	29	-
Order: Isopoda					
Family: Anthuridae					
Amakusanthura sp.	-	-	-	-	-
Anthuridae (LPIL)	-	29	-	-	-
Cyathura sp.	-	-	-	-	-
Family: Sphaeromatidae					
Cassidinidea sp.	-	-	-	-	-
Order: Mysida					
Family: Unspecified					
Mysidacea (LPIL)	14	-	57	-	29
Order: Tanaidacea					
Family: Kalliapseudidae					
Kalliapseudidae (LPIL)	-	-	14	-	-
Family: Metapseudidae					
Calozodion sp.	-	-	-	-	-
Family: Unspecified					
Metapseudidae (LPIL)	-	-	-	-	-
Order: Unspecified					
Family: Unspecified					
Malacostraca (LPIL)	-	-	-	-	-
Class: Entognatha					
Order: Collembola					
Family: Unspecified					
Collembola (LPIL)	-	-	-	-	-
Class: Insecta					
Order: Diptera					
Family: Unspecified					
Diptera (LPIL)	-	-	-	-	-
Phylum: Mollusca					
Class: Gastropoda					
Order: Caenogastropoda					
Family: Eulimidae					
Melanella sp.	-	-	-	14	-
Order: Heterostropha					

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Number of Replicates Pooled	3	3	3	3	3
Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Family: Pyramidellidae					
Pyramidellidae (LPIL)	-	-	-	14	-
Order: Littorinimorpha					
Family: Naticidae					
Sinum sp.	-	-	43	43	-
Order: Neogastropoda					
Family: Cystiscidae					
Plesiocystiscus sp.	-	-	14	-	-
Order: Neotaenioglossa					
Family: Caecidae					
Caecum sp.	-	-	101	129	-
Cerithiidae (LPIL)	-	14	-	-	-
Family: Calyptraeidae					
Calyptraea sp.	-	14	14	-	-
Crepidula sp.	-	-	-	-	-
Family: Cerithiidae					
Cerithium sp.	-	-	-	-	-
Family: Eulimidae					
Melanella sp.	-	-	43	-	-
Family: Hydrobiidae					
Hydrobiidae (LPIL)	-	-	-	-	-
Order: Unspecified					
Family: Unspecified					
Gastropoda (LPIL)	-	-	14	-	14
Class: Bivalvia					
Order: Unspecified					
Family: Unspecified					
Bivalvia (LPIL)	-	29	57	14	14
Order: Arcoida					
Family: Arcidae					
Anadara sp.	-	-	-	-	14
Order: Carditoida					
Family: Carditidae					
Pleuromeris sp.	-	-	-	-	86
Order: Myoida					
Family: Myidae					
Myidae (LPIL)	-	-	-	-	-
Order: Mytiloida					
Family: Mytilidae					
Musculus sp.	-	-	14	-	-
Mytilidae (LPIL)	-	-	-	-	-
Order: Nuculoida					
Family: Nuculidae					
Nucula sp.	-	-	29	43	-
Order: Ostreoida					
Family: Anomiidae					
Anomia sp.	-	-	474	-	-

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	Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Order: Veneroida						
Family: Unspecified						
Veneroida (LPIL)		-	57	-	-	-
Family: Corbulidae						
Caryocorbula sp.		-	-	29	29	14
Corbula sp.		-	-	201	230	-
Corbulidae (LPIL)		-	14	-	57	-
Family: Lucinidae						
Lucinidae (LPIL)		-	14	-	-	-
Parvilucina sp.		-	57	-	-	-
Family: Mactridae						
Mactridae (LPIL)		-	-	-	-	-
Family: Montecutidae						
Mysella sp.		-	29	86	144	29
Family: Tellinidae						
Macoma sp.		-	29	-	57	-
Tellinidae (LPIL)		14	-	43	14	-
Family: Veneridae						
Veneridae (LPIL)		-	-	-	-	-
Phylum: Phoronida						
Class: Unspecified						
Order: Unspecified						
Family: Unspecified						
Phoronida (LPIL)		-	14	-	-	-
Phylum: Echinodermata						
Class: Ophiuroidea						
Order: Ophiurida						
Family: Amphiuridae						
Amphiodia/Amphipholis complex		-	144	359	359	-
Amphioplus sp.		-	-	-	-	-
Amphiura sp.		-	-	-	-	14
Amphiuridae (LPIL)		-	345	172	244	72
Ophiophragmus sp.		-	-	14	-	-
Order: Unspecified						
Family: Unspecified						
Ophiuroidea (LPIL)		-	115	57	-	-
Phylum: Platyhelminthes						
Class: Rhabditophora						
Order: Polycladida						
Family: Unspecified						
Polycladida (LPIL)		-	-	-	14	-
Phylum: Bryozoa						
Class: Gymnolaemata						
Order: Ctenostomatida						
Family: Unspecified						
Ctenostomatida (LPIL)		-	-	-	-	-
Phylum: Bryozoa						

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Station	13BG	14BG	15BG	16BG	17BG
Number of Replicates Pooled	3	3	3	3	3
Collection Date	08/21/13	08/24/13	08/27/13	08/27/13	08/26/13
Class: Unspecified					
Order: Unspecified					
Family: Unspecified					
Bryozoa (LPIL)	-	-	43	57	-
Phylum: Chaetognatha					
Class: Unspecified					
Order: Unspecified					
Family: Unspecified					
Chaetognatha (LPIL)	-	43	29	29	29
Phylum: Brachiopoda					
Class: Lingulata					
Order: Lingulida					
Family: Lingulidae					
Lingula sp.	-	-	-	-	-
Total Organisms	86	6724	4095	2888	1609
Number of Taxa	6	62	57	53	36

Prepared For: Golder Associates, Inc.
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Number per Sq. Meter

	1BG	2BG	3BG	4BG	5BG	6BG	7BG	8BG	9BG	10BG	11BG	12BG	13BG	14BG	15BG	16BG	17BG
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	08/15/2013	08/15/2013	08/17/2013	08/17/2013	08/16/2013	08/16/2013	08/19/2013	08/19/2013	08/22/2013	08/22/2013	08/24/2013	08/24/2013	08/21/2013	08/24/2013	08/27/2013	08/27/2013	08/26/2013
Cliona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0
Demospongiae (LPIL)	0	0	0	0	14	0	0	0	0	0	0	14	0	0	14	0	0
Demospongiae boring (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	129	0	0
Demospongiae encrusting (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86	0	0
Porifera (LPIL)	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoathecata (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	201	14	0
Aglaopheniidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0
Campanulariidae (LPIL)	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Lovenellidae (LPIL)	0	0	0	0	0	0	0	0	0	0	273	0	0	0	273	57	129
Sertularia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Sertulariidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	0
Leptothecata (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144	43	0
Plumulariidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Hydroida (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0
Hydroidolina (LPIL)	0	0	0	0	72	0	0	0	0	0	0	0	0	0	14	0	0
Hydrozoa (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0
Actiniaria (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Scleraxonia (LPIL)	0	0	0	0	0	0	0	0	0	0	0	86	0	29	0	0	0
Kophobelemnon sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0
Scleractinia (LPIL)	0	0	0	0	0	0	0	0	0	0	14	14	0	29	0	0	0
Anthozoa (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Nemertea (LPIL)	0	0	0	0	43	0	0	0	0	72	0	129	14	201	273	86	43
Sipuncula (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	101	0	0
Amphinomidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0
Capitellidae (LPIL)	0	0	0	0	14	0	0	0	0	0	0	115	0	0	0	0	0
Capitobranchus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0
Decamastus sp.	0	0	0	14	14	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0	57	0	144	0	144	0	0	72
Mediomastus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	101
Notomastus sp.	57	86	101	86	115	158	0	0	0	0	0	0	0	0	0	0	0
Maldanidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	72	0	72	0	0	0
Cossura delta	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Protodorvillea egena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Schistomeringos rudolphii	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Augeneria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Lumbrineris meteorana	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Scoletoma impatiens	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Oenonidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Diopatra sp.	0	0	0	0	0	0	0	0	0	0	0	230	0	29	14	0	0
Armandia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	86
Proscoloplos sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	144	0	0	0
Scoloplos acmeceps	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
Scoloplos sp.	0	0	0	0	0	0	0	0	0	43	0	72	0	101	0	14	216
Aricidea cerrutii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Aricidea fragilis	0	0	0	0	0	0	0	0	0	0	0	14	0	29	0	0	0
Aricidea simplex	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Aricidea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Aricidea wassi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Cirrophorus branchiatus	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	86
Levinsenia gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0

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	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	08/15/2013	08/15/2013	08/17/2013	08/17/2013	08/16/2013	08/16/2013	08/19/2013	08/19/2013	08/22/2013	08/22/2013	08/24/2013	08/24/2013	08/21/2013	08/24/2013	08/27/2013	08/27/2013	08/26/2013
Cliona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0
Paraonidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Paraonis fulgens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Glycera africana	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	14
Glycera alba	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	29	14
Glycera sp.	0	0	0	0	0	0	0	0	0	29	0	29	0	29	14	43	29
Glycinde kameruniana	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0
Goniada multidentata	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
Goniada sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Goniadella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Goniadidae (LPIL)	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
Gyptis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Kefersteinia sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Aglaophamus sp.	0	0	115	0	72	273	445	57	259	0	0	0	0	14	0	0	0
Micronephtys stammeri	0	0	0	0	0	0	0	0	0	0	0	57	0	29	115	72	14
Neanthes sp.	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0
Nereididae (LPIL)	0	0	0	14	0	0	0	14	0	0	0	0	0	0	0	0	0
Nereis sp.	0	0	0	0	43	0	0	0	14	0	0	0	0	0	0	14	0
Eteone sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Ancistrosyllis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Cabira sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Sigambra bassi	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Sigambra sp.	14	14	57	57	201	244	14	0	0	14	0	14	0	0	0	0	0
Malmgreniella sp.	0	0	0	0	0	0	0	0	0	0	0	43	0	43	57	29	0
Ephesiella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	101	0	0	0
Eusyllis assimilis	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Eusyllis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Exogone sp.	0	0	0	0	0	0	0	0	0	0	0	43	0	0	14	14	0
Pionosyllis sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Sphaerosyllis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	0
Galathowenia oculata	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Galathowenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Sabellaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Sabellariidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Spiochaetopterus sp.	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
Magelona cincta	0	0	0	0	0	0	0	0	0	0	0	43	0	29	0	0	14
Magelona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Minuspio sp.	0	0	0	0	0	0	0	0	14	29	0	0	0	431	72	57	0
Scolelepis sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Spionidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	29	14
Ampharete sp.	0	0	0	0	0	0	0	0	0	0	0	101	0	0	0	0	0
Lysippe sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Aphelochaeta marioni	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
Aphelochaeta sp.	0	0	0	0	0	0	0	0	0	0	0	86	0	0	0	0	0
Cirratulidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	43	0	14	14	0	14
Monticellina sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	43	0	0	0
Eupolymnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Polychaeta (LPIL)	0	0	0	0	0	0	0	0	0	0	0	86	0	0	0	0	0
Enchytraeidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Naididae (LPIL)	0	115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Prepared For: Golder Associates, Inc.
Project Name: Rio Cacheu Benthic Assessment (Wet S
Sample Group: Wet Season

Sample Method: Petite Ponar
Conversion Factor: 0.0232
Report Generated: 10/09/2013
Number per Sq. Meter

	1BG	2BG	3BG	4BG	5BG	6BG	7BG	8BG	9BG	10BG	11BG	12BG	13BG	14BG	15BG	16BG	17BG
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	08/15/2013	08/15/2013	08/17/2013	08/17/2013	08/16/2013	08/16/2013	08/19/2013	08/19/2013	08/22/2013	08/22/2013	08/24/2013	08/24/2013	08/21/2013	08/24/2013	08/27/2013	08/27/2013	08/26/2013
Cliona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0
Nais sp.	57	316	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0
Tubificoid Naididae (LPIL)	115	0	57	57	244	43	0	0	201	0	0	29	0	0	0	0	230
Ampelisca sp.	0	0	0	0	0	0	0	0	0	0	0	1078	0	14	0	0	0
Aoridae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Bathyporeia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Cheiriphotis sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0
Corophiidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	29	0	0
Nototropis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Eriopisella sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	14	0
Isaeidae (LPIL)	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
Ischyroceridae (LPIL)	0	0	0	0	14	0	0	0	0	0	0	0	0	0	14	0	0
Idunella sp.	0	0	0	0	0	0	0	0	0	14	0	0	0	72	0	57	14
Liljeborgiidae (LPIL)	0	0	0	0	0	0	0	0	0	14	0	0	0	14	0	14	14
Lysianassidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Oedicerotidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Perioculodes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Photidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Basuto stimpsoni	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
Urothoe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	330	0
Amphipoda (LPIL)	0	0	0	0	14	0	0	0	0	29	0	72	0	0	0	0	0
Apocuma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0
Bodotriidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0
Leuconidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0
Cumacea (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Decapoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	29	43	0	0
Callianassa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	29	0
Callianassidae (LPIL)	0	0	0	0	0	0	0	0	0	273	0	14	0	230	29	0	0
Pisinae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Paguridae zoea larva	0	0	0	0	0	0	0	0	0	0	0	0	14	3362	14	0	0
Paguristes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Porcellanidae zoea larva	0	0	0	0	0	0	0	0	0	0	0	0	14	14	0	0	0
Brachyura zoea larva	0	0	0	0	0	0	0	0	0	0	14	0	14	14	244	29	0
Amakusanthura sp.	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0
Anthuridae (LPIL)	14	0	0	0	14	0	0	0	0	0	0	0	0	29	0	0	0
Cyathura sp.	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Cassidinidea sp.	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0
Mysidacea (LPIL)	0	0	0	0	14	0	0	0	0	0	43	0	14	0	57	0	29
Kalliapseudidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Calozodion sp.	0	0	0	0	0	0	0	0	0	0	0	244	0	0	0	0	0
Metapseudidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0
Malacostraca (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Collembola (LPIL)	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0
Diptera (LPIL)	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Melanella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0
Pyramidellidae (LPIL)	0	0	0	0	29	0	0	0	0	14	0	0	0	0	0	14	0
Sinum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	43	0
Plesiocystiscus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Caecum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	129	0
Cerithiidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0

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	1BG	2BG	3BG	4BG	5BG	6BG	7BG	8BG	9BG	10BG	11BG	12BG	13BG	14BG	15BG	16BG	17BG
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taxon	08/15/2013	08/15/2013	08/17/2013	08/17/2013	08/16/2013	08/16/2013	08/19/2013	08/19/2013	08/22/2013	08/22/2013	08/24/2013	08/24/2013	08/21/2013	08/24/2013	08/27/2013	08/27/2013	08/26/2013
Cliona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0
Calyptraea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	0	0
Crepidula sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Cerithium sp.	0	43	14	287	14	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiidae (LPIL)	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda (LPIL)	0	0	14	0	129	0	0	0	0	0	0	43	0	0	14	0	14
Bivalvia (LPIL)	14	29	14	0	273	0	0	0	0	0	14	29	0	29	57	14	14
Anadara sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Pleuromeris sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86
Myidae (LPIL)	0	0	72	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Musculus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
Mytilidae (LPIL)	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
Nucula sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	29	43	0
Anomia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	474	0	0
Veneroida (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0
Caryocorbula sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	29	14
Corbula sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	201	230	0
Corbulidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	57	0
Lucinidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Parvilucina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0
Mactridae (LPIL)	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0
Mysella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	29	86	144	29
Macoma sp.	14	43	0	0	0	14	14	0	0	0	0	29	0	29	0	57	0
Tellinidae (LPIL)	0	0	43	0	0	0	0	0	0	0	0	0	14	0	43	14	0
Veneridae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
Phoronida (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Amphiodia/Amphipholis complex	0	0	0	0	0	0	0	0	0	0	0	0	0	144	359	359	0
Amphioplus sp.	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0
Amphiura sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Amphiuridae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	57	0	345	172	244	72
Ophiophragmus sp.	0	0	0	0	0	0	0	0	0	0	0	14	0	0	14	0	0
Ophiuroidea (LPIL)	0	0	0	0	0	0	0	0	0	0	0	14	0	115	57	0	0
Polycladida (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
Ctenostomatida (LPIL)	0	0	0	0	0	0	0	0	0	0	302	0	0	0	0	0	0
Bryozoa (LPIL)	0	0	0	0	230	0	0	0	0	0	0	0	0	0	43	57	0
Chaetognatha (LPIL)	0	0	0	0	0	0	0	0	0	14	0	72	0	43	29	29	29
Lingula sp.	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0

APPENDIX F5

Fish and Invertebrate Data (Dry Season and Wet Season)

January 2014
Report No. 13514950200.550/B.0

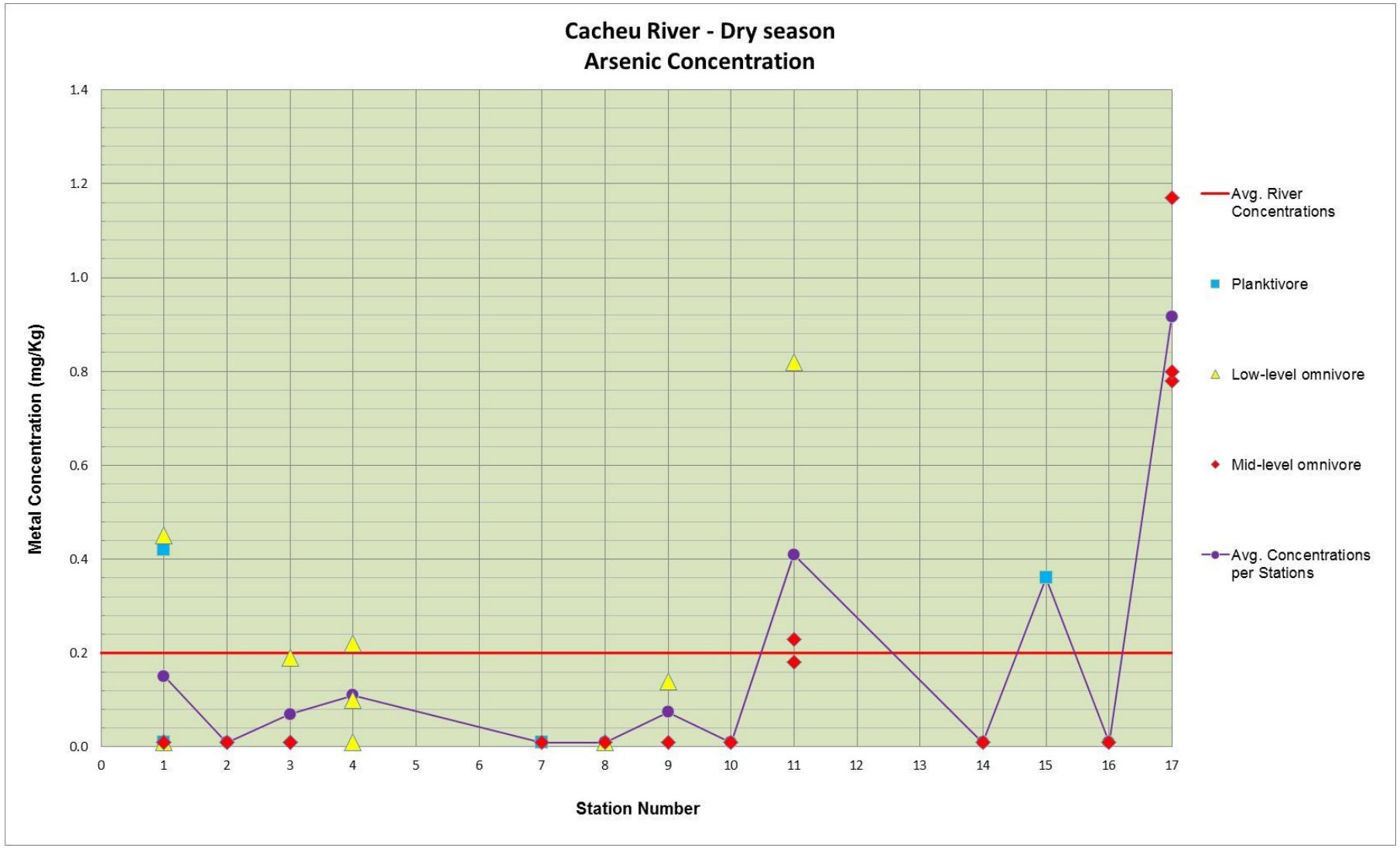
Dry Season Fish and Macroinverterbrate Average Lengths and Weights

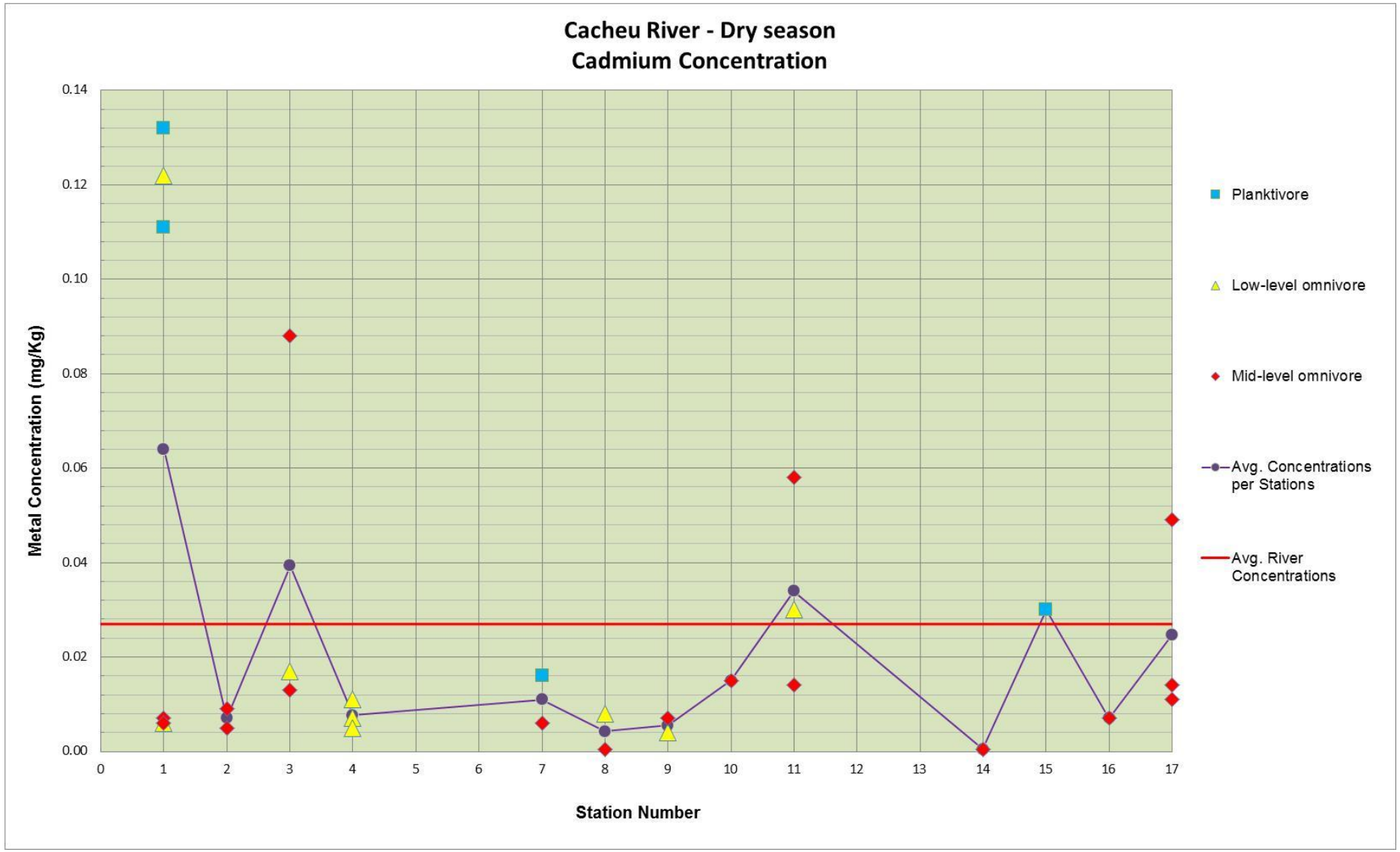
Lowest Taxonomic ID	N*	Average Length (millimeters)	Average Weight (grams)
Alpheidae	1	16	0.5
Arius sp.	22	122	52.8
Batrachoididae	1	40	0.8
Brachydeuterus auritus	12	118	24.5
Callinectes sp.	36	72	51.7
Carangidae	1	11	0.1
Caridea	107 (97)	7	0.5
Citharichthys stampflii	4	105	12.1
Clupeidae	6	48	5.6
Cynoglossus senegalensis	28	234	99.2
Echinoida	4	24	6.2
Ephippidae	1	15	0.2
Ephippion guttifer	4	169	62.1
Ethmalosa fimbriata	1	244	107.0
Ethmalosa sp.	1	91	5.5
Eucinostomus melanopterus	1	143	36.5
Galeiodes decadactylus	8	35	0.8
Gobiidae	1	22	0.1
Ilisha africana	91 (90)	114	14.8
Lagocephalus laevigatus	2	149	56.4
Leptocephalus	2	44	0.1
Liza falcipinnis	1	321	359.0
Liza grandisquamis	10	157	63.0
Loliginidae	6	24	3.4
Monodactylus sebae	7	117	37.0
Penaeidae	65	18	2.9
Penaeidea	1	43	35.6
Penaeoidea	26	13	1.3
Pentanemus quinquarius	1	196	58.5
Plectorhinchus macrolepis	1	293	270.0
Poeciliidae	2	45	0.8
Polydactylus quadrifilis	17	303	222.0
Pomadasys peroteti	2	150	52.1
Pseudotolithus brachygnathus	10	97	23.1
Pseudotolithus elongatus	30	76	15.9
Pseudotolithus senegalensis	42 (41)	70	16.3

Dry Season Fish and Macroinverterbrate Average Lengths and Weights

Lowest Taxonomic ID	N*	Average Length (millimeters)	Average Weight (grams)
Pseudotolithus sp.	14	75	2.2
Selene dorsalis	1	76	4.8
Sicyonia sp.	7	2	0.03
Stomatopoda	5	75	19.7
Trichiurus lepturus	4	366	58.5

*N for weight provided in parentheses if different from N for lengths


Cacheu River - Dry season
Arsenic Concentration
Metal Concentration (mg/Kg)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Station Number
Avg. River Concentrations
Planktivore
Low-level omnivore
Mid-level omnivore
Avg. Concentrations per Stations



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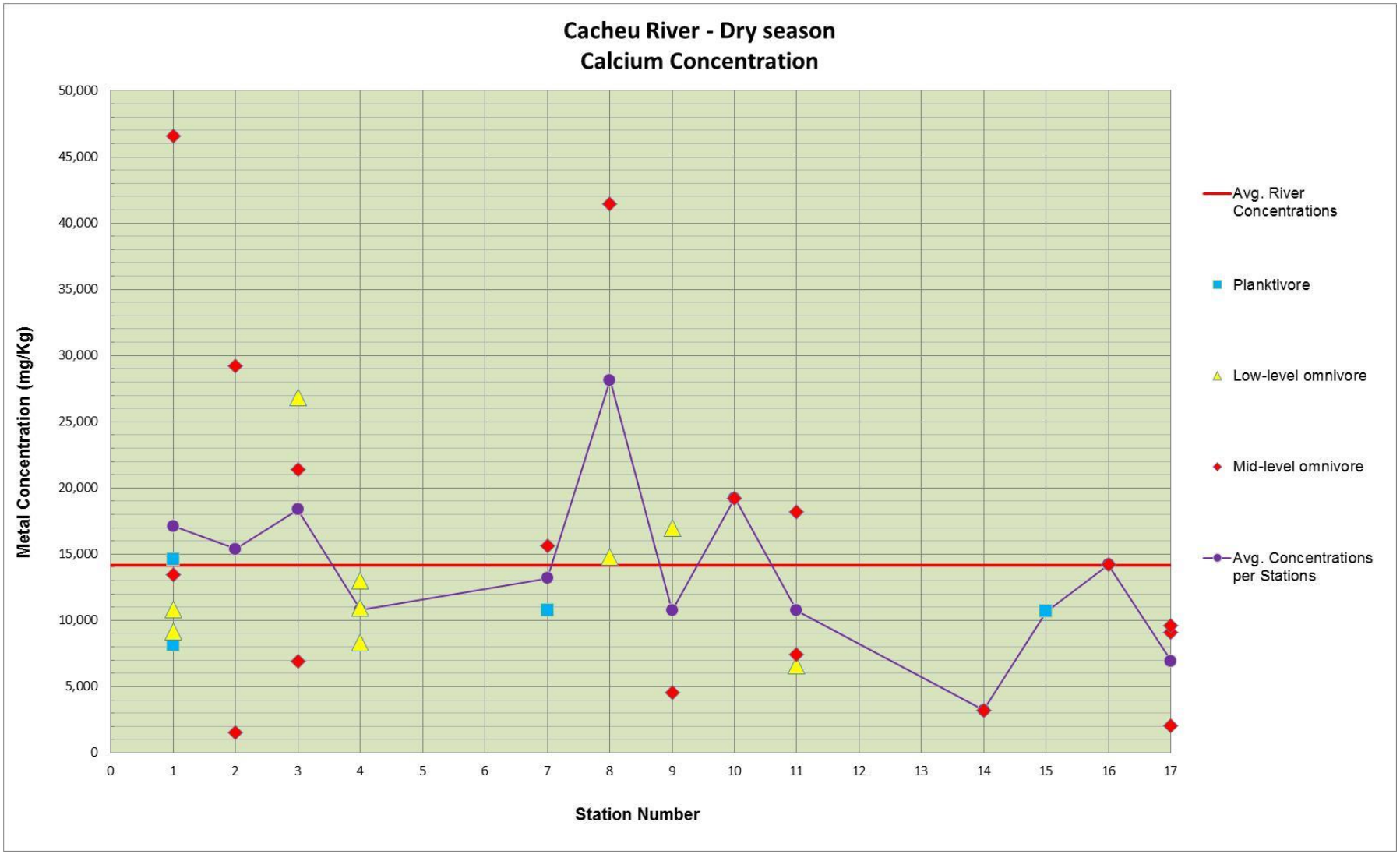

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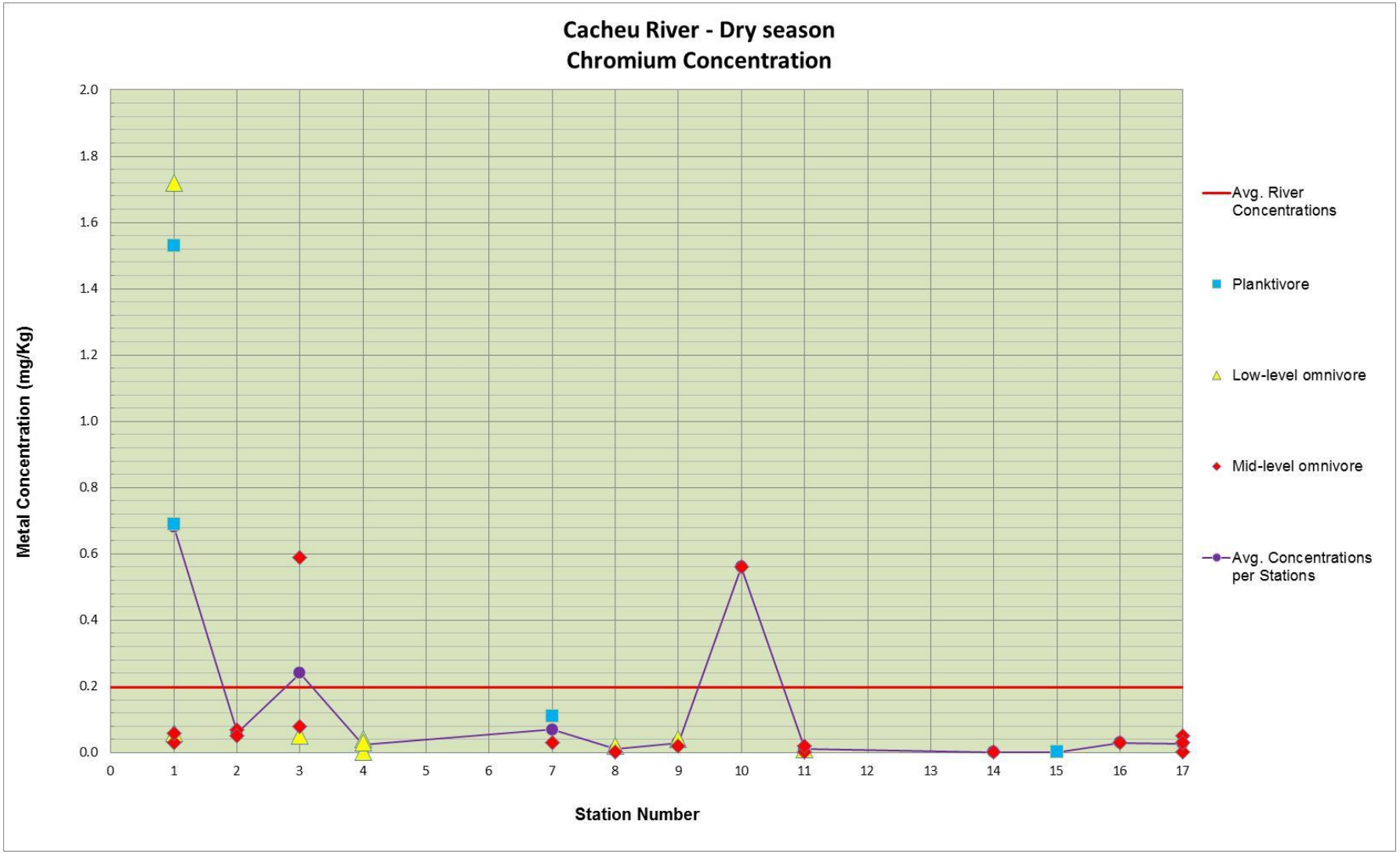
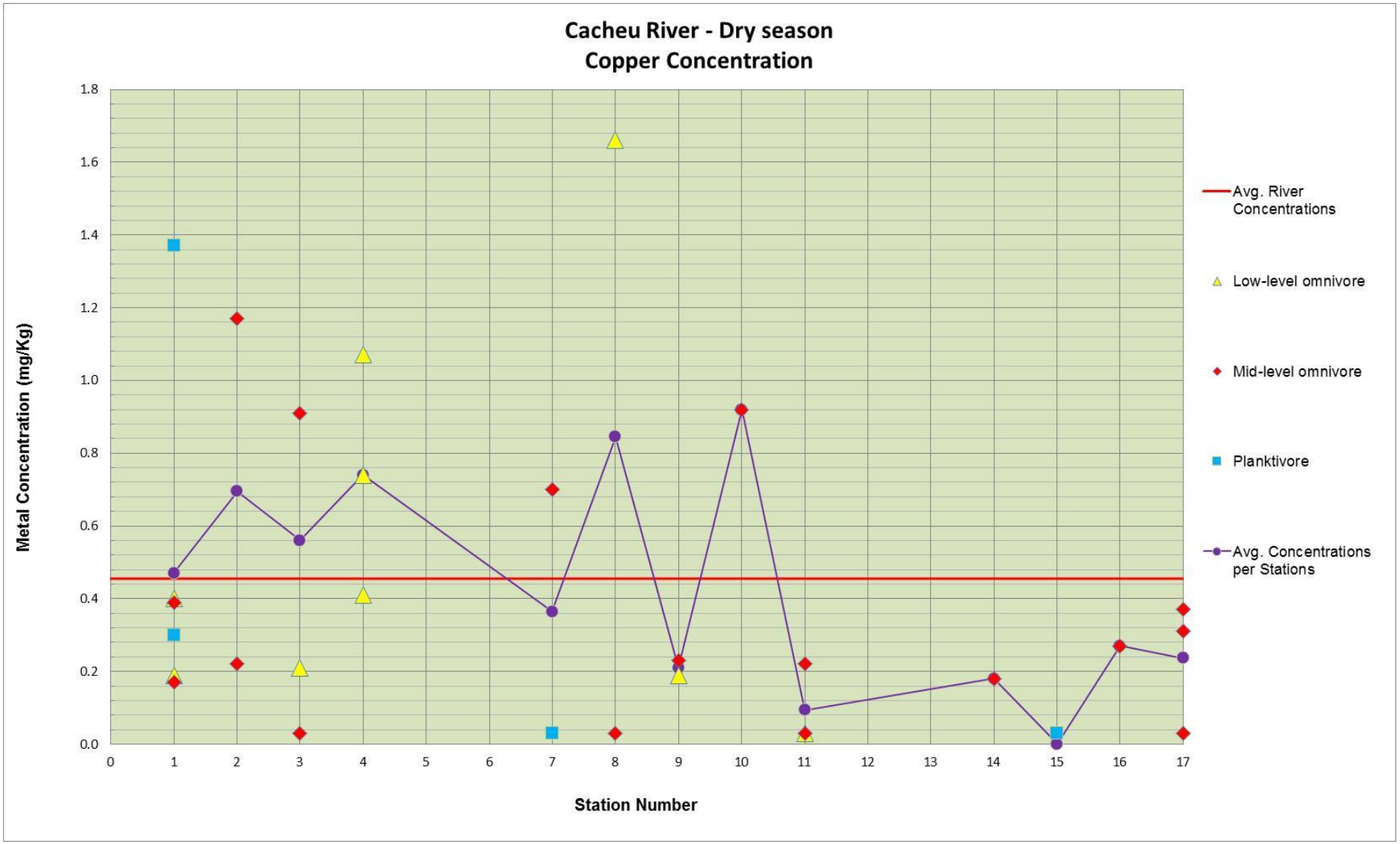

Cacheu River - Dry season
Chromium Concentration
Metal Concentration (mg/Kg)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Station Number
Avg. River Concentrations
Planktivore
Low-level omnivore
Mid-level omnivore
Avg. Concentrations per Stations



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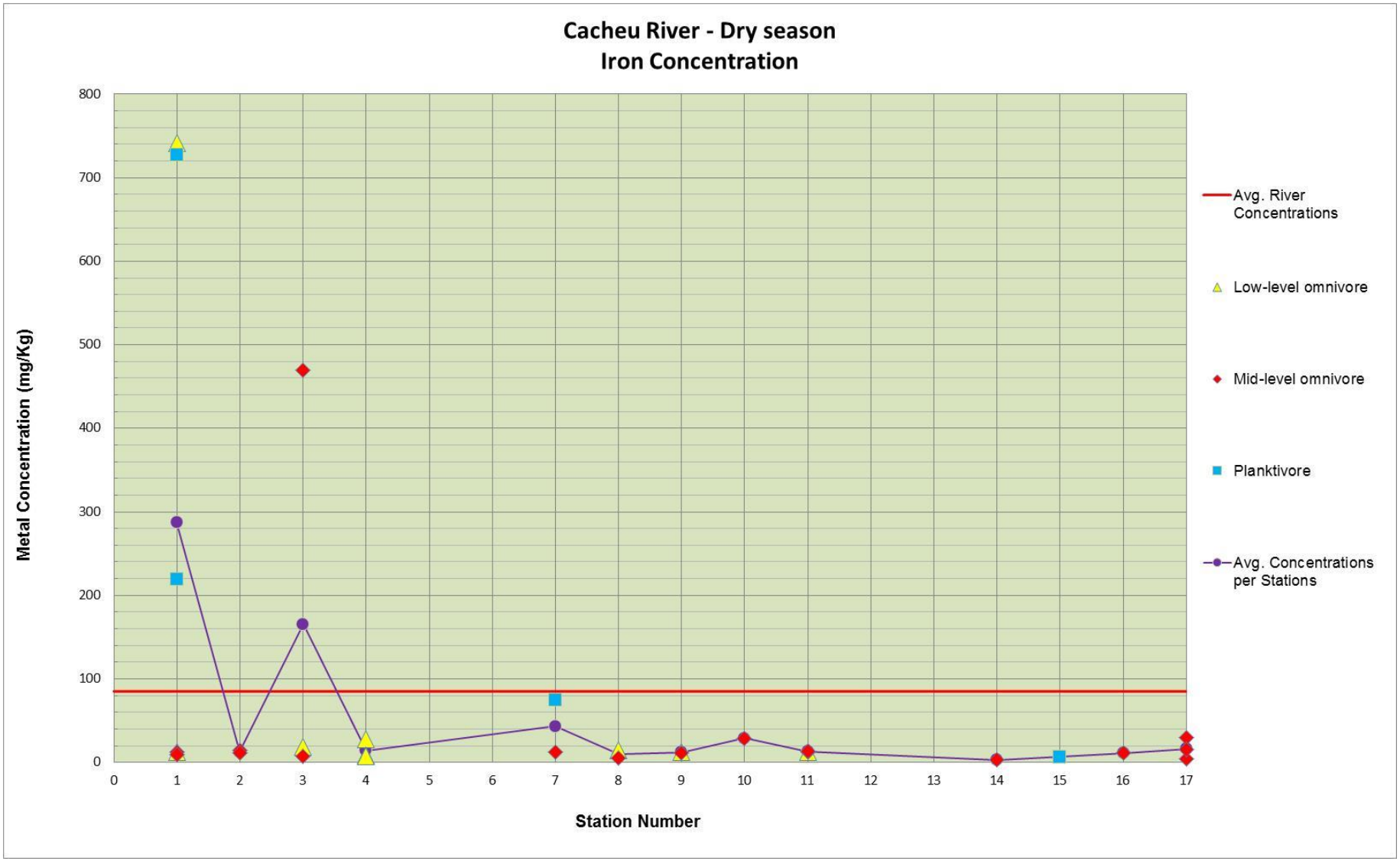

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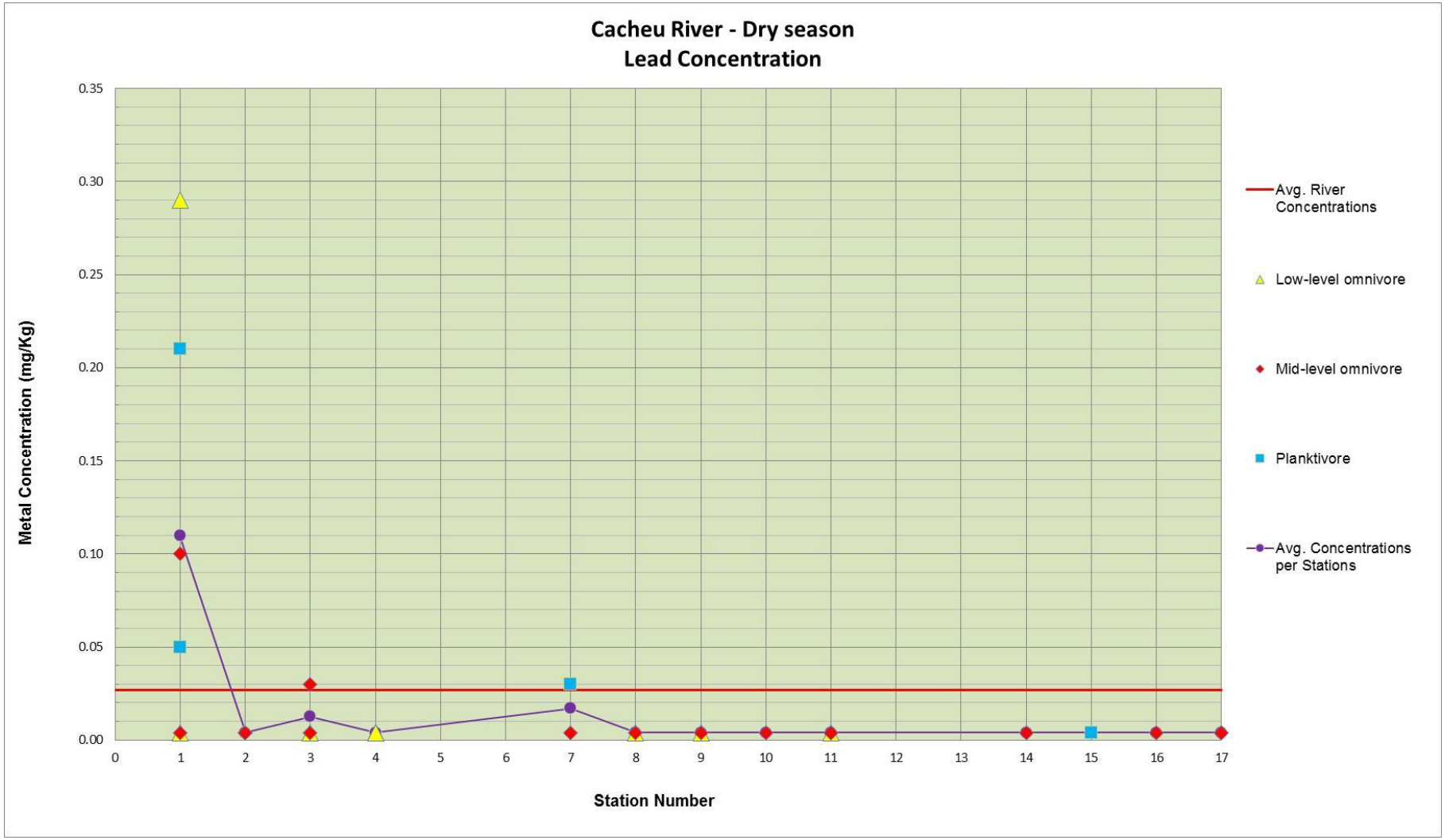
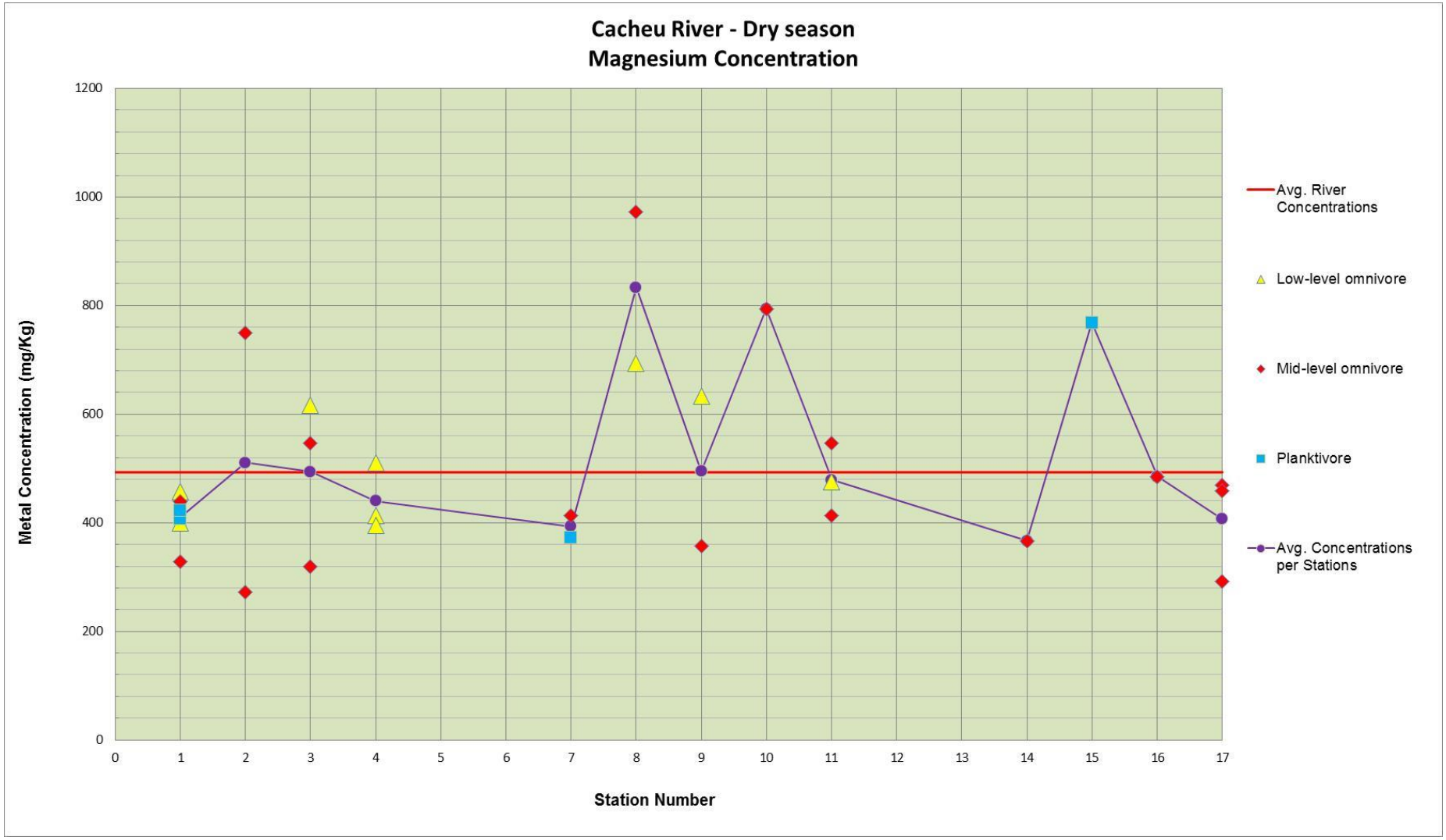

Cacheu River - Dry season
Lead Concentration
Metal Concentration (mg/Kg)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations



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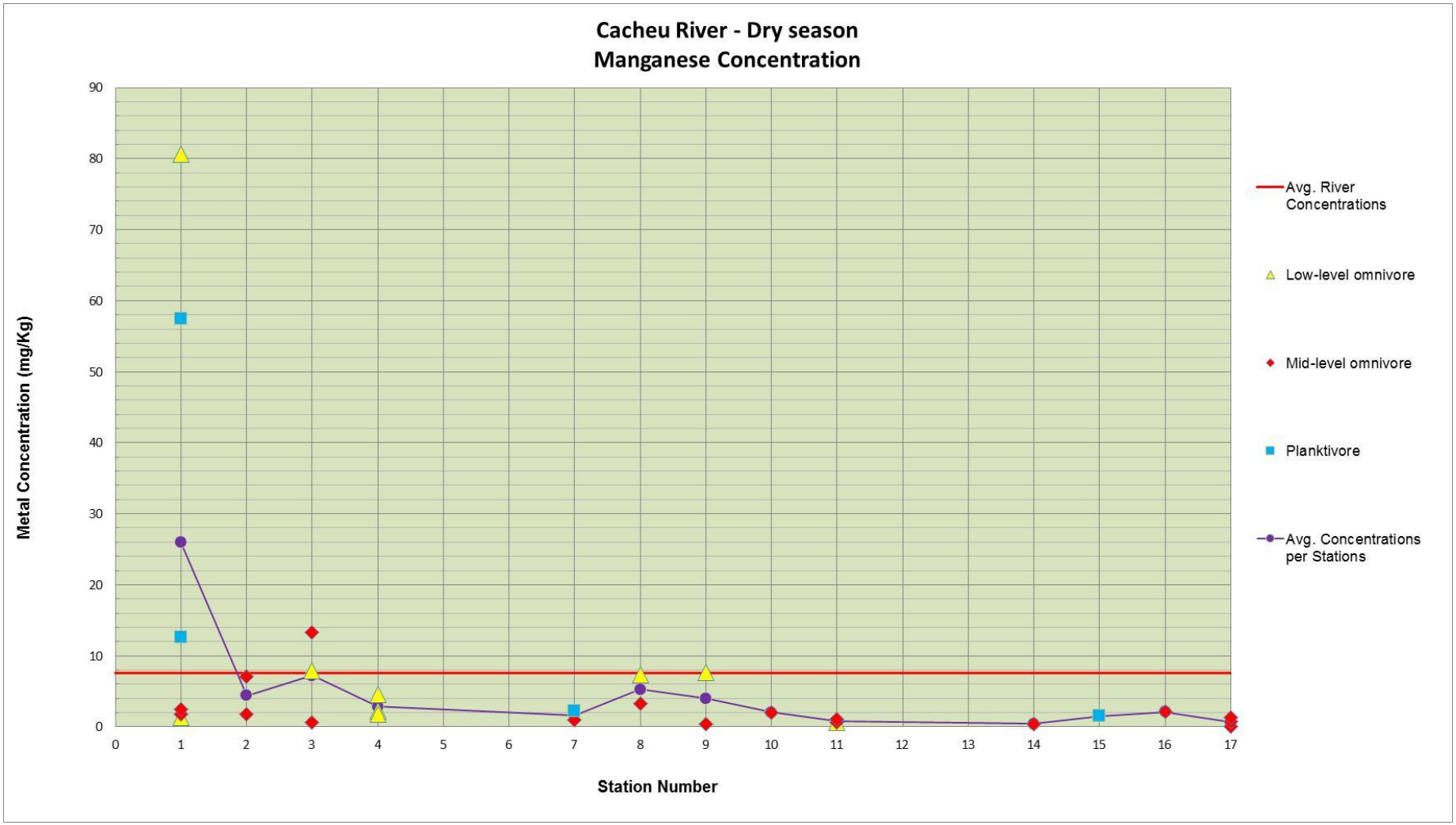
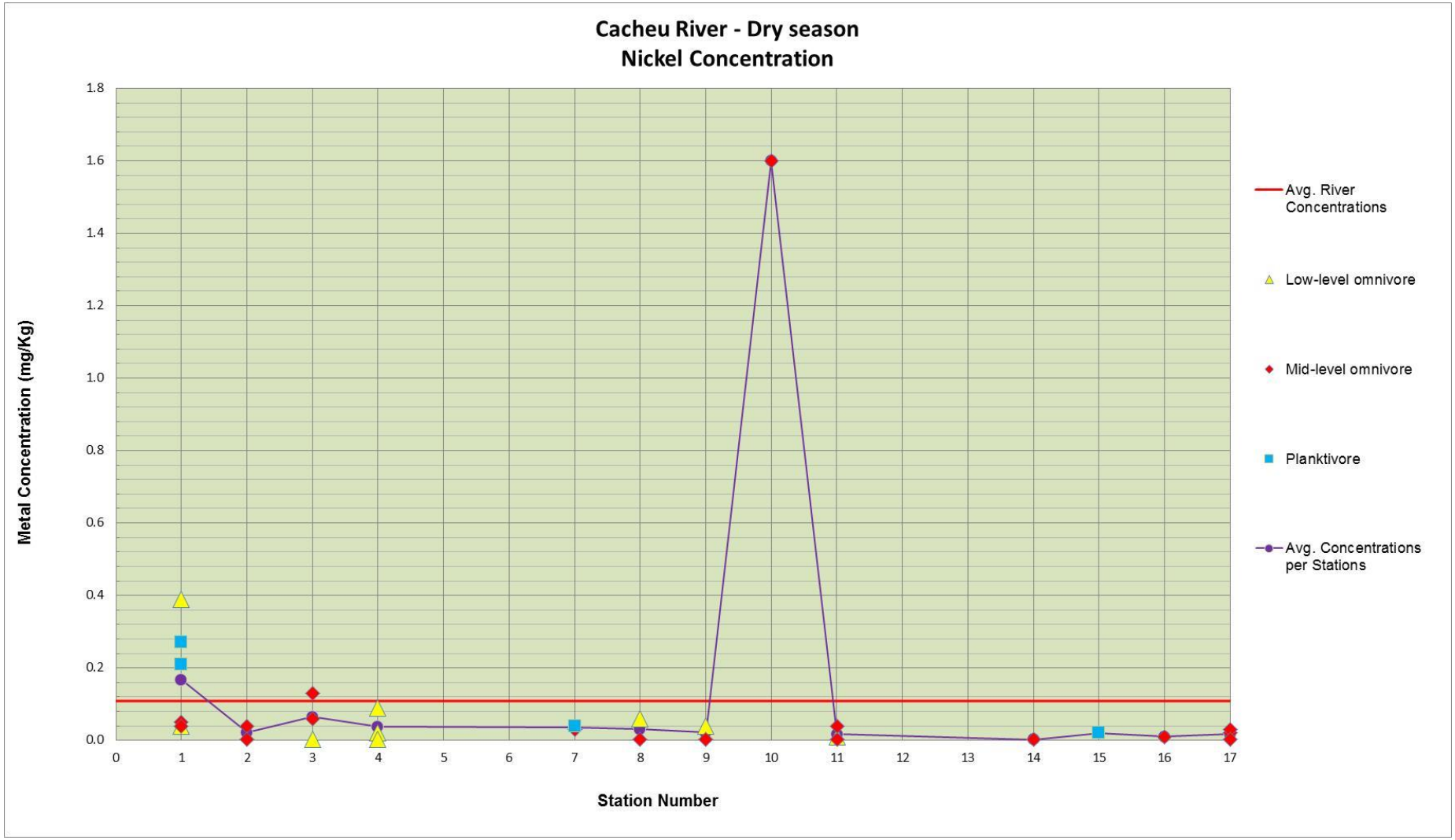
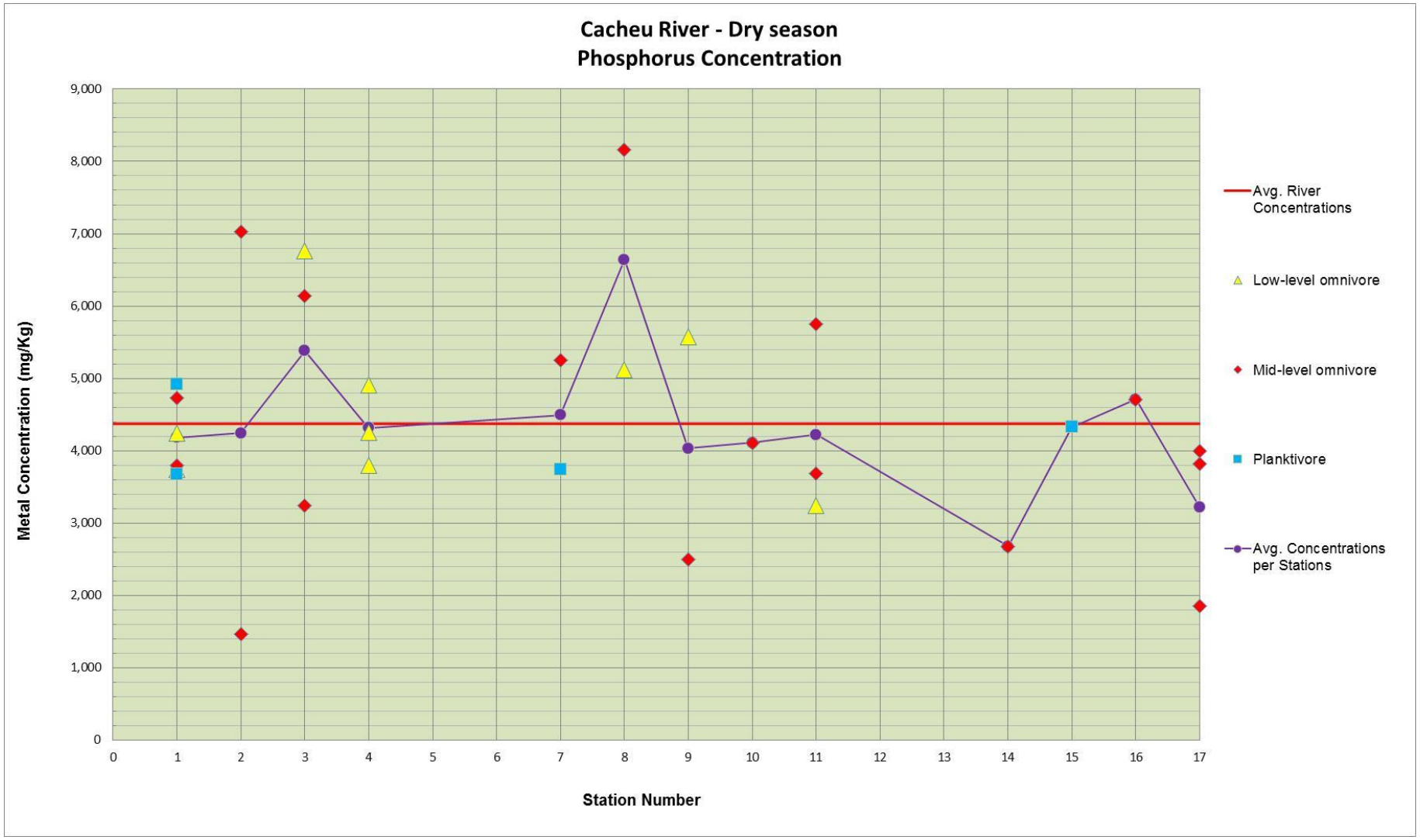
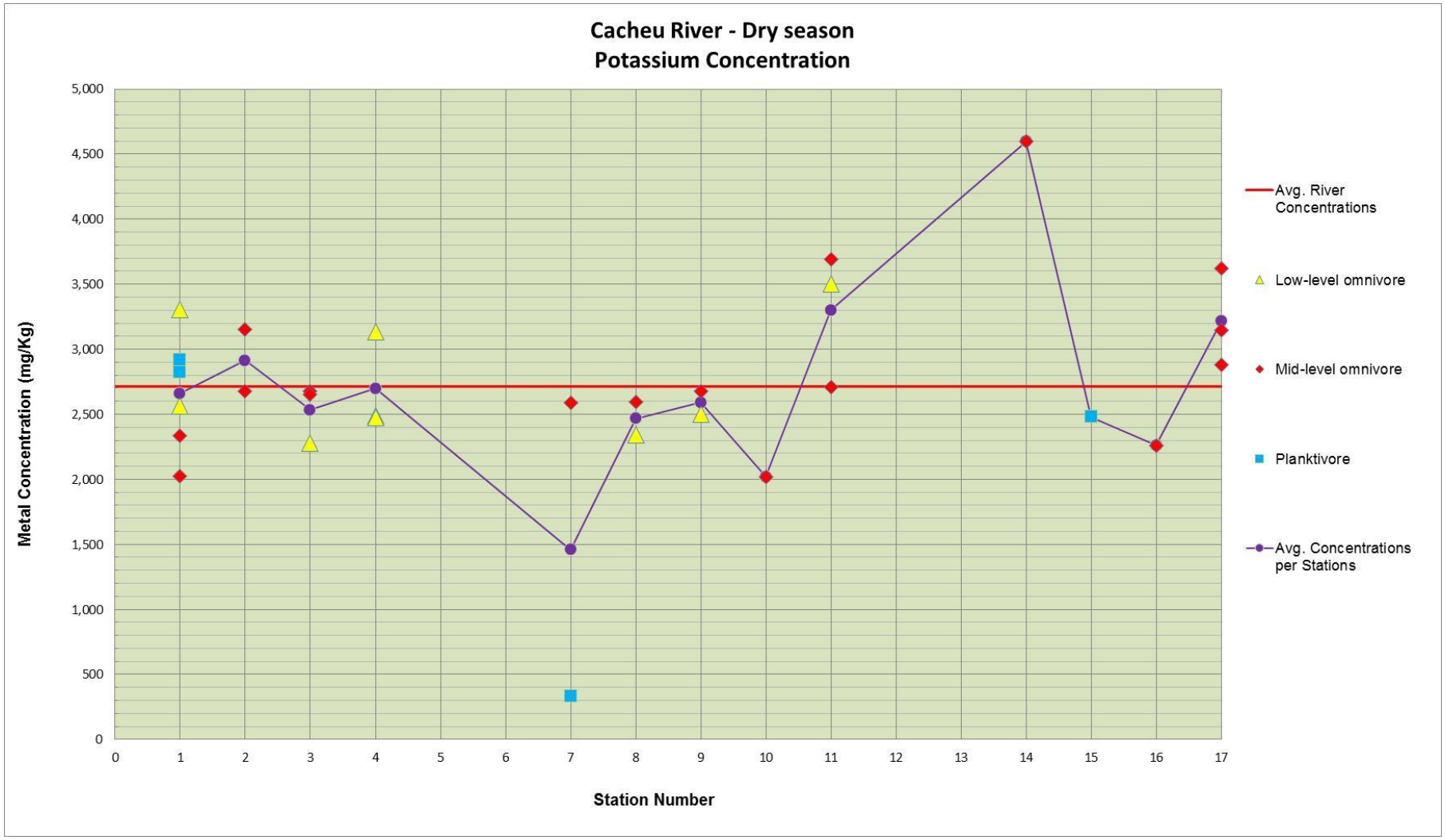
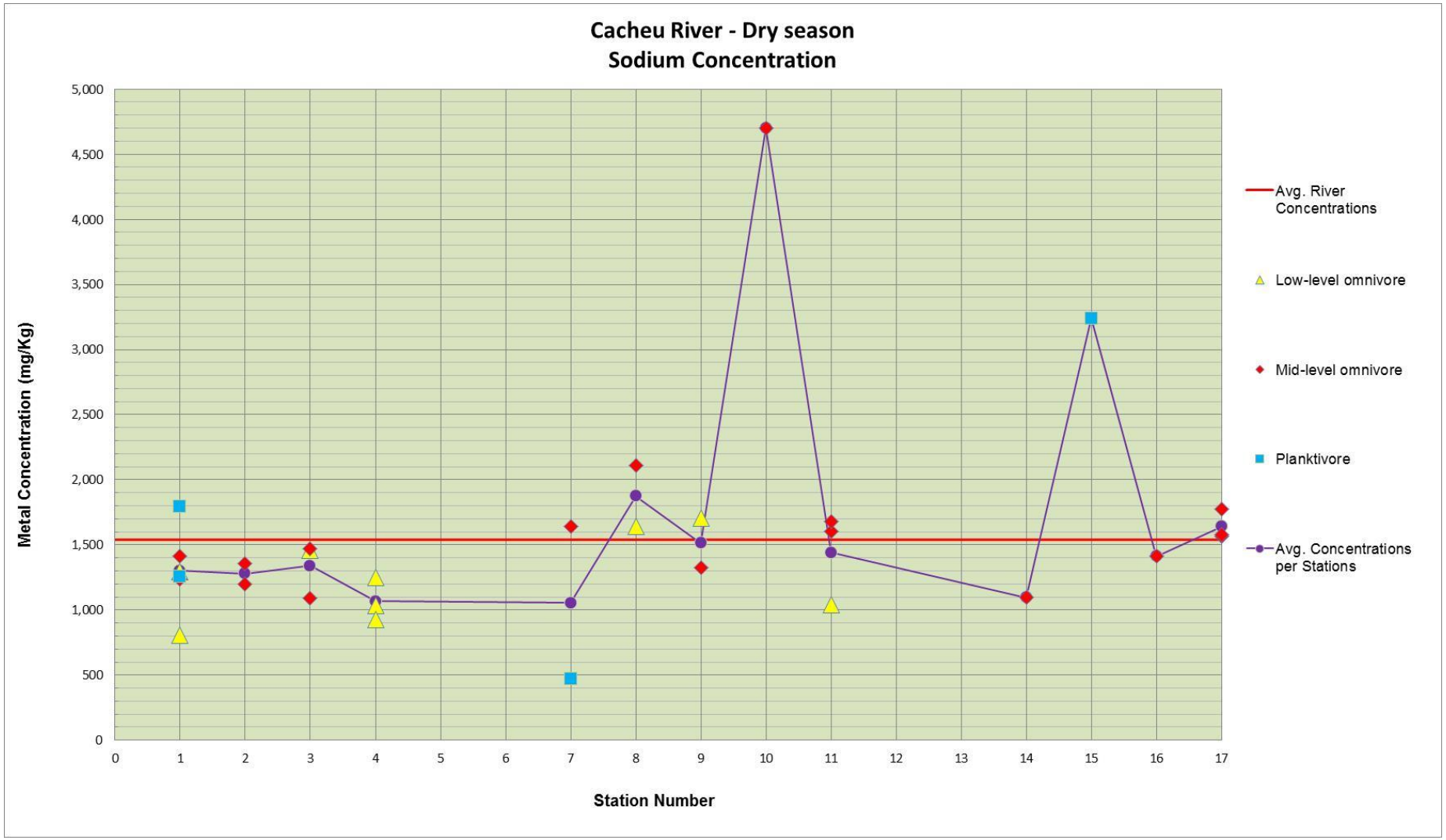
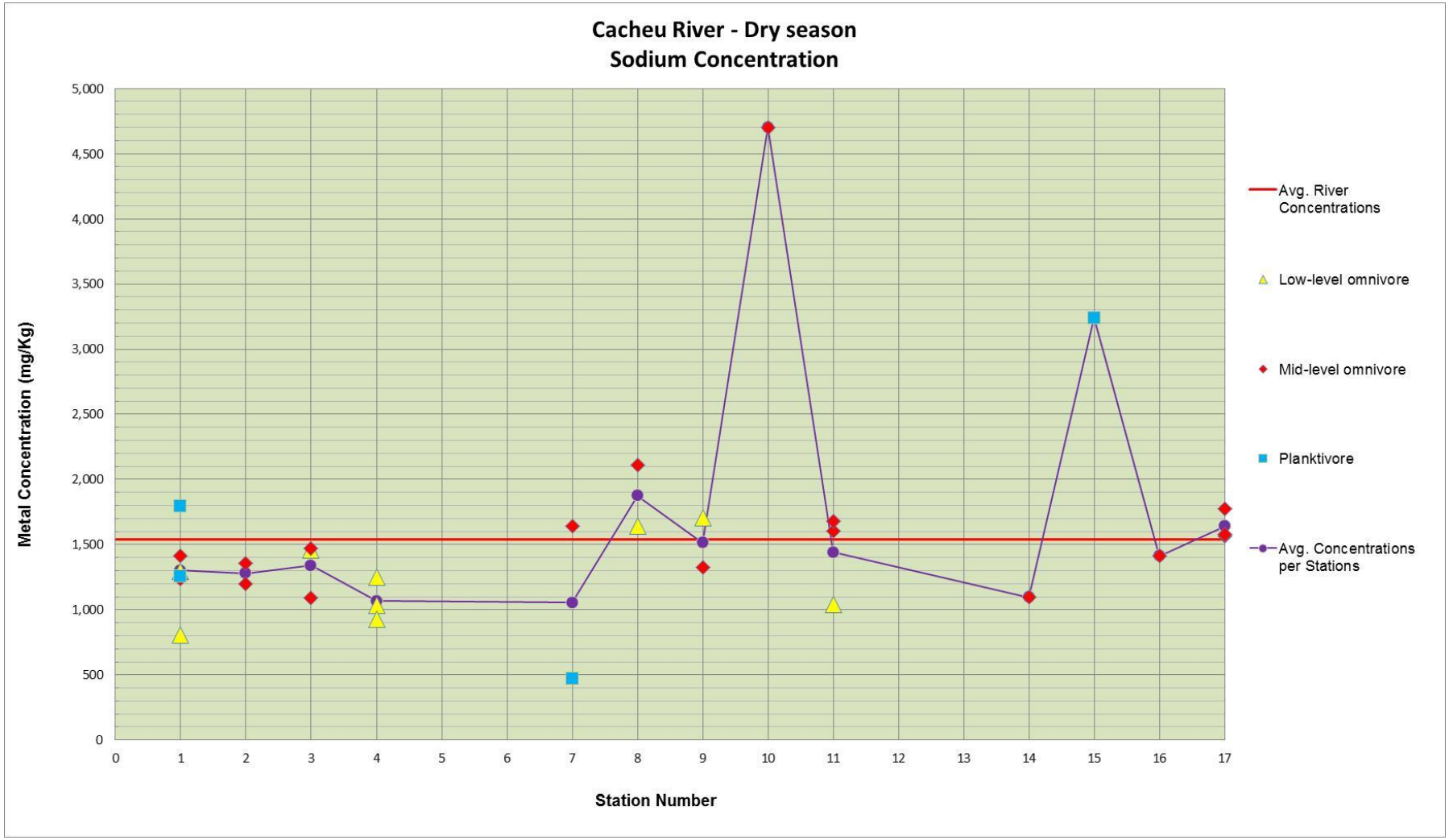

Cacheu River - Dry season
Manganese Concentration
Metal Concentration (mg/Kg)
Station Number
0
10
20
30
40
50
60
70
80
90
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations

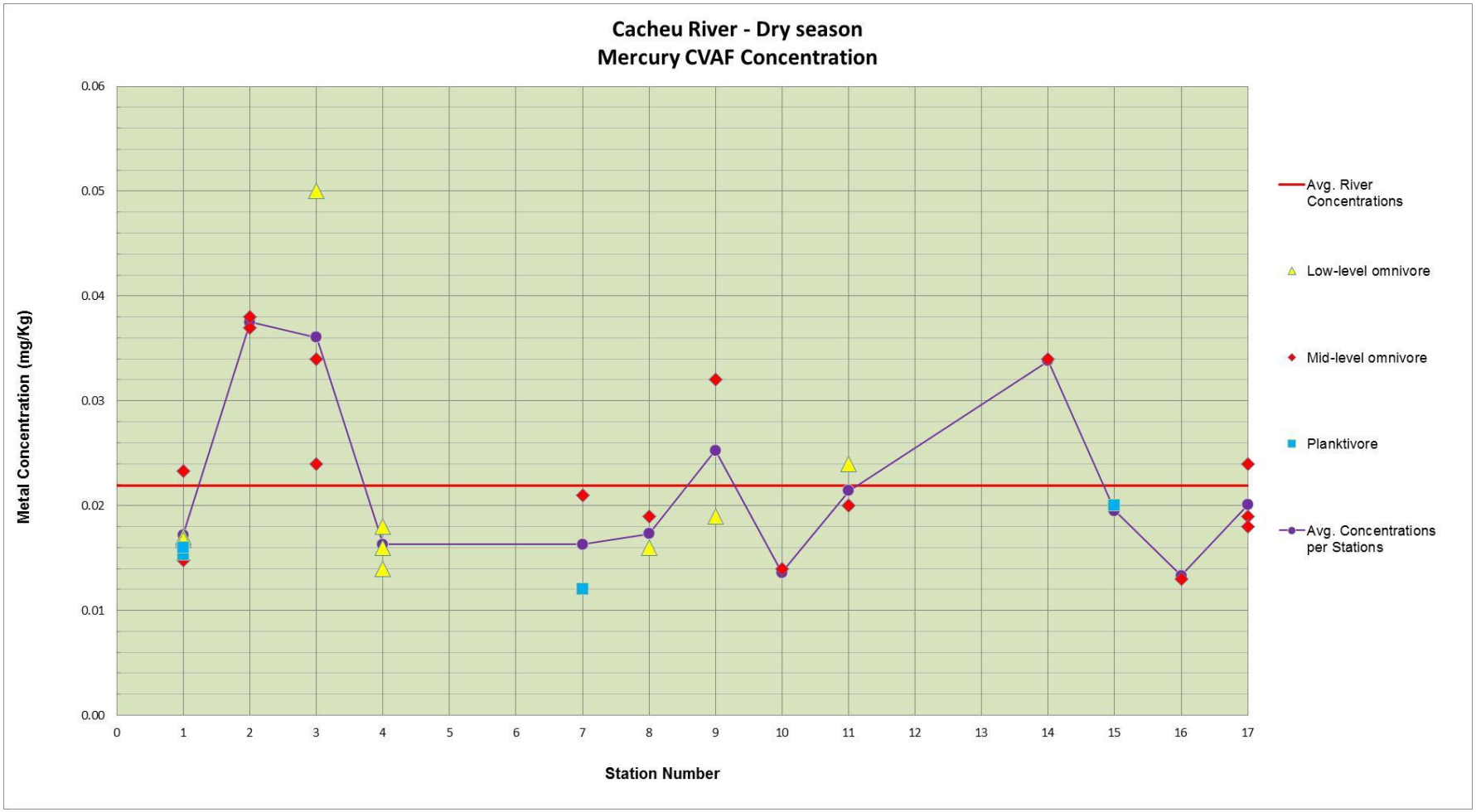

Cacheu River - Dry season
Nickel Concentration
Metal Concentration (mg/Kg)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations


Cacheu River - Dry season
Phosphorus Concentration
Metal Concentration (mg/Kg)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations


Cacheu River - Dry season
Potassium Concentration
Metal Concentration (mg/Kg)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations


Cacheu River - Dry season
Sodium Concentration
Metal Concentration (mg/Kg)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations


Cacheu River - Dry season
Sodium Concentration
Metal Concentration (mg/Kg)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations


Cacheu River - Dry season
Mercury CVAF Concentration
Metal Concentration (mg/Kg)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Station Number
Avg. River Concentrations
Low-level omnivore
Mid-level omnivore
Planktivore
Avg. Concentrations per Stations

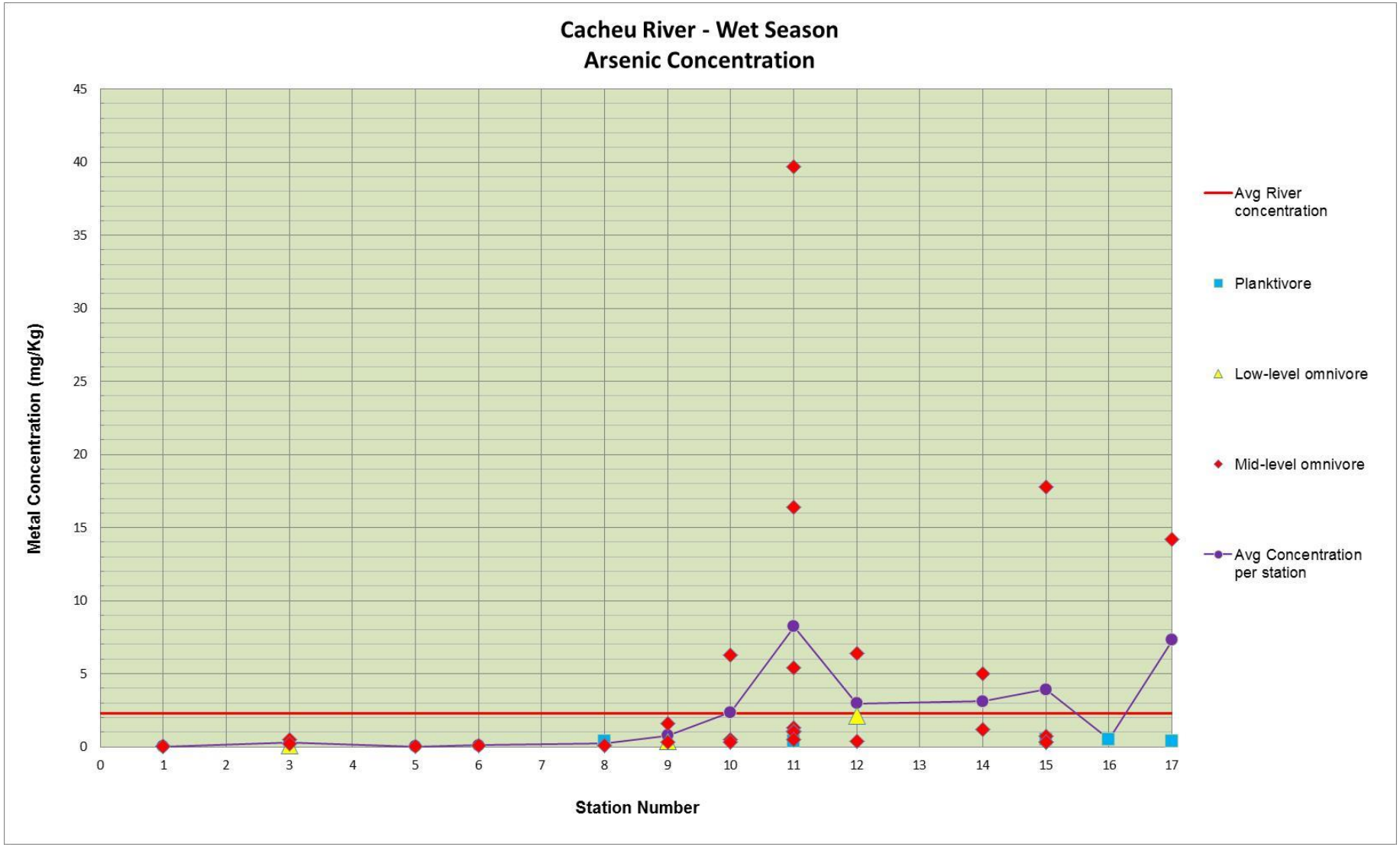
Wet Season Fish and Macroinverterbrate Average Lengths and Weights

Lowest Taxonomic ID	N*	Average Length (millimeters)	Average Weight (grams)
Arius gigas	83	119	20.5
Batrachoides liberiensis	3	61	4.5
Brachydeuterus auritus	5	98	13.8
Butis koilomatodon	17	37	2.7
Callinectes pallidus	172	89	77.9
Caridea-*Alpheus* spp.	6	5	0.5
Caridea-*Eualus* sp.	1	9	0.8
Caridea-*Latreutes* spp.	50	2	0.0
Caridea-*Macrobrachium* spp.	2	20	4.6
Caridea-*Plesionika* spp.	113	8	0.7
Chrysichthys sp.	1	263	163.8
Clupeidae	1	30	0.2
Cynoglossus senegalensis	34	133	29.9
Dasyatis margaritella	13 (7)	200	596.4
Decabrachia-Loliginidae	1	18	1.7
Decabrachia-Sepiidae	10	24	4.3
Drepane africana	14	36	2.2
Elopomorpha-Leptocephalus	6	38	0.1
Ephippion guttifer	5 (4)	182	67.2
Ethmalosa fimbriata	1	98	7.8
Galeiodes decadactylus	84	58	5.6
Gobionellus occidentalis	2	84	2.1
Ilisha africana	31	140	24.1
Isopoda-Asellidae	10	10	0.1
Larvae-Clupeidae	23	23	0.1
Larvae-Scianidae	14	21	0.1
Majoidea-*Eurynome* spp.	2	5	0.1
Majoidea-*Herbstia* spp.	1	10	0.4
Melongenidae	3		1.7
Melongenidae-Pugilina morio	1		80.3
Monodactylus sebae	1	62	5.7
Paguridae	2		11.5
Pellonula leonensis	12	105	9.8
Penaeidae-Farfantepenaeus notialis	168	13	2.1
Penaeidae-*Parapenaeopsis* sp.	2	29	10.9
Pentanemus quinquarius	6	181	39.5
Polydactylus quadrifilis	6	303	278.0

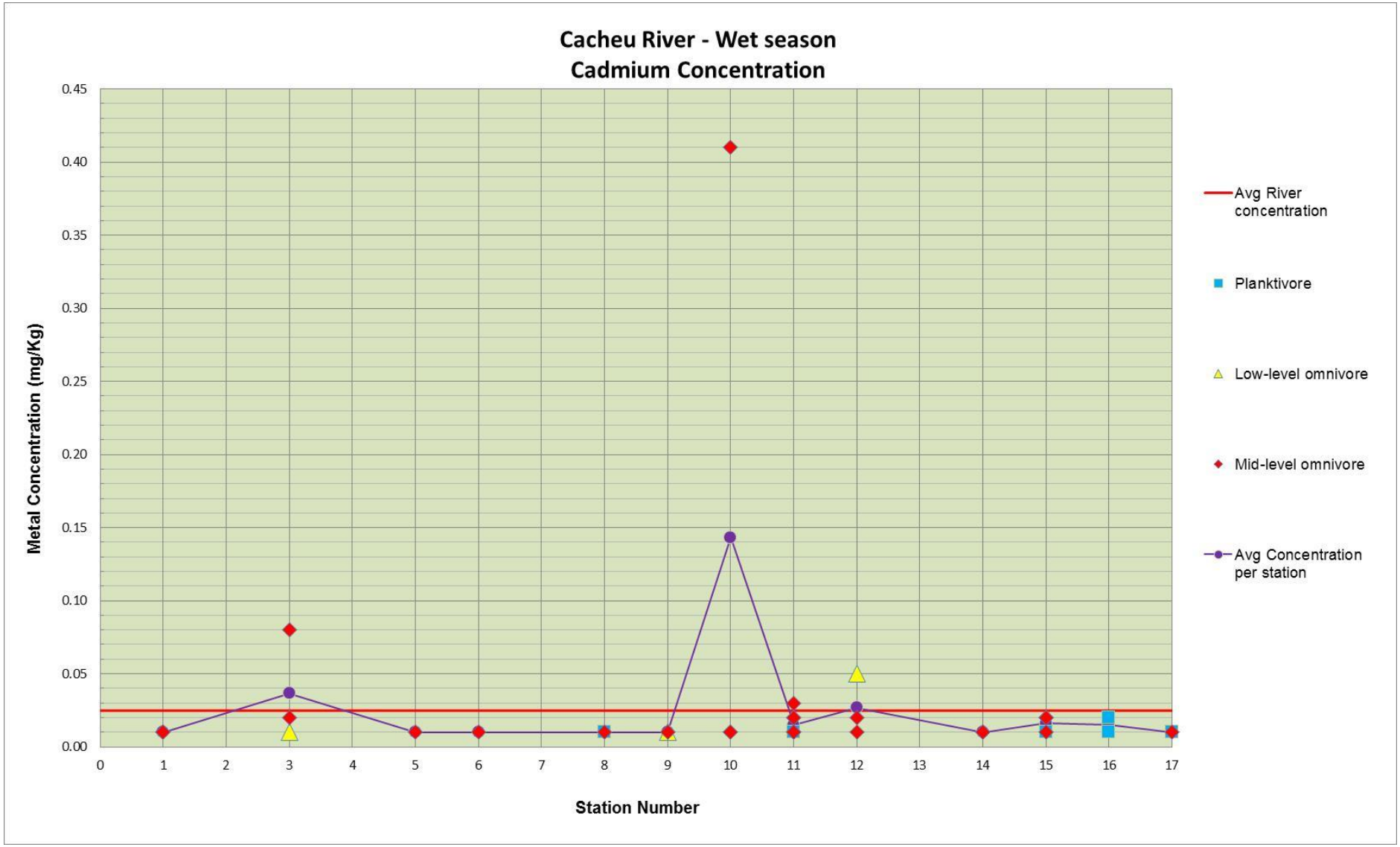
Wet Season Fish and Macroinverterbrate Average Lengths and Weights

Lowest Taxonomic ID	N*	Average Length (millimeters)	Average Weight (grams)
Pomadasys peroteti	1	121	23.9
Porogobius schlegelii	7	50	1.1
Pseudotolithus brachygnathus	18	133	35.8
Pseudotolithus elongatus	169	73	11.2
Pseudotolithus senegalensis	49	100	23.6
Pseudotolithus typus	1	156	29.6
Squilla sp.	5	17	8.0
Synaptura lusitanica	2	115	11.2
Trichiurus lepturus	1	399	30.9
Xanthidae	3	10	0.7

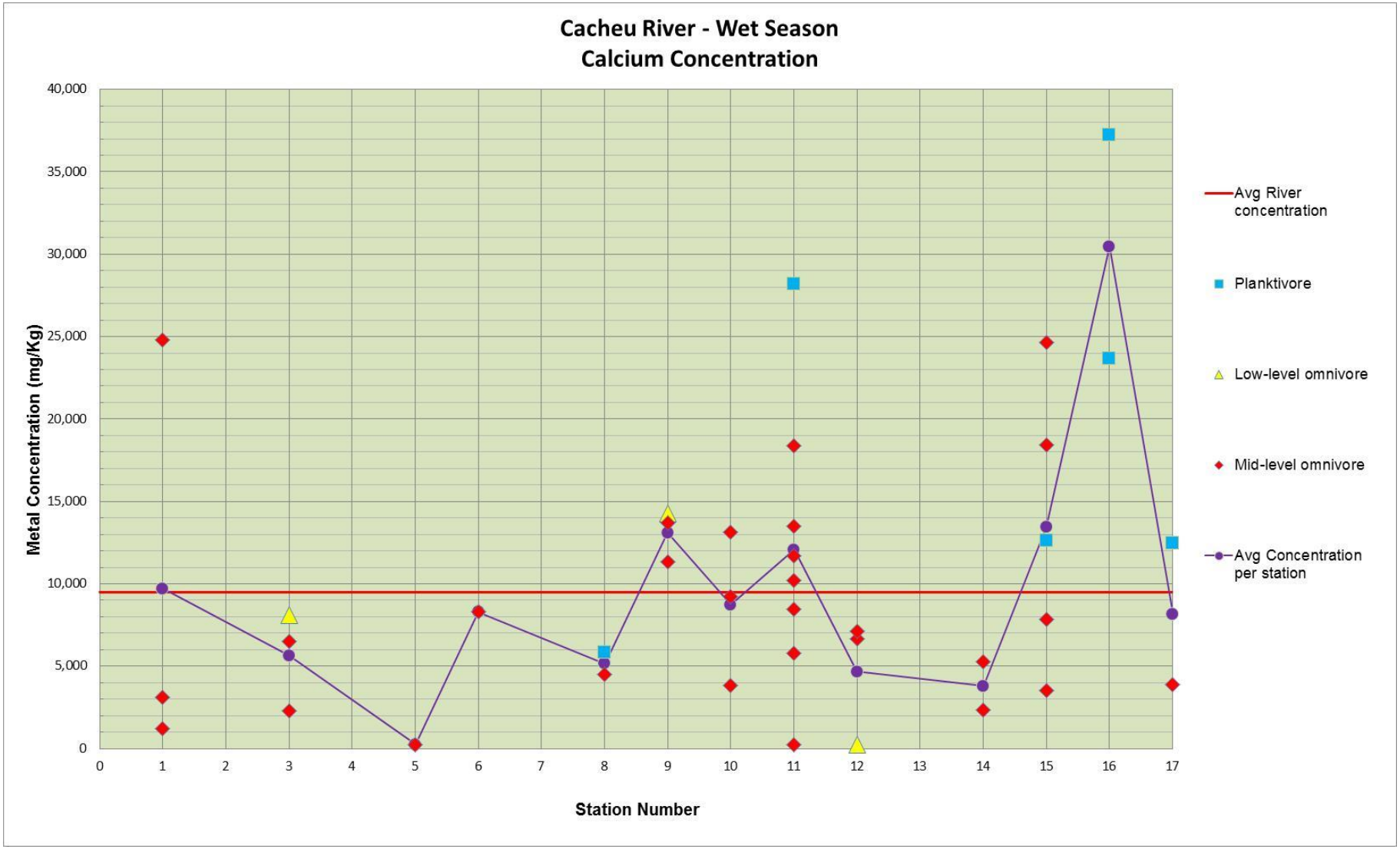
*N for weight provided in parentheses if different from N for lengths



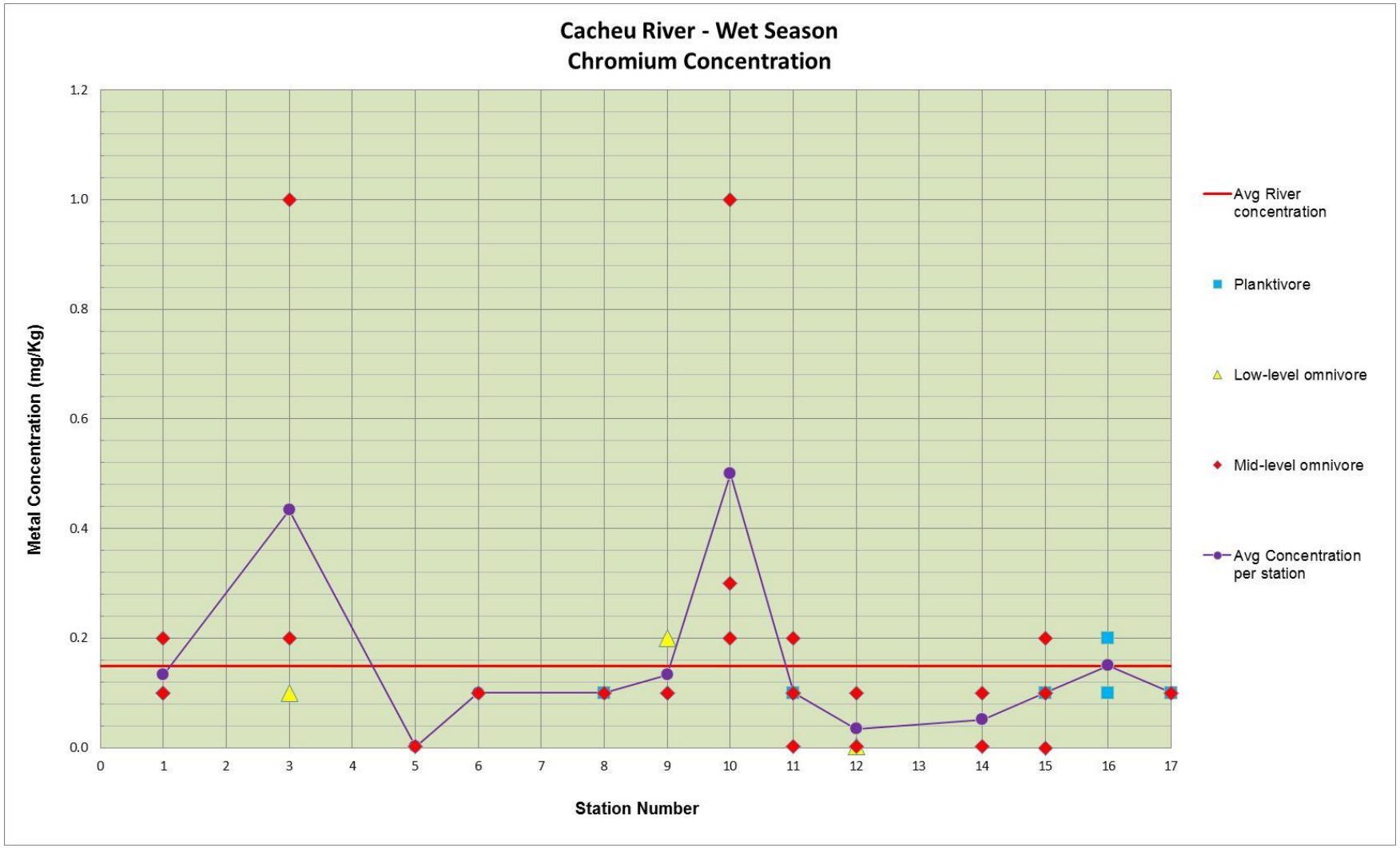
Everything greater than 5 mg/kg is a catfish or stingray

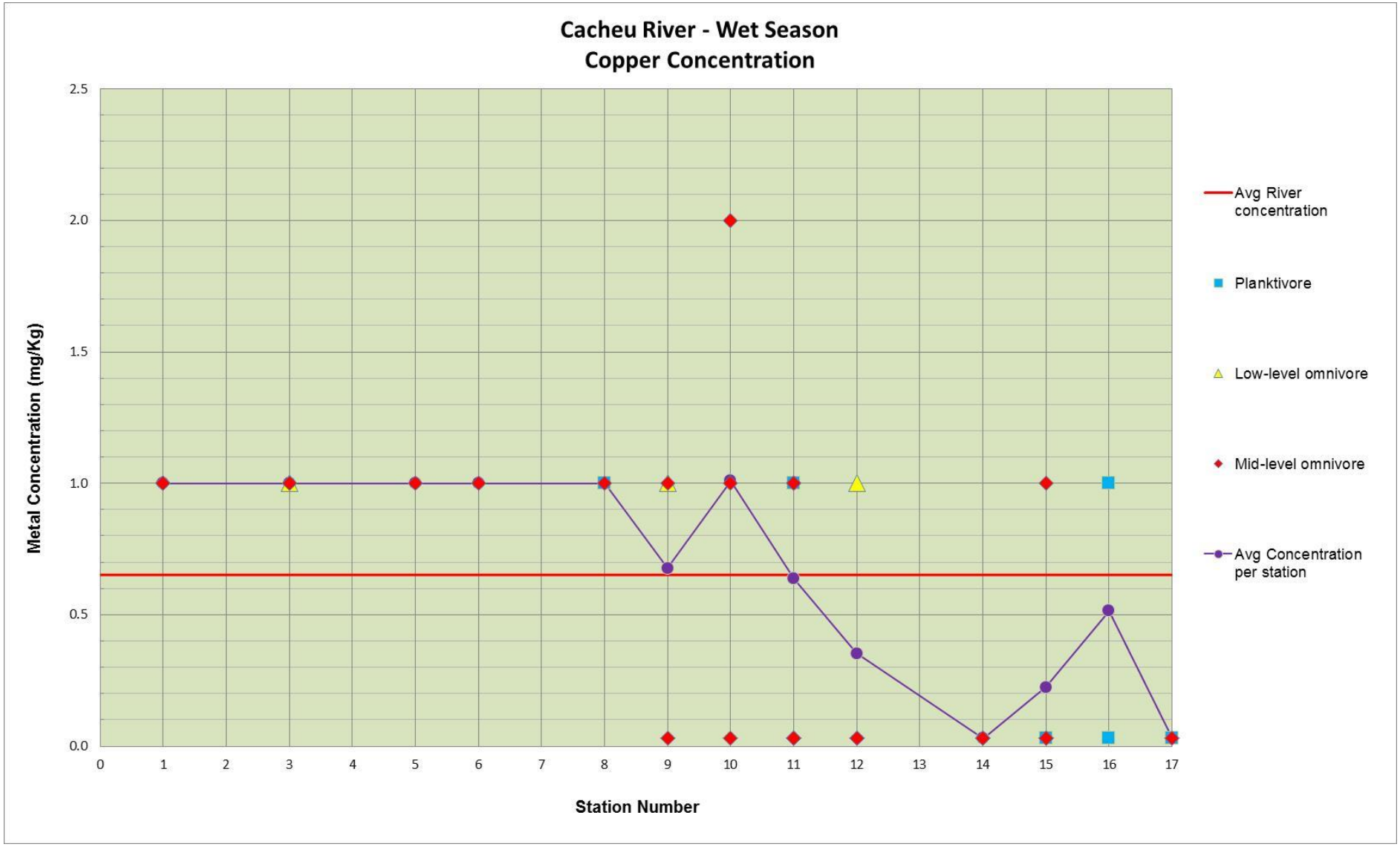


Highest value is a catfish

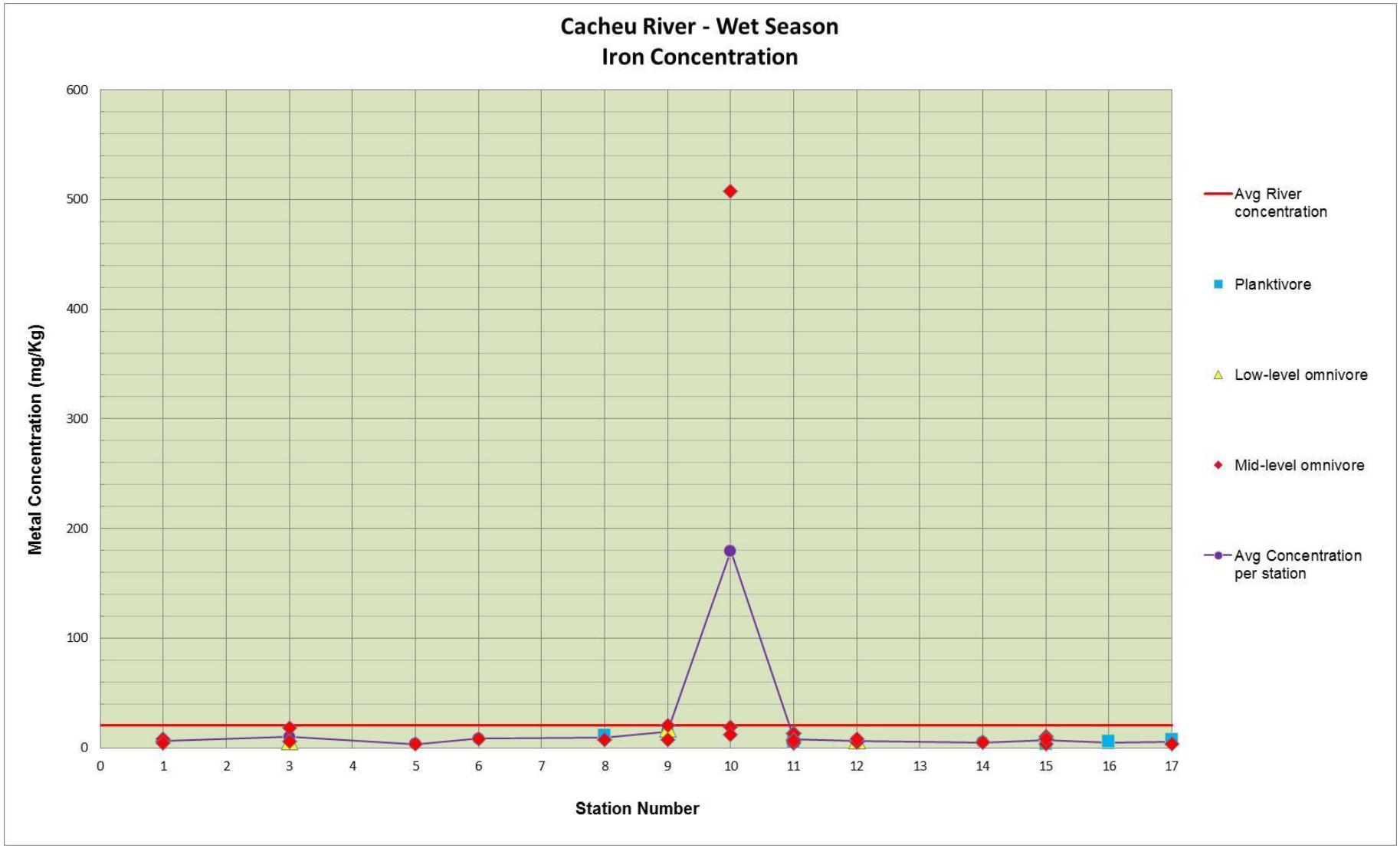


Golder Associates

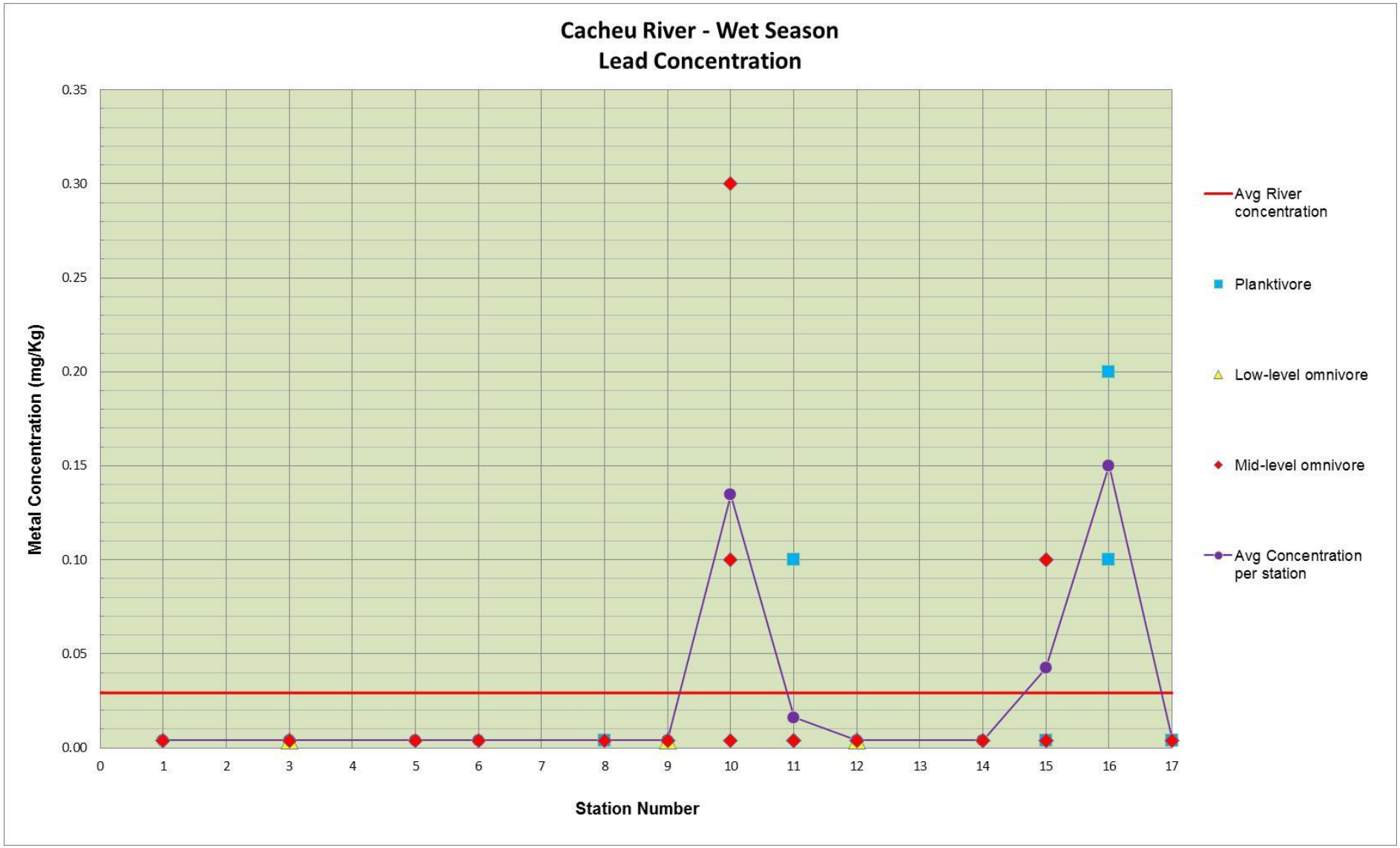

Cacheu River - Wet Season
Chromium Concentration
Metal Concentration (mg/Kg)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Station Number
Avg River concentration
Planktivore
Low-level omnivore
Mid-level omnivore
Avg Concentration per station



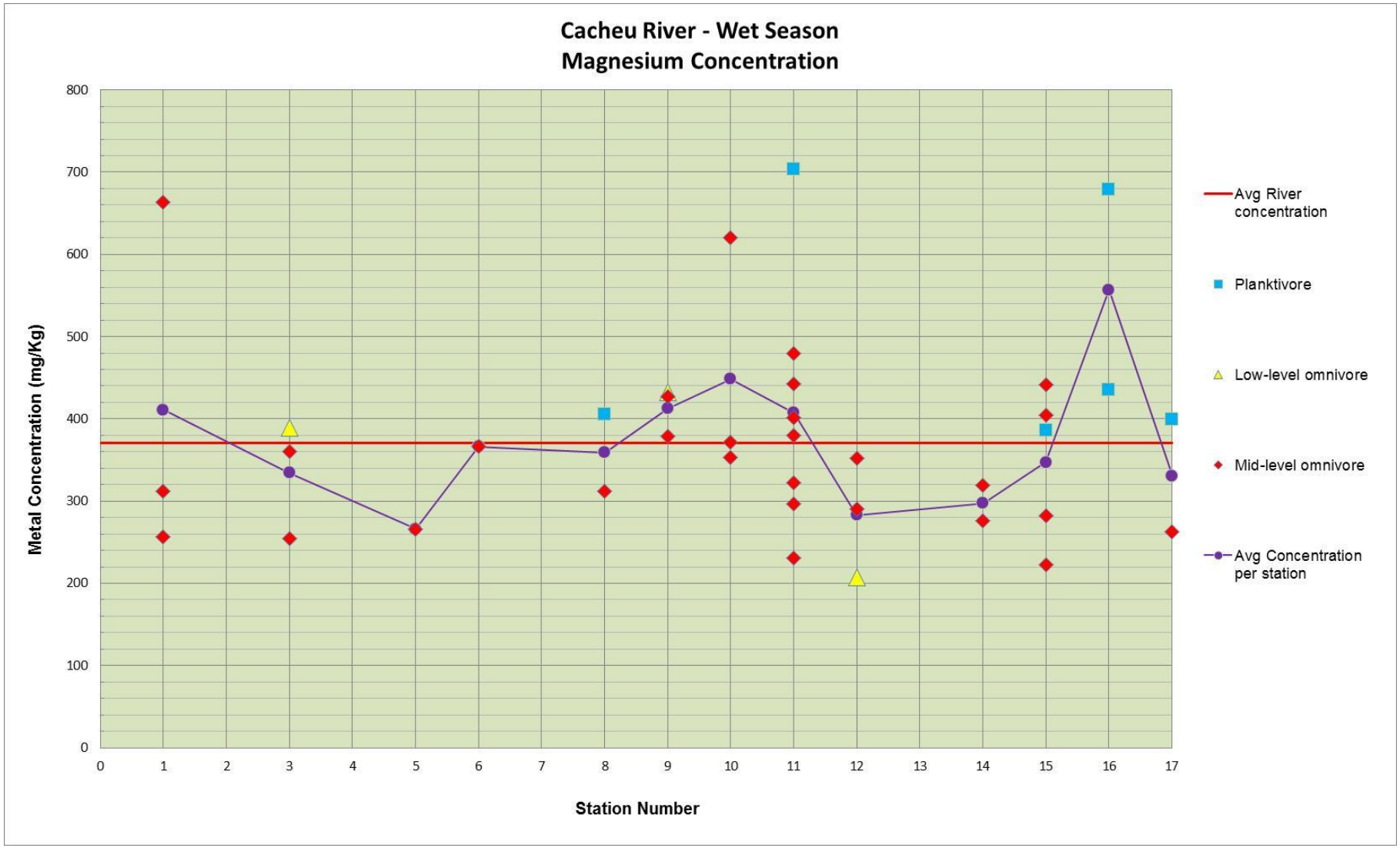
Golder Associates

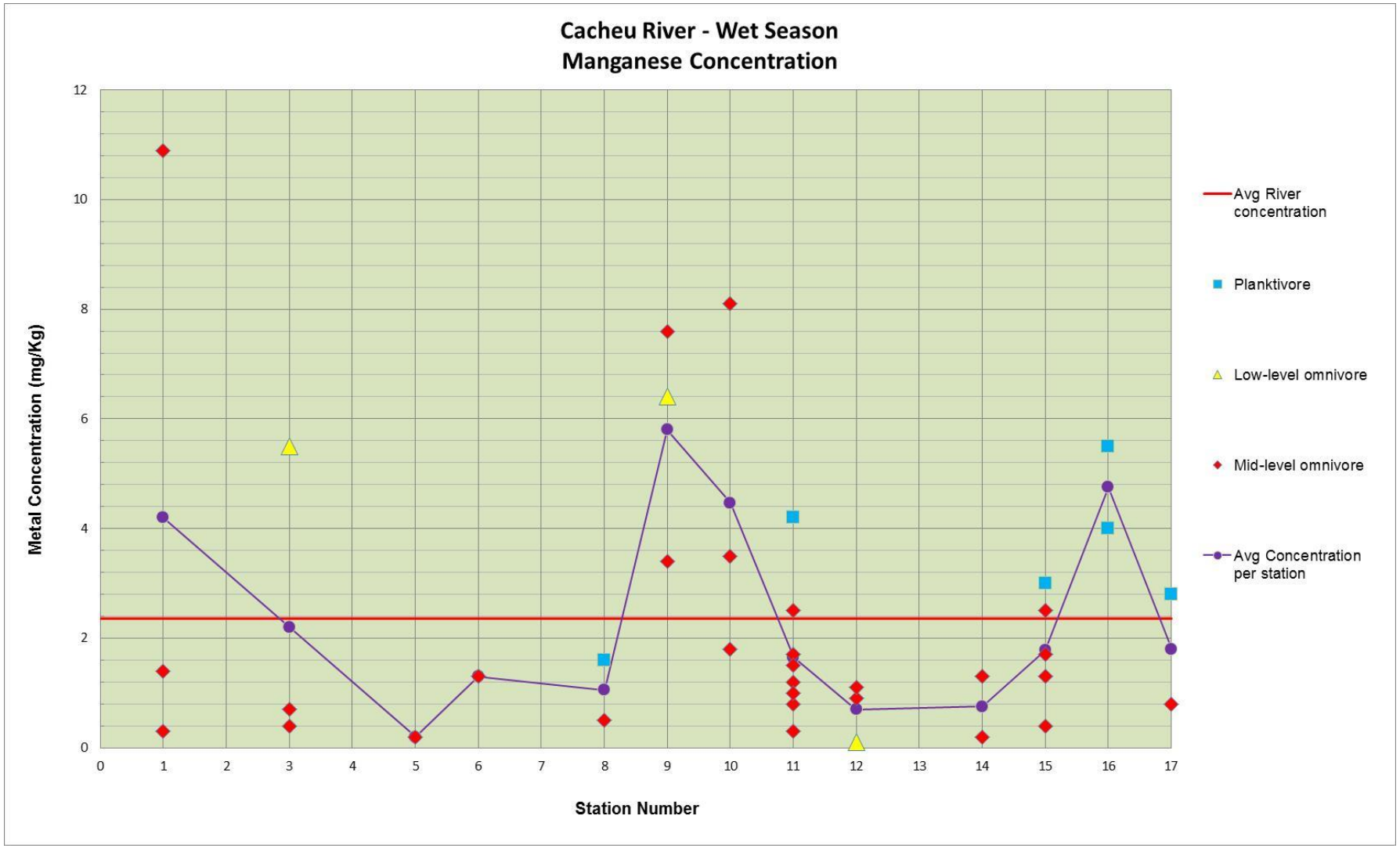


Peak is a catfish

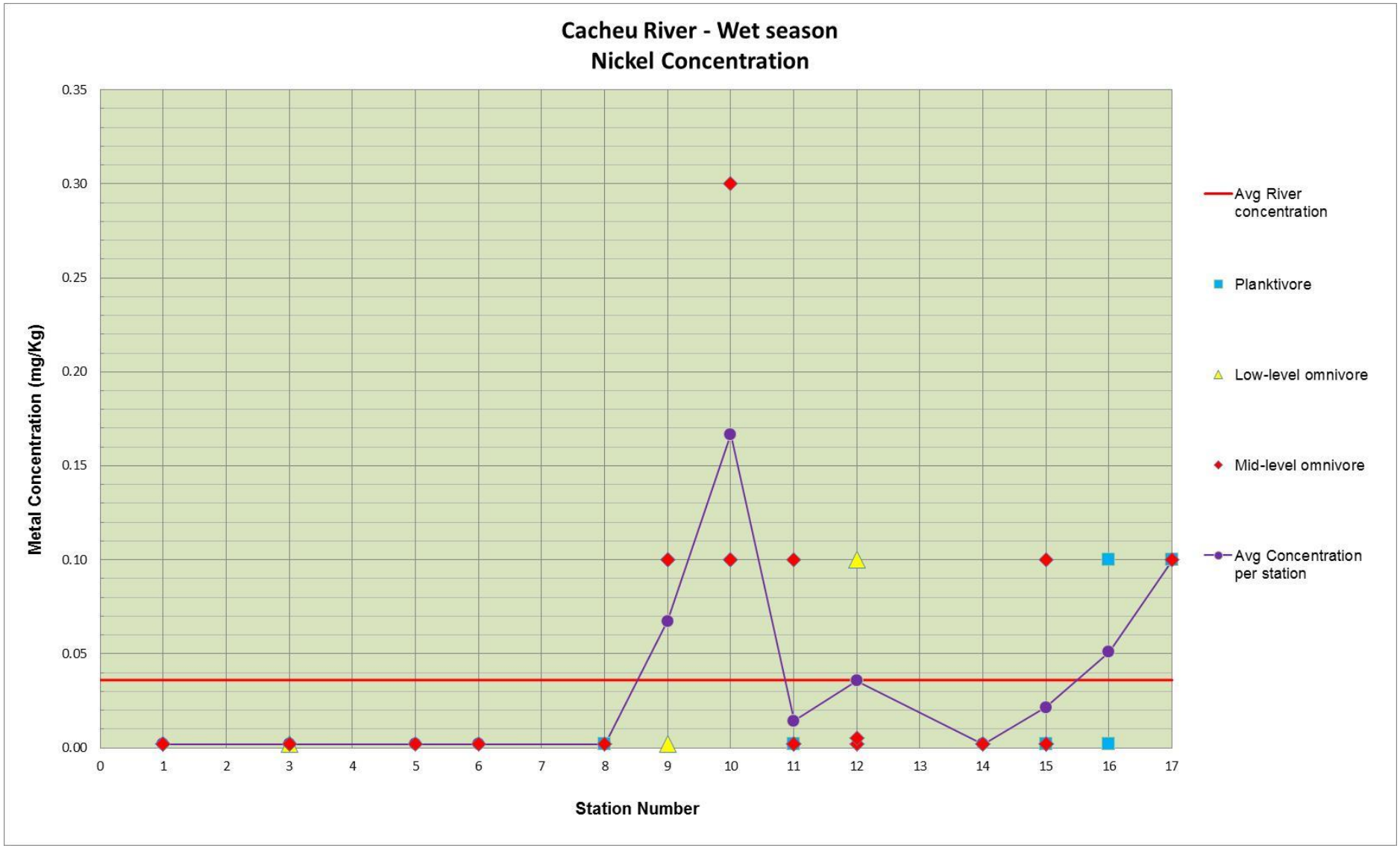


Golder Associates

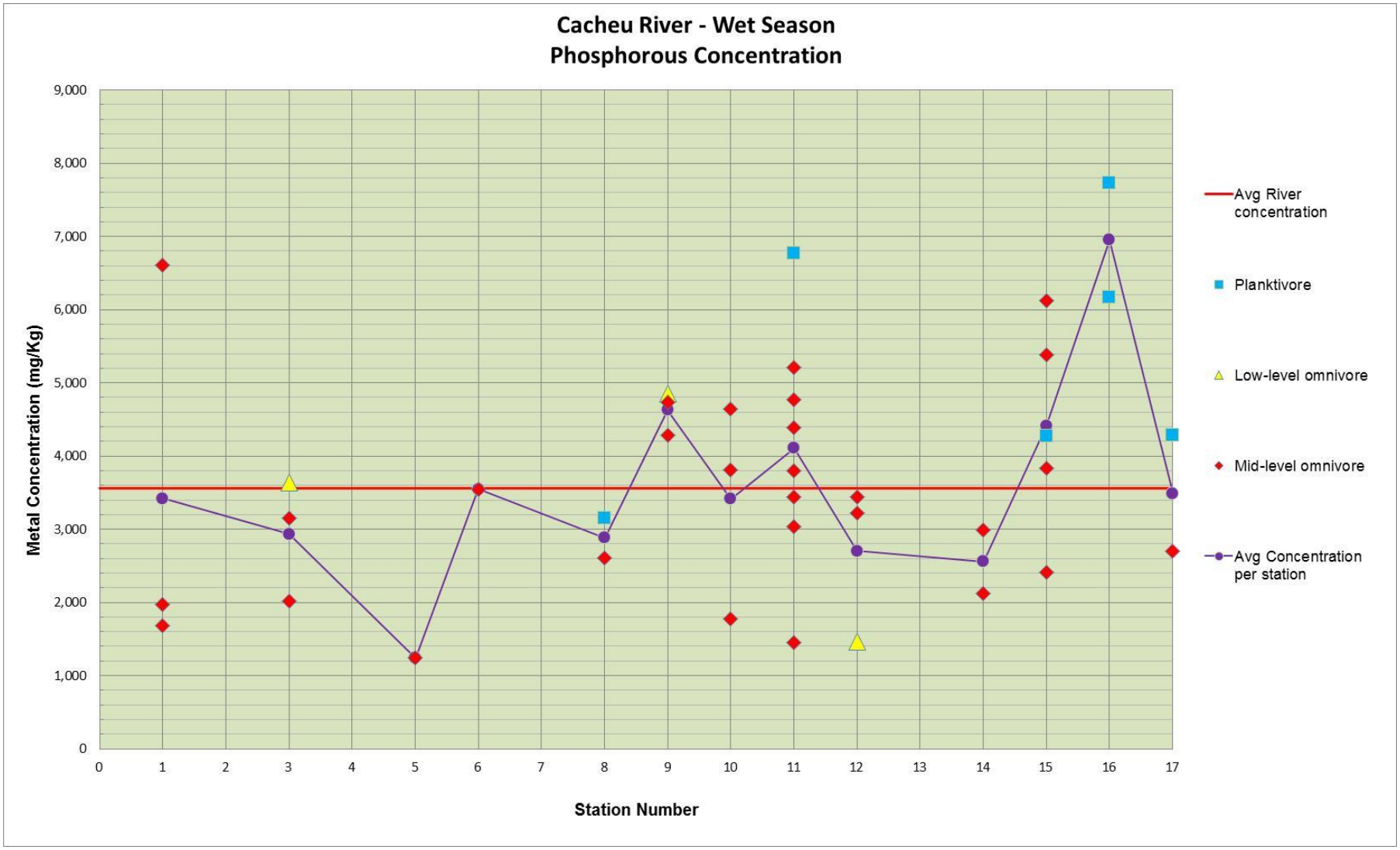

Cacheu River - Wet Season
Magnesium Concentration
Metal Concentration (mg/Kg)
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg River concentration
Planktivore
Low-level omnivore
Mid-level omnivore
Avg Concentration per station

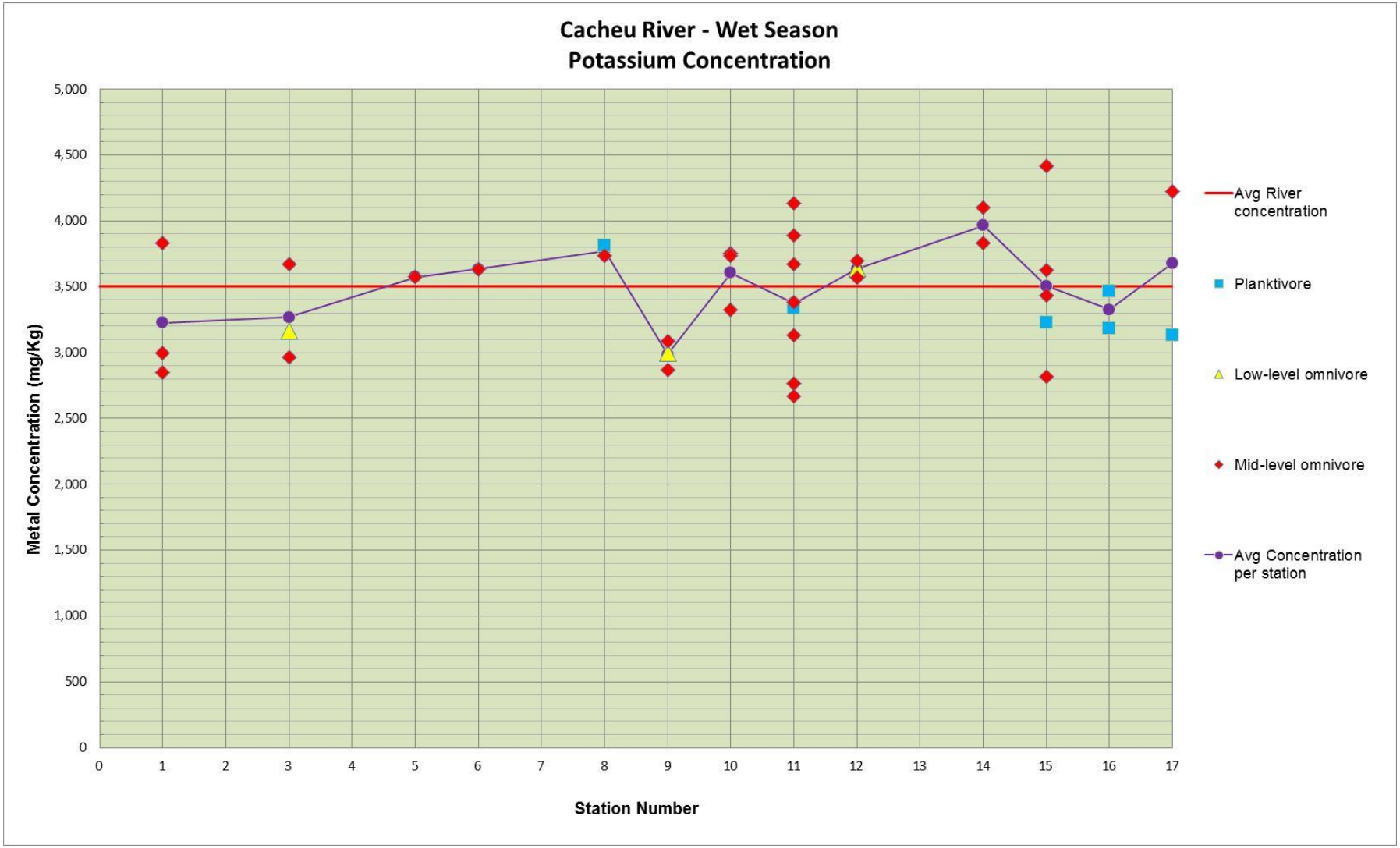


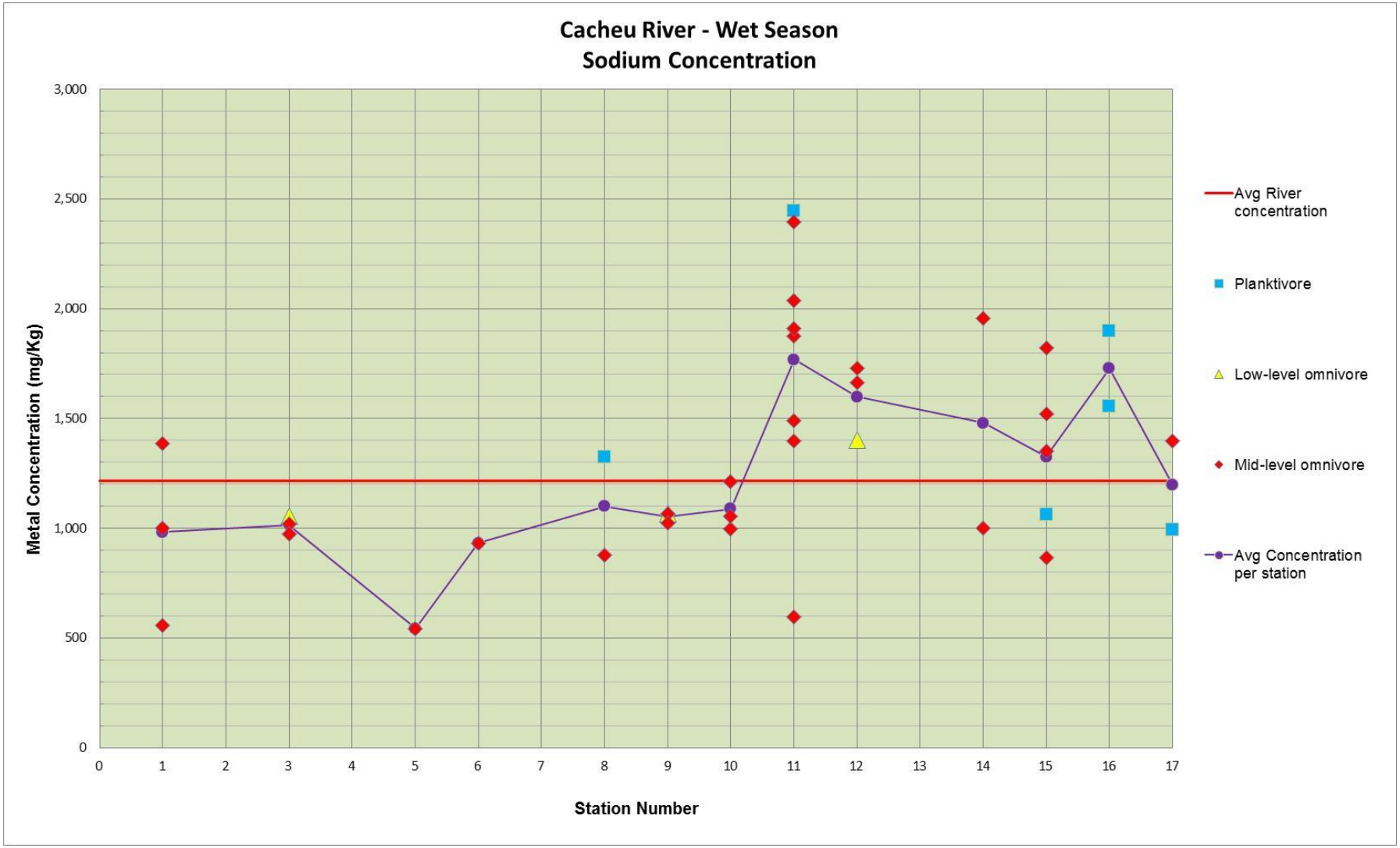
The three high red values are all catfish

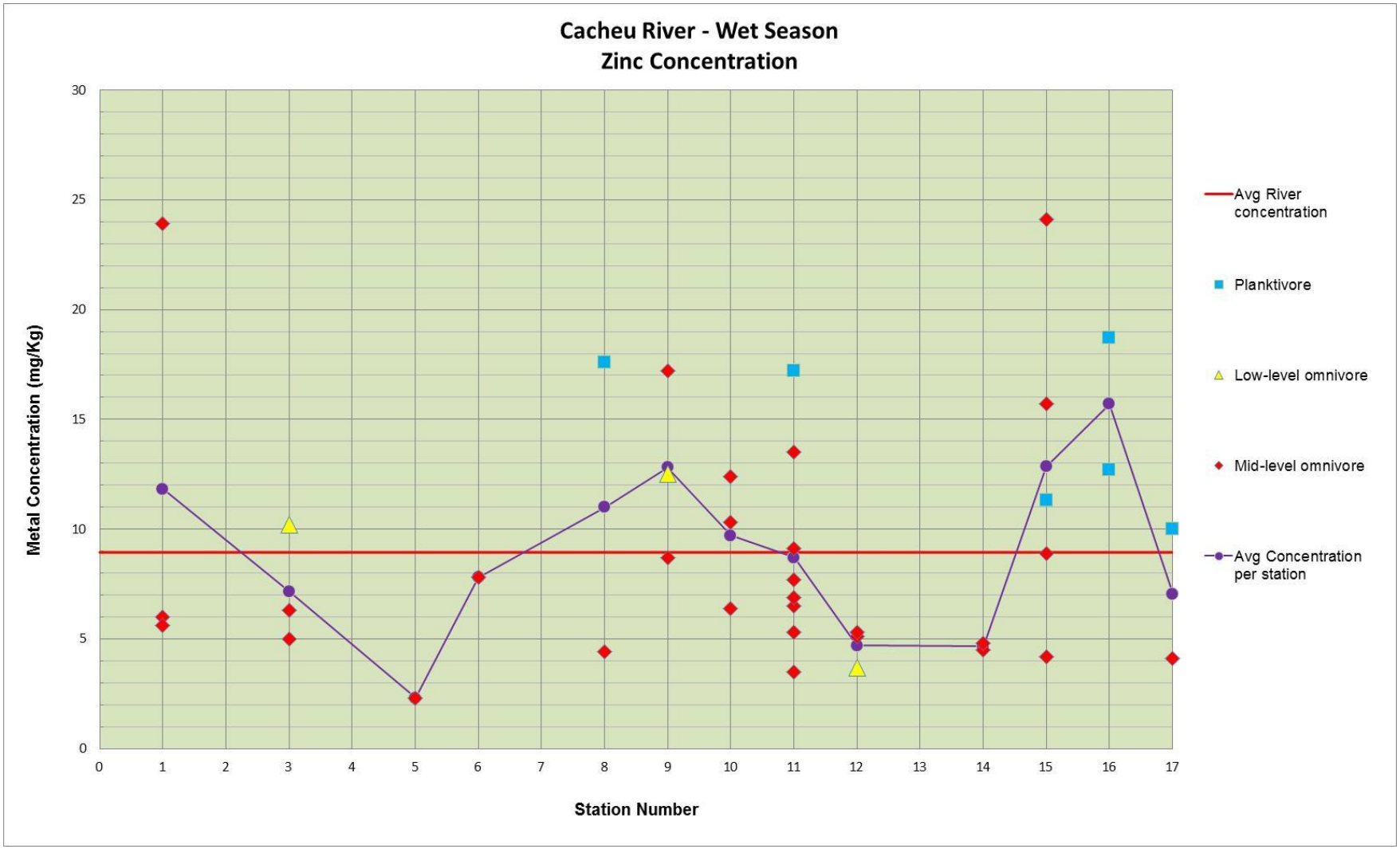


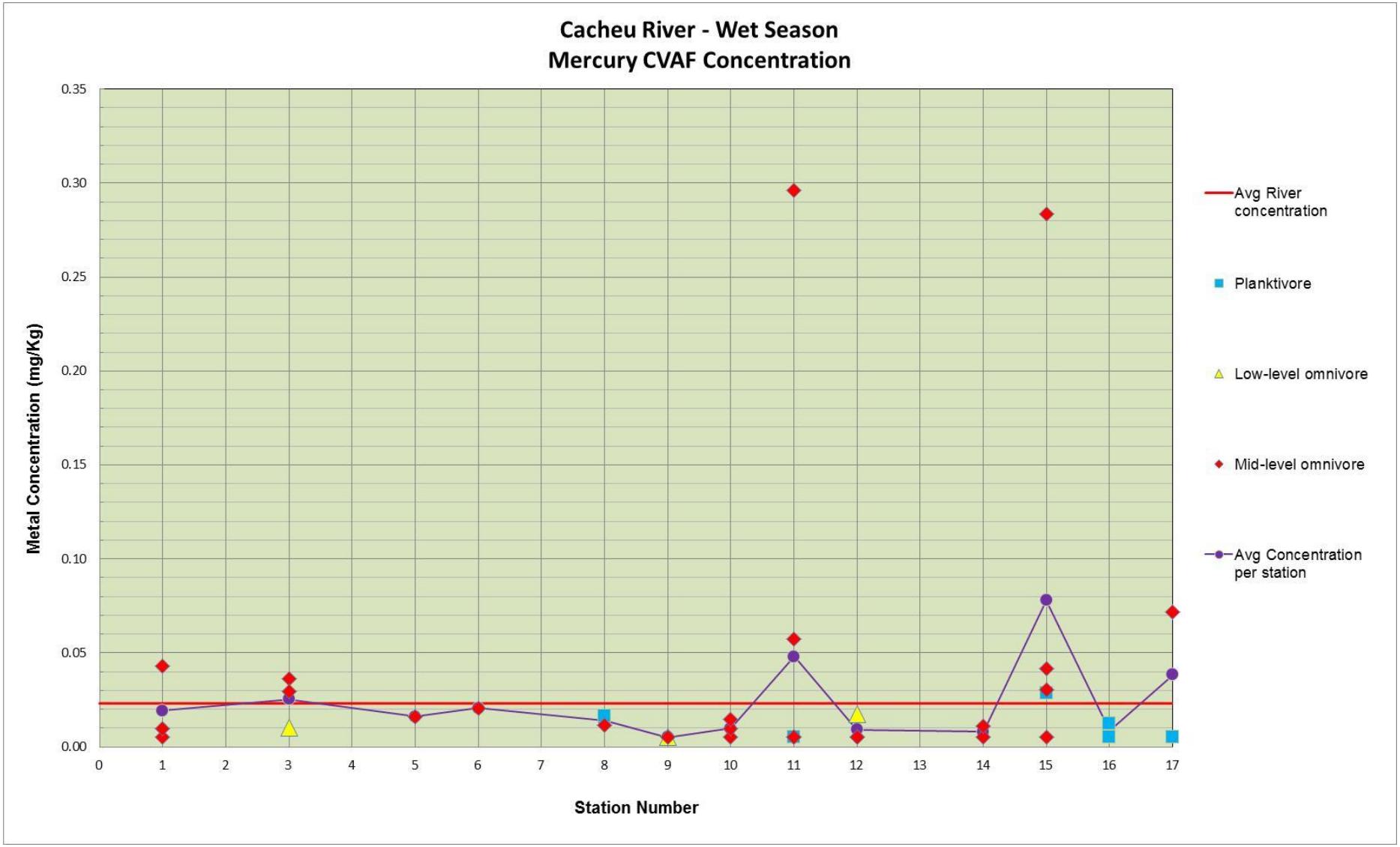
High red value is a catfish


Cacheu River - Wet Season
Phosphorous Concentration
Metal Concentration (mg/Kg)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg River concentration
Planktivore
Low-level omnivore
Mid-level omnivore
Avg Concentration per station


Cacheu River - Wet Season
Potassium Concentration
Metal Concentration (mg/Kg)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg River concentration
Planktivore
Low-level omnivore
Mid-level omnivore
Avg Concentration per station


Cacheu River - Wet Season
Sodium Concentration
Metal Concentration (mg/Kg)
3,000
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Station Number
Avg River concentration
Planktivore
Low-level omnivore
Mid-level omnivore
Avg Concentration per station


Cacheu River - Wet Season
Zinc Concentration
Metal Concentration (mg/Kg)
Station Number
0
5
10
15
20
25
30
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Avg River concentration
Planktivore
Low-level omnivore
Mid-level omnivore
Avg Concentration per station



Both high values are stingrays

APPENDIX F6

Fish Tissue Data (Dry Season and Wet Season)

January 2014
Report No. 13514950200.550/B.0

Jones Environmental Laboratory

Unit 3 Deeside Point
Zone 3
Deeside Industrial Park
Deeside
CH5 2UA

Tel: +44 (0) 1244 833780
Fax: +44 (0) 1244 833781

Golder Associates Ltd
1 Alie Street
London
E1 8DE

No.4225

Attention :	Darren King
Date :	26th June, 2013
Your reference :	13514950200
Our reference :	Test Report 13/5297 Batch 1
Location :	FARIM MINE
Date samples received :	7th June, 2013
Status :	Final Report
Issue :	1

Thirty one samples were received for analysis on 7th June, 2013. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Compiled By:

Paul Lee-Boden B.Sc
Project Manager

Bob Millward B.Sc FRSC
Principal Chemist

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Report **Solid**

Reference: 13514950200

Location: FARIM MINE

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Contact: Darren King

JE Job No.: 13/5297

J E Sample No.	1	2	3	4	5	6	7	8	9	10			
Sample ID	STN1GN-A	STN1GN-B	STN1GN-C	STN1GN-D	STN1GN-E	STN1GN-F	STN2GN-A	STN2GN-B	STN3MT-A	STN4GN-A			
Depth											Please see attached notes for all abbreviations and acronyms		
COC No / misc													
Containers	B	B	B	B	B	B	B	B	B	B			
Sample Date	14/05/2013	14/05/2013	14/05/2013	14/05/2013	14/05/2013	14/05/2013	16/05/2013	16/05/2013	15/05/2013	15/05/2013			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD	Units	Method No.
Date of Receipt	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013			
Arsenic	<0.018	<0.018	0.420	<0.018	<0.018	0.450	<0.018	<0.018	<0.018	0.100	<0.018	mg/kg	TM30/PM15
Cadmium	0.007	0.006	0.132	0.006	0.111	0.122	0.005	0.009	0.088	0.011	<0.001	mg/kg	TM30/PM15
Calcium	46550.00	13420.00	8151.00	10810.00	14610.00	9136.00	29230.00	1552.00	21370.00	10980.00	<0.05	mg/kg	TM30/PM15
Chromium	0.030	0.060	1.530	0.060	0.690	1.720	0.070	0.050	0.590	0.040	<0.004	mg/kg	TM30/PM15
Copper	0.170	0.390	1.370	0.190	0.300	0.400	0.220	1.170	0.910	0.740	<0.060	mg/kg	TM30/PM15
Iron	12.890	9.120	727.300	12.650	218.700	741.300	14.770	11.060	469.200	27.200	<0.094	mg/kg	TM30/PM15
Lead	<0.008	0.100	0.210	<0.008	0.050	0.290	<0.008	<0.008	0.030	<0.008	<0.008	mg/kg	TM30/PM15
Magnesium	328.0	439.0	407.0	457.0	423.0	399.0	749.0	273.0	546.0	414.0	<0.1	mg/kg	TM30/PM15
Manganese	1.790	2.480	57.400	1.370	12.620	80.560	7.050	1.740	13.250	2.240	<0.030	mg/kg	TM30/PM15
Nickel	0.050	0.040	0.270	0.040	0.210	0.390	0.040	<0.004	0.130	0.090	<0.004	mg/kg	TM30/PM15
Phosphorus	3799.00	4727.00	3672.00	4236.00	4923.00	3738.00	7027.00	1461.00	6141.00	4251.00	<0.05	mg/kg	TM30/PM15
Potassium	2025.0	2337.0	2917.0	3305.0	2821.0	2561.0	2676.0	3151.0	2676.0	2484.0	<0.1	mg/kg	TM30/PM15
Sodium	1415.00	1237.00	1254.00	1292.00	1796.00	809.00	1359.00	1200.00	1468.00	1031.00	<0.05	mg/kg	TM30/PM15
Zinc	16.200	24.230	27.890	6.190	24.530	17.090	17.580	10.580	27.750	9.600	<0.030	mg/kg	TM30/PM15
Mercury CVAF	0.015	0.023	0.015	0.017	0.016	0.017	0.037	0.038	0.024	0.014	<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	~	~	~	<5	<5	<5	<5	<5	~	~	<5	ug/kg	Subcontracted

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Reference: 13514950200

Location: FARIM MINE

Contact: Darren King

JE Job No.: 13/5297

Report **Solid**

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	11	12	13	14	15	16	17	18	19	20	LOD	Units	Method No.
Sample ID	STN4T1-A	STN4GN-B	STN3GN-A	STN3T1-A	STN10T1-A	STN8MT-A	STN7T1-A	STN9T1-A	STN7GN-A	STN8GN-A			
Depth													
COC No / misc													
Containers	B	B	B	B	B	B	B	B	B	B			
Sample Date	15/05/2013	15/05/2013	15/05/2013	15/05/2013	25/05/2013	18/05/2013	17/05/2013	25/05/2013	17/05/2013	18/05/2013			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013			
Arsenic	<0.018	0.220	0.190	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	mg/kg	TM30/PM15
Cadmium	0.005	0.007	0.017	0.013	0.015	0.008	0.016	0.007	0.006	<0.001	<0.001	mg/kg	TM30/PM15
Calcium	8342.00	13030.00	26840.00	6920.00	19240.00	14790.00	10740.00	4524.00	15620.00	41460.00	<0.05	mg/kg	TM30/PM15
Chromium	0.030	<0.004	0.050	0.080	0.560	0.020	0.110	0.020	0.030	<0.004	<0.004	mg/kg	TM30/PM15
Copper	0.410	1.070	0.210	<0.060	0.920	1.660	<0.060	0.230	0.700	<0.060	<0.060	mg/kg	TM30/PM15
Iron	6.920	7.890	18.640	7.660	28.730	14.250	74.060	11.730	12.360	4.930	<0.094	mg/kg	TM30/PM15
Lead	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.030	<0.008	<0.008	<0.008	<0.008	mg/kg	TM30/PM15
Magnesium	395.0	511.0	616.0	320.0	794.0	694.0	373.0	357.0	413.0	973.0	<0.1	mg/kg	TM30/PM15
Manganese	4.570	1.760	7.930	0.580	2.010	7.260	2.220	0.440	1.000	3.220	<0.030	mg/kg	TM30/PM15
Nickel	<0.004	0.020	<0.004	0.060	1.600	0.060	0.040	<0.004	0.030	<0.004	<0.004	mg/kg	TM30/PM15
Phosphorus	3792.00	4909.00	6764.00	3246.00	4111.00	5121.00	3741.00	2492.00	5251.00	8161.00	<0.05	mg/kg	TM30/PM15
Potassium	2475.0	3131.0	2277.0	2650.0	2021.0	2342.0	329.0	2679.0	2586.0	2593.0	<0.1	mg/kg	TM30/PM15
Sodium	1246.00	929.00	1458.00	1091.00	4701.00	1643.00	472.00	1325.00	1640.00	2109.00	<0.05	mg/kg	TM30/PM15
Zinc	18.030	10.290	32.220	12.100	16.160	53.780	25.920	9.500	13.850	25.270	<0.030	mg/kg	TM30/PM15
Mercury CVAF	0.018	0.016	0.050	0.034	0.014	0.016	0.012	0.032	0.021	0.019	<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	~	<5	<5	<5	~	~	~	<5	<5	<5	<5	ug/kg	Subcontracted

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Reference: 13514950200

Location: FARIM MINE

Contact: Darren King

JE Job No.: 13/5297

Report **Solid**

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	21	22	23	24	25	26	27	28	29	30	LOD	Units	Method No.
Sample ID	STN9GN-A	STN15T2-A	STN11T1-B	STN11T1-C	STN16T1-A	STN17T1-B	STN17T2-A	STN11T1-A	STN14T2-A	STN17T1-A			
Depth													
COC No / misc													
Containers	B	B	B	B	B	B	B	B	B	B			
Sample Date	25/05/2013	23/05/2013	19/05/2013	19/05/2013	23/05/2013	24/05/2013	24/05/2013	19/05/2013	22/05/2013	24/05/2013			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013	07/06/2013			
Arsenic	0.140	0.360	0.820	0.180	<0.018	1.170	0.800	0.230	<0.018	0.780	<0.018	mg/kg	TM30/PM15
Cadmium	0.004	0.030	0.030	0.058	0.007	0.049	0.011	0.014	<0.001	0.014	<0.001	mg/kg	TM30/PM15
Calcium	16970.00	10690.00	6596.00	18210.00	14220.00	9107.00	9604.00	7413.00	3210.00	2058.00	<0.05	mg/kg	TM30/PM15
Chromium	0.040	<0.004	0.010	0.020	0.030	0.050	0.030	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM15
Copper	0.190	<0.060	<0.060	<0.060	0.270	0.370	0.310	0.220	0.180	<0.060	<0.060	mg/kg	TM30/PM15
Iron	12.800	6.500	12.740	13.630	11.190	29.580	15.230	12.400	3.120	4.130	<0.094	mg/kg	TM30/PM15
Lead	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	mg/kg	TM30/PM15
Magnesium	633.0	768.0	476.0	547.0	485.0	470.0	458.0	414.0	367.0	292.0	<0.1	mg/kg	TM30/PM15
Manganese	7.600	1.520	0.610	1.090	2.070	0.740	1.290	0.630	0.430	<0.030	<0.030	mg/kg	TM30/PM15
Nickel	0.040	0.020	0.010	0.040	0.010	0.030	<0.004	<0.004	<0.004	0.020	<0.004	mg/kg	TM30/PM15
Phosphorus	5572.00	4325.00	3243.00	5746.00	4710.00	3820.00	3996.00	3681.00	2680.00	1852.00	<0.05	mg/kg	TM30/PM15
Potassium	2501.0	2478.0	3502.0	2710.0	2261.0	3144.0	2880.0	3692.0	4596.0	3621.0	<0.1	mg/kg	TM30/PM15
Sodium	1703.00	3239.00	1039.00	1681.00	1411.00	1774.00	1581.00	1601.00	1097.00	1568.00	<0.05	mg/kg	TM30/PM15
Zinc	21.810	17.010	20.460	16.270	17.440	13.290	17.310	10.110	5.820	5.750	<0.030	mg/kg	TM30/PM15
Mercury CVAF	0.019	0.020	0.024	0.020	0.013	0.019	0.018	0.020	0.034	0.024	<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	<5	<5	<5	<5	~	<5	<5	<5	<5	<5	<5	ug/kg	Subcontracted

Jones Environmental Laboratory

Unit 3 Deeside Point
Zone 3
Deeside Industrial Park
Deeside
CH5 2UA

Tel: +44 (0) 1244 833780
Fax: +44 (0) 1244 833781

Golder Associates Ltd
1 Alie Street
London
E1 8DE

Attention :	Darren King
Date :	01st October, 2013
Your reference :	13514950200
Our reference :	Test Report 13/8043 Batch 1
Location :	Farim Mine
Date samples received :	3rd September, 2013
Status :	Final Report
Issue :	1

Thirty eight samples were received for analysis on 3rd September, 2013. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Compiled By:

Brice Leslie
Project Co-ordinator

Bob Millward BSc FRSC
Principal Chemist

Farim Project - Wet Season Tissue Chemical Analysis

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Reference: 13514950200

Location: Farim Mine

Contact: Darren King

JE Job No.: 13/8043

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1	2	3	4	5	6	7	8	9	10	LOD	Units	Method No.
Sample ID	STN1GN-A	STN1GN-B	STN1GN-C	STN3GN-A	STN3GN-B	STN3TN-A	STN5TN-A	STN6TN-A	STN8GN-A	STN8GN-B			
Depth													
COC No / misc	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE			
Containers	B	B	B	B	B	B	B	B	B	B			
Sample Date	15/08/2013	15/08/2013	15/08/2013	17/08/2013	17/08/2013	17/08/2013	16/08/2013	16/08/2013	19/08/2013	19/08/2013			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013			
Arsenic	<0.018	<0.018	<0.018	0.200	0.500	0.100	<0.018	0.100	0.400	0.100	<0.018	mg/kg	TM30/PM15
Cadmium	0.010	0.010	0.010	0.080	0.020	0.010	0.010	0.010	0.010	0.010	<0.001	mg/kg	TM30/PM15
Calcium	3098.00	24790.00	1197.00	2310.00	6526.00	8078.00	<500	8293.00	5822.00	4474.00	<0.05	mg/kg	TM30/PM15
Chromium	0.100	0.200	0.100	1.000	0.200	0.100	<0.004	0.100	0.100	0.100	<0.004	mg/kg	TM30/PM15
Copper	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.060	mg/kg	TM30/PM15
Iron	5.900	7.800	4.400	17.800	6.200	5.900	3.400	8.500	11.200	7.400	<0.094	mg/kg	TM30/PM15
Lead	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	mg/kg	TM30/PM15
Magnesium	257.0	664.0	312.0	254.0	360.0	389.0	266.0	366.0	406.0	312.0	<0.1	mg/kg	TM30/PM15
Manganese	1.400	10.900	0.300	0.400	0.700	5.500	0.200	1.300	1.600	0.500	<0.030	mg/kg	TM30/PM15
Nickel	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM15
Phosphorus	1974.00	6604.00	1685.00	2019.00	3152.00	3641.00	1238.00	3549.00	3153.00	2610.00	<0.05	mg/kg	TM30/PM15
Potassium	2852.0	2995.0	3829.0	2968.0	3673.0	3161.0	3574.0	3635.0	3811.0	3733.0	<0.1	mg/kg	TM30/PM15
Sodium	1001.00	1387.00	558.00	974.00	1018.00	1053.00	543.00	931.00	1324.00	877.00	<0.05	mg/kg	TM30/PM15
Zinc	6.000	23.900	5.600	6.300	5.000	10.200	2.300	7.800	17.600	4.400	<0.030	mg/kg	TM30/PM15
Mercury CVAF	<0.010	0.010	0.043	0.029	0.036	,0.010	0.016	0.021	0.016	0.011	<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5	ug/kg	Subcontracted

Farim Project - Wet Season Tissue Chemical Analysis

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Reference: 13514950200

Location: Farim Mine

Contact: Darren King

JE Job No.: 13/8043

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	11	12	13	14	15	16	17	18	19	20	LOD	Units	Method No.
Sample ID	STN9TN-A	STN9TN-B	STN9TN-C	STN10GN-A	STN10GN-B	STN10GN-C	STN11T1-A	STN11T1-B	STN11T2-A	STN11T2-B			
Depth													
COC No / misc	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE			
Containers	B	B	B	B	B	B	B	B	B	B			
Sample Date	22/08/2013	22/08/2013	22/08/2013	22/08/2013	22/08/2013	22/08/2013	21/08/2013	21/08/2013	21/08/2013	21/08/2013			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013			
Arsenic	1.600	0.400	0.300	0.300	6.300	0.500	1.000	1.300	39.700	1.100	<0.018	mg/kg	TM30/PM15
Cadmium	0.010	0.010	0.010	0.010	0.010	0.410	0.010	0.010	0.030	0.020	<0.001	mg/kg	TM30/PM15
Calcium	13700.00	14270.00	11310.00	13120.00	9206.00	3825.00	11700.00	13510.00	<500	8455.00	<0.05	mg/kg	TM30/PM15
Chromium	0.100	0.200	0.100	0.200	0.300	1.000	0.200	0.100	<0.004	0.100	<0.004	mg/kg	TM30/PM15
Copper	1.000	1.000	<0.060	<0.060	1.000	2.000	1.000	<0.060	<0.060	1.000	<0.060	mg/kg	TM30/PM15
Iron	20.200	17.700	7.000	12.000	18.800	507.500	7.400	4.400	13.500	7.100	<0.094	mg/kg	TM30/PM15
Lead	<0.008	<0.008	<0.008	0.100	<0.008	0.300	<0.008	<0.008	<0.008	<0.008	<0.008	mg/kg	TM30/PM15
Magnesium	427.0	432.0	379.0	353.0	372.0	620.0	380.0	480.0	231.0	322.0	<0.1	mg/kg	TM30/PM15
Manganese	7.600	6.400	3.400	1.800	3.500	8.100	1.000	1.200	0.300	1.700	<0.030	mg/kg	TM30/PM15
Nickel	0.100	<0.004	0.100	0.100	0.100	0.300	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM15
Phosphorus	4741.00	4848.00	4289.00	4648.00	3811.00	1780.00	4393.00	4773.00	1455.00	3439.00	<0.05	mg/kg	TM30/PM15
Potassium	3086.0	2997.0	2871.0	3736.0	3756.0	3325.0	3384.0	3674.0	4135.0	3135.0	<0.1	mg/kg	TM30/PM15
Sodium	1067.00	1065.00	1025.00	1214.00	996.00	1054.00	1489.00	1909.00	594.00	1397.00	<0.05	mg/kg	TM30/PM15
Zinc	17.200	12.500	8.700	6.400	12.400	10.300	6.900	9.100	3.500	6.500	<0.030	mg/kg	TM30/PM15
Mercury CVAF	<0.010	<0.010	<0.010	0.014	<0.010	0.010	<0.010	<0.010	0.296	<0.010	<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5	ug/kg	Subcontracted

Farim Project - Wet Season Tissue Chemical Analysis

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Reference: 13514950200

Location: Farim Mine

Contact: Darren King

JE Job No.: 13/8043

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	21	22	23	24	25	26	27	28	29	30	LOD	Units	Method No.
Sample ID	STN11T3-A	STN11T3-B	STN11T3-C	STN11T3-D	STN12T1-A	STN12T2-A	STN12T3-A	STN14T2-A	STN14T3-A	STN15T1-A			
Depth													
COC No / misc	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE			
Containers	B	B	B	B	B	B	B	B	B	B			
Sample Date	21/08/2013	21/08/2013	21/08/2013	21/08/2013	24/08/2013	24/08/2013	24/08/2013	24/08/2013	24/08/2013	27/08/2013			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013			
Arsenic	16.400	5.400	0.400	0.500	2.100	6.400	0.400	5.000	1.200	0.300	<0.018	mg/kg	TM30/PM15
Cadmium	0.020	0.010	0.010	0.010	0.050	0.020	0.010	0.010	0.010	0.010	<0.001	mg/kg	TM30/PM15
Calcium	5766.00	10210.00	28170.00	18400.00	<500	6665.00	7105.00	5270.00	2325.00	18440.00	<0.05	mg/kg	TM30/PM15
Chromium	0.100	0.100	0.100	0.100	<0.004	<0.004	0.100	0.100	<0.004	0.100	<0.004	mg/kg	TM30/PM15
Copper	<0.060	1.000	1.000	1.000	1.000	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	mg/kg	TM30/PM15
Iron	6.100	13.100	5.300	6.800	6.300	5.000	7.800	4.700	5.000	3.400	<0.094	mg/kg	TM30/PM15
Lead	<0.008	<0.008	0.100	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.100	<0.008	mg/kg	TM30/PM15
Magnesium	297.0	443.0	704.0	401.0	207.0	290.0	352.0	276.0	319.0	442.0	<0.1	mg/kg	TM30/PM15
Manganese	0.800	2.500	4.200	1.500	0.100	0.900	1.100	1.300	0.200	1.300	<0.030	mg/kg	TM30/PM15
Nickel	<0.004	0.100	<0.004	<0.004	0.100	<0.004	<0.01	<0.004	<0.004	0.100	<0.004	mg/kg	TM30/PM15
Phosphorus	3032.0	3796.0	6769.0	5205.0	1461.0	3219.0	3436.0	2989.0	2128.0	5386.0	<0.05	mg/kg	TM30/PM15
Potassium	3889.0	2763.0	3337.0	2668.0	3641.0	3567.0	3700.0	3832.0	4100.0	3433.0	<0.1	mg/kg	TM30/PM15
Sodium	1877.00	2394.00	2447.00	2037.00	1403.00	1727.00	1664.00	1958.00	1002.00	1353.00	<0.05	mg/kg	TM30/PM15
Zinc	5.300	13.500	17.200	7.700	3.700	5.100	5.300	4.500	4.800	15.700	<0.030	mg/kg	TM30/PM15
Mercury CVAF	0.058	<0.010	<0.010	<0.010	0.017	<0.010	<0.010	<0.010	0.011	0.042	<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5	ug/kg	Subcontracted

Farim Project - Wet Season Tissue Chemical Analysis

Jones Environmental Laboratory

Client Name: Golder Associates Ltd

Reference: 13514950200

Location: Farim Mine

Contact: Darren King

JE Job No.: 13/8043

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	31	32	33	34	35	36	37	38			LOD	Units	Method No.
Sample ID	STN15T1-B	STN15T1-C	STN15T2-A	STN15T2-B	STN16T2-A	STN16T2-B	STN17T1-A	STN17T3-A					
Depth													
COC No / misc	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE					
Containers	B	B	B	B	B	B	B	B					
Sample Date	27/08/2013	27/08/2013	27/08/2013	27/08/2013	26/08/2013	26/08/2013	26/08/2013	26/08/2013					
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid					
Batch Number	1	1	1	1	1	1	1	1					
Date of Receipt	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013	03/09/2013					
Arsenic	0.700	0.500	17.800	0.300	0.500	0.500	14.200	0.400			<0.018	mg/kg	TM30/PM15
Cadmium	0.020	0.010	0.020	0.020	0.010	0.020	0.010	0.010			<0.001	mg/kg	TM30/PM15
Calcium	7814.00	12630.00	3537.00	24660.00	23670.00	37240.00	3871.00	12440.00			<0.05	mg/kg	TM30/PM15
Chromium	0.200	0.100	0.000	0.100	0.100	0.200	0.100	0.100			<0.004	mg/kg	TM30/PM15
Copper	<0.060	<0.060	1.000	<0.060	<0.060	1.000	<0.060	<0.060			<0.060	mg/kg	TM30/PM15
Iron	8.100	3.600	10.400	7.900	4.400	5.500	3.600	7.300			<0.094	mg/kg	TM30/PM15
Lead	<0.008	<0.008	<0.008	0.100	0.100	0.200	<0.008	<0.008			<0.008	mg/kg	TM30/PM15
Magnesium	282.0	386.0	223.0	404.0	435.0	679.0	263.0	399.0			<0.1	mg/kg	TM30/PM15
Manganese	0.400	3.000	2.500	1.700	4.000	5.500	0.800	2.800			<0.030	mg/kg	TM30/PM15
Nickel	<0.004	<0.004	<0.004	<0.004	<0.004	0.100	0.100	0.100			<0.004	mg/kg	TM30/PM15
Phosphorus	3832.000	4274.000	2413.000	6125.000	6171.000	7734.000	2695.000	4285.000			<0.05	mg/kg	TM30/PM15
Potassium	4419.0	3231.0	3625.0	2819.0	3186.0	3466.0	4227.0	3133.0			<0.1	mg/kg	TM30/PM15
Sodium	866.00	1061.00	1522.00	1823.00	1555.00	1899.00	1399.00	992.00			<0.05	mg/kg	TM30/PM15
Zinc	24.100	11.300	4.200	8.900	12.700	18.700	4.100	10.000			<0.030	mg/kg	TM30/PM15
Mercury CVAF	<0.010	0.029	0.283	0.030	0.012	<0.010	0.072	<0.010			<0.010	mg/kg	TM61/PM15
PAH MS													
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Benzo(bk)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Indeno(123cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Benzo(ghi)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
PAH 16 Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	mg/kg	TM4/PM8
Dimethyl Mercury*	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0			<5	ug/kg	Subcontracted

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 13/8043

SOILS

Please note we are only MCERTS accredited for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. If we are instructed to keep samples, a storage charge of £1 (1.5 Euros) per sample per month will be applied until we are asked to dispose of them.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

WATERS

Please note we are not a Drinking Water Inspectorate (DWI) Approved Laboratory . It is important that detection limits are carefully considered when requesting water analysis.

UKAS accreditation applies to surface water and groundwater and one other matrix which is analysis specific, any other liquids are outside our scope of accreditation

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

NOTE

Data is only accredited when all the requirements of our Quality System have been met. In certain circumstances where the requirements have not been met, the laboratory may issue the data in an interim report but will remove the accreditation, in this instance results should be considered indicative only. Where possible samples will be re-extracted and a final report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

ABBREVIATIONS and ACRONYMS USED

#	UKAS accredited.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance.
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to a Jones Environmental approved laboratory.
CO	Suspected carry over
OC	Outside Calibration Range
NFD	No Fibres Detected

Jones Environmental Laboratory

Method Code Appendix

JE Job No 13/8043

Test Method No.	Description	Prep Method No. (if appropriate)	Description	UKAS	MCERTS (soils only)	Analysis done on As Received (AR) or Air Dried (AD)	Reported on dry weight basis
TM73	pH in by Metrohm	PM11	1:2.5 soil/water extraction			AR	No

pH

Sample Number	pH	LR (t/ha)	Sample Number	pH	LR (t/ha)	Sample Number	pH	LR (t/ha)
1	5.18	3.45	41	5.76	1.61	81	5.48	20.05
2	4.74	5.25	42	5.28	1.77	82	5.54	3.31
3	6.14	2.73	43	5.60	2.44	83	5.67	3.39
4	5.87	3.12	44	5.02	3.21	84	5.72	3.62
5	4.61	11.27	45	5.96	2.89	85	5.34	-0.89
6	4.07	10.51	46	6.08	1.03	86	4.98	1.00
7	6.21	1.91	47	5.89	0.25	87	5.32	-15.67
8	6.29	1.45	48	5.92	0.58	88	5.66	2.43
9	4.79	6.12	49	6.76	-0.90	89	5.94	3.05
10	5.00	5.63	50	6.09	-0.05	90	5.76	3.22
11	5.04	5.72	51	4.96	6.42	91	4.11	26.16
12	5.01	6.68	52	5.14	3.08	92	4.32	14.88
13	4.44	10.33	53	5.67	-0.15	93	4.87	5.42
14	3.86	8.09	54	5.21	0.12	94	4.78	6.93
15	4.00	33.98	55	5.60	4.29	95	5.23	7.57
16	4.04	24.64	56	5.06	4.93	96	5.27	5.87
17	4.29	15.38	57	5.67	2.85	97	5.32	3.21
18	4.04	9.72	58	4.97	4.80	98	5.10	4.40
19	5.14	3.08	59	5.78	3.07	99	5.44	4.32
20	5.02	4.76	60	5.67	1.58	100	5.04	6.23
21	5.87	3.03	61	5.54	1.06	101	5.29	3.60
22	5.56	2.76	62	5.21	1.34	102	5.00	6.21
23	7.54	0.76	63	4.95	8.30			
24	6.83	0.62	64	4.93	12.42			
25	6.94	1.03	65	5.36	1.24			
26	6.98	-0.63	66	5.18	1.49			
27	5.68	-0.30	67	5.32	2.54			
28	4.92	4.45	68	5.61	2.58			
29	4.99	4.85	69	5.82	2.49			
30	4.87	5.14	70	5.23	4.55			
31	5.54	2.31	71	5.67	3.55			
32	5.06	2.86	72	5.04	4.15			
33	5.87	2.91	73	5.46	2.72			
34	4.94	3.23	74	5.13	3.57			
35	5.67	3.08	75	5.62	1.98			
36	5.44	3.10	76	5.46	2.50			
37	5.53	1.87	77	5.70	5.13			
38	5.32	2.79	78	5.84	5.53			
39	5.72	3.38	79	5.12	10.38			
40	5.87	1.03	80	4.91	13.48			

Salinity

Sample Number	EC (mS/m)	Sample Number	EC (mS/m)	Sample Number	EC (mS/m)
1	200	41	32	81	12
2	121	42	12	82	17
3	101	43	17	83	12
4	90	44	12	84	16
5	55	45	17	85	11
6	87	46	18	86	10
7	21	47	16	87	2
8	11	48	18	88	11
9	47	49	34	89	15
10	23	50	14	90	11
11	24	51	34	91	25
12	22	52	32	92	21
13	117	53	12	93	32
14	176	54	17	94	12
15	108	55	12	95	17
16	53	56	18	96	12
17	28	57	34	97	17
18	29	58	14	98	18
19	2	59	34	99	16
20	14	60	32	100	18
21	16	61	12	101	10
22	18	62	17	102	20
23	34	63	85		
24	14	64	114		
25	21	65	34		
26	34	66	14		
27	32	67	21		
28	12	68	34		
29	15	69	32		
30	18	70	12		
31	17	71	17		
32	12	72	12		
33	17	73	17		
34	18	74	18		
35	16	75	16		
36	18	76	18		
37	34	77	34		
38	14	78	14		
39	21	79	34		
40	34	80	32		

Sodium

Sample Number	Na (cmol(+)/kg)	CEC (cmol(+)/kg)	ESP (%)
1	0.120	7.882	1.52%
2	0.111	15.175	0.73%
3	0.121	9.653	1.25%
4	0.085	13.258	0.64%
5	0.608	20.185	3.01%
6	0.572	16.777	3.41%
7	0.064	7.577	0.84%
8	0.090	11.021	0.82%
9	3.496	21.591	16.19%
10	2.843	21.679	13.11%
11	2.799	20.924	13.38%
12	3.489	19.880	17.55%
13	10.679	23.434	45.57%
14	11.845	21.916	54.05%
15	9.892	35.460	27.90%
16	5.232	32.082	16.31%
17	2.686	17.491	15.36%
18	3.119	22.169	14.07%
19	0.100	4.600	2.17%
20	0.101	5.910	1.71%
21	0.206	6.892	2.99%
22	0.209	3.735	5.60%
23	0.084	6.860	1.22%
24	0.063	5.398	1.17%
25	0.076	12.305	0.62%
26	0.191	8.181	2.33%
27	0.074	5.436	1.36%
28	0.060	5.545	1.08%
29	0.079	7.067	1.12%
30	0.065	7.021	0.93%
31	0.065	4.163	1.56%
32	0.061	5.784	1.05%
33	0.087	3.528	2.47%
34	0.054	11.995	0.45%
35	0.060	9.866	0.61%
36	0.058	8.648	0.67%
37	0.041	4.804	0.85%
38	0.050	5.585	0.90%
39	0.057	4.874	1.17%
40	0.062	7.217	0.86%
41	0.069	7.692	0.90%
42	0.052	4.176	1.25%
43	0.066	5.410	1.22%
44	0.048	7.790	0.62%
45	0.049	6.379	0.77%
46	0.061	9.332	0.65%
47	0.048	4.916	0.98%
48	0.043	4.516	0.95%
49	0.042	6.718	0.63%
50	0.077	7.773	0.99%
51	0.076	8.515	0.89%
52	0.071	4.349	1.63%
53	0.043	3.246	1.32%
54	0.070	2.717	2.58%
55	0.048	7.336	0.65%
56	0.048	7.865	0.61%
57	0.053	6.608	0.80%
58	0.046	8.317	0.55%
59	0.066	8.772	0.75%
60	0.071	6.793	1.05%
61	0.087	4.892	1.78%
62	0.096	5.092	1.89%
63	8.064	16.207	49.76%
64	11.123	23.046	48.26%
65	0.322	1.252	25.72%
66	0.130	8.716	1.49%
67	0.089	2.355	3.78%
68	0.068	8.266	0.82%
69	0.076	12.567	0.60%
70	0.081	14.912	0.54%
71	0.082	9.922	0.83%
72	0.080	9.412	0.85%
73	0.084	8.125	1.03%
74	0.092	7.407	1.24%
75	0.062	6.201	1.00%
76	0.067	6.441	1.04%
77	0.207	16.652	1.24%
78	0.283	16.056	1.76%
79	0.797	18.097	4.40%
80	0.815	21.918	3.72%
81	0.058	5.624	1.03%
82	0.061	7.103	0.86%
83	0.074	7.228	1.02%
84	0.090	7.537	1.19%
85	1.588	19.454	8.16%
86	1.898	21.029	9.03%
87	0.072	4.480	1.61%
88	0.076	3.387	2.24%
89	0.085	5.550	1.53%
90	0.077	6.888	1.12%
91	2.409	29.226	8.24%
92	2.478	19.501	12.71%
93	0.114	7.139	1.60%
94	0.123	17.263	0.71%
95	0.417	19.176	2.17%
96	0.432	18.842	2.29%
97	0.080	2.742	2.92%
98	0.068	3.892	1.75%
99	0.067	5.718	1.17%
100	0.077	7.090	1.09%
101	0.062	4.002	1.55%
102	0.057	2.470	2.31%

Metal Suite

Element		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Li	(mg/kg)	0.142	0.18	0.111	0.185	0.167	0.084	0.034	0.116	0.177	0.225	0.259	6.587	0.108	0.153	0.279	0.363	0.099	0.081	0.018	0.305	0.038	0.203	0.015	0.154	0.032	0.066	0.016	0.015	0.015	0.015
Be	(mg/kg)	0.005	0.002	0.005	0.005	0.003	<0.001	0.001	0.003	<0.001	0.002	0.002	0.005	<0.001	0.004	0.004	<0.001	0.001	0.001	0.001	0.001	0.001	0.003	<0.001	0.004	0.001	<0.001	<0.001	<0.001	0.001	<0.001
B	(mg/kg)	0.035	0.011	0.061	0.015	0.006	0.067	0.015	0.027	0.099	0.042	0.025	0.024	0.07	0.052	0.058	0.039	0.055	0.067	0.002	0.007	0.011	0.005	0.002	0.012	0.056	0.066	0.003	0.049	0.071	0.006
Ti	(mg/kg)	15.48	8.83	16.28	26.54	6.273	0.409	3.777	16.56	0.149	4.608	5.744	13.96	0.039	0.014	0.008	0.006	2.425	0.07	2.35	6.054	2.88	7.542	2.079	14.06	3.767	2.619	2.833	1.474	3.864	2.491
V	(mg/kg)	0.208	0.107	0.253	0.348	0.099	0.01	0.085	0.22	0.025	0.079	0.096	0.252	0.041	0.062	0.09	0.032	0.05	0.019	0.047	0.116	0.114	0.176	0.055	0.232	0.084	0.102	0.048	0.022	0.056	0.041
Cr	(mg/kg)	0.381	0.184	0.392	0.63	0.168	0.007	0.087	0.379	0.004	0.127	0.165	0.438	0.005	0.009	0.012	0.008	0.071	0.008	0.06	0.154	0.073	0.197	0.056	0.449	0.081	0.069	0.047	0.022	0.064	0.039
Mn	(mg/kg)	0.239	0.072	0.273	0.271	0.056	0.137	0.119	0.249	0.332	0.03	0.048	0.117	3.033	3.793	0.196	0.054	0.075	0.172	0.107	0.107	0.164	0.294	0.091	0.212	0.307	0.209	0.254	0.08	0.131	0.06
Co	(mg/kg)	0.027	0.011	0.027	0.041	0.017	0.01	0.008	0.029	0.009	0.009	0.012	0.03	0.058	0.149	0.008	0.001	0.007	0.005	0.004	0.01	0.007	0.018	0.004	0.027	0.012	0.008	0.006	0.003	0.008	0.005
Ni	(mg/kg)	0.135	0.048	0.122	0.189	0.06	<0.001	0.038	0.143	0.003	0.03	0.046	0.126	0.187	0.225	0.013	<0.001	0.018	0.015	0.016	0.045	0.023	0.058	0.022	0.173	0.083	0.033	0.028	0.02	0.031	0.011
Cu	(mg/kg)	0.116	0.037	0.151	0.126	0.053	0.113	0.076	0.108	0.015	0.019	0.044	0.07	0.017	0.075	0.017	0.002	0.033	0.039	0.029	0.041	0.049	0.143	0.067	0.102	0.066	0.044	0.047	0.019	0.048	0.028
Zn	(mg/kg)	0.138	0.164	0.415	0.26	0.165	0.17	0.207	0.424	0.17	0.062	0.219	0.211	1.135	0.728	0.154	0.272	0.254	0.692	0.074	0.234	0.145	0.357	0.276	0.456	0.309	0.169	0.15	0.156	0.069	0.213
As	(mg/kg)	0.012	0.002	0.015	0.022	<0.001	0.001	0.002	0.012	0.003	0.009	0.005	0.02	0.003	0.015	0.02	0.006	<0.001	0.004	0.003	0.008	0.009	0.012	0.003	0.016	0.011	0.007	0.006	<0.001	0.007	<0.001
Br	(mg/kg)	0.096	0.046	0.079	0.05	0.185	0.146	0.109	0.155	1.726	0.876	0.891	0.614	3.643	4.871	5.905	2.436	1.231	1.193	0.115	0.131	0.205	0.104	<0.001	0.051	0.031	0.069	0.006	<0.001	0.029	0.012
Se	(mg/kg)	0.012	0.002	0.009	0.004	0.001	<0.001	<0.001	0.001	0.015	0.015	0.003	<0.001	0.022	0.036	0.056	0.017	<0.001	0.011	0.004	<0.001	0.002	0.01	0.007	0.002	0.01	0.004	0.012	0.001	0.004	<0.001
Rb	(mg/kg)	0.098	0.05	0.127	0.177	0.039	0.018	0.057	0.097	0.023	0.037	0.04	0.087	0.042	0.076	0.049	0.025	0.027	0.012	0.034	0.04	0.024	0.045	0.056	0.116	0.057	0.038	0.037	0.019	0.046	0.024
Sr	(mg/kg)	0.138	0.062	0.139	0.213	0.062	0.072	0.06	0.169	0.498	0.115	0.136	0.219	0.888	1.998	0.178	0.072	0.054	0.045	0.033	0.082	0.026	0.078	0.202	0.213	0.127	0.076	0.028	0.015	0.038	0.02
Mo	(mg/kg)	0.008	0.004	0.01	0.013	0.004	0.001	0.003	0.007	<0.001	0.001	0.003	0.004	0.001	<0.001	<0.001	0.002	0.002	0.001	0.001	0.003	0.015	0.003	0.004	0.006	0.004	0.004	0.009	0.002	0.001	<0.001
Cd	(mg/kg)	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sn	(mg/kg)	0.006	<0.001	0.003	0.01	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb	(mg/kg)	0.002	0.001	0.002	0.002	0.001	0.001	0.001	0.001	<0.001	0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	0.002	0.001	0.001	<0.001	0.001	0.001	<0.001
Te	(mg/kg)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
I	(mg/kg)	0.033	0.037	0.028	0.026	0.005	0.002	0.02	0.04	0.005	<0.001	<0.001	<0.001	0.003	0.003	<0.001	<0.001	<0.001	<0.001	0.004	0.031	0.002	<0.001	0.005	0.017	0.039	0.042	0.034	0.082	0.092	0.152
Cs	(mg/kg)	0.059	0.085	0.099	0.046	0.02	0.014	0.07	0.034	0.027	0.013	0.099	0.062	0.049	0.199	0.012	0.053	0.021	0.007	0.109	0.02	0.042	0.105	0.018	0.034	0.02	0.058	0.016	0.023	0.027	0.048
Ba	(mg/kg)	<0.001	0.078	<0.001	0.081	0.072	<0.001	0.11	<0.001	<0.001	<0.001	0.044	<0.001	<0.001	<0.001	0.053	<0.001	<0.001	<0.001	0.019	0.014	<0.001	0.094	0.071	0.12	<0.001	<0.001	<0.001	<0.001	<0.001	0.027
La	(mg/kg)	0.103	0.043	0.102	0.157	0.051	0.002	0.028	0.107	0.002	0.033	0.043	0.119	<0.001	0.024	0.001	<0.001	0.025	0.001	0.017	0.047	0.023	0.062	0.017	0.134	0.034	0.023	0.019	0.008	0.03	0.015
W	(mg/kg)	0.007	0.004	0.007	0.01	0.003	0.001	0.002	0.006	<0.001	0.002	0.002	0.004	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	0.002	0.001	0.002	0.001	0.006	0.001	0.001	0.001	<0.001	0.002	0.001
Pt	(mg/kg)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Hg	(mg/kg)	0.014	0.01	0.007	0.002	0.002	0.005	<0.001	0.003	0.012	0.006	<0.001	<0.001	0.004	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tl	(mg/kg)	0.002	0.001	0.001	0.002	0.001	0.001	<0.001	0.001	<0.001	0.001	0.001	0.001	0.001	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pb	(mg/kg)	0.076	0.037	0.081	0.133	0.033	0.009	0.017	0.079	0.004	0.025	0.032	0.078	0.004	0.007	0.002	<0.001	0.014	0.002	0.011	0.032	0.016	0.051	0.016	0.092	0.026	0.018	0.017	0.007	0.028	0.013
Bi	(mg/kg)	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	(mg/kg)	0.008	0.004	0.011	0.016	0.006	<0.001	0.003	0.01	<0.001	0.002	0.003	0.007	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.002	0.003	0.007	0.01	0.002	0.01	0.002	0.002	0.002	0.001	0.003	0.002

Element		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Li	(mg/kg)	0.01	0.375	0.013	0.006	0.003	0.003	0.049	0.029	<0.001	0.019	0.011	0.006	0.146	0.005	0.007	0.102	0.01	0.052	0.098	0.024	0.004	0.013	0.014	0.014	0.05	0.045	0.058	0.016	0.025	0.032
Be	(mg/kg)	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.003	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.006	0.003	0.003	0.001	0.001	0.002
B	(mg/kg)	0.056	0.066	0.065	0.017	0.044	0.05	0.006	0.007	<0.001	0.014	0.08	0.007	0.064	0.002	0.001	0.013	0.012	0.015	0.02	0.03	0.012	0.009	0.007	0.01	0.03	0.018	0.009	0.007	0.006	0.012
Ti	(mg/kg)	3.252	3.496	4.463	2.064	2.186	2.215	1.134	2.07	1.249	3.936	3.677	3.374	2.221	1.79	3.183	20.68	3.145	13.85	4.299	7.584	1.203	1.73	2.023	3.249	13.72	13.21	15.88	4.439	7.465	9.94
V	(mg/kg)	0.046	0.04	0.087	0.032	0.055	0.052	0.019	0.027	0.02	0.053	0.072	0.059	0.051	0.043	0.062	0.349	0.074	0.277	0.093	0.146	0.027	0.035	0.064	0.08	0.187	0.177	0.241	0.067	0.123	0.194
Cr	(mg/kg)	0.044	0.045	0.076	0.029	0.042	0.044	0.015	0.029	0.016	0.058	0.057	0.048	0.035	0.028	0.057	0.414	0.052	0.216	0.076	0.127	0.028	0.034	0.055	0.079	0.269	0.178	0.189	0.084	0.081	0.14
Mn	(mg/kg)	0.392	0.106	0.531	0.068	0.154	0.086	0.074	0.118	0.062	0.165	0.192	0.088	0.136	0.065	0.221	0.431	0.413	0.883	0.328	0.246	0.044	0.21	0.177	0.077	0.678	0.376	0.799	0.156	0.758	0.533
Co	(mg/kg)	0.01	0.006	0.012	0.003	0.006	0.005	0.003	0.003	0.002	0.006	0.007	0.006	0.005	0.004	0.007	0.05	0.008	0.031	0.01	0.015	0.005	0.004	0.005	0.007	0.024	0.019	0.026	0.007	0.014	0.017
Ni	(mg/kg)	0.05	0.024	0.026	<0.001	0.018	0.004	<0.001	0.002	<0.001	0.023	0.024	0.009	0.01	0.026	0.062	1.304	0.028	0.196	0.081	0.08	0.082	0.015	0.041	0.014	0.117	0.118	0.152	0.048	0.058	0.078
Cu	(mg/kg)	0.029	0.022	0.036	0.02	0.019	0.021	0.025	0.024	0.013	0.027	0.024	0.02	0.027	0.099	0.041	0.241	0.203	0.195	0.096	0.163	0.065	0.104	0.148	0.089	0.066	0.046	0.07	0.024	0.047	0.054
Zn	(mg/kg)	0.076	0.115	0.04	0.035	0.073	0.091	0.039	0.063	0.067	0.12	0.16	0.049	0.099	0.521	0.063	0.475	0.58	0.762	0.51	0.305	0.618	0.593	0.618	0.345	0.162	0.106	0.157	0.048	0.131	0.077
As	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.016	0.014	0.023	0.008	0.009	0.017
Br	(mg/kg)	0.023	0.017	0.07	<0.001	0.04	0.072	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	0.009	0.067	0.02	0.034	0.053	0.018	<0.001	<0.001	<0.001	<0.001	0.111	0.111	0.071	0.057	0.064	0.085
Se	(mg/kg)	0.01	<0.001	0.017	<0.001	0.003	0.007	0.011	<0.001	0.004	<0.001	0.001	0.008	0.004	0.017	0.002	0.006	0.001	0.008	0.011	<0.001	<0.001	0.008	<0.001	0.004	0.007	0.002	0.008	0.009	0.008	0.013
Rb	(mg/kg)	0.049	0.033	0.056	0.016	0.04	0.024	0.027	0.022	0.036	0.045	0.032	0.013	0.025	0.014	0.042	0.13	0.049	0.086	0.055	0.054	0.016	0.03	0.028	0.033	0.1	0.077	0.132	0.032	0.056	0.044
Sr	(mg/kg)	0.031	0.029	0.044	0.017	0.039	0.032	0.009	0.027	0.006	0.026	0.02	0.019	0.022	0.017	0.038	0.184	0.048	0.108	0.047	0.06	0.035	0.031	0.028	0.038	0.117	0.05	0.108	0.025	0.07	0.052
Mo	(mg/kg)	0.001	0.004	0.002	<0.001	0.001	0.001	0.001	0.002	<0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.007	0.001	0.005	0.004	0.003	0.003	<0.001	0.002	0.001	0.009	0.004	0.005	0.001	0.002	0.004
Cd	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.015	<0.001	<0.001	<0.001	<0.001	<0.001
Sn	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.075	0.054	0.069	0.108	0.099	0.073	0.069	0.078	0.043	0.049	0.071	0.075	0.005	0.002	<0.001	0.033	<0.001	<0.001
Sb	(mg/kg)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.005	0.001	0.001	<0.001	0.001	0.002
Te	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
I	(mg/kg)	0.029	0.071	0.04	0.118	0.063	0.164	0.012	0.01	0.003	0.007	0.01	0.016	0.012	0.026	0.002	0.017	0.008	0.018	0.021	0.037	0.061	0.015	<0.001	<0.001	0.05	0.064	0.037	0.077	0.044	0.083
Cs	(mg/kg)	0.058	0.025	0.385	0.086	0.017	0.01	0.01	0.016	0.099	0.016	0.021	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	<0.001	<0.001	<0.001	<0.001
Ba	(mg/kg)	<0.001	<0.001	<0.001	0.017	<0.001	<0.001	<0.001	0.01	<0.001	0.094	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.047	0.036	0.052	0.01	0.022	0.024
La	(mg/kg)	0.022	0.022	0.035	0.014	0.018	0.018	0.007	0.012	0.007	0.023	0.019	0.021	0.012	0.011	0.02	0.144	0.025	0.071	0.029	0.047	0.01	0.023	0.015	0.027	0.132	0.119	0.141	0.036	0.057	0.065
W	(mg/kg)	0.001	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	0.001	0.006	<0.001	0.004	0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.011	0.007	0.007	0.003	0.003	0.004
Pt	(mg/kg)	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
Hg	(mg/kg)	<0.001	0.002	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.015	0.008	0.006	0.004	0.004	0.002
Tl	(mg/kg)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	0.001	0.001	<0.001	<0.001	0.001
Pb	(mg/kg)	0.019	0.017	0.027	0.011	0.015	0.018	0.008	0.011	0.008	0.016	0.019	0.014	0.011	0.026	0.014	0.101	0.029	0.077	0.025	0.045	0.011	0.026	0.026	0.043	0.066	0.061	0.065	0.017	0.024	0.045
Bi	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.001	<0.001	<0.001	<0.001	<0.001
U	(mg/kg)	0.002	0.001	0.003	0.001	0.003	0.001	<0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.008	0.001	0.005	0.002	0.003	<0.001	0.001	0.001	0.002	0.011	0.006	0.009	0.002	0.004	0.006

Element		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Li	(mg/kg)	0.054	0.121	0.269	0.369	0.041	0.127	0.174	0.043	0.21	0.275	0.035	0.041	0.022	0.031	0.076	0.027	0.053	0.275	0.489	0.24	0.079	0.117	0.129	0.16	0.173	0.203	0.017	0.093	0.04	0.084
Be	(mg/kg)	0.002	0.004	0.011	0.025	0.001	0.005	0.007	0.002	0.01	0.011	0.002	0.002	0.001	0.001	0.003	0.001	0.003	0.022	0.015	0.013	0.003	0.004	0.004	0.004	0.013	0.008	0.001	0.006	0.002	0.004
B	(mg/kg)	0.01	0.016	0.146	0.252	0.009	0.013	0.018	0.009	0.052	0.012	<0.001	0.005	<0.001	<0.001	0.003	<0.001	0.006	0.015	0.054	0.011	<0.001	<0.001	0.001	0.003	0.032	0.04	<0.001	0.006	<0.001	<0.001
Ti	(mg/kg)	13.38	26	22.46	28.17	5.695	22.51	39.81	9.593	33.42	41.33	8.795	12.26	5.847	7.999	19.53	7.168	7.826	34.69	45.01	24.11	10.08	23.85	18.59	24.43	17.29	13.04	4.081	24.26	11.33	23.6
V	(mg/kg)	0.179	0.302	0.61	0.739	0.127	0.455	0.423	0.119	0.41	0.449	0.118	0.147	0.107	0.144	0.398	0.158	0.2	0.746	0.73	0.46	0.243	0.368	0.327	0.426	0.308	0.304	0.053	0.301	0.139	0.281
Cr	(mg/kg)	0.233	0.47	0.647	0.732	0.117	0.554	0.684	0.16	0.447	0.546	0.106	0.14	0.08	0.113	0.337	0.12	0.212	0.985	1.064	0.58	0.308	0.505	0.427	0.578	0.495	0.545	0.058	0.401	0.189	0.425
Mn	(mg/kg)	0.342	0.289	0.375	0.277	0.373	1.493	0.697	0.738	1.321	0.605	0.561	0.521	0.431	0.32	0.893	0.391	0.618	0.454	1.032	0.665	0.723	0.394	0.46	0.321	0.711	0.279	0.302	0.527	0.298	0.065
Co	(mg/kg)	0.013	0.03	0.051	0.058	0.014	0.046	0.053	0.014	0.056	0.065	0.016	0.019	0.011	0.014	0.036	0.013	0.016	0.055	0.102	0.052	0.024	0.033	0.023	0.031	0.043	0.03	0.005	0.029	0.015	0.029
Ni	(mg/kg)	0.561	0.2	0.242	0.232	0.171	0.233	0.275	0.082	0.258	0.233	0.102	0.084	0.047	0.077	0.284	0.077	0.056	0.236	0.363	0.158	0.094	0.649	0.103	0.136	0.141	0.137	0.044	0.135	0.185	0.159
Cu	(mg/kg)	0.047	0.088	0.102	0.237	0.029	0.106	0.126	0.061	0.141	0.123	0.054	0.048	0.035	0.034	0.088	0.043	0.05	0.147	0.207	0.14	0.058	0.096	0.064	0.078	0.148	0.101	0.037	0.095	0.064	0.1
Zn	(mg/kg)	0.154	0.206	0.271	0.67	0.178	0.226	0.282	0.209	0.36	0.321	0.143	0.129	0.118	0.101	0.187	0.116	0.168	0.274	0.4	0.202	0.161	0.216	0.164	0.143	0.256	0.17	0.116	0.151	0.188	0.202
As	(mg/kg)	0.015	0.022	0.064	0.05	0.009	0.026	0.031	0.011	0.024	0.017	0.011	0.013	0.012	0.015	0.047	0.021	0.02	0.045	0.056	0.033	0.018	0.03	0.033	0.04	0.031	0.026	0.002	0.015	0.009	0.021
Br	(mg/kg)	0.04	0.045	3.78	5.108	0.173	0.142	0.138	0.065	0.069	0.025	0.056	0.073	0.018	0.021	0.003	0.007	0.136	0.147	0.407	0.163	0.048	0.091	0.065	0.075	0.977	0.491	0.031	0.068	0.057	0.1
Se	(mg/kg)	0.009	0.011	0.036	0.041	0.01	0.01	0.01	0.006	0.008	0.009	0.007	0.004	0.007	0.008	0.01	0.009	<0.001	0.01	0.003	0.008	0.012	0.012	0.003	0.011	0.021	0.003	0.005	0.013	<0.001	0.009
Rb	(mg/kg)	0.088	0.123	0.132	0.17	0.06	0.173	0.295	0.125	0.264	0.2	0.077	0.064	0.052	0.04	0.109	0.046	0.072	0.141	0.22	0.119	0.104	0.111	0.113	0.127	0.14	0.118	0.052	0.135	0.074	0.123
Sr	(mg/kg)	0.081	0.17	0.335	0.31	0.048	0.161	0.347	0.089	0.28	0.244	0.062	0.07	0.037	0.037	0.126	0.051	0.103	0.206	0.417	0.224	0.13	0.193	0.163	0.129	0.228	0.162	0.034	0.164	0.073	0.155
Mo	(mg/kg)	0.004	0.006	0.008	0.009	0.003	0.008	0.008	0.003	0.008	0.005	0.002	0.002	0.003	0.003	0.008	0.002	0.004	0.013	0.014	0.007	0.004	0.006	0.006	0.008	0.007	0.007	0.001	0.007	0.004	0.007
Cd	(mg/kg)	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sn	(mg/kg)	<0.001	0.006	0.012	0.007	<0.001	0.011	0.013	<0.001	<0.001	0.011	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	0.012	0.301	0.005	0.003	0.007	<0.001	0.006	<0.001	0.003	<0.001	0.004	<0.001	0.004
Sb	(mg/kg)	0.001	0.002	0.002	0.003	0.001	0.003	0.003	0.001	0.003	0.003	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.003	0.004	0.002	0.001	0.002	0.002	0.006	0.002	0.002	0.001	0.002	0.002	0.002
Te	(mg/kg)	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
I	(mg/kg)	0.015	0.014	0.015	0.013	0.01	0.036	0.055	0.018	0.022	0.006	0.016	0.073	0.014	0.039	0.027	0.014	0.013	0.012	0.018	0.003	0.012	0.035	0.009	0.013	0.01	0.003	0.002	0.021	0.018	0.035
Cs	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.028	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ba	(mg/kg)	0.04	0.07	0.095	0.135	0.026	0.076	0.129	0.037	0.131	0.129	0.029	0.025	0.017	0.014	0.048	0.02	0.045	0.147	0.194	0.163	0.056	0.07	0.068	0.082	0.096	0.063	0.014	0.085	0.028	0.069
La	(mg/kg)	0.078	0.149	0.233	0.35	0.064	0.226	0.319	0.098	0.185	0.211	0.073	0.079	0.039	0.05	0.117	0.049	0.067	0.301	0.295	0.315	0.107	0.178	0.078	0.168	0.289	0.206	0.034	0.244	0.079	0.221
W	(mg/kg)	0.005	0.01	0.008	0.009	0.003	0.01	0.014	0.003	0.011	0.013	0.003	0.004	0.002	0.003	0.007	0.003	0.003	0.014	0.016	0.008	0.005	0.009	0.006	0.01	0.006	0.007	0.001	0.008	0.004	0.007
Pt	(mg/kg)	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg	(mg/kg)	0.003	0.002	0.007	0.003	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Tl	(mg/kg)	0.001	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.001	<0.001	<0.001	0.001	<0.001	0.001	0.002	0.003	0.002	0.001	0.001	0.001	0.001	0.002	0.001	<0.001	0.001	0.001	0.001
Pb	(mg/kg)	0.054	0.116	0.102	0.166	0.023	0.108	0.16	0.039	0.114	0.141	0.038	0.038	0.016	0.023	0.078	0.025	0.036	0.183	0.211	0.156	0.061	0.103	0.078	0.108	0.158	0.139	0.015	0.122	0.044	0.104
Bi	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	(mg/kg)	0.01	0.017	0.021	0.054	0.006	0.014	0.019	0.006	0.019	0.023	0.005	0.006	0.003	0.004	0.011	0.005	0.011	0.055	0.031	0.042	0.011	0.018	0.017	0.022	0.049	0.045	0.003	0.019	0.007	0.017

Element		91	92	93	94	95	96	97	98	99	100	101	102
Li	(mg/kg)	0.486	0.079	0.03	0.023	0.061	0.055	0.015	0.012	0.015	0.016	0.01	0.006
Be	(mg/kg)	0.013	<0.001	0.002	0.001	0.017	0.009	0.001	0.001	0.001	<0.001	<0.001	<0.001
B	(mg/kg)	0.022	0.008	0.032	0.026	0.033	0.034	0.027	0.023	0.029	0.027	0.023	0.024
Ti	(mg/kg)	16.09	0.538	4.276	3.636	4.406	3.338	3.268	3.637	2.88	3.082	2.672	1.944
V	(mg/kg)	0.315	0.008	0.087	0.059	0.16	0.125	0.061	0.07	0.065	0.037	0.065	0.046
Cr	(mg/kg)	0.496	0.005	0.122	0.084	0.159	0.123	0.065	0.075	0.051	0.045	0.04	0.022
Mn	(mg/kg)	0.253	0.004	0.053	0.026	0.383	0.219	0.107	0.114	0.374	0.177	0.278	0.142
Co	(mg/kg)	0.041	0.001	0.006	0.004	0.019	0.015	0.005	0.005	0.007	0.005	0.005	0.003
Ni	(mg/kg)	0.148	<0.001	0.02	0.013	0.132	0.1	0.019	0.014	0.031	0.009	0.033	0.005
Cu	(mg/kg)	0.112	<0.001	0.041	0.042	0.106	0.075	0.022	0.021	0.033	0.009	0.032	0.014
Zn	(mg/kg)	0.194	0.041	0.061	0.057	0.105	0.077	0.04	0.067	0.093	0.029	0.052	0.021
As	(mg/kg)	0.013	0.001	0.005	0.004	0.007	0.005	0.006	0.008	0.009	0.001	0.004	<0.001
Br	(mg/kg)	1.084	0.853	0.082	0.077	0.046	0.031	0.048	0.09	0.089	0.047	0.042	0.033
Se	(mg/kg)	0.01	0.004	0.004	0.006	<0.001	<0.001	0.001	<0.001	0.01	<0.001	0.002	0.004
Rb	(mg/kg)	0.09	0.005	0.029	0.015	0.039	0.035	0.023	0.019	0.042	0.02	0.038	0.014
Sr	(mg/kg)	0.197	0.025	0.04	0.018	0.171	0.081	0.03	0.034	0.024	0.021	0.015	0.007
Mo	(mg/kg)	0.005	<0.001	0.003	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.002	0.001
Cd	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001
Sn	(mg/kg)	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb	(mg/kg)	0.003	<0.001	0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Te	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
I	(mg/kg)	0.008	0.01	0.021	0.013	0.006	0.003	0.02	0.058	0.046	0.086	0.034	0.046
Cs	(mg/kg)	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ba	(mg/kg)	0.077	0.002	0.02	0.009	0.189	0.121	0.008	0.009	0.011	0.006	0.008	0.001
La	(mg/kg)	0.468	0.004	0.095	0.051	0.357	0.214	0.022	0.029	0.025	0.024	0.023	0.014
W	(mg/kg)	0.009	<0.001	0.005	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.001
Pt	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg	(mg/kg)	0.002	<0.001	0.01	0.007	0.005	0.002	0.005	0.004	0.003	0.002	0.002	0.005
Tl	(mg/kg)	0.002	<0.001	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pb	(mg/kg)	0.128	<0.001	0.044	0.019	0.109	0.068	0.011	0.011	0.014	0.006	0.015	<0.001
Bi	(mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	(mg/kg)	0.042	0.001	0.014	0.008	0.052	0.026	0.003	0.004	0.005	0.002	0.003	0.001

Nitrogen, Phosphorus and Potassium

Sample Number	NO_3 (mg/kg)	P (mg/kg)	K (mg/kg)	Sample Number	NO_3 (mg/kg)	P (mg/kg)	K (mg/kg)	Sample Number	NO_3 (mg/kg)	P (mg/kg)	K (mg/kg)
1	10.8	1	30.42	41	9.4	0.9	24.96	81	22	0.9	38.22
2	3.1	2	31.2	42	2.8	0.4	16.38	82	4.2	0.4	21.84
3	1.5	1	103.74	43	29.3	6	26.13	83	9.4	6	23.4
4	0.3	0.3	144.3	44	8.7	6	17.16	84	2.5	6	25.35
5	1.5	0.4	54.21	45	20.2	0.7	35.49	85	17.7	0.7	111.15
6	1.3	0.6	48.75	46	1.2	0.3	23.01	86	1.8	0.3	132.6
7	8.1	0.9	49.92	47	44.1	0.9	44.46	87	29.6	0.9	33.15
8	3.6	2	39.78	48	17.8	0.2	30.03	88	3.1	4	20.28
9	3.3	5	30.81	49	21.8	4	38.61	89	3.6	8	40.95
10	3.7	4	42.51	50	14.8	8	141.96	90	3.3	7	70.98
11	4.6	1	42.51	51	16.6	7	31.98	91	3.5	6	115.44
12	3.8	3	44.07	52	18.1	0.9	35.88	92	2.7	0.7	144.69
13	49.8	0.7	178.23	53	20.2	0.4	18.72	93	14	0.3	24.96
14	17.5	0.9	183.3	54	8.8	6	16.77	94	4.5	0.9	18.72
15	54.3	0.4	338.13	55	19.4	3	40.17	95	3.3	0.2	28.86
16	10.5	6	279.63	56	8	0.7	23.01	96	4.8	4	35.49
17	1.7	6	110.37	57	15.	0.9	30.42	97	1.8	8	32.76
18	2.6	0.7	111.15	58	6.6	0.4	20.67	98	1	7	21.45
19	24	0.3	55.38	59	39	6	39	99	1.4	0.9	53.43
20	7.4	0.9	26.13	60	12.6	6	30.42	100	2.1	0.4	28.08
21	1.1	0.2	23.79	61	5	0.7	27.3	101	17.1	6	39.78
22	0.5	4	30.03	62	0.6	0.3	28.86	102	15.1	3	30.81
23	30.3	8	33.54	63	6.7	0.9	214.5				
24	16.5	7	40.95	64	91.8	0.2	287.04				
25	8.2	9	28.86	65	6.9	4	28.08				
26	2.6	3	26.52	66	6.8	8	19.11				
27	3.6	8	23.01	67	10.5	7	28.08				
28	1.8	0.6	19.89	68	29	6	34.32				
29	1.6	0.9	27.69	69	76.5	0.7	143.52				
30	0.3	2	29.25	70	5.3	0.3	70.2				
31	1.9	5	27.3	71	8.9	0.9	42.9				
32	3.7	4	18.33	72	6.3	0.2	20.67				
33	1.4	1	32.76	73	26	4	23.4				
34	1.7	3	24.96	74	6.8	8	21.45				
35	6.7	0.7	46.41	75	11.1	7	22.23				
36	4.3	0.9	31.59	76	4.3	0.9	26.91				
37	32.6	0.4	34.32	77	43.3	0.4	58.89				
38	14.1	6	26.91	78	2.8	6	40.17				
39	21.9	3	34.71	79	3.7	3	53.82				
40	3.9	0.7	28.86	80	2.2	0.7	44.07				

Calcium, Magnesium and Potassium

Sample Number	Ca (cmol(+)/kg)	Mg (cmol(+)/kg)	K (cmol(+)/kg)	Ca:Mg (cmol(+)/kg)	Mg:K (cmol(+)/kg)	Ca+Mg/K (cmol(+)/kg)
1	1.349	0.868	0.078	1.554	11.128	12.477
2	1.184	1.021	0.080	1.160	12.763	13.947
3	1.933	1.242	0.266	1.556	4.669	6.602
4	1.889	1.738	0.370	1.087	4.697	6.586
5	1.813	1.854	0.139	0.978	13.338	15.151
6	1.164	1.368	0.125	0.851	10.944	12.108
7	2.964	1.673	0.128	1.772	13.070	16.034
8	2.516	1.825	0.102	1.379	17.892	20.408
9	4.818	7.757	0.079	0.621	98.190	103.008
10	4.393	7.357	0.109	0.597	67.495	71.888
11	4.515	7.609	0.109	0.593	69.807	74.322
12	3.986	6.181	0.113	0.645	54.699	58.685
13	3.545	10.255	0.457	0.346	22.440	25.985
14	6.225	9.121	0.470	0.682	19.406	25.631
15	0.657	2.882	0.867	0.228	3.324	3.981
16	0.693	2.826	0.717	0.245	3.941	4.634
17	0.933	2.321	0.283	0.402	8.201	9.134
18	1.305	3.119	0.285	0.418	10.944	12.249
19	1.020	0.589	0.142	1.732	4.148	5.168
20	1.057	0.838	0.067	1.261	12.507	13.564
21	1.260	0.756	0.061	1.667	12.393	13.653
22	0.853	0.623	0.077	1.369	8.091	8.944
23	6.932	0.643	0.086	10.781	7.477	14.409
24	1.971	1.283	0.105	1.536	12.219	14.190
25	6.597	1.000	0.074	6.597	13.514	20.111
26	4.506	0.739	0.068	6.097	10.868	15.374
27	0.914	0.729	0.059	1.254	12.356	13.270
28	0.369	0.511	0.051	0.722	10.020	10.389
29	0.622	0.879	0.071	0.708	12.380	13.002
30	0.557	0.662	0.075	0.841	8.827	9.384
31	0.765	0.567	0.070	1.349	8.100	8.865
32	0.613	0.771	0.047	0.795	16.404	17.017
33	1.364	1.078	0.084	1.265	12.833	14.197
34	0.572	0.792	0.064	0.722	12.375	12.947
35	2.563	1.234	0.119	2.077	10.370	12.933
36	1.289	1.117	0.081	1.154	13.790	15.079
37	1.044	0.493	0.088	2.118	5.602	6.646
38	0.715	0.495	0.069	1.444	7.174	7.889
39	1.323	0.421	0.089	3.143	4.730	6.053
40	1.378	0.424	0.074	3.250	5.730	7.108
41	1.240	0.527	0.064	2.353	8.234	9.474
42	0.641	0.564	0.042	1.137	13.429	14.070
43	1.426	0.778	0.067	1.833	11.612	13.038
44	0.643	0.562	0.044	1.144	12.773	13.416
45	3.786	0.931	0.091	4.067	10.231	14.017
46	2.738	0.912	0.059	3.002	15.458	18.196
47	2.617	0.585	0.114	4.474	5.132	7.749
48	2.487	0.463	0.077	5.371	6.013	8.500
49	3.406	1.176	0.099	2.896	11.879	15.285
50	1.399	1.306	0.364	1.071	3.588	4.987
51	1.072	0.599	0.082	1.790	7.305	8.377
52	1.040	0.529	0.092	1.966	5.750	6.790
53	1.165	0.582	0.048	2.002	12.125	13.290
54	0.630	0.497	0.043	1.268	11.558	12.188
55	2.198	1.026	0.103	2.142	9.961	12.159
56	1.069	0.508	0.059	2.104	8.610	9.679
57	2.303	0.803	0.078	2.868	10.295	12.598
58	0.820	0.596	0.053	1.376	11.245	12.065
59	3.566	1.271	0.100	2.806	12.710	16.276
60	2.258	0.721	0.078	3.132	9.244	11.502
61	1.510	0.835	0.070	1.808	11.929	13.439
62	1.506	1.039	0.074	1.449	14.041	15.547
63	1.994	4.155	0.550	0.480	7.555	9.549
64	2.083	5.192	0.736	0.401	7.054	9.137
65	0.856	0.581	0.072	1.473	8.069	8.925
66	0.683	0.524	0.049	1.303	10.694	11.377
67	1.887	0.715	0.072	2.639	9.931	11.818
68	2.971	0.820	0.088	3.623	9.318	12.289
69	5.446	2.024	0.368	2.691	5.500	10.946
70	2.218	1.461	0.180	1.518	8.117	10.335
71	1.549	0.932	0.110	1.662	8.473	10.022
72	0.898	0.615	0.053	1.460	11.604	12.502
73	1.160	0.589	0.060	1.969	9.817	10.977
74	0.781	0.673	0.055	1.160	12.236	13.017
75	0.788	0.643	0.057	1.226	11.281	12.069
76	0.862	0.740	0.069	1.165	10.725	11.587
77	4.471	2.616	0.151	1.709	17.325	21.796
78	3.173	2.964	0.103	1.071	28.777	31.950
79	2.803	1.501	0.138	1.867	10.877	13.680
80	2.527	1.475	0.113	1.713	13.053	15.580
Sample Number	Ca (cmol(+)/kg)	Mg (cmol(+)/kg)	K (cmol(+)/kg)	Ca:Mg (cmol(+)/kg)	Mg:K (cmol(+)/kg)	Ca+Mg/K (cmol(+)/kg)
81	1.480	0.785	0.098	1.885	8.010	9.490
82	0.925	1.429	0.056	0.647	25.518	26.443
83	2.013	1.229	0.060	1.638	20.483	22.496
84	1.581	1.352	0.065	1.169	20.800	22.381
85	1.841	2.926	0.285	0.629	10.267	12.108
86	1.444	3.293	0.340	0.439	9.685	11.129
87	1.407	0.684	0.085	2.057	8.047	9.454
88	1.114	0.753	0.052	1.479	14.481	15.595
89	1.945	1.037	0.105	1.876	9.876	11.821
90	1.735	1.385	0.182	1.253	7.610	9.345
91	1.051	2.188	0.296	0.480	7.392	8.443
92	1.239	3.239	0.371	0.383	8.730	9.969
93	1.127	0.818	0.064	1.378	12.781	13.908
94	0.734	0.607	0.048	1.209	12.646	13.380
95	4.763	2.527	0.074	1.885	34.149	38.912
96	5.489	2.922	0.091	1.879	32.110	37.599
97	0.391	0.364	0.084	1.074	4.333	4.724
98	0.331	0.288	0.055	1.149	5.236	5.567
99	0.866	0.578	0.137	1.498	4.219	5.085
100	0.711	0.386	0.072	1.842	5.361	6.072
101	0.663	0.441	0.102	1.503	4.324	4.987
102	0.621	0.365	0.079	1.701	4.620	5.241

Sulphur

Sample Number	SO_4 (mg/kg)	Sample Number	SO_4 (mg/kg)	Sample Number	SO_4 (mg/kg)
1	10.2	41	3.1	81	2.3
2	2.9	42	1.8	82	2.3
3	1.2	43	3.2	83	2.1
4	0.7	44	2.2	84	1.5
5	5.7	45	3.4	85	119.1
6	4.1	46	1.1	86	178.6
7	6.9	47	2.9	87	8.1
8	6	48	1.9	88	5.9
9	5.2	49	2.9	89	1.9
10	56.6	50	8.9	90	6.1
11	74.6	51	5.5	91	160.8
12	397.7	52	4.2	92	165.3
13	1296.4	53	1.4	93	7
14	3085.8	54	0.8	94	5.2
15	328.7	55	1.8	95	28.7
16	210.1	56	1.9	96	54.7
17	193.4	57	2.5	97	4.8
18	214.8	58	4.5	98	2
19	9	59	2.4	99	2.7
20	5.9	60	1.9	100	2.7
21	5	61	2.8	101	2
22	2.1	62	4	102	10.3
23	3.5	63	330.9		
24	9.6	64	506.1		
25	7.4	65	11.4		
26	27.2	66	4.2		
27	2.9	67	2.9		
28	6.2	68	4.4		
29	6.7	69	14.7		
30	3.8	70	22.7		
31	3.7	71	3.1		
32	2.6	72	2.5		
33	3.6	73	1.9		
34	2.9	74	3.7		
35	4.8	75	2.2		
36	5.1	76	3		
37	1.7	77	7.4		
38	1.9	78	3		
39	1.8	79	22.3		
40	1.2	80	30.3		

Chloride

Sample Number	Cl (mg/kg)	Sample Number	Cl (mg/kg)	Sample Number	Cl (mg/kg)
1	0.26	41	0.25	81	0.23
2	0.20	42	0.20	82	0.22
3	0.28	43	0.22	83	0.21
4	0.24	44	0.23	84	0.20
5	0.26	45	0.23	85	0.22
6	0.22	46	0.22	86	0.25
7	0.33	47	0.21	87	0.20
8	0.33	48	0.20	88	0.22
9	0.25	49	0.22	89	0.23
10	0.23	50	0.30	90	0.23
11	0.20	51	0.29	91	0.22
12	0.27	52	0.34	92	0.21
13	0.34	53	0.22	93	0.20
14	0.40	54	0.22	94	0.22
15	0.30	55	0.20	95	0.30
16	0.37	56	0.22	96	0.29
17	0.38	57	0.36	97	0.34
18	0.55	58	0.22	98	0.22
19	0.36	59	0.27	99	0.22
20	0.44	60	0.23	100	0.20
21	0.46	61	0.27	101	0.22
22	0.45	62	0.25	102	0.36
23	0.34	63	0.20		
24	0.25	64	0.32		
25	0.25	65	0.14		
26	0.33	66	0.47		
27	0.26	67	0.29		
28	0.27	68	0.13		
29	0.23	69	0.13		
30	0.27	70	0.11		
31	0.25	71	0.12		
32	0.20	72	0.17		
33	0.22	73	0.12		
34	0.23	74	0.17		
35	0.20	75	0.32		
36	0.33	76	0.47		
37	0.26	77	0.25		
38	0.27	78	0.20		
39	0.23	79	0.22		
40	0.27	80	0.23		

Boron

Sample Number	B (mg/kg)	Sample Number	B (mg/kg)	Sample Number	B (mg/kg)
1	0.53	41	0.22	81	0.23
2	0.33	42	0.21	82	0.19
3	0.40	43	0.20	83	0.22
4	0.40	44	0.22	84	0.26
5	0.33	45	0.21	85	0.65
6	0.27	46	0.35	86	0.80
7	0.34	47	0.25	87	0.10
8	0.40	48	0.30	88	0.25
9	0.30	49	0.29	89	0.14
10	0.37	50	0.34	90	0.30
11	0.38	51	0.22	91	0.41
12	0.55	52	0.22	92	0.19
13	0.36	53	0.20	93	0.21
14	0.44	54	0.22	94	0.12
15	0.46	55	0.36	95	0.50
16	0.45	56	0.22	96	0.36
17	0.34	57	0.19	97	0.10
18	0.25	58	0.12	98	0.10
19	0.25	59	0.16	99	0.14
20	0.28	60	0.15	100	0.12
21	0.24	61	0.19	101	0.13
22	0.26	62	0.21	102	0.11
23	0.22	63	0.99		
24	0.33	64	1.98		
25	0.33	65	0.16		
26	0.25	66	0.22		
27	0.23	67	0.32		
28	0.23	68	0.14		
29	0.24	69	0.47		
30	0.22	70	0.29		
31	0.33	71	0.13		
32	0.26	72	0.13		
33	0.27	73	0.11		
34	0.23	74	0.12		
35	0.27	75	0.17		
36	0.25	76	0.12		
37	0.20	77	0.17		
38	0.22	78	0.32		
39	0.23	79	0.47		
40	0.23	80	0.58		

Particle Size Distribution

Sample Number	Sand (2-0.5mm)	Silt (0,05-0,002mm)	Clay (<0,002mm)
1	58.0	18.0	24.0
2	42.0	16.0	42.0
7	68.0	12.0	20.0
8	60.0	10.0	30.0
15	22.0	24.0	54.0
16	16.0	18.0	66.0
23	70.0	14.0	16.0
24	64.0	14.0	22.0
31	78.0	8.0	14.0
32	64.0	6.0	30.0
39	86.0	2.0	12.0
40	78.0	4.0	18.0
47	84.0	2.0	14.0
48	74.0	4.0	22.0
55	66.0	8.0	26.0
56	58.0	6.0	36.0
65	80.0	8.0	12.0
66	76.0	8.0	16.0
75	80.0	4.0	16.0
76	74.0	6.0	20.0
83	62.0	16.0	22.0
84	56.0	18.0	26.0
89	70.0	10.0	20.0
90	58.0	10.0	32.0
95	24.0	26.0	50.0
96	22.0	22.0	56.0
97	88.0	2.0	10.0
98	82.0	2.0	16.0
101	86.0	0.0	14.0
102	60.0	2.0	38.0

SURVEY LOCATION 1

Ficha de Estudo de Trafego - Farin

DATA: _____

OBSERVADOR: _____

LOCALIZAÇÃO: **Farim Main Street**

HORA DE INICIO: 07:00 A.M.

HORA DE TERMINO: 13:00 P.M.

TIPO DE VEÍCULO

Time	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Pedestre		Viajando em charrete		Outro	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
7:00 – 8:00																						
8:00 – 9:00																						
9:00 – 10:00																						
10:00 – 11:00																						
11:00 – 12:00																						
12:00 – 13:00																						

SURVEY LOCATION 1

Ficha de Estudo de Trafego - Farin

DATA: _____

OBSERVADOR: _____

LOCALIZAÇÃO: **Farim Main Street**

HORA DE INICIO: 13:00 P.M.

HORA DE TERMINO: 19:00 P.M.

TIPO DE VEÍCULO

Time	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Pedestre		Viajando em charrete		Outro	
	N	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**
13:00 – 14:00																						
14:00 – 15:00																						
15:00 – 16:00																						
16:00 – 17:30																						
17:00 – 18:00																						
18:00 – 19:00																						
TOTAL																						

T1 - Farim North Access Road
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00														1		5						12	18	12	6
8:00 – 9:00														2	3	2		1			4	21	33	25	8
9:00 – 10:00														1	3	5					8	23	40	31	9
10:00 – 11:00													1		6	3	2				2	1	15	3	12
11:00 – 12:00															1						1	2	4	3	1
12:00 – 13:00													2		3	1	1				8	8	23	16	7
13:00 – 14:00															6	3					10	2	21	12	9
14:00 – 15:00															6	4					5	3	18	8	10
15:00 – 16:00														2	3	1		1			7	3	17	10	7
16:00 – 17:00															8	6					17	3	34	20	14
17:00 – 18:00													1		2						4		7	4	3
18:00 – 19:00														1	1	6					2		10	2	8
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**7**	**42**	**36**	**3**	**2**	**0**	**0**	**68**	**78**	**240**	**146**	**94**

T1 - Farim North Access Road
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00													1	1	3	1							6	0	6
8:00 – 9:00													1	1	6	9	1	1			5	9	33	14	19
9:00 – 10:00													2		7	6					1	7	23	8	15
10:00 – 11:00														1	7	3	1				3		15	3	12
11:00 – 12:00															1	2					4		7	4	3
12:00 – 13:00															4	2					2		8	2	6
13:00 – 14:00													1	3	3	5		1				2	15	2	13
14:00 – 15:00															3	7					7		17	7	10
15:00 – 16:00															4	5					1	5	15	6	9
16:00 – 17:00															3						7		10	7	3
17:00 – 18:00													1	1	2	3						3	10	3	7
18:00 – 19:00														1	2	2	1				2		8	2	6
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**8**	**45**	**45**	**3**	**2**	**0**	**0**	**32**	**26**	**167**	**58**	**109**

T1 - Farim North Access Road
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00															2	3		2				11	18	11	7
8:00 – 9:00													1		5	5					2	10	23	12	11
9:00 – 10:00															7	5						13	25	13	12
10:00 – 11:00													1	1	4	3	1				1	8	19	9	10
11:00 – 12:00														1	6	11		1			3	7	29	10	19
12:00 – 13:00															2	1					1		4	1	3
13:00 – 14:00															3	6					3	2	14	5	9
14:00 – 15:00														1	2	5	1				14	8	31	22	9
15:00 – 16:00													2		3	3					1	1	10	2	8
16:00 – 17:00													1			3		1			8	7	20	15	5
17:00 – 18:00															2	1	1	1			12		17	12	5
18:00 – 19:00															4	2					11	2	19	13	6
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**3**	**40**	**48**	**3**	**5**	**0**	**0**	**56**	**69**	**229**	**125**	**104**

T1 - Farim North Access Road
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time												
7:00 – 8:00	0	0	0	0	0	0	1	5	1	0	8	6
8:00 – 9:00	0	0	0	0	0	0	2	10	1	0	17	13
9:00 – 10:00	0	0	0	0	0	0	1	11	0	0	17	12
10:00 – 11:00	0	0	0	0	0	0	1	9	1	0	5	11
11:00 – 12:00	0	0	0	0	0	0	0	7	0	0	6	8
12:00 – 13:00	0	0	0	0	0	0	1	4	0	0	6	5
13:00 – 14:00	0	0	0	0	0	0	1	9	0	0	6	10
14:00 – 15:00	0	0	0	0	0	0	0	9	0	0	12	10
15:00 – 16:00	0	0	0	0	0	0	1	6	0	0	6	8
16:00 – 17:00	0	0	0	0	0	0	0	7	0	0	14	7
17:00 – 18:00	0	0	0	0	0	0	1	3	1	0	6	5
18:00 – 19:00	0	0	0	0	0	0	1	6	0	0	6	7
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**11**	**85**	**6**	**0**	**110**	**102**

T2 - Sarajobe Village
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00													10	5	20	20	10	5			20	10	100	30	70
8:00 – 9:00													7	10	28	31	10	7			50	45	188	95	93
9:00 – 10:00													10	13	40	28	15	10			50	22	188	72	116
10:00 – 11:00					3	1							5	13	35	22	7	7			68	22	183	90	93
11:00 – 12:00													3	5	8	3	1	2			33	20	75	53	22
12:00 – 13:00						1							1	2	13	20		2			43	35	117	78	39
13:00 – 14:00														15	20	25					20	25	105	45	60
14:00 – 15:00									1				6	5	20	10	2				10	7	61	17	44
15:00 – 16:00														3	18	20	1	1			10	16	69	26	43
16:00 – 17:00															18	17					15	20	70	35	35
17:00 – 18:00															8	12					13	20	53	33	20
18:00 – 19:00														2	8	5	1				15	3	34	18	16
TOTAL	**0**	**0**	**0**	**0**	**3**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**42**	**73**	**236**	**213**	**47**	**34**	**0**	**0**	**347**	**245**	**1243**	**592**	**651**

T2 - Sarajobe Village
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00													25	10	70	45	20	30			80	70	350	150	200
8:00 – 9:00													30	28	53	52	15	10			88	70	346	158	188
9:00 – 10:00													3	2	20	40	10	8			80	58	221	138	83
10:00 – 11:00													15	5	33	43	12	3			58	67	236	125	111
11:00 – 12:00													1	2	18	2	3	1			33	37	97	70	27
12:00 – 13:00					2								2	5	13	13	3	2			33	23	96	56	40
13:00 – 14:00	3							1	1				8	7	15	13	2	1			15	15	81	30	51
14:00 – 15:00													8	7	12	17	2	1			25	18	90	43	47
15:00 – 16:00													7	12	30	18	1	5			30	25	128	55	73
16:00 – 17:00	1												15	15	30	21	1	2			25	30	140	55	85
17:00 – 18:00														13	15	20	2	3			17	13	83	30	53
18:00 – 19:00									1				3	7	20	17	3				25	25	101	50	51
TOTAL	**4**	**0**	**0**	**0**	**2**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**117**	**113**	**329**	**301**	**74**	**66**	**0**	**0**	**509**	**451**	**1969**	**960**	**1009**

T2 - Sarajobe Village
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00														2	23	20	23	22			28	8	126	36	90
8:00 – 9:00														2	38	18	13	7			50	43	171	93	78
9:00 – 10:00													7	2	15	23	2	1			58	22	130	80	50
10:00 – 11:00															22	35	1	2			47	23	130	70	60
11:00 – 12:00													3	2	3	11		2			52	33	106	85	21
12:00 – 13:00	1				2	1							3	3	17	13		1			28	21	90	49	41
13:00 – 14:00	1									3			12	12	17	17	6	7	1		20	20	116	40	76
14:00 – 15:00	2												13	16	43	23	7	3	7		36	37	187	73	114
15:00 – 16:00	2												8	12	17	22	2	2	1		27	17	110	44	66
16:00 – 17:00	2								4				17	16	22	25	2	2	1		25	33	149	58	91
17:00 – 18:00									1				17	17	40	36		3	1		40	40	195	80	115
18:00 – 19:00	1												12	12	38	45	2	3	6		40	50	209	90	119
TOTAL	**9**	**0**	**0**	**0**	**2**	**1**	**0**	**0**	**5**	**3**	**0**	**0**	**92**	**96**	**295**	**288**	**58**	**55**	**17**	**0**	**451**	**347**	**1719**	**798**	**921**

T2 - Sarajobe Village
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time												
7:00 – 8:00	0	0	0	0	0	0	17	66	37	0	72	120
8:00 – 9:00	0	0	0	0	0	0	26	73	21	0	115	120
9:00 – 10:00	0	0	0	0	0	0	12	55	15	0	97	83
10:00 – 11:00	0	0	1	0	0	0	13	63	11	0	95	88
11:00 – 12:00	0	0	0	0	0	0	5	15	3	0	69	23
12:00 – 13:00	0	0	2	0	0	0	5	30	3	0	61	40
13:00 – 14:00	1	0	0	0	1	0	18	36	5	0	38	62
14:00 – 15:00	1	0	0	0	0	0	18	42	5	2	44	68
15:00 – 16:00	1	0	0	0	0	0	14	42	4	0	42	61
16:00 – 17:00	1	0	0	0	1	0	21	44	2	0	49	70
17:00 – 18:00	0	0	0	0	0	0	16	44	3	0	48	63
18:00 – 19:00	0	0	0	0	0	0	12	44	3	2	53	62
TOTAL	**4**	**0**	**3**	**0**	**4**	**0**	**178**	**554**	**111**	**6**	**783**	**860**

T3 - Farim Through Road
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00	4	1					1						5	5	38	28					80	30	192	110	82
8:00 – 9:00	4	10					2	2					10	6	58	32	2	1			100	35	262	135	127
9:00 – 10:00	4	2											3	9	54	35	15				185	15	322	200	122
10:00 – 11:00	2	1					1						9	11	60	66	5	3			170	160	488	330	158
11:00 – 12:00	5	3											10	9	53	52	2	1			110	155	400	265	135
12:00 – 13:00	4	8											10	7	53	65		1			55	85	288	140	148
13:00 – 14:00	3	1	1										14	14	50	65	1	1			40	59	249	99	150
14:00 – 15:00	1	2		2				1					10	10	40	42		1			25	52	186	77	109
15:00 – 16:00	1	1	1										9	6	49	45		3			68	61	244	129	115
16:00 – 17:00	3	2		1									10	12	53	61	1	1			76	78	298	154	144
17:00 – 18:00	1	3		1			1						14	6	50	55					40	15	186	55	131
18:00 – 19:00								1					6	12	37	55	1	1			23	65	201	88	113
TOTAL	**32**	**34**	**2**	**4**	**0**	**0**	**5**	**4**	**0**	**0**	**0**	**0**	**110**	**107**	**595**	**601**	**27**	**13**	**0**	**0**	**972**	**810**	**3316**	**1782**	**1534**

T3 - Farim Through Road
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W** 2	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00	1	2					4						6	4	44	16	2				74	22	175	96	79
8:00 – 9:00	1	2					1	1					9	9	58	41		2			175	59	358	234	124
9:00 – 10:00	7	5						1					23	16	81	51	2	1			263	116	566	379	187
10:00 – 11:00	6	4							1				15	14	75	89		1			179	199	583	378	205
11:00 – 12:00	2	2											11	6	32	45	2	1			42	72	215	114	101
12:00 – 13:00	2	2											3	5	11	20	1				22	36	102	58	44
13:00 – 14:00	4	5					1						6	13	22	41	2				33	82	209	115	94
14:00 – 15:00	2							1					8	2	45	29	1	1			28	51	168	79	89
15:00 – 16:00	2					1							8	17	61	53	3	1			77	44	267	121	146
16:00 – 17:00	1	3			2	1	2						14	20	51	29	2	4			208	48	385	256	129
17:00 – 18:00		1											11	12	32	50	1	1			69	90	267	159	108
18:00 – 19:00	1	1											4	5	41	53	1	2			52	74	234	126	108
TOTAL	**29**	**27**	**0**	**0**	**2**	**2**	**8**	**3**	**1**	**0**	**0**	**0**	**118**	**123**	**553**	**517**	**17**	**14**	**0**	**0**	**1222**	**893**	**3529**	**2115**	**1414**

T3 - Farim Through Road
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00	4	2						7					6	7	55	37	2				70	30	220	100	120
8:00 – 9:00	3	4					1						5	4	71	42	5	1			225	99	460	324	136
9:00 – 10:00	2							1					13	7	89	75	2	1			185	115	490	300	190
10:00 – 11:00	2	3											9	15	64	70	4	8			140	185	500	325	175
11:00 – 12:00	1	1											9	14	54	62	3	3			70	70	287	140	147
12:00 – 13:00	2	1					3	1					16	11	58	61	2	2			75	90	322	165	157
13:00 – 14:00		3					1	1					3	7	37	41		3			101	151	348	252	96
14:00 – 15:00	4	2					4	1					7	6	47	47		1			13	150	282	163	119
15:00 – 16:00		2						2					6	6	30	26	1	2			43	21	139	64	75
16:00 – 17:00	1	2			1		4	2					6	7	40	45	1	3			44	31	187	75	112
17:00 – 18:00	1	1											7	9	29	39	1				17	23	127	40	87
18:00 – 19:00	2	2			1	1		1					10	6	34	53					135	235	480	370	110
TOTAL	**22**	**23**	**0**	**0**	**2**	**1**	**13**	**16**	**0**	**0**	**0**	**0**	**97**	**99**	**608**	**598**	**21**	**24**	**0**	**0**	**1118**	**1200**	**3842**	**2318**	**1524**

T3 - Farim Through Road
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time												
7:00 – 8:00	5	0	0	4	0	0	11	73	1	0	102	94
8:00 – 9:00	8	0	0	2	0	0	14	101	4	0	231	129
9:00 – 10:00	7	0	0	1	0	0	24	128	7	0	293	166
10:00 – 11:00	6	0	0	0	0	0	24	141	7	0	344	179
11:00 – 12:00	5	0	0	0	0	0	20	99	4	0	173	128
12:00 – 13:00	6	0	0	1	0	0	17	89	2	0	121	116
13:00 – 14:00	5	0	0	1	0	0	19	85	2	0	155	113
14:00 – 15:00	4	1	0	2	0	0	14	83	1	0	106	106
15:00 – 16:00	2	0	0	1	0	0	17	88	3	0	105	112
16:00 – 17:00	4	0	1	3	0	0	23	93	4	0	162	128
17:00 – 18:00	2	0	0	0	0	0	20	85	1	0	85	109
18:00 – 19:00	2	0	1	1	0	0	14	91	2	0	195	110
TOTAL	**56**	**2**	**2**	**16**	**0**	**0**	**218**	**1157**	**39**	**0**	**2072**	**1491**

T4 - Farim North River
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00							1						3	2	7	8					38	17	76	55	21
8:00 – 9:00	5	5								1				1	18	25	1	1			58	50	165	108	57
9:00 – 10:00	2												1	3	16	17	10	8			47	40	144	87	57
10:00 – 11:00		1												2	25	16	5	3			70	57	179	127	52
11:00 – 12:00		1											6	5	25	27	8	11			55	65	203	120	83
12:00 – 13:00	2	2	1										2	3	13	15	2	3			53	46	142	99	43
13:00 – 14:00		1			1								4	6	12	25	7	4			30	52	142	82	60
14:00 – 15:00										1			9	7	13	20	4	7			30	34	125	64	61
15:00 – 16:00	2	3							1	1			2	2	23	15	3	3			31	58	144	89	55
16:00 – 17:00		1											3	3	11	18	2	4			36	34	112	70	42
17:00 – 18:00	2	2											3	6	21	16	4	5			16	46	121	62	59
18:00 – 19:00	1	1	1	1									2	3	18	17	1	1			17	81	144	98	46
TOTAL	**14**	**17**	**2**	**1**	**1**	**0**	**1**	**0**	**1**	**3**	**0**	**0**	**35**	**43**	**202**	**219**	**47**	**50**	**0**	**0**	**481**	**580**	**1697**	**1061**	**636**

T4 - Farim North River
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00													4	5	26	30	2	1			49	39	156	88	68
8:00 – 9:00							1						3	7	42	26	5	5			64	71	224	135	89
9:00 – 10:00	2	3											3	3	29	34	6	6			70	71	227	141	86
10:00 – 11:00	2	2											4	3	29	27	5	2			77	80	231	157	74
11:00 – 12:00													1	2	15	13	6	4			30	29	100	59	41
12:00 – 13:00	1													2	5	8		3			17	45	81	62	19
13:00 – 14:00		2					2						4	3	6	8	5	2			42	54	128	96	32
14:00 – 15:00	4	3											3	4	15	7	5	5			58	36	140	94	46
15:00 – 16:00	1												7	5	22	17	10	5			85	101	253	186	67
16:00 – 17:00	2	1	1										2	2	17	17	5	10			62	28	147	90	57
17:00 – 18:00	2	2	1	1									2	4	23	24	3	2			30	67	161	97	64
18:00 – 19:00	2	1				1				1			6	3	20	23	1				93	64	215	157	58
TOTAL	**16**	**14**	**2**	**1**	**0**	**1**	**3**	**0**	**0**	**1**	**0**	**0**	**39**	**43**	**249**	**234**	**53**	**45**	**0**	**0**	**677**	**685**	**2063**	**1362**	**701**

T4 - Farim North River
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00									1				5	2	22	18	6	4			49	24	131	73	58
8:00 – 9:00	2	1		1						2			1	1	21	20	13	5			56	27	150	83	67
9:00 – 10:00	1												2	4	17	27	5	5			69	45	175	114	61
10:00 – 11:00	1								1	1			2	3	16	12	8	5			80	50	179	130	49
11:00 – 12:00									1				3	4	20	15	3	2			41	24	113	65	48
12:00 – 13:00		3													12	15	10	1			44	55	140	99	41
13:00 – 14:00														1	14	10	5	3			40	24	97	64	33
14:00 – 15:00	2	1								1			1	2	8	9	2	3			32	22	83	54	29
15:00 – 16:00	1			1					2	2					6	5	4	1			17	9	48	26	22
16:00 – 17:00	2	3	1		1	1							1	3	15	9	7	9			57	29	138	86	52
17:00 – 18:00	2													1	6	5	5	3		1	18	51	92	69	23
18:00 – 19:00		1	1		1								1	2	10	14	2	1			19	60	112	79	33
TOTAL	**11**	**9**	**2**	**2**	**2**	**1**	**0**	**0**	**5**	**6**	**0**	**0**	**16**	**23**	**167**	**159**	**70**	**42**	**0**	**1**	**522**	**420**	**1458**	**942**	**516**

T4 - Farim North River
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time												
7:00 – 8:00	0	0	0	0	0	0	7	37	4	0	72	49
8:00 – 9:00	4	0	0	0	1	0	4	51	10	0	109	71
9:00 – 10:00	3	0	0	0	0	0	5	47	13	0	114	68
10:00 – 11:00	2	0	0	0	1	0	5	42	9	0	138	58
11:00 – 12:00	0	0	0	0	0	0	7	38	11	0	81	57
12:00 – 13:00	3	0	0	0	0	0	2	23	6	0	87	34
13:00 – 14:00	1	0	0	1	0	0	6	25	9	0	81	42
14:00 – 15:00	3	0	0	0	1	0	9	24	9	0	71	45
15:00 – 16:00	2	0	0	0	2	0	5	29	9	0	100	48
16:00 – 17:00	3	1	1	0	0	0	5	29	12	0	82	50
17:00 – 18:00	3	1	0	0	0	0	5	32	7	0	76	49
18:00 – 19:00	2	1	1	0	0	0	6	34	2	0	111	46
TOTAL	**27**	**3**	**2**	**1**	**5**	**0**	**66**	**410**	**102**	**0**	**1122**	**618**

T5 - Farim South River
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00			1		1	1									3	11					5	10	32	15	17
8:00 – 9:00		1											2	6	9	13					9	20	60	29	31
9:00 – 10:00	5	4			2	2	1		1				5	3	5	12					25	15	80	40	40
10:00 – 11:00	1	1			3								2	4	12	8					22	12	65	34	31
11:00 – 12:00	1		1	1		1		1					3	2	10	8					33	10	71	43	28
12:00 – 13:00	1	1		1	2								2	4	7	10		1			16	10	55	26	29
13:00 – 14:00	5	5			5	6							10		25	1	1				10	30	98	40	58
14:00 – 15:00	5	5				5							5	3	5	10					27	12	77	39	38
15:00 – 16:00	5				6	5	1							2	11	5					27	23	85	50	35
16:00 – 17:00					1	5							5		3	6					10	16	46	26	20
17:00 – 18:00	1	1			2	2		1					3	2	21	10					12	31	86	43	43
18:00 – 19:00		1			2										5	2					3	40	53	43	10
TOTAL	**24**	**19**	**2**	**2**	**24**	**27**	**2**	**2**	**1**	**0**	**0**	**0**	**37**	**26**	**116**	**96**	**1**	**1**	**0**	**0**	**199**	**229**	**808**	**428**	**380**

T5 - Farim South River
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00					5	1	2	1					1	2	8	23					17	16	76	33	43
8:00 – 9:00	1	1			2	2		1					2	3	8	12					14	66	112	80	32
9:00 – 10:00		1		1	3		3	1	1	1			2	1	5	19					26	38	102	64	38
10:00 – 11:00	3	3		1	3	3	2	1					3	5	14	14					16	19	87	35	52
11:00 – 12:00			1	1	1		2	2					2	1	3	5					1	10	29	11	18
12:00 – 13:00			1	2	2	3								1	8			1			22	1	41	23	18
13:00 – 14:00	1	1			2	5							1		8	2					15	16	51	31	20
14:00 – 15:00					1	3									12	15	1				22	35	89	57	32
15:00 – 16:00	5	1			3	1	5	1				1	5		45	5		1			46	43	162	89	73
16:00 – 17:00	2				6	1	2							5	16	7	1				43	32	115	75	40
17:00 – 18:00	10	2			6	6							3	2	10	8	1				50	3	101	53	48
18:00 – 19:00	5	1			3	5							2	2	7	3					5	2	35	7	28
TOTAL	**27**	**10**	**2**	**5**	**37**	**30**	**16**	**7**	**1**	**1**	**0**	**1**	**21**	**22**	**144**	**113**	**3**	**2**	**0**	**0**	**277**	**281**	**1000**	**558**	**442**

T5 - Farim South River
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00					2	1		2					2	1	4	13	**2**	3			7	24	61	31	30
8:00 – 9:00		1	1		3									1	14	12	1				16	27	76	43	33
9:00 – 10:00	3		1	2	1	3								1	8	7		1			21	2	50	23	27
10:00 – 11:00		1		3	3								1	3	6	10					20	2	49	22	27
11:00 – 12:00	1				1	1							2		9	5	1				20	5	45	25	20
12:00 – 13:00		2	1			1							1		7	7	1	1			19	5	45	24	21
13:00 – 14:00	1				3	1							1	1	16	10					13	6	52	19	33
14:00 – 15:00					3	2							1	1	1						3	15	26	18	8
15:00 – 16:00	2	2			2	2	1						2	2		8	1	1				7	30	7	23
16:00 – 17:00	3	1			7						1	1	1	2	3	2					30	15	66	45	21
17:00 – 18:00					2	3	2							3	5	3					16	35	69	51	18
18:00 – 19:00	1				1	1	1						2	2	18	3					3	11	43	14	29
TOTAL	**11**	**7**	**3**	**5**	**28**	**15**	**4**	**2**	**0**	**0**	**1**	**1**	**13**	**17**	**91**	**80**	**6**	**6**	**0**	**0**	**168**	**154**	**612**	**322**	**290**

T5 - Farim South River
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time												
7:00 – 8:00	0	0	4	2	0	0	2	21	2	0	26	30
8:00 – 9:00	1	0	2	0	0	0	5	23	0	0	51	32
9:00 – 10:00	4	1	4	2	1	0	4	19	0	0	42	35
10:00 – 11:00	3	1	4	1	0	0	6	21	0	0	30	37
11:00 – 12:00	1	1	1	2	0	0	3	13	0	0	26	22
12:00 – 13:00	1	2	3	0	0	0	3	13	1	0	24	23
13:00 – 14:00	4	0	7	0	0	0	4	21	0	0	30	37
14:00 – 15:00	3	0	5	0	0	0	3	14	0	0	38	26
15:00 – 16:00	5	0	6	3	0	0	4	25	1	0	49	44
16:00 – 17:00	2	0	7	1	0	1	4	12	0	0	49	27
17:00 – 18:00	5	0	7	1	0	0	4	19	0	0	49	36
18:00 – 19:00	3	0	4	0	0	0	3	13	0	0	21	22
TOTAL	**33**	**6**	**54**	**11**	**1**	**1**	**45**	**213**	**6**	**0**	**436**	**371**

T6 - Sancalanco Village
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00													4	1	9	3			1		9	3	30	12	18
8:00 – 9:00													2	1	8	10		1			4	10	36	14	22
9:00 – 10:00					1								3		8	6					8	1	27	9	18
10:00 – 11:00													3		8	5					6	3	25	9	16
11:00 – 12:00													3	2	4	4		2			10	12	37	22	15
12:00 – 13:00	1												1		5	3					12	2	24	14	10
13:00 – 14:00													5		13	3					11		32	11	21
14:00 – 15:00													4		10	6	1		1		8	2	32	10	22
15:00 – 16:00	1												5	2	13	3	2				11	7	44	18	26
16:00 – 17:00													4		17	3	4				16	4	48	20	28
17:00 – 18:00													6	1	11	4					7	8	37	15	22
18:00 – 19:00	1												6		18						21	8	54	29	25
TOTAL	**3**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**46**	**7**	**124**	**50**	**7**	**3**	**2**	**0**	**123**	**60**	**426**	**183**	**243**

T6 - Sancalanco Village
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00													4	1	9	3			2		9	7	35	16	19
8:00 – 9:00													4	2	13	16		3			9	28	75	37	38
9:00 – 10:00							1						8		16	6					10	6	47	16	31
10:00 – 11:00													7		10	13		2			4	8	44	12	32
11:00 – 12:00															3	2		1					6	0	6
12:00 – 13:00	1												3		4	5					6	1	20	7	13
13:00 – 14:00													2		6	4		2			5	3	22	8	14
14:00 – 15:00													2		8	3					15		28	15	13
15:00 – 16:00	1												8	2	13	6					8		38	8	30
16:00 – 17:00													18	3	15	1			1		19		57	19	38
17:00 – 18:00													12		13	5	2				22	13	67	35	32
18:00 – 19:00													7		16	2					22		47	22	25
TOTAL	**2**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**75**	**8**	**126**	**66**	**2**	**8**	**3**	**0**	**129**	**66**	**486**	**195**	**291**

T6 - Sancalanco Village
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00													4	1	6	5			6		5	8	35	13	22
8:00 – 9:00	2												1		16	8		1			10	10	48	20	28
9:00 – 10:00													3	1	13	9					14	6	46	20	26
10:00 – 11:00								1					2		7	7		3			14	7	41	21	20
11:00 – 12:00															5	12		1			23		41	23	18
12:00 – 13:00								1					5		12	8		1	2		9	4	42	13	29
13:00 – 14:00													5		15	1	1		3		21		46	21	25
14:00 – 15:00	1												2	1	15	6	1		2		16	2	46	18	28
15:00 – 16:00					1								7		10	3	1		3		8	3	36	11	25
16:00 – 17:00							1						3		7	4					7	4	26	11	15
17:00 – 18:00	1												7		11	6					27	6	58	33	25
18:00 – 19:00	3				1						1		11		14	2		2	2		17	2	55	19	36
TOTAL	**7**	**0**	**0**	**0**	**2**	**0**	**1**	**2**	**0**	**0**	**1**	**0**	**50**	**3**	**131**	**71**	**3**	**8**	**18**	**0**	**171**	**52**	**520**	**223**	**297**

T6 - Sancalanco Village
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel	Double Rear-axle	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
7:00 – 8:00	0	0	0	0	0	0	5	12	0	3	14	20
8:00 – 9:00	1	0	0	0	0	0	3	24	2	0	24	29
9:00 – 10:00	0	0	0	0	0	0	5	19	0	0	15	25
10:00 – 11:00	0	0	0	0	0	0	4	17	2	0	14	23
11:00 – 12:00	0	0	0	0	0	0	2	10	1	0	15	13
12:00 – 13:00	1	0	0	0	0	0	3	12	0	1	11	17
13:00 – 14:00	0	0	0	0	0	0	4	14	1	1	13	20
14:00 – 15:00	0	0	0	0	0	0	3	16	1	1	14	21
15:00 – 16:00	1	0	0	0	0	0	8	16	1	1	12	27
16:00 – 17:00	0	0	0	0	0	0	9	16	1	0	17	27
17:00 – 18:00	0	0	0	0	0	0	9	17	1	0	28	26
18:00 – 19:00	1	0	0	0	0	0	8	17	1	1	23	29
TOTAL	**4**	**0**	**1**	**1**	**0**	**0**	**63**	**189**	**10**	**8**	**200**	**277**

T7 - Farim West Access Road
DAY 1

DAY 1	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**Thursday Total Traffic**	**Total Pedestrian**	**Day 1 Total Traffic**
7:00 – 8:00													1	1	11	8					41	7	69	48	21
8:00 – 9:00														2	22	18	6				44	9	101	53	48
9:00 – 10:00									2	3				1	18	14					7	26	71	33	38
10:00 – 11:00													5		11	11	1				14	15	57	29	28
11:00 – 12:00	1												3	4	5	18		2			2	31	66	33	33
12:00 – 13:00		1								1				2	9	14		2			10	20	59	30	29
13:00 – 14:00													2	2	10	6				1	8	27	56	35	21
14:00 – 15:00														1	11	9		2			5	25	53	30	23
15:00 – 16:00									1				3	2	10	7					35	22	80	57	23
16:00 – 17:00										1			1	1	13	12					17	13	58	30	28
17:00 – 18:00									1				1		14	13				1	25	12	67	37	30
18:00 – 19:00									1				3	1	4	17	2	2			27		57	27	30
TOTAL	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**5**	**0**	**0**	**19**	**17**	**138**	**147**	**9**	**8**	**0**	**2**	**235**	**207**	**794**	**442**	**352**

T7 - Farim West Access Road
DAY 2

DAY 2	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**Friday Total Traffic**	**Total Pedestrian**	**Day 2 Total Traffic**
7:00 – 8:00													1	1	39	2	5				43	12	103	55	48
8:00 – 9:00													6	2	22	12	1	1			36	11	91	47	44
9:00 – 10:00	1												4	1	26	7	1				50	12	102	62	40
10:00 – 11:00													8		29	20		2			7	7	73	14	59
11:00 – 12:00	1					1									5	14					8	16	45	24	21
12:00 – 13:00													1	1	4	9					1	15	31	16	15
13:00 – 14:00														1	5	12		3				44	65	44	21
14:00 – 15:00																12		1			10	10	33	20	13
15:00 – 16:00													7	5	18	21					40	28	119	68	51
16:00 – 17:00													5	2	33	13					40	15	108	55	53
17:00 – 18:00													1	2	17	25		1			30	24	100	54	46
18:00 – 19:00													4	8	18	30		1			27	37	125	64	61
TOTAL	**2**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**37**	**23**	**216**	**177**	**7**	**9**	**0**	**0**	**292**	**231**	**995**	**523**	**472**

T7 - Farim West Access Road
DAY 3

DAY 3	Carro Pessoal		Taxi		Passageiro de Onibus		Caminhao de eixo simples		Caminhao de eixo duplo		Retroescavadeira, escavadeira, trator		Motocicleta		Bicicleta		Viajando em charrete		Outro		Pedestre		Incl. Ped		Excl. Ped
Time	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**E**	**W**	**Sunday Total Traffic**	**Total Pedestrian**	**Day 3 Total Traffic**
7:00 – 8:00														3	37	23	3				65	27	158	92	66
8:00 – 9:00	1													7	32	23					42	28	133	70	63
9:00 – 10:00													3	5	34	23	4				33	27	129	60	69
10:00 – 11:00													2	1	12	11		2			10	41	79	51	28
11:00 – 12:00													2	2	10	19		5			5	50	93	55	38
12:00 – 13:00													2	3	10	11		2			7	41	76	48	28
13:00 – 14:00													3	1	11	10	1		5		31	22	84	53	31
14:00 – 15:00		1												5	17	13					15	7	58	22	36
15:00 – 16:00													2	4	18	21		1	1		23	32	102	55	47
16:00 – 17:00													6	3	29	15					28	36	117	64	53
17:00 – 18:00	1												3	7	13	18	3		1		22	32	100	54	46
18:00 – 19:00													7	8	18	24	1				30	36	124	66	58
TOTAL	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**30**	**49**	**241**	**211**	**12**	**10**	**7**	**0**	**311**	**379**	**1253**	**690**	**563**

T7 - Farim West Access Road
AVERAGE FOR 3 DAYS
TWO WAY FLOWS

Time	Personal Car	Taxi	Passenger Bus	Single Rear-axel Pickup Truck	Double Rear-axle Truck	Backhoe, bulldozer, tractor	Motorcycle	Bicycle	Travel by animal and cart	Other	Pedestrian	Total Traffic
Time	**Personal Car**	**Taxi**	**Passenger Bus**	**Single Rear-axel**	**Double Rear-axle**	**Backhoe, bulldozer, tractor**	**Motorcycle**	**Bicycle**	**Travel by animal and cart**	**Other**	**Pedestrian**	**Total Traffic**
7:00 – 8:00	0	0	0	0	0	0	2	40	3	0	65	45
8:00 – 9:00	0	0	0	0	0	0	6	43	3	0	57	52
9:00 – 10:00	0	0	0	0	2	0	5	41	2	0	52	49
10:00 – 11:00	0	0	0	0	0	0	5	31	2	0	31	38
11:00 – 12:00	1	0	0	0	0	0	4	24	2	0	37	31
12:00 – 13:00	0	0	0	0	0	0	3	19	1	0	31	24
13:00 – 14:00	0	0	0	0	0	0	3	18	1	2	44	24
14:00 – 15:00	0	0	0	0	0	0	2	21	1	0	24	24
15:00 – 16:00	0	0	0	0	0	0	8	32	0	0	60	40
16:00 – 17:00	0	0	0	0	0	0	6	38	0	0	50	45
17:00 – 18:00	0	0	0	0	0	0	5	33	1	1	48	41
18:00 – 19:00	0	0	0	0	0	0	10	37	2	0	52	50
TOTAL	**2**	**0**	**0**	**0**	**3**	**0**	**58**	**377**	**18**	**3**	**552**	**462**

Lycopodium Minerals Canada Ltd. Environmental and Social Impact Assessment for the Farim Phosphate Project

Air Dispersion Modeling Final Report

August 2015

Rev. No.	Date	Description	KP Perú	KP North Bay
0	August 6, 2015	Final Report	Alejandro Delgado	Richard Cook
A	June 26, 2015	Issued for review	Alejandro Delgado	Richard Cook

Lycopodium Minerals Canada Ltd.
Environmental and Social Impact Assessment for the Farim Phosphate Project

Air Dispersion Modeling
Final Report

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Lycopodium Minerals Canada Ltd.
Environmental and Social Impact Assessment for the Farim Phosphate Project

Air Dispersion Modeling
Draft Report

1.0 Introduction

This study describes the Atmospheric Dispersion Modeling (ADM) conducted for the Farim Phosphate Project's Environmental and Social Impact Assessment (ESIA), prepared for GB Minerals Ltd. under contract for Lycopodium Minerals Canada Ltd. (Lycopodium Minerals) by Knight Piésold Consultores S.A. (KP Lima-Peru), in association with Knight Piésold Ltd. (KP North Bay-Canada). The ADM undertaken envisages four project scenarios at the mine site for years 2, 8, 15 and 25 of the mining operation. Year 2 comprises South Pit mining activities; year 8 comprises South Pit and North Pit mining; years 15 and 25 comprise mining of the North Pit only. Lastly, ADM results at the proposed Port Site at Ponta Chugue are also presented.

Activities considered include pit mining, ore and waste overburden extraction, hauling of these materials, and phosphate concentrate transport to the concentrate warehouse at the Port Site for subsequent ocean shipment.

These activities were identified as generating potential emissions of particles and gases, and, as such, they were included in the inventory of air emissions, which was prepared by applying emission factors by type of activity, following the methodology suggested by AP-42 guidelines (USEPA, 1995b), the Australian government NPI (NPI, 2008, 2012a), the Mojave Desert Air Quality Management (MDAQMD, 2000), and technical data sheets for diesel generators, 3512B and 3412C CAT models (CAT, 2011a, 2011b). With this information, the impact of such activities was analyzed using the CALPUFF dispersion model (Scire, Strimaitis, & Yamartino, 2000).

The weather information entered into the dispersion model derives from data recorded at stations located within the project (Farim) and the Osvaldo Vieira International Airport (GGOV), which include hourly data series from 2012 to 2014. Since no upper atmosphere monitoring stations (i.e. radiosondes) were available, information from the vertical atmospheric profile generated by the Weather Research and Forecasting (WRF) model was used.

Species modeled correspond to particulate matter (PM) with an aerodynamic diameter below 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). Below is a description of the objectives, the methodology used and the results obtained.

2.0 Objectives

The objectives of the study are as follows:

- To estimate emissions of dustfall, particulate matter (PM_{10} and $PM_{2.5}$) and gases (SO_2, NO_x, CO) released into the atmosphere as a result of the project activities at the Mine Site, the phosphate concentrate transport route and the Port Site.
- To forecast particulate matter and gas concentrations in the Farim Phosphate Project environment caused by phosphate mining, transport, storage and shipping activities.

3.0 Air Quality Standards – Farim Phosphate Project

In accordance with the criteria set by the International Finance Corporation (IFC, 2007), air quality standards applicable to the project correspond to those set by the World Health Organization (WHO). Chart 3.1 shows project applicable standards.

Chart 3.1
Project Air Quality Standards

Pollutant	Average Time	World Health Organization		
		Limit (µg/m^3)		Form
Sulphur dioxide (SO_2)	Annual	50 [1]		Annual mean
	24-hr	Interim Target 1	125	24 hour average
		Interim Target 2	50	
		Guideline	20	
	1-hr	200 [2]		99th of 1-hour daily maximum concentrations
Nitrogen dioxide (NO_2)	Annual	40		Annual mean
	1-hr	190 [2]		98th of 1-hour daily maximum
Carbon monoxide (CO)	8-hr	10 000		Daily maximum concentrations
	1-hr	30 000		1-hour daily maximum concentrations
PM_{10}	Annual	Interim Target 1	70	Annual mean
		Interim Target 2	50	
		Interim Target 3	30	
		Guideline	20	
	24-hr	Interim Target 1	150	24 hour average
		Interim Target 2	100	
		Interim Target 3	75	
		Guideline	50	
$PM_{2.5}$ [3]	Annual	Interim Target 1	35	Annual mean
		Interim Target 2	25	
		Interim Target 3	15	
		Guideline	10	
	24-hr	Interim Target 1	75	24 hour average
		Interim Target 2	50	
		Interim Target 3	37.5	
		Guideline	25	
Dustfall [4]	24-hr	Residential	6 mg/dm^2/day	Daily mean from 30-day collected sample
		Industrial	12 mg/dm^2/day	
		Alert level	24 mg/dm^2/day	

Prepared by Knight Piésold Consultores.

Notes:

[1] WHO global guidelines do not include annual SO_2 limit therefore who Europe standards were used.
[2] National Ambient Air Quality Standards (NAAQS) – U.S. Environmental Protection Agency.
[3] WHO interim 3 for $PM_{2.5}$ concentration is 99 percentile.
[4] WHO guidelines do not include dust fall limits therefore; South African National Standards were used.

The IFC guidelines include interim targets as well as guidelines that will vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations and various other political and social factors, which in turn will depend on, among other things, the level of development and national capability in air quality management (WHO, 2005). That is, the interim targets provide more achievable targets that may be applied and more easily achieved within less developed countries.

4.0 Methodology

The methodology for forecasting air quality conditions in the proposed scenarios considered the use of CALPUFF, which it is a non-steady-state Lagrangian Gaussian puff model containing modules for terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal, and simple chemical transformation (Scire, Strimaitis, et al., 2000), capable of simulating the dispersion of particle and gas emissions in the atmosphere from multiple simultaneous sources, considering spatial variations of weather conditions on the transport of species. CALPUFF can be applied to simulate long-range transport in complex terrain as well as during very low wind speeds. The dispersion model was fed with topography, weather and land use information. The model is recommended by the US Environmental Protection Agency (USEPA, 2014) for regulatory application.

The meteorological preprocessor of CALPUFF is CALMET (Scire, Robe, Fernau, & Yamartino, 2000). The quality of a meteorological preprocessor is one of the main determinants of the overall quality of the air dispersion model, and this is particularly true for the CALPUFF/CALMET modeling system in a wide range of conditions (Visscher, 2013). The main purpose of CALMET is to obtain the best possible meteorological data based on the available information. In particular, CALMET can receive measured data (e.g., meteorological registers from Farim and GGOV meteorological stations), modeled data (i.e., generated by a meteorological model like WRF), or both.

4.1 Project Information

The Farim Phosphate project involves phosphate extraction, to which end two open pits will be mined for a 26 year period. The South Open Pit will be mined between Years 0 and 8, while the North Open Pit will be mined between Years 8 and 26. Chart 4.1 shows the earthworks corresponding to the arrangement of the surface soil, the ore, waste rock and phosphate production. As shown in Graph 4.1, scenarios by year of operation were chosen because they reflect the maximum amount of ore extraction and the location of emission sources close to surrounding villages.

According to the project information (Lycopodium, 2014), operational activities at the mine site will take place 24/365, so 68% hours a year are estimated to be available for use, equivalent to 6,000 hours of operation per year. Taking this into consideration, and in order to determine machinery operation schedules, 6,000 hours of operation per year are equivalent to 16.32 hours per day. The list of equipment to be used in Years 2, 8, 15 and 25 are shown in Chart 4.2.

As noted above, 2 open pits, a processing plant, surface soil deposits, a waste rock facility, haul roads, conveyors, the phosphate concentrate loading area and the paved road for phosphate concentrate transport will be built at the mine site. Figure 4.1 shows the general

arrangement of the mine area. Figure 4.2 shows the phosphate concentrate transport route between the Mine area and the Port Site, which was considered in the emissions inventory. In the Port area, facilities for concentrate storage and shipment will be built, as shown in Figure 4.3.

Considering the project information (Lycopodium, 2014) and process flow diagrams, material transport by conveyors will include measures to control particulate matter emissions, such as conveyor wetting and roofing. The use of two tank trucks for emission control on haul roads through irrigation is also envisaged. Lastly, surface soil deposits will be covered with local vegetation upon completion of their useful life.

Phosphate concentrate transport from the Mine Site in Farim to the Port Site will take place between 6:00 and 20:00 hours (Lycopodium, 2014). Concentrate storage facilities at the Port Site will include covered conveyors, roofed warehouses and stockpile encapsulation.

4.2 Meteorological Data

While emissions from various activities are the main source of air quality degradation, it is atmospheric conditions that determine pollutant concentration levels, their transformation into secondary pollutants, transport to other areas and, lastly, their removal (Seinfeld & Pandis, 2006). Therefore, weather information is critical in modeling air pollutant dispersion.

As mentioned above, weather information in CALPUFF was processed by the CALMET module, where the following information was processed:

- Hourly surface weather records from automatic stations located at the mine site (Farim station) and the station located at Osvaldo Vieira International Airport (GGOV Station) as representative of Port site conditions.
- Surface and vertical weather data from the results generated by the Weather Research and Forecasting (WRF) model for the entire modeling area.

The following briefly details the analysis of meteorological data used, in addition to its processing, to be entered in CALPUFF through CALMET.

4.2.1 Weather Station Information

Hourly information from Farim and GGOV stations was used for the simulation period between January 2012 and December 2014. GGOV information may be found in the global surface observation database of the University of Wyoming[1], which was downloaded through a *shell* script for the simulation period. This simulation period is representative, in addition to capturing the daily and monthly variation of each parameter, including the year 2012, which

[1] http://weather.uwyo.edu/surface/index.html

was an atypical year, as it was one of the warmest on record (i.e. ninth warmest[2]). Chart 4.1 shows the properties of each station.

Chart 4.1
Weather Station Information

Station	Latitude	Longitude	Altitude	Distance from site	Variables
Farim	11.88 N	15.65 W	7 m	4 km	P, T, TD, HR, WD, WS
GGOV	12.46 N	15.24 W	36 m	77 km	T, RH, SR, WS, WD, RR

Prepared by Knight Piésold Consultores.
Notes:
P: Atmospheric Pressure, T: Air Temperature, TD: Dew point Temperature, WD: Wind Direction, WS: Wind Speed, SR: Solar Radiation, RR: Precipitation

The Farim station did not record significant missing data. However, GOVV station did not have about 30% of the information. To complete the data, a linear interpolation was performed for each variable. After comparing the results of the interpolation against the original data, we found that annual mean values for each variable did not vary significantly, so the interpolation was appropriate.

4.2.2 Meteorological Parameters Entered to CALMET

Weather stations provide time surface information of the following variables:

- Relative humidity (Graphs 4.2 and 4.3)
- Precipitation (Graph 4.4)
- Wind speed and direction (Graphs 4.5 and 4.6)
- Temperature (Graphs 4.7 and 4.8)
- Solar radiation (Graph 4.9)
- Atmospheric pressure (Graph 4.10)
- Cloud height and cover

Chart 4.2 shows the mean values for the simulation period.

Chart 4.2
Mean Values for the Simulation Period (2012 – 2014) for Meteorological Parameters Entered to CALMET

Station	P (hPa)	T (°C)	Td (°C)	RH (%)	WS (m/s)	WD	SR (W/m^2)	RR (mm) [(1)]
Farim	-	26.1	-	71	1.1	SW, NE	189	4,034
GGOV	1011	27.7	19.3	66	3.2	W, SW, NE	-	-

Prepared by Knight Piésold Consultores.
Notes:
[(1)] Accumulated.

[2] https://www.wmo.int/pages/mediacentre/press_releases/pr_972_en.html

An analysis of precipitation and relative humidity monthly behavior shows that the wet season covers the months from May to October, while the dry season runs from November to April. During the wet period, recorded relative humidity and accumulated precipitation values are higher, reaching 90% and 87% in Farim and GGOV, respectively, and accumulated monthly precipitation is above 400 mm (Chart 4.3). In general, relative humidity values between both GGOV and Farim stations show a similar behavior during the three years. However, the Farim station has higher values which are similar to those from Kolda weather station (Knight Piésold, 2015).

The year 2012 was recorded as one of the warmest years in several regions worldwide. The beginning of the year was characterized by the presence of La Niña[3] and the western African region being hit by extreme flooding. This accounts for the higher precipitation values recorded in 2012, with the highest accumulated precipitation recorded in August 2012, reaching 572 mm. The months between December and April did not exceed 5 mm.

As to wind direction, Farim shows similar values to GOVV station. It is important to note the change in wind direction from wet to dry season, with prevailing winds from the southwest and northeast, respectively. As to wind speed, the GGOV station shows speeds that are twice higher than those recorded by Farim. The wind speed in Farim also has a distinct amplitude, recording an intensification from March to June followed by weakening later in the year. GGOV winds also recorded an increase between March and May, but on average, are more constant throughout the year.

The average monthly temperature of the Farim station is closer to the weather value recorded by the Kolda station (Knight Piésold, 2015) and has a higher annual amplitude, with monthly averages ranging from 21°C to 29°C. The GGOV station has a higher temperature, especially in the dry season, and monthly averages ranging between 26°C and 29°C.

Average solar radiation was higher in 2012 and 2014 compared to 2013 (Graph 4.9). The atmospheric pressure is lower in February and April (approximately 1,009 hPa) and higher in July, ranging between 1,012 and 1,013 hPa (Graph 4.10).

Chart 4.3
Rain Rate Accumulated by Month (mm) - Farim Weather Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2012	0	0	0	0	11.6	213.6	400.6	572.4	454.6	105.4	11.2	3.2	**1,772.6**
2013	2	0.4	0.2	0	53.6	57	244.4	351.2	160	204.8	4.8	2.4	**1,080.8**
2014	1.8	0	0	0	49.8	118.8	111.4	374.8	439.4	80.6	2.8	1	**1,180.4**

Prepared by Knight Piésold Consultores.

[3] http://www.ncdc.noaa.gov/sotc/global/201213

4.2.2.1 Cloudiness

The GOVV station presents cloud height and cover information in METAR format, only for the months from May to October, i.e. for the wet period. To complete the missing information, the highest values of cloud height for the day and night, respectively, were used. For cloud cover, Teixeira's approach (2001) was used within CALMET. This algorithm is used in global atmospheric models and it calculates the low cloud cover based on relative humidity information at the 850 hPa level, generated by weather forecast models. In this case, WRF model information was used.

4.2.3 Information from the Weather Research and Forecasting Model

To complement surface meteorological data from weather stations, WRF simulation information for the study area and the same evaluation period was also used. This information was requested from Lakes Environmental and is in a format to be entered directly to CALMET (file extension *.DAT). Chart 4.4 shows the main simulation information.

Chart 4.4
Simulation Information of the WRF Meteorological Model

Simulation Time	2012 – 2014
Domain Center Point	Lat: 12.2511 N – Lon: 15.42944 W
WRF Domain size	100 km x 100 km
WRF Horizontal Resolution	12 km
Vertical Levels	35

Prepared by Knight Piésold Consultores.
Source: Lakes Environmental Inc.

4.2.4 CALMET Processing Results

Graphs 4.11 and 4.12 show the CALMET pre-processing results for determining wind flows during the dry and wet season.

4.3 Background Air Quality

Background air quality levels were determined using the baseline study of air quality by Golder (2014). Monitored species correspond to NO_x, NO_2, SO_2, PM_{10}, $PM_{2.5}$ and dust deposition. Chart 4.5 shows the concentrations results from air quality sampling stations by Golder (2014). From this information, background air quality levels for the wet and dry seasons included in the CALPUFF model were determined.

Chart 4.5
Air Quality Baseline at the Mine Site

Location	Period	NO_X [(1)] (µg/m^3)	NO_2 [(1)] (µg/m^3)	SO_2 [(1)] (µg/m^3)	Dust fall [(1)] mg/m^2/day	PM_{10} [(2)] (µg/m^3)	$PM_{2.5}$ [(2)] (µg/m^3)
GB 1 Censenhe	Average	4.66	2.59	1.20	94	-	-
	Minimum	1.67	0.89	0.39	17	-	-
	Maximum	8.55	5.66	2.02	255	-	-
GB 2 Saliquenhe	Average	4.92	2.76	1.49	77	-	-
	Minimum	2.48	1.12	1.03	13	-	-
	Maximum	8.43	5.28	2.20	159	-	-
GB 3 Proposed Plant Area	Average	4.89	2.23	1.07	85	-	-
	Minimum	1.55	0.38	0.84	4	-	-
	Maximum	10.35	4.58	1.44	213	-	-
GB 4 Farim	Average	7.08	4.94	1.57	143	69.6	13.7
	Minimum	4.86	1.71	1.07	25	19	4
	Maximum	9.89	8.16	3.13	245	123.4	23.9
GB 5 Saliquenhedim	Average	5.60	3.13	1.33	100	-	-
	Minimum	2.00	0.64	0.45	33	-	-
	Maximum	9.05	5.61	2.39	228	-	-
GB 6 Mansaba	Average	5.99	5.71	1.11	135	-	-
	Minimum	4.26	2.58	0.46	70	-	-
	Maximum	9.22	7.82	1.90	252	-	-
GB 7 Monsoa	Average	7.63	5.81	1.71	114	-	-
	Minimum	4.67	3.32	0.95	39	-	-
	Maximum	11.68	7.57	2.71	164	-	-
GB 8 Diuja (Bissau)	Average	6.08	2.87	1.54	78	-	-
	Minimum	2.24	1.05	0.93	23	-	-
	Maximum	9.63	5.15	2.03	143	-	-
Wet season Background	Average	5.86	3.76	1.38	103.3	20	4
Dry season Background	Average	5.86	3.76	1.38	207.4	123.4	23.9

Prepared by Knight Piésold Consultores.
Source: Golder (2014).
Notes:
(1) Result based on eight monthly datasets (Golder, 2014).
(2) Result of short-term 24 hour of PM collected during site visits in September 6th and 7th of 2012 and September 24th – 26th of 2013 (Golder, 2014).
Legend for PM_{10} (24 hour average):

> Interim Target 1
> Interim Target 2
> Interim Target 3
> Guideline

The results of the measurements made by Golder (2014) show days where PM_{10} concentrations (in 24 hour average) exceed the air quality standards (Chart 4.6). In September 2012, concentrations were lower (19 and 20 µg/m^3 for PM_{10} and 4 µg/m^3 for $PM_{2.5}$) than those recorded in September 2013 (between 85.48 and 123.41 µg/m^3 for PM_{10} and between 16.68 and 23.9µg/m^3 for $PM_{2.5}$). This behavior suggests that the influence of different precipitation levels recorded in 2012 (36.8 mm for September 6 and 7) would be the main cause behind the reduction in concentrations. From the annual average for PM_{10}, it

appears that standards are exceeded due to natural conditions, especially during the dry season.

Chart 4.6
Particulate Matter Concentrations in 24 Hour Average – Station GB 4 Farim

Date	Fine and coarse particulate (PM_{10}) in µg/m^3	Fine particulate ($PM_{2.5}$) in µg/m^3
September 6th, 2012	20.00	4.00
September 7th, 2012	19.00	4.00
September 24th, 2013	100.07	20.05
September 25th, 2013	123.41	23.90
September 26th, 2013	85.48	16.68

Prepared by Knight Piésold Consultores.
Source: Golder (2014).
Legend for PM_{10} and $PM_{2.5}$ standards (24 hour average):

> Interim Target 1
> Interim Target 2
> Interim Target 3
> Guideline

According to Golder (2014) and Schwanghart & Schütt (2008), particulate matter concentrations in the region primarily result from natural sources and wind erosion created by the Harmattan winds from the northeast (NE) during the dry season (November to April), which influences increased air dust concentrations. This behavior was observed in wind roses at Farim and GGOV stations. Therefore, the entire region would be exposed to high PM_{10} concentration levels due to the transport of particulate matter from the NE during the dry season, as shown in Graph 4.13 (Schwanghart & Schütt, 2008).

Thus, based on the information presented and considering the projected facilities at the mine site and wind flows during the wet season (May-Oct) and dry season (Nov-Apr), representative background concentrations during the wet season are 20 µg/m^3 for PM_{10} and 4 µg/m^3 for $PM_{2.5}$, where these concentrations are dispersed toward the northeast (NE). On the other hand, representative background concentrations during the dry season are higher than 123.4 µg/m^3 for PM_{10} and 23.9 µg/m^3 for $PM_{2.5}$, where these concentrations are wind dispersed toward the southwest (SW) by wind erosion resulting from natural sources (Schwanghart & Schütt, 2008).

In order to estimate NO_2 concentrations resulting from NO_x emissions in the dispersion model, data from the average ratio of NO_2 concentrations to NO_x concentrations, which is 0.57, was considered for input into the model. Chart 4.7 shows the values for NO_2/NO_x used to estimate the average ratio.

Chart 4.7
Ratio of NO_2/NO_x (November 2011 – October 2012)

Location	8 month Value	NO_x µg/m^3	NO_2 µg/m^3	NO_2/NO_x
GB 1 Censenhe	average	4.66	2.59	0.56
	minimum	1.67	0.89	0.53
	maximum	8.55	5.66	0.66
GB 2 Saliquenhe/Box Cut	average	4.92	2.76	0.56
	minimum	2.48	1.12	0.45
	maximum	8.43	5.28	0.63
GB 3 Proposed Plant Area	average	4.89	2.23	0.46
	minimum	1.55	0.38	0.25
	maximum	10.35	4.58	0.44
GB 4 Farim	average	7.08	4.94	0.70
	minimum	4.86	1.71	0.35
	maximum	9.89	8.16	0.83
GB 5 Saliquenhedim	average	5.6	3.13	0.56
	minimum	2	0.64	0.32
	maximum	9.05	5.61	0.62
Average		**5.43**	**3.13**	**0.57**

Prepared by Knight Piésold Consultores.
Source: Appendix A1 Air Quality Monitoring Results - Golder (2014).

4.4 Atmospheric Emissions Inventory

Quantification of PM_{10} and $PM_{2.5}$ particulate matter emissions and CO, NO_x and SO_2 gas emissions were based on emission factors from international environmental guidelines and equipment technical data sheets:

- Guideline, *AP 42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources:*
  - *11.9 Western Surface Coal Mining* (USEPA, 1998)
  - *13.2 Fugitive Dust Sources*
    - *13.2.1 Paved Roads* (USEPA, 2011)
    - *13.2.2 Unpaved Roads* (USEPA, 2006a)
    - *13.2.4 Aggregate Handling and Storage Piles* (USEPA, 2006b)
    - *13.2.5 Industrial Wind Erosion* (USEPA, 2006c)
  - *11.19 Introduction to Construction and Aggregate Processing*
    - *11.19.2 Crushed Stone Processing and Pulverized Mineral Processing*
  - *11.21 Phosphate Rock Processing* (USEPA, 1995a)

- Australian government NPI guidelines:

  - *Emission Estimation Technique Manual for Mining* (NPI, 2012b)
  - *Emission Estimation Technique Manual for Combustion Engines* (NPI, 2008)
  - *Estimation Technique Manual for Maritime operations* (NPI, 2012a)

- *Emissions Inventory guidance – Mineral Handling and Processing Industries* (MDAQMD, 2000 Rev. 2013)

- Technique sheet of Diesel generators (CAT, 2011a, 2011b)

These guidelines suggest emission factors based on the nature of the mining industry. Emission estimates are generally made by applying the following equation[4].

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

Where *E* is emission rates (in units of mass per time, g/s or kg/year), *A* is the activity rate (i.e. fuel consumption per year), *EF* is the substance emission factor (i.e. grams of substance *i* per quantity of fuel consumed) and *ER* is the rate of reduction efficiency through air emissions control technologies.

4.5 Mine Site

The inventory of air emissions of particulate matter (PM_{10}, $PM_{2.5}$) and gases (SO_2, CO and NO_2) per year of operation at the Mine Site is shown in Appendix A. This appendix details the calculation for estimating emissions by using emission factors.

Sources of emission of particles and gases that were entered into the model are shown in Figure 4.4 for Year 2 of operation, where it appears that operations are restricted to ore and waste rock extraction in the South Pit. Emission sources representing the mining of North and South Pits are shown in Figure 4.5. Emission sources entered for Years 15 and 25 of operation are shown in Figures 4.6 and 4.7.

The results of the emissions inventory for particles and gases for Years 2, 8, 15 and 25 of operation are shown in Graph 4.14.

[4] Available at http://www.epa.gov/ttnchie1/ap42/

4.6 Ponta Chugue Port Site and Paved Access Roads

The phosphate concentrate will be transported to the Port Site by trucks, which will unload the concentrate into the conveyor system. The phosphate concentrate will be transported to a storage stack where a front loader will feed concentrate into the drying system to reduce humidity from 8% to 3% (Lycopodium, 2014). Lastly, the concentrate to 3% humidity will be stored in a closed stack for subsequent shipment through a belt system feeding ship hoppers.

The results of particle and gas emission quantification, calculated using the emission factor method, were classified into emission sources for each species, these being CO (carbon monoxide), NO_x (nitrogen oxides), SO_2 (sulfur dioxide), PM_{10} (particulate matter below 10 microns in size) and $PM_{2.5}$ (particulate matter below 2.5 microns in size). Graph 4.15 shows the emission results per species in units of kilograms per year. Details of the calculations for preparing the emissions inventory are shown in Appendix A.

Activities identified as generating potential sources of emission of particles and gases involve concentrate handling, concentrate drying, front loader fuel consumption, truck traffic on paved roads, truck fuel consumption, and ship fuel consumption during concentrate shipment. Sources of emission of particles and gases that were entered into the model are shown in Figure 4.8.

4.7 Model Domain - Receptors

Determining the spatial dispersion was performed by configuring two nested grids with different spacing levels; one at the mine site (Farim) and another in the projected facilities for the Port Site. Regarding the phosphate concentrate transport route between the mine site and the Port Facility, a sampling grid was configured (Graphs 4.16, 4.17, and 4.18).

Lastly, discrete receptors were assigned to areas where human populations are located, close to the projected facilities, and along the Product Transport Route. Receptors were evaluated in the CALPUFF air dispersion model. Table 4.3 shows the location of sensitive receptors entered into the model. R1 (Ponta Capsec), R3 (Ponta Zeca), R4 (Saliquenhe), R5 (Canico) and R6 (Tambato) receptors are communities to be relocated so they will not be subject to evaluation in terms of the impact of air quality dispersion analysis.

4.8 Topographic Relief

Satellite topographic information from the ASTER global model (NASA)[5], which has high resolution (15 m) information on all the earth's surface, was used. The study area has no topographic relief complex so it is considered as flat relief with minimal influence on wind deflection.

[5] http://asterweb.jpl.nasa.gov/gdem.asp

4.9 Model Output Options

Species configured on the model corresponded to SO_2, NO_x, CO, PM_{10} and $PM_{2.5}$ for the concentration determination for the different average periods as well as total dustfall (PM_{10} dry and wet dustfall). Selected options for determination of average periods for each species are shown in Chart 4.8.

Chart 4.8
Averaging Period Options

Species	1-Hour	8-Hour	24-Hour	Run-Length (1)
SO_2	x		x	x
NO_x	x			x
NO_2				x
CO	x	x		
PM_{10}			x	x
$PM_{2.5}$			x	x

Prepared by Knight Piésold Consultores.
Notes:
(1) 3 Years of meteorological data from Farim station, GGOV station and WRF model for 2012 to 2014.

The model has the ability to generate concentration and value isolines according to the receptor assigned, considering the top highest values (up to the first 10). Percentiles for each species were configured according to the format specified in air quality standards. Thus, SO_2 was set for the 99th percentile for the average 1-hour and 24-hour periods; NO_x was set for the 98th percentile for the average 1-hour period. CO did not require assignment of percentiles. Instead, the first highest value (Rank 1) for the average 1-hour and 8-hour period was assigned. Just as $PM_{2.5}$, PM_{10} was configured for the 98th percentile for the average 24-hour period. Average annual values did not require setting percentiles. For estimation of annual NO_2 average, the ratio (NO_2/NO_x) was deemed equal to 0.57 (Chart 4.6).

To determine limit dispersion isolines generated by the model, air quality standard values were considered (Chart 3.1), as well as 10% of the standard value for the guideline as upper limit of negative impact on air quality. Values below 10% of the guideline value represent areas of no negative impacts on or significant contributions to background air quality levels.

Dispersion levels above 10% of the guideline value generated by the model for particles and gases represent different levels of effects on air quality, as shown in Chart 4.9. Based on this classification, the types of effects exerted on evaluated discrete receptors were determined.

Chart 4.9
Effects Dispersion Levels

Level	Description	PM_{10}	$PM_{2.5}$	SO_2	NO_2	CO
High effect of impact	Guideline value and lowest interim target value exceeded; or only guideline value exceeded for specific parameters (species)	>IT1	>IT1	>200 (1-hr) >IT1 (24-hr) >50 (annual)	>190 (1-hr) >40 (annual)	>30 000 (1-hr) >10 000 (8-hr)
Moderate effect of impact	Guideline value and lowest interim target value exceeded.	>IT3	>IT3	>IT2 (24-hr)	-	-
Medium effect of impact	Guideline value exceeded but result below the lowest interim target value.	>Guideline	>Guideline	>Guideline (24-hr)	-	-
Low effects of impact	More than 10% of the guideline value but result below guideline value.	>10% guideline	>10% guideline	>10% guideline	>10% guideline	>10% guideline
Insignificant effects	Less than 10% of guideline value	<10% guideline	<10% guideline	<10% guideline	<10% guideline	<10% guideline

Prepared by Knight Piésold Consultores.
IT = Interim Target (IFC, 2007).

5.0 Results

The spatial dispersion results for the modeled species are shown in Appendix B, where Appendix B-1 corresponds to the dispersion of species on the Port site, Appendix B-2 corresponds to the dispersion for Scenario 1 (Year 2), Appendix B-3 corresponds to Scenario 2 (Year 8), Appendix B-4 corresponds to Scenario 3 (Year 15), and Appendix B-5 corresponds to Scenario 4 (Year 25).

Dispersion results on each discrete receptor according to each scenario are presented in Tables 5.1 to 5.5. It must be noted that results shown do not consider background air quality levels because this section only discusses dispersion effects generated exclusively by project activities.

5.1 Mine Site

Dispersion results estimated for different scenarios by the CALPUFF model per year of operation are described below.

5.1.1 Dustfall

The effects of total PM_{10} dustfall (wet and dry seasons) for Year 2 generated by the project activities determine a maximum deposition rate of 0.966 µg/m^2/s, equivalent to 83.5 mg/m^2/day within the South Pit. Calculations using the model for Year 8 determined a maximum deposition rate of 1.25 µg/m^2/s, equivalent to 108 mg/m^2/day at the North Pit source. For Year 15, maximum dustfall was estimated at 0.791 µg/m^2/s, equivalent to 68.3 mg/m^2/day, located in the northeast area of the North Pit. Lastly, for Year 25, maximum deposition rate was estimated at 1.251 µg/m^2/s, equivalent to 108.1 mg/m^2/day, located in the western part of North Pit. In receptors, as shown in Tables 5.1 to 5.4, maximum total PM_{10} dustfall was estimated at 16.07 mg/m^2/day for Year 2 in Bani.

In general, maximum calculated deposition rate on average represent 15% of the standard for residential areas, equal to 600 mg/m^2.day, according to South African National Standard values.

5.1.2 Particulate Matter

According to the model results for different average periods for Scenario 1 (Year 2), the project would generate low, medium and moderate dispersion effects for an average 24-hour period (98th percentile) (Table 5.1). The definitions for different levels of dispersion effects is provided in Chart 4.9. Villages receiving moderate effects for an average 24-hour period (98th percentile) are Bani, Army Base (Nema), Nema, Farim, Saliquenhedim (K3) and Tungina. The villages of Army Base (Nema), Cancenha, Fafaco and Tungina would receive medium effects. All other villages receive low dispersion contributions.

On average per year for a 3-year simulation, Bani would receive moderate dispersion effects, Nema and Farim would receive medium dispersion effects, while other evaluated receptors would receive low and insignificant effects (Table 5.1).

For Scenario 2 (Year 8 of operation), it appears that the number of receptors receiving moderate dispersion effects decreases, with only Bani and Saliquenhedim receiving this kind of effect (during the dry season). Further, Bani, Nema, Farim and Tungina would receive medium dispersion effects. All other villages would receive low dispersion effects, and effects would be insignificant for certain villages during the dry season. On an annual average, all populations receive low and insignificant dispersion effects (Table 5.2).

For Scenario 3 (Year 15 of operation), it appears that due to the location of emission sources, Bani could receive high dispersion effects for the average 24-hour period (98th percentile). However, on an annual average Bani would receive moderate dispersion effects; Army Base (Nema), Nema and Sara Loba could receive medium dispersion effects, while other villages would receive low and insignificant effects (Table 5.3).

For Scenario 4 (Year 25 year of operation), it appears that Cancenha would receive high dispersion effects during the dry season and low dispersion effects during the wet season. Bani would receive moderate dispersion effects; Ufude would also receive moderate dispersion effects and medium dispersion effects during the wet season. However, on an annual average villages would receive low and insignificant dispersion effects (Table 5.4).

Graph 5.1 shows the PM_{10} dispersion results on an annual average on discrete receptors; it appears that higher dispersion effects occur in Year 15 due to the closeness of emission sources to receptors. Bani would receive a maximum concentration of 65.5 $\mu g/m^3$ of PM_{10} concentrations on average per year resulting from project activities during Year 15 of mine operation.

Graph 5.2 shows the $PM_{2.5}$ dispersion results on an average annual on discrete receptors; it appears that higher dispersion effects occur in Year 15 due to the location of emission sources. In addition, Tables 5.1 to 5.4 show receptors and the types of effects each would receive according to the average evaluation period.

5.1.3 Sulfur Dioxide (SO_2)

According to the model results for different average periods, in Scenario 1, Nema (R9) and Farim (R10) would receive maximum contributions of 29.1 $\mu g/m^3$ and 25.1 $\mu g/m^3$ for the average 1-hour period (99th percentile), respectively. For Scenario 2 (Year 8,) Bani would receive maximum contributions of 21.2 $\mu g/m^3$ on an average 1-hour period, while in other villages concentration contributions are below 10.7 $\mu g/m^3$. For Scenario 3 (Year 15), Sara Loba and Bani would receive maximum contributions of 29.6 $\mu g/m^3$ and 26.7 $\mu g/m^3$ on an average 1-hour period. For Scenario 4 (Year 25) SO_2 concentration contributions on an

average 1-hour period are below 20 µg/m^3, corresponding to 10% of the guideline value (200 µg/m^3 for the average 1-hour period), thus insignificant dispersion effects are expected.

Regarding dispersion results for the average 24-hour period (99th percentile), it appears that evaluated receptors with concentration contributions above 2 µg/m^3, corresponding to 10% of the guideline value (20 µg/m^3 for the average 24-hour period) would receive low effects. No concentration contributions with medium, moderate or high effects were estimated. Graph 5.3 shows the SO_2 dispersion results for an average 24-hour period for the 99th percentile on discrete receptors; it appears that the highest dispersion effects occur in Years 8, 15 and 25.

For the average annual period, no SO_2 concentration contributions above 5 µg/m^3 appear, corresponding to 10% of the guideline value (50 µg/m^3). Therefore, dispersion effects are insignificant, i.e. no negative impact on the air quality baseline for SO_2 would occur.

5.1.3.1 Nitrogen Dioxide (NO_2)

Dispersion model results obtained for Scenario 1 on receptors show that only Nema and Farim would receive maximum concentration contributions of 341.6 µg/m^3 and 284.1 µg/m^3, respectively; these values present high effects because contributions are above the standard value for the average 1-hour period (190 µg/m^3). For Scenario 2 (Year 8), Bani alone would receive contributions of 247.4 µg/m^3, which represents high effects on the receptor. For Scenario 3 (Year 15), Bani and Sara Loba alone would receive maximum concentration contributions of 287.2 µg/m^3 and 318.4 µg/m^3, respectively. For Scenario 4, no concentration contributions with high effects are expected, i.e. concentration contributions represent low effects because they are below the standard value (190 µg/m^3).

On an annual average, during Scenario 1, NO_2 dispersion on discrete receptors ranges between 0.3 µg/m^3 and 20.8 µg/m^3. In Scenario 2 dispersion decreases, ranging between 0.4 µg/m^3 and 15.6 µg/m^3. In Scenario 3, annual NO_2 dispersion increased, with concentrations of 33.5 µg/m^3 (Bani) and 37.0 µg/m^3 (Sara Loba). Lastly, in Scenario 4, NO_2 dispersion on receptors ranges between 1.8 µg/m^3 and 17.9 µg/m^3. These values would represent low to moderate dispersion effects in the case of dispersion values close to the standard value of 40 µg/m^3, as in the case of Bani and Sara Loba in Scenario 4.

Graph 5.4 shows annual average NO_2 dispersion results on discrete receptors; it appears that higher dispersion effects occur in Years 8, 15 and 25 due to the location of emission sources.

5.1.3.2 Carbon Monoxide (CO)

The results of CO dispersion are shown in Appendix B; according to the results for evaluated discrete receptors, no low or high dispersion effects were observed because results represent insignificant effects below 10% of the standard value (Chart 3.1).

5.2 Access Road and Port Site

The results of particle and gas dispersion are shown in Appendix B-1. Moreover, dispersion results on discrete receptors are shown in Table 5.5.

5.2.1 Dustfall

The effects of total PM_{10} dustfall (wet and dry) representative of all scenarios (Years 2, 8, 15 and 25), as a result of project activities, determine a maximum dustfall of 3.31 mg/m^2.day for the maximum average 24-hour period. This maximum value was estimated at receptor R51 (Table 5.5).

5.2.2 Particulate Matter

PM_{10} dispersion results on discrete receptors for the average 24-hour period correspond to low and insignificant dispersion effects. However, the village of Mandinga could receive medium effects during the dry season (Table 5.5). The values estimated by the model were found between 2.5 $\mu g/m^3$ and 53.0 $\mu g/m^3$ for the average 24-hour period. On an annual average, the estimated dispersion values range between 0.7 $\mu g/m^3$ and 6.4 $\mu g/m^3$, which represent insignificant and low effects (Table 5.5).

Similarly, $PM_{2.5}$ dispersion on an average 24-hour period (98th percentile) in the villages located along the access road and the Port site would represent insignificant and low effects. Mandinga and Colimessen Cunda would receive 21.9 $\mu g/m^3$ and 13.9 $\mu g/m^3$ concentrations, respectively, during the dry season, while these concentrations decrease during the wet season due to weather changes in these two seasons. $PM_{2.5}$ dispersion ranges between 0.2 $\mu g/m^3$ and 2.4 $\mu g/m^3$ on the annual average.

5.2.3 Sulfur Dioxide (SO_2)

According to Table 5.5, SO_2 dispersion results in average 1 hour and 24 hour-periods for the 98th percentile, villages represent low and insignificant effects on most. Average dispersion effects are estimated only in the area close to the Port site, at the corresponding Fishing Beach (R70) receptor. On an annual average, dispersion results range between 0 $\mu g/m^3$ and 4.8 $\mu g/m^3$.

5.2.4 Nitrogen Dioxide (NO_2)

Along the access road, dispersion results in villages are insignificant. In the area close to the Port site, the effects of dispersion for the maximum time period for receptors R64 to R69 represent lower effects, while for receptor R70 (Fishing Beach), the maximum hourly concentration it may receive is 232.5 $\mu g/m^3$, which represents high effects. On an annual average, it appears that Village Chief (R69) receptor would receive low dispersion effects, equal to 5.1 $\mu g/m^3$, while Fishing Beach (R70) receptor would receive high effects, equal to 54.4 $\mu g/m^3$.

5.2.5 Carbon Monoxide (CO)

Estimated dispersion results for receptors represent low effects below 10% of the standard values for the average time period and the average 8-hour period.

6.0 Air Quality Forecast

The air quality forecast was estimated as the sum of the background concentrations (particles and gases) and project-generated dispersion results (Appendix B). Total concentrations in discrete particulate material for gases and receptors are shown in Tables 6.1 to 6.5. Only parameters that have a significant influence on background air quality levels were considered.

6.1 Mine Site

Below is an analysis of the main parameters presenting between low and high dispersion effects.

6.1.1 Particulate Matter

The parameter PM_{10} is deemed the primary air quality indicator representating mining activities, due to the nature of the activities as potentially generating higher PM_{10} emissions. According to meteorological conditions, applying the wet season baseline to the air quality forecast is deemed representative because the primary sensitive receptors are located downwind of the project without the influence of natural wind erosion from the northeast, which occurs and results in naturally elevated PM_{10} concentrations during the dry season.

Table 6.1 presents the results of PM_{10} concentrations for the average 24-hour period (98th percentile) and the annual period. It appears that total PM_{10} concentrations do not exceed the PM_{10} standard IT1 during the wet season. Only for Scenario 3 (Table 6.3), Bani may not meet the standard for PM_{10} (TS1) for the 24-hour period during the wet season.

Spatially, PM_{10} concentrations are dispersed by the wind direction during the wet and dry season, according to the wind direction magnitude, considering the type of atmospheric stability as calculated by CALMET.

Figure 6.1 shows total PM_{10} concentrations for Scenario 1 (Year 2), where it appears that annual average background concentrations were estimated at 70 µg/m^3, which exceeds the annual average PM_{10} standards due to natural conditions, especially during the dry season (Schwanghart & Schütt, 2008). The influence of mining activities is seen in 75 µg/m^3 concentrations, which extend approximately to 11 kilometers to the NE due to the influence of winds from the SW during the wet season, while to the SW 75 µg/m^3 concentrations of PM_{10} reach 8.5 kilometers due to the influence of winds from the NE, mainly during the dry season.

Figure 6.2 shows total PM_{10} concentrations corresponding to Scenario 2 (Year 8) on average per year. It appears that the range of 80 µg/m^3 concentrations include Bani (R2), Army Base (R8), Nema (R9), Farim (R10) and Ufude (R14) receptors (Table 6.2). Due to wind patterns,

concentrations up to 75 µg/m^3 reach about 10 km NE of emission sources, while the range is 7.5 km to the SW.

Figure 6.3 shows total PM_{10} concentrations corresponding to Scenario 3 (Year 15) on average per year, which shows that the range of 80 µg/m^3 concentrations include Bani (R2), Army Base (R8), Nema (R9), Farim (R10), Cancenha (R13), Saliquenhedim (R14), Sara Loba (R15), Sancalanco (R17) and Fafaco (R18) receptors (Table 6.3). The range of 75 µg/m^3 concentrations in terms of emission sources is 12.6 km to the NE, while the range is approximately 11 km to the SW.

Figure 6.4 shows total PM_{10} concentrations corresponding to Scenario 4 (Year 25) on average per year, which shows that the range of 80 µg/m^3 concentrations include Bani (R2), Army Base (R8) Nema (R9), Farim (R10), Ufude (R11), Cancenha (R13), Saliquenhedim (R14) and Sara Loba (R15) receptors (Table 6.4). The range of 75 µg/m^3 concentrations in terms of emission sources is 9.6 km to the NE, while the range is approximately 8.3 km to the SW.

Total $PM_{2.5}$ concentrations met air quality standards for maximum interim target limit (IT1) at most receptors. However, concentrations in Bani, Army Base (Nema) and Cacenha receptors (during the dry season) are predicted to exceed with the IT1 standard. In Scenarios 1 and 2, predicted concentrations meet the maximum permissible standard of 75 µg/m^3 (24-hour average) and 35 µg/m^3 (annual average). In Scenario 3, Annual average $PM_{2.5}$ concentrations at Bani will not meet the 35 µg/m^3 standard. In Scenario 4, Cancenha concentrations for the dry season would meet the 75 µg/m^3 standard on an average 24-hour period.

6.1.2 Gases

Total SO_2 concentrations are predicted to meet air quality standards for all scenarios.

Total NO_2 concentrations (1 hour average) at select receptor locations would not meet air quality standards. In Scenario 1, Nema and Farim is predicted to not meet standards for the average 1-hour period. In Scenario 2, Bani will not meet the standard for the average 1-hour period. In Scenario 3, Bani and Sara Loba will not meet standards for the average 1-hour period and Sara Loba may show concentrations that are slightly beyond the standard in annual average of NO_2. Scenario 4 shows that villages meet the NO_2 standards.

6.2 Access Road and Port Site

Table 6.5 shows the results of total particle and gas concentration along the phosphate concentrate transport route and the Port site. It appears that total SO_2 concentrations meet air quality standards. At the Port site, NO_2 standards may not be met for the Fishing Beach (R70) receptor.

No total PM_{10} concentrations beyond the standard appear along the access road and the Port site, even considering the highest standards. Figure 6.5 shows the spatial results of total PM_{10} concentrations.

Total $PM_{2.5}$ concentrations meet IT1 and IT2 standards for both the 24-hour average period and the annual average.

7.0 Conclusions and Recommendations

Atmospheric dispersion modeling is based on conservative conditions where continuous emissions were estimated throughout the year, except for traffic on the concentrate transport road, where emissions were configured to occur between 6:00 and 20:00 hours. As such,the Project`s estimated that concentration contributions from the project, both in terms of particulate matter and gases, may be lower given the variability in operating activities and the fact that they do not occur at a steady pace, as was considered in the CALPUFF model.

7.1 Conclusions

- At the mine site, highest emissions are related to NO_x generation from the operation of heavy machinery and electrical generators. The second highest emissions correspond to PM_{10}, while the third highest emissions are $PM_{2.5}$ emissions. However, even though CO emissions are higher in the Port site, the impact on air quality is not significant.
- PM_{10} emissions generated are largely the result of hauling material on unpaved roads, earthworks in the pits and material transport. The highest PM_{10} generation is for Year 15, Scenario 3.
- Particulate matter concentrations during the dry season exceed standard limit values due to natural sources. For this reason, predicted annual average PM_{10} concentrations exceed the maximum permissible standard value of 70 µg/m^3.
- Scenario 3 has the highest concentration values for PM_{10} and $PM_{2.5}$. PM_{10} concentrations in an average 24-hour period (98th percentile) during the wet season may only be exceeded in Bani for Scenario 3. Similarly, predicted annual average $PM_{2.5}$ concentrations may be exceeded in Bani for Scenario 3.
- During the wet season, the PM_{10} standard for the average 24-hour period at the mine site exceeded the 50 µg/m^3 standard by 63%, the 75 µg/m^3 standard by 25%, the 100 µg/m^3 standard by 13%, and the 150 ug/m^3 standard by 1%, on discrete receptors, considering all scenarios.
- During the wet season, the $PM_{2.5}$ standard for the average 24-hour period at the mine site exceeded the 25 µg/m^3 standard by 25%, the 37.5 µg/m^3 standard by 9%, the 50 µg/m^3 standard by 3%, and the 75 µg/m^3 standard by 0% on discrete receptors, considering all scenarios. On an annual average, the standard exceeded the 10 µg/m^3 standard by 100% (due to background concentrations), the 15 µg/m^3 standard by 74%, the 25 µg/m^3 standard by 4%, and the 35 µg/m^3 standard by 1%.
- The predicted SO_2 and CO concentrations meet air quality standards for most receptors, given that background air quality levels are not significant.
- The predicted NO_2 concentrations may not meet the standard for the average 1 hour period in Bani, Nema, Farim, Sara Loba and the Fishing Beach area, near the Port facilities. Sara Loba and the Fishing Beach area may not meet the annual NO_2 standard equal to 40 µg/m^3.

7.2 Recommendations

- In order to evaluate the efficiency of reducing particulate emissions in haul roads, monitoring the percentage of fines (<75 µg) and surface soil moisture on a biannual basis is recommended, given that increased PM_{10} emissions come from haul roads.
- The estimated efficiency of reducing particulate emissions in haul roads from the use of tank trucks is 87% (Appendix A), whereas the increase in humidity reaches 4 times the humidity level without irrigation in the haul road surface. For this reason, and in order to manage water use, evaluating other mitigation measures, such as calcium chloride or magnesium chloride hexahydrate, is recommended, where it will be necessary to ensure that the control efficiency of the application of these agents is higher than the 87% efficiency achieved through the intensity and frequency of irrigation using two tank trucks.
- To facilitate dispersion of NO_x emissions from diesel generators, increasing the chimney height from 3 to 6 meters is recommended, which would reduce dispersion concentrations discrete receivers may receive.
- To reduce NO_x, PM_{10} and $PM_{2.5}$ emissions generated by vehicle exhaust, proper maintenance of these is recommended, in addition to plugging truck hoppers for phosphate concentrate transport from the mine site to the port.
- Because discrete receptors were identified that may not meet air quality standards for PM_{10}, $PM_{2.5}$ and NO_2, installing permanent monitoring stations in the following receptors is recommended:
    - Bani (R2)
    - Nema (R9), representative of stations Army Base and Farim.
    - Sara Loba (R15)
    - Fishing Beach (R70),
- The recommended frequency of monitoring is every six days in suggested stations during the wet season. During the dry season, measurements are recommended for 24 hours on a monthly basis. At Fishing Beach receptor, monitoring NO_x and NO_2 parameter concentrations on a quarterly basis is recommended. Installing an automatic weather station is suggested at the stations themselves. The recorded information will help define particle concentrations (PM_{10} and $PM_{2.5}$) and NO_2 dispersion routes and improve the quality of weather information input for future modeling studies.

8.0 Bibliography

CAT. (2011a). Diesel generator Set - CAT 3412C.

CAT. (2011b). Diesel generator Set - CAT 3512B.

Golder. (2014). *Mine Component Environmental and Social Baseline Studies*. London - UK: Golder Associates (UK) LTD.

IFC. (2007). Environmental, Health, and Safety general guidelines. World Bank group.

Knight Piésold. (2015). Farim Phosphate Project - Design Climatology Assessment. Prepared for Lycopodium Minerals Canada Ltd.

Lycopodium. (2014). *Farim Phosphate Project - Process Design Criteria*.

MDAQMD. (2000). Emissions Inventory guidance Mineral Handling and Processing Industries. Mojave Desert Air Quality Management District. Antelope Valley Air Pollution Control District. Revised during 2013.

NPI. (2008). *Emission estimation technique manual for Combustion engines* (version 3.). Canberra-Australia: Department of the Environment, Water, Heritage and the Arts. Retrieved from http://www.npi.gov.au/reporting/industry-reporting-materials/emission-estimation-technique-manuals

NPI. (2012a). *Emission estimation technique manual for Maritime operations Version 2.1*. Canberra: Australia government. Department of Sustainability, Environment, Water, Population and Communities.

NPI. (2012b). EMISSION ESTIMATION TECHNIQUE MANUAL FOR MINING VERSION 3 . 1. Camberra: Australia government. Department of Sustainability, Environment, Water, Population and Communities.

Schwanghart, W., & Schütt, B. (2008). Meteorological causes of Harmattan dust in West Africa. g*eomorphology*, *95*(3-4), 412–428. doi:10.1016/j.geomorph.2007.07.002

Scire, J. S., Robe, F. R., Fernau, M. E., & Yamartino, R. J. (2000). A User's guide ofr the CALMET Meteorological Model. Concord, MA: Earth Tech.

Scire, J. S., Strimaitis, D. g., & Yamartino, R. J. (2000). *A User's guide for the CALPUFF Dispersion Model*. 196 Baker Avenue. Concord, MA 01742.

Seinfeld, J. H., & Pandis, S. N. (2006). *Atmospheric Chemistry and Physics: from air pollution to climate change* (Second.). John Wiley & Sons, INC.

Teixeira, J. (2001). Cloud Fraction and Relative Humidity in a Prognostic Cloud Fraction Scheme. *Monthly Weather Review*. doi:10.1175/1520-0493(2001)129<1750:CFARHI>2.0.CO;2

USEPA. (1995a). 11.21 Phosphate Rock Processing. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42 Fifth Edition* (Fifth Edit., Vol. 1, pp. 1–10). NC: U. S. Environmental Protection Agency.

USEPA. (1995b). *Compilation of Air Pollutant Emission Factors - Volume I: Stationary Point and Area Sources* (Fifth Edit.). NC: U. S. Environmental Protection Agency. Retrieved from http://www.epa.gov/ttn/chief/ap42/index.html

USEPA. (1998). 11.9 Western Surface Coal Mining. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–14). NC: U. S. Environmental Protection Agency.

USEPA. (2006a). 13.2.2 Unpaved Roads. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–20). NC: U. S. Environmental Protection Agency.

USEPA. (2006b). 13.2.4 Aggregate Handling And Storage Piles. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–6). NC: U. S. Environmental Protection Agency.

USEPA. (2006c). 13.2.5 Industrial Wind Erosion. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–15). NC: U. S. Environmental Protection Agency.

USEPA. (2011). 13.2.1 Paved Roads. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42.*

USEPA. (2014). Support Center for Regulatory Atmospheric Modeling - Preferred Recommended Models. Retrieved August 20, 2014, from http://www.epa.gov/ttn/scram/dispersion_prefrec.htm

Visscher, A. De. (2013). *Air Dispersion Modeling*. Hoboken, NJ: John Wiley & Sons, Inc. doi:10.1002/9781118723098

WHO. (2005). *WHO air quality guidelines global update 2005*. Copenhagen, Denmark.

Knight Piésold Consultores S.A.

Prepared by: _____
Alejandro Delgado
Environmental Engineer KP Perú

Reviewed by: _____
Edgardo Enríquez
Project Manager KP Perú

Approved by: _____
Claudia Sandoval
Environmental Manager KP Perú

Tables

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 4.1
Material handling per year (kilo tonnes) - Farim Phosphate Project

Description	Year																									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
ROM Waste from South Open Pit	12 218	23 460	31 335	30 068	27 465	24 985	22 990	27 819	17 326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Integrated Waste Landform (IWL)	*12 218*		*11 439*	*2 257*																							
South Pit SOS				*5 986*	*3 644*				*3 185*																		
Deposited to South Pit (In-pit)		*6 541*	*17 019*	*21 825*	*23 822*	*24 985*	*22 990*	*27 819*	*14 141*																		
South-East Waste Dump		*8 804*																									
North-East Waste Dump		*8 116*	*2 877*																								
ROM Waste from North Open Pit	0	0	0	0	0	0	0	0	19 846	38 574	36 230	37 713	40 937	40 976	40 891	40 854	41 065	39 492	36 971	36 917	31 708	31 890	32 277	35 783	40 994	44 691	5 967
Integrated Waste Landform (IWL)															*7 979*	*17 469*	*7 041*	*965*									
South Pit SOS										*8 978*	*5 257*	*6 731*	*9 171*	*11 037*	*9 370*	*918*	*2 877*	*2 825*									
Deposited to North Pit (In-pit)									*19 846*	*29 596*	*25 715*	*24 252*	*22 596*	*18 902*	*14 172*	*21 550*	*28 270*	*32 877*	*36 971*	*36 917*	*31 708*	*31 890*	*32 277*	*35 783*	*40 994*	*44 691*	*5 967*
North Pit SOS											*5 257*	*6 731*	*9 171*	*11 037*	*9 370*	*918*	*2 877*	*2 825*									
ROM Plant feed from South Open Pit	0	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 361	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROM Plant feed from North Open Pit	0	0	0	0	0	0	0	0	389	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	1 750	257
Maximum product from South Open Pit	0	1 250	1 250	1 250	1 250	1 250	1 250	1 250	972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum product from North Open Pit	0	0	0	0	0	0	0	0	278	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	183
Tailing Storage Facility	0	525	**525**	525	525	525	525	525	**525**	525	525	525	525	525	525	**525**	525	525	525	525	525	525	525	525	525	**525**	77
Material from South Open Pit	12 218	25 210	**33 085**	31 818	29 215	26 735	24 740	29 569	**18 687**	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	**0**	0
Material from North Open Pit	0	0	**0**	0	0	0	0	0	**20 235**	40 324	37 980	39 463	42 687	42 726	42 641	**42 604**	42 815	41 242	38 721	38 667	33 458	33 640	34 027	37 533	42 744	**46 441**	6 224

Prepared by Knight Piésold Consultores.

Notes:

Density of "Bank Cubic Meter" for waste = 2,1 t/m^3

Scenario 1 (Year 2) =

Scenario 2 (Year 8) =

Scenario 3 (Year 15) =

Scenario 4 (Year 25) =

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 4.2
Summary - Number of equipment units

Description	Years																										Engine power kW [1]
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	
Caterpillar 374DL - Excavator	-	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	355
Caterpillar 336DL - Excavator	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	200
Caterpillar 992K - Wheel Loader	3	5	6	6	6	5	5	6	7	8	7	7	8	8	8	8	8	8	7	7	6	6	7	7	8	8	607
Caterpillar D9R - Dozer [2]	2	4	5	5	4	4	4	4	6	6	5	6	6	6	6	6	6	6	5	5	5	5	5	5	6	7	302
Caterpillar 777G - End Dump Truck	12	14	17	14	15	11	10	12	19	20	18	18	23	27	33	32	24	18	21	20	17	16	15	17	19	20	704
Caterpillar 770 - End Dump Truck	1	6	6	7	7	7	7	8	8	7	8	7	8	8	9	8	9	10	8	9	9	10	10	11	12	12	355
Caterpillar 16M - Motor Grader [2]	2	2	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	221
Caterpillar CS-56 - Compactor	3	4	6	6	5	5	4	5	7	7	7	7	7	7	7	7	7	7	7	7	6	6	6	7	7	8	116
Caterpillar 428F - Backhoe Loader	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	66,2
Caterpillar 770 - Water Truck	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	355
Fuel/Lube Truck	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	4	4	4	-
Mechanic's Truck	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	2	-
Pickup Truck	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	-
Liebherr LTM 1095 - Mobile Crane	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-
Welding Machine	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-
Light Plant	5	8	10	10	9	9	8	9	12	12	12	12	13	13	13	13	13	13	12	12	11	11	11	12	13	14	-
Screening Plant	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-

Prepared by Knight Piésold Consultores.

Notes:

[1] Technical sheet of equipment

[2] Heavy equipment related to bulldozing

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 4.3
Air Quality Receptor Locations

Zone	Code	East - X (m)	North - Y (m)	Receptor
Mine site	R2	473 539	1 380 590	Bani
	R3	472 822	1 379 808	Ponta Zeca
	R4	471 784	1 379 666	Saliquenhe
	R5	470 663	1 377 155	Canico
	R6	470 042	1 379 774	Tambato Mandinka
	R7	471 451	1 384 269	Canico Tumanna
	R8	475 307	1 381 393	Army Base (Nema)
	R9	475 727	1 380 498	Nema
	R10	476 526	1 379 984	Farim
	R11	467 479	1 379 940	Ufude
	R12	467 098	1 381 200	Sandjal
	R13	467 156	1 377 649	Cancenha
	R14	475 929	1 376 653	Saliquenhedim (K3)
	R15	474 211	1 383 392	Sara Loba
	R16	472 140	1 384 558	Urqui (Seidi)
	R17	478 600	1 384 226	Sancalanco
	R18	479 054	1 381 010	Fafaco
	R19	466 182	1 381 270	Tambandinto
	R20	469 292	1 385 691	Sintchan Maudie
	R21	480 633	1 384 258	Bolumbato
	R22	473 104	1 375 236	Tungina
Access road	R23	472 111	1 373 945	Mandinga
	R24	476 318	1 373 422	Colimessen Cunda
	R25	476 727	1 369 836	Djalicunda
	R26	478 044	1 366 292	Bironqui
	R27	479 863	1 363 349	Calingue Fula
	R28	481 403	1 359 002	Mansaba
	R29	481 019	1 357 093	Mansaba-Sutu
	R30	480 274	1 355 429	Serraco
	R31	478 415	1 353 750	Manbonco
	R32	474 753	1 345 041	Cutia
	R33	470 457	1 340 690	Querene
	R34	470 122	1 340 110	Cureyni
Access road	R35	469 887	1 339 748	Cussac
	R36	469 086	1 338 540	San Saunto
	R37	465 535	1 334 500	Mansoa
	R38	463 910	1 332 112	-
	R39	463 997	1 331 985	-
	R40	463 691	1 331 694	-
	R41	462 525	1 330 718	-
	R42	461 739	1 330 377	-
	R43	458 118	1 328 830	Uaque
	R44	454 657	1 327 513	-
	R45	454 534	1 327 343	-
	R46	454 145	1 327 269	-
	R47	454 166	1 327 003	-
	R48	453 322	1 326 752	-
	R49	453 191	1 326 681	-
	R50	453 100	1 326 631	-
	R51	452 990	1 326 599	-
	R52	452 798	1 326 487	-
	R53	451 373	1 325 821	Dugal
	R54	451 451	1 325 785	Dugal
	R55	451 379	1 325 741	Dugal
	R56	451 764	1 325 439	-
	R57	451 724	1 325 217	-
	R58	452 239	1 325 348	-
	R59	451 954	1 324 457	-
	R60	453 350	1 324 081	Cunteda
	R61	453 361	1 323 771	Cunteda
	R62	453 616	1 323 520	Cunteda
	R63	453 272	1 323 441	Cunteda
	R64	452 801	1 322 155	Arote
	R65	452 894	1 322 028	Arote
	R66	452 923	1 321 807	-
	R67	452 421	1 321 384	-
	R68	452 429	1 320 949	Ancone
Port site	R69	452 474	1 320 599	Village Chief
	R70	452 716	1 320 121	Fishing Beach

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.1
Dispersion results from emissions of the project in discrete receptors for Mine Site - Scenario 1 (Year 2)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3				$PM_{2.5}$ µg/m^3				SO_2 µg/m^3			NO_x µg/m^3	NO_2 µg/m^3		CO µg/m^3		PM_{10} deposition mg/m^2.day
				3 years 24 hour 98th	Wet season (1) 24 hour 98th	Dry season (2) 24 hour 98th	3 years average	3 years 24 hour 98th	Wet season (1) 24 hour 98th	Dry season (2) 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years 1 hour 98th	3 years average	1 hour - Rank 1 of 3 years	8 hour - Rank 1 of 3 years	3 years 24 hour (Rank 1)
R2	473 539	1 380 590	Bani	95,7	98,6	83,8	32,1	38,9	37,7	30,9	12,2	8,4	4,6	0,6	93,4	53,2	10,7	1 537,2	403,5	16,07
R7	471 451	1 384 269	Canico Tumanna	21,2	24,9	11,1	2,4	9,0	9,6	4,2	0,9	0,7	1,0	0,1	9,7	5,5	0,9	827,9	138,5	4,11
R8	475 307	1 381 393	Army Base (Nema)	67,5	82,8	59,5	17,7	30,0	32,1	21,2	7,1	14,7	4,9	0,5	144,8	82,5	9,0	1 454,2	480,8	6,81
R9	475 727	1 380 498	Nema	98,9	99,4	76,3	27,8	46,4	38,5	31,2	11,5	29,1	7,5	1,2	599,4	341,6	20,8	2 080,7	583,0	11,67
R10	476 526	1 379 984	Farim	93,1	92,6	111,1	24,4	43,1	32,9	40,3	10,1	25,1	6,4	1,0	498,4	284,1	17,7	2 103,9	342,8	9,02
R11	467 479	1 379 940	Ufude	31,1	25,6	17,8	3,0	13,1	8,5	6,6	1,2	1,2	0,7	0,0	14,1	8,0	0,8	493,8	129,2	5,08
R12	467 098	1 381 200	Sandjal	21,8	21,8	6,5	1,9	9,1	8,2	2,5	0,7	0,6	0,8	0,0	5,8	3,3	0,6	390,8	98,8	3,55
R13	467 156	1 377 649	Cancenha	55,1	34,6	55,1	7,1	22,4	13,4	19,7	2,7	1,9	1,1	0,1	27,4	15,6	1,3	592,7	132,2	4,28
R14	475 929	1 376 653	Saliquenhedim (K3)	81,8	43,7	126,0	17,2	38,4	15,1	51,1	6,2	11,8	5,4	0,5	128,0	73,0	8,3	1 796,0	523,9	7,32
R15	474 211	1 383 392	Sara Loba	35,2	35,2	22,1	6,1	15,3	13,9	8,3	2,4	1,5	1,7	0,1	33,2	18,9	2,3	780,0	198,3	5,14
R16	472 140	1 384 558	Urqui (Seidi)	19,9	26,2	17,5	2,3	9,2	9,6	5,9	0,9	0,7	0,8	0,0	9,8	5,6	0,8	612,4	78,8	6,31
R17	478 600	1 384 226	Sancalanco	36,5	40,5	35,6	6,2	16,2	15,9	13,0	2,5	6,2	2,1	0,2	49,2	28,0	3,4	960,9	132,7	2,52
R18	479 054	1 381 010	Fafaco	50,2	47,6	42,0	10,4	22,8	18,5	18,6	4,3	11,7	3,1	0,4	192,3	109,6	6,9	1 048,9	242,7	5,40
R19	466 182	1 381 270	Tambandinto	15,3	15,2	5,0	1,2	6,3	5,3	1,8	0,5	0,4	0,4	0,0	2,6	1,5	0,3	501,4	101,0	4,21
R20	469 292	1 385 691	Sintchan Maudie	13,0	11,4	5,7	1,0	5,6	4,3	2,0	0,4	0,3	0,5	0,0	2,6	1,5	0,4	378,0	52,5	3,03
R21	480 633	1 384 258	Bolumbato	30,8	30,9	34,5	5,0	13,7	12,2	13,8	2,1	6,1	1,9	0,2	51,5	29,3	3,1	731,9	239,4	3,02
R22	473 104	1 375 236	Tungina	63,4	36,3	81,8	9,1	33,0	15,1	31,6	3,9	10,0	4,1	0,3	81,4	46,4	5,8	1 854,4	477,8	3,80

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(1) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(2) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:

- No effects of impact
- Low effects of impact - more than 10% of the guideline value.
- Medium effect of impact - Guideline value exceeded but result below the lowest interim target value.
- Moderate effect of impact - Guideline value and lowest interim target value exceeded
- Hight effect of impact - Guideline value and lowest interim target value exceeded; or only guideline value exceeded

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.2
Dispersion results from emissions of the project in discrete receptors - Scenario 2 (Year 8)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3				$PM_{2.5}$ µg/m^3				SO_2 µg/m^3			NO_x µg/m^3	NO_2 µg/m^3		CO µg/m^3		PM_{10} deposition mg/m^2.day
				3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years 1 hour 98th	3 years average	1 hour - Rank 1 of 3	8 hour - Rank 1 of 3	3 years 24 hour (Rank 1)
R2	473 539	1 380 590	Bani	65,7	81,1	66,0	16,1	22,6	27,0	24,0	5,6	21,2	4,9	0,9	434,1	247,4	15,6	1 137,6	318,0	10,5
R7	471 451	1 384 269	Canico Tumanna	16,0	11,6	4,3	1,3	6,0	4,7	1,4	0,5	1,0	1,1	0,1	10,3	5,9	1,0	447,7	140,5	5,6
R8	475 307	1 381 393	Army Base (Nema)	47,1	47,7	45,4	9,7	14,9	17,3	16,1	3,3	9,6	2,2	0,4	194,0	110,6	7,7	782,6	174,3	5,1
R9	475 727	1 380 498	Nema	56,5	67,8	51,0	13,6	19,2	20,9	16,6	4,5	10,7	2,7	0,6	224,8	128,2	10,0	635,6	246,0	5,6
R10	476 526	1 379 984	Farim	61,4	58,4	69,1	12,3	20,2	19,9	23,2	4,1	9,7	2,8	0,5	194,7	111,0	8,4	739,1	204,0	6,1
R11	467 479	1 379 940	Ufude	18,3	12,3	3,9	1,2	6,5	4,9	1,9	0,5	0,9	1,1	0,0	8,9	5,1	0,9	513,6	91,9	3,5
R12	467 098	1 381 200	Sandjal	13,3	17,1	1,8	0,9	4,9	6,0	0,8	0,3	0,5	1,0	0,0	4,6	2,6	0,7	495,7	107,7	2,2
R13	467 156	1 377 649	Cancenha	28,5	16,0	27,9	2,1	10,5	6,0	9,9	0,8	1,7	1,3	0,1	20,4	11,6	1,4	793,3	157,7	3,9
R14	475 929	1 376 653	Saliquenhedim (K3)	49,3	47,2	86,7	6,7	17,3	15,8	26,5	2,5	6,6	2,5	0,2	98,4	56,1	3,9	762,9	235,2	5,7
R15	474 211	1 383 392	Sara Loba	28,0	29,9	17,7	3,3	9,5	10,6	6,3	1,2	4,6	1,7	0,2	57,9	33,0	2,9	496,7	131,7	2,8
R16	472 140	1 384 558	Urqui (Seidi)	14,4	14,1	3,4	1,3	5,3	5,1	1,1	0,5	1,2	1,0	0,1	12,5	7,1	1,0	402,6	120,1	10,3
R17	478 600	1 384 226	Sancalanco	22,8	23,8	22,2	3,4	7,8	8,3	7,5	1,2	4,0	1,1	0,1	71,6	40,8	2,5	325,3	64,0	1,7
R18	479 054	1 381 010	Fafaco	34,8	41,8	40,6	5,8	12,3	13,4	14,5	2,0	5,5	1,6	0,2	103,4	58,9	4,0	418,2	128,4	2,4
R19	466 182	1 381 270	Tambandinto	8,4	9,0	0,8	0,6	3,3	3,5	0,3	0,2	0,3	0,6	0,0	1,6	0,9	0,4	319,5	79,5	2,4
R20	469 292	1 385 691	Sintchan Maudie	8,5	9,2	0,5	0,6	3,0	2,7	0,2	0,2	0,3	0,6	0,0	2,1	1,2	0,4	264,8	90,5	1,8
R21	480 633	1 384 258	Bolumbato	19,5	23,0	28,6	2,8	6,7	8,1	10,3	1,0	3,3	1,0	0,1	57,7	32,9	2,0	224,1	70,5	2,1
R22	473 104	1 375 236	Tungina	58,7	40,2	70,3	6,9	20,5	14,0	26,4	2,6	6,3	2,5	0,2	96,0	54,7	3,8	847,8	237,9	4,7

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.
[1,2] Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.
[1,2] Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:

- No effects of impact
- Low effects of impact - more than 10% of the guideline value.
- Medium effect of impact - Guideline value exceeded but result below the lowest interim target value.
- Moderate effect of impact - Guideline value and lowest interim target value exceeded
- Hight effect of impact - Guideline value and lowest interim target value exceeded; or only guideline value exceeded

Knight Piésold CONSULTING

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.3
Dispersion results from emissions of the project in discrete receptors - Scenario 3 (Year 15)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3				$PM_{2.5}$ µg/m^3				SO_2 µg/m^3			NO_x µg/m^3	NO_2 µg/m^3		CO µg/m^3		PM_{10} deposition mg/m^2.day
				3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years 1 hour 98th	3 years average	1 hour - Rank 1 of 3 years	8 hour - Rank 1 of 3 years	3 years 24 hour (Rank 1)
R2	473 539	1 380 590	Bani	231,0	148,4	318,7	65,5	96,3	58,0	137,3	26,3	29,6	9,8	1,1	503,9	287,2	33,5	1 577,3	807,6	15,27
R7	471 451	1 384 269	Canico Tumanna	49,6	47,0	30,8	5,5	20,4	18,1	13,0	2,2	3,7	3,2	0,2	26,8	15,3	5,5	1 413,9	271,8	9,22
R8	475 307	1 381 393	Army Base (Nema)	113,0	98,8	122,4	29,8	48,2	39,3	51,6	11,8	18,9	5,5	0,7	324,7	185,1	21,9	1 016,8	362,7	7,44
R9	475 727	1 380 498	Nema	103,7	91,2	111,1	25,4	42,6	35,8	46,4	9,6	9,7	3,5	0,4	131,0	74,7	12,3	1 230,5	264,6	6,77
R10	476 526	1 379 984	Farim	80,6	76,2	87,6	18,4	29,9	28,9	35,5	6,7	4,7	1,8	0,2	56,6	32,3	6,9	608,7	155,4	8,92
R11	467 479	1 379 940	Ufude	53,3	39,5	53,3	5,8	21,3	15,3	21,6	2,2	1,5	1,6	0,1	20,8	11,9	3,0	812,2	263,0	7,43
R12	467 098	1 381 200	Sandjal	40,3	36,7	16,2	3,2	16,2	13,6	6,1	1,2	0,7	1,0	0,0	8,6	4,9	1,4	774,7	143,2	6,81
R13	467 156	1 377 649	Cancenha	105,6	47,6	114,1	13,4	42,1	16,8	45,3	5,1	4,3	2,0	0,2	56,0	31,9	4,8	1 000,0	174,6	7,30
R14	475 929	1 376 653	Saliquenhedim (K3)	56,4	39,2	80,9	13,5	20,5	14,1	31,3	4,1	1,8	1,0	0,1	31,0	17,7	4,3	561,2	139,6	6,80
R15	474 211	1 383 392	Sara Loba	109,3	111,1	92,0	23,6	46,2	47,5	39,6	9,8	26,7	7,2	1,2	558,5	318,4	37,0	1 284,8	403,0	13,13
R16	472 140	1 384 558	Urqui (Seidi)	52,9	49,8	33,1	5,7	21,9	20,3	13,0	2,3	5,1	3,0	0,2	31,5	17,9	6,2	780,3	258,6	13,11
R17	478 600	1 384 226	Sancalanco	48,4	60,0	56,1	9,8	20,2	24,9	21,7	3,9	8,4	2,1	0,3	142,2	81,0	8,9	814,8	188,3	3,02
R18	479 054	1 381 010	Fafaco	53,2	48,1	68,2	10,2	21,5	20,5	29,9	3,9	3,7	1,7	0,2	35,6	20,3	4,7	628,8	169,2	4,17
R19	466 182	1 381 270	Tambandinto	28,8	29,8	7,7	2,0	10,7	11,1	2,8	0,8	0,4	0,6	0,0	4,2	2,4	0,8	523,8	73,0	4,89
R20	469 292	1 385 691	Sintchan Maudie	27,7	24,3	22,0	2,2	11,3	10,7	8,1	0,9	0,7	1,4	0,1	4,9	2,8	1,9	458,9	132,1	4,69
R21	480 633	1 384 258	Bolumbato	39,9	47,9	40,3	7,0	15,5	19,7	15,9	2,8	5,1	1,6	0,2	79,1	45,1	5,3	454,0	109,8	2,82
R22	473 104	1 375 236	Tungina	49,3	25,9	59,4	6,6	18,3	8,8	22,4	2,3	1,2	1,1	0,1	21,8	12,4	2,2	436,7	155,2	4,01

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(4) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(4) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:

- No effects of impact
- Low effects of impact - more than 10% of the guideline value.
- Medium effect of impact - Guideline value exceeded but result below the lowest interim target value.
- Moderate effect of impact - Guideline value and lowest interim target value exceeded
- Hight effect of impact - Guideline value and lowest interim target value exceeded; or only guideline value exceeded

Knight Piésold CONSULTING

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.4
Dispersion results from emissions of the project in discrete receptors - Scenario 4 (Year 25)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3				$PM_{2.5}$ µg/m^3				SO_2 µg/m^3			NO_x µg/m^3	NO_2 µg/m^3		CO µg/m^3		PM_{10} deposition mg/m^2.day
				3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years 1 hour 98th	3 years average	1 hour - Rank 1 of 3 years	8 hour - Rank 1 of 3 years	3 years 24 hour (Rank 1)
R2	473 539	1 380 590	Bani	95,3	90,8	86,1	19,3	33,8	33,1	30,8	6,9	14,3	3,7	0,6	262,3	149,5	17,9	871,8	314,9	8,83
R7	471 451	1 384 269	Canico Tumanna	47,3	68,6	23,9	4,8	16,6	24,2	8,4	1,7	6,6	2,3	0,2	47,4	27,0	5,7	667,5	200,0	9,96
R8	475 307	1 381 393	Army Base (Nema)	63,7	63,8	47,0	11,6	22,5	22,5	18,6	4,0	9,3	2,7	0,3	155,0	88,3	10,5	798,3	207,4	7,40
R9	475 727	1 380 498	Nema	56,7	53,8	74,2	11,3	19,8	18,0	24,7	3,7	7,3	2,3	0,3	101,7	57,9	8,4	606,5	276,0	7,45
R10	476 526	1 379 984	Farim	52,7	52,6	55,9	9,2	17,6	16,2	20,9	2,9	4,6	1,9	0,2	52,7	30,0	5,7	740,5	210,8	5,04
R11	467 479	1 379 940	Ufude	125,9	67,7	121,7	11,5	44,5	23,9	43,4	4,1	14,9	5,2	0,4	108,0	61,6	13,4	1 710,8	370,4	12,04
R12	467 098	1 381 200	Sandjal	56,4	46,2	51,4	4,5	20,3	16,7	18,0	1,6	3,5	2,9	0,2	20,6	11,7	5,0	1 562,4	317,3	11,21
R13	467 156	1 377 649	Cancenha	127,6	26,8	164,8	15,1	45,6	10,4	58,8	5,5	14,9	4,6	0,5	213,0	121,4	13,5	1 275,1	419,2	7,15
R14	475 929	1 376 653	Saliquenhedim (K3)	37,9	31,3	47,2	10,2	12,1	8,9	16,2	2,9	1,2	0,8	0,1	23,9	13,6	3,6	412,0	101,4	6,23
R15	474 211	1 383 392	Sara Loba	55,5	44,9	74,3	8,9	19,9	16,3	26,2	3,2	10,0	2,8	0,3	161,2	91,9	10,1	1 019,2	239,7	8,01
R16	472 140	1 384 558	Urqui (Seidi)	47,7	62,1	27,8	5,0	16,8	21,7	9,8	1,8	7,1	2,3	0,2	62,8	35,8	6,1	646,8	190,9	3,61
R17	478 600	1 384 226	Sancalanco	30,4	41,4	26,8	4,8	10,8	14,7	8,9	1,7	4,7	1,4	0,2	68,4	39,0	4,6	652,3	115,7	3,09
R18	479 054	1 381 010	Fafaco	32,8	37,2	39,8	5,1	12,0	13,0	14,5	1,7	3,7	1,3	0,1	33,4	19,0	3,8	428,0	178,0	2,49
R19	466 182	1 381 270	Tambandinto	31,8	19,2	18,6	2,3	11,1	7,1	6,6	0,8	0,7	1,7	0,1	4,8	2,7	2,2	970,5	319,8	5,73
R20	469 292	1 385 691	Sintchan Maudie	22,3	22,1	4,2	1,7	8,0	7,8	1,5	0,6	0,6	1,0	0,1	3,3	1,9	1,8	686,0	160,2	7,18
R21	480 633	1 384 258	Bolumbato	20,7	21,4	18,8	3,3	7,3	8,1	6,8	1,1	3,3	0,9	0,1	39,0	22,2	3,1	327,6	105,5	6,09
R22	473 104	1 375 236	Tungina	30,4	9,6	56,8	3,4	11,7	3,6	20,3	1,2	1,0	0,8	0,1	16,5	9,4	1,8	282,0	86,1	2,71

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(1) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(2) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:

- No effects of impact
- Low effects of impact - more than 10% of the guideline value.
- Medium effect of impact - Guideline value exceeded but result below the lowest interim target value.
- Moderate effect of impact - Guideline value and lowest interim target value exceeded
- Hight effect of impact - Guideline value and lowest interim target value exceeded; or only guideline value exceeded

Knight Piésold CONSULTING

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.5
Dispersion results from emissions of the project in discrete receptors for Access Road and Port Site

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3				$PM_{2.5}$ µg/m^3				SO_2 µg/m^3			NO_x µg/m^3	NO_2 µg/m^3		CO µg/m^3		PM_{10} deposition mg/m^2.day
				3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 24 hour 98th	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years 1 hour 98th	3 years average	1 hour - Rank 1 of 3 years	8 hour - Rank 1 of 3 years	3 years 24 hour (Rank 1)
R23	472 111	1 373 945	Mandinga	43,1	15,6	53,0	5,7	21,3	6,0	21,9	2,4	3,2	3,0	0,2	33,1	18,9	2,8	1 189,0	223,0	2,54
R24	476 318	1 373 422	Colimessen Cunda	24,1	16,7	32,9	4,6	10,8	6,0	13,9	1,5	1,0	1,2	0,1	12,8	7,3	1,5	537,8	158,2	2,43
R25	476 727	1 369 836	Djalicunda	13,4	5,9	17,4	2,9	5,6	1,9	6,4	0,9	0,4	0,6	0,0	5,7	3,2	0,7	498,1	71,9	2,62
R26	478 044	1 366 292	Bironqui	13,5	8,7	16,4	3,7	3,9	2,2	4,9	1,0	0,5	0,2	0,0	9,3	5,3	0,7	321,6	53,6	2,34
R27	479 863	1 363 349	Calingue Fula	9,2	5,0	11,3	2,3	2,5	1,3	3,2	0,6	0,2	0,1	0,0	3,5	2,0	0,3	93,3	17,4	1,63
R28	481 403	1 359 002	Mansaba	8,5	7,7	10,6	2,3	2,2	1,9	2,7	0,6	0,3	0,2	0,0	5,4	3,1	0,4	152,3	27,2	3,03
R29	481 019	1 357 093	Mansaba-Sutu	10,2	8,1	12,2	2,6	2,6	2,1	3,1	0,7	0,4	0,2	0,0	6,2	3,5	0,4	107,0	20,6	1,70
R30	480 274	1 355 429	Serraco	9,4	7,6	10,6	3,3	2,5	1,9	2,9	0,8	0,4	0,1	0,0	6,7	3,8	0,5	114,8	16,8	1,54
R31	478 415	1 353 750	Manbonco	8,6	5,7	8,6	2,6	2,2	1,5	2,4	0,7	0,4	0,1	0,0	6,8	3,8	0,4	95,2	21,3	1,60
R32	474 753	1 345 041	Cutia	5,1	3,0	5,4	1,5	1,3	0,8	1,4	0,4	0,3	0,2	0,0	3,4	1,9	0,2	71,7	9,9	1,07
R33	470 457	1 340 690	Querene	4,8	3,0	5,9	1,1	1,2	0,8	1,5	0,3	0,4	0,2	0,0	3,6	2,0	0,2	139,2	18,5	1,41
R34	470 122	1 340 110	Cureyni	5,4	4,4	7,4	1,2	1,4	1,1	1,9	0,3	0,4	0,2	0,0	4,2	2,4	0,2	88,8	12,3	2,64
R35	469 887	1 339 748	Cussac	6,8	7,6	8,0	1,5	1,7	1,9	2,0	0,4	0,5	0,3	0,0	5,1	2,9	0,3	113,8	18,1	2,64
R36	469 086	1 338 540	San Saunto	5,5	5,9	6,6	1,8	1,4	1,5	1,7	0,4	0,5	0,2	0,0	5,0	2,9	0,3	71,6	11,5	2,40
R37	465 535	1 334 500	Mansoa	5,9	4,2	6,4	2,5	1,5	1,1	1,6	0,6	0,7	0,4	0,1	6,7	3,8	0,5	62,1	12,5	1,68
R38	463 910	1 332 112	-	23,0	11,9	27,7	6,4	5,8	3,0	7,0	1,6	1,5	0,5	0,1	19,9	11,3	1,3	406,6	60,0	2,82
R39	463 997	1 331 985	-	13,2	7,1	15,6	4,4	3,3	1,8	3,9	1,1	1,1	0,6	0,1	12,1	6,9	0,9	136,1	24,2	1,94
R40	463 691	1 331 694	-	8,0	3,3	8,9	2,1	2,0	0,8	2,3	0,5	1,1	0,5	0,1	7,7	4,4	0,5	119,2	17,5	1,35
R41	462 525	1 330 718	-	5,4	4,2	6,6	1,2	1,4	1,1	1,7	0,3	1,2	0,7	0,1	6,9	3,9	0,4	67,7	13,7	1,51
R42	461 739	1 330 377	-	4,9	5,3	6,3	1,7	1,2	1,4	1,6	0,4	1,4	0,7	0,1	7,3	4,2	0,5	86,0	13,2	2,29
R43	458 118	1 328 830	Uaque	4,5	4,9	5,7	1,7	1,1	1,2	1,4	0,4	1,4	1,1	0,1	6,8	3,9	0,5	61,5	9,5	1,84
R44	454 657	1 327 513	-	5,6	4,8	8,3	1,5	1,4	1,2	2,1	0,4	0,7	1,1	0,1	5,2	3,0	0,5	140,1	21,5	3,11
R45	454 534	1 327 343	-	5,6	4,2	6,8	1,3	1,4	1,1	1,7	0,3	0,7	1,2	0,1	5,3	3,0	0,5	88,3	14,5	3,27
R46	454 145	1 327 269	-	5,6	6,2	6,0	1,2	1,4	1,6	1,5	0,3	0,6	1,3	0,1	4,8	2,7	0,4	85,4	13,5	2,15
R47	454 166	1 327 003	-	3,3	2,5	3,8	1,0	0,9	0,7	1,0	0,3	0,5	1,4	0,1	4,0	2,3	0,4	62,0	10,7	1,42
R48	453 322	1 326 752	-	8,5	8,5	10,4	2,3	2,2	2,2	2,6	0,6	0,8	1,3	0,1	7,6	4,3	0,6	131,8	27,2	2,51
R49	453 191	1 326 681	-	9,1	9,5	10,5	2,6	2,4	2,4	2,6	0,7	0,8	1,2	0,1	7,9	4,5	0,7	173,5	30,6	2,43
R50	453 100	1 326 631	-	9,8	10,9	9,8	3,0	2,5	2,8	2,5	0,8	0,8	1,2	0,1	8,6	4,9	0,7	266,5	40,3	2,65
R51	452 990	1 326 599	-	15,5	19,3	15,6	4,1	3,9	4,9	3,9	1,0	1,0	1,2	0,1	11,4	6,5	0,9	322,8	46,6	3,31
R52	452 798	1 326 487	-	19,3	10,4	19,8	5,7	4,9	2,6	5,0	1,5	1,0	1,2	0,1	15,9	9,1	1,2	371,1	47,5	2,91
R53	451 373	1 325 821	Dugal	5,1	3,0	5,4	0,7	1,3	0,8	1,4	0,2	0,4	1,5	0,1	2,3	1,3	0,3	76,9	16,8	3,22
R54	451 451	1 325 785	Dugal	5,2	3,8	6,4	1,1	1,4	1,0	1,6	0,3	0,4	1,6	0,1	3,3	1,9	0,4	121,2	22,3	2,23
R55	451 379	1 325 741	Dugal	4,9	3,4	5,7	0,9	1,3	0,9	1,5	0,2	0,4	1,6	0,1	2,8	1,6	0,3	86,3	17,6	1,82
R56	451 764	1 325 439	-	6,5	5,2	4,6	1,5	1,6	1,4	1,2	0,4	0,6	1,1	0,1	3,7	2,1	0,5	152,4	30,1	2,38
R57	451 724	1 325 217	-	3,5	3,2	3,6	1,3	0,9	0,9	0,9	0,3	0,6	1,3	0,1	3,7	2,1	0,5	78,4	14,8	1,98
R58	452 239	1 325 348	-	3,9	3,5	4,5	1,5	1,1	1,0	1,2	0,4	0,6	1,5	0,1	4,0	2,3	0,5	100,1	15,6	1,43
R59	451 954	1 324 457	-	3,7	3,4	4,2	1,5	1,0	0,9	1,1	0,4	1,4	2,0	0,1	4,8	2,7	0,6	85,1	13,2	0,94
R60	453 350	1 324 081	Cunteda	6,3	5,6	6,4	2,0	1,6	1,4	1,6	0,5	3,8	2,7	0,2	12,7	7,2	0,9	95,3	24,3	1,78
R61	453 361	1 323 771	Cunteda	10,1	9,9	10,3	2,7	2,6	2,6	2,6	0,7	4,7	2,9	0,2	20,5	11,7	1,2	104,6	31,8	2,50
R62	453 616	1 323 520	Cunteda	7,5	7,9	7,1	2,2	2,0	2,1	1,8	0,6	6,4	2,9	0,3	30,9	17,6	1,4	82,1	18,4	2,22
R63	453 272	1 323 441	Cunteda	7,5	8,6	7,3	2,8	2,0	2,3	1,9	0,7	6,0	3,3	0,3	24,8	14,1	1,4	105,1	22,7	2,15
R64	452 801	1 322 155	Arote	5,3	4,6	5,8	1,6	1,5	1,2	1,6	0,4	8,8	5,6	0,4	35,4	20,2	1,8	146,0	23,3	1,11
R65	452 894	1 322 028	Arote	6,7	5,6	6,9	2,1	1,8	1,5	1,9	0,6	8,8	5,3	0,4	47,2	26,9	2,1	184,5	38,7	1,19
R66	452 923	1 321 807	-	10,8	10,5	10,6	4,4	2,9	2,9	2,7	1,2	10,1	6,1	0,5	66,7	38,0	2,9	168,5	44,5	2,48
R67	452 421	1 321 384	-	5,4	4,4	6,7	1,4	1,5	1,4	1,8	0,4	11,2	6,5	0,5	37,4	21,3	2,2	163,3	33,4	1,50
R68	452 429	1 320 949	Ancone	7,8	6,5	8,5	2,4	2,2	1,8	2,4	0,7	17,8	9,0	0,7	72,6	41,4	3,1	280,1	58,3	1,80
R69	452 474	1 320 599	Village Chief	11,8	10,4	12,8	3,6	3,2	3,0	3,4	1,0	24,2	9,7	0,9	156,1	89,0	5,1	291,6	87,3	2,06
R70	452 716	1 320 121	Fishing Beach	7,1	7,9	6,7	3,0	2,6	2,6	2,6	1,1	62,9	21,6	4,8	407,9	232,5	54,4	798,5	138,4	2,10

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

[a/] Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

[c/] Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:

- No effects of impact
- Low effects of impact - more than 10% of the guideline value.
- Medium effect of impact - Guideline value exceeded but result below the lowest interim target value.
- Moderate effect of impact - Guideline value and lowest interim target value exceeded
- Hight effect of impact - Guideline value and lowest interim target value exceeded; or only guideline value exceeded

Knight Piésold CONSULTING

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.1
Air quality forecast in discrete receptors for Mine Site - Scenario 1 (Year 2)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3			$PM_{2.5}$ µg/m^3			SO_2 µg/m^3			NO_2 µg/m^3	
				Wet season (1) 24 hour 98th	Dry season (2) 24 hour 98th	3 years average	Wet season (1) 24 hour 98th	Dry season (2) 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years average
R2	473 539	1 380 590	Bani	118,6	207,2	101,8	41,7	54,8	25,0	9,8	6,0	2,0	57,0	14,5
R7	471 451	1 384 269	Canico Tumanna	44,9	134,5	73,5	33,5	28,1	14,7	2,1	2,3	1,4	9,3	4,6
R8	475 307	1 381 393	Army Base (Nema)	102,8	182,9	87,9	32,1	45,1	20,1	16,1	6,3	1,9	86,3	12,8
R9	475 727	1 380 498	Nema	119,4	199,7	97,0	38,5	55,1	23,7	30,5	8,9	2,6	345,4	24,6
R10	476 526	1 379 984	Farim	112,6	234,5	93,9	32,9	64,2	22,5	26,4	7,8	2,4	287,8	21,5
R11	467 479	1 379 940	Ufude	45,6	141,2	74,2	8,5	30,5	14,9	2,5	2,1	1,4	11,8	4,5
R12	467 098	1 381 200	Sandjal	41,8	129,9	73,1	8,2	26,4	14,5	2,0	2,2	1,4	7,1	4,3
R13	467 156	1 377 649	Cancenha	54,6	178,5	78,1	13,4	43,6	16,4	3,3	2,5	1,5	19,4	5,1
R14	475 929	1 376 653	Saliquenhedim (K3)	63,7	249,4	87,4	15,1	75,0	19,2	13,1	6,7	1,9	76,7	12,0
R15	474 211	1 383 392	Sara Loba	55,2	145,5	77,1	13,9	32,2	16,1	2,9	3,1	1,5	22,7	6,0
R16	472 140	1 384 558	Urqui (Seidi)	46,2	140,9	73,5	9,6	29,8	14,7	2,1	2,2	1,4	9,3	4,6
R17	478 600	1 384 226	Sancalanco	60,5	159,0	77,1	15,9	36,9	16,1	7,6	3,5	1,6	31,8	7,2
R18	479 054	1 381 010	Fafaco	67,6	165,4	80,9	18,5	42,5	17,5	13,1	4,4	1,8	113,3	10,6
R19	466 182	1 381 270	Tambandinto	35,2	128,4	72,4	5,3	25,7	14,3	1,8	1,8	1,4	5,2	4,1
R20	469 292	1 385 691	Sintchan Maudie	31,4	129,1	72,2	4,3	25,9	14,2	1,7	1,9	1,4	5,2	4,2
R21	480 633	1 384 258	Bolumbato	50,9	157,9	75,9	12,2	37,7	15,7	7,5	3,3	1,6	33,1	6,8
R22	473 104	1 375 236	Tungina	56,3	205,2	79,5	15,1	55,5	17,1	11,3	5,4	1,7	50,2	9,6

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(1) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(2) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:	PM_{10} and $PM_{2.5}$	SO_2 - 1 hour	SO_2 - 24 hours	SO_2 annual	NO_2	CO
	IT1	-	IT1	-	-	-
	IT2	-	IT2	-	-	-
	IT3	-	-	-	-	-
	Guideline	Guideline	Guideline	Guideline	Guideline	Guideline

Knight Piésold CONSULTING

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.2
Air quality forecast in discrete receptors - Scenario 2 (Year 8)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3			$PM_{2.5}$ µg/m^3			SO_2 µg/m^3			NO_2 µg/m^3	
				Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years average
R2	473 539	1 380 590	Bani	31,6	150,4	88,0	31,0	47,9	19,6	22,6	6,2	2,3	251,2	19,4
R7	471 451	1 384 269	Canico Tumanna	67,7	128,1	72,7	8,7	25,3	14,4	2,3	2,4	1,4	9,6	4,8
R8	475 307	1 381 393	Army Base (Nema)	87,8	140,7	81,6	21,3	40,0	17,3	11,0	3,6	1,8	114,4	11,4
R9	475 727	1 380 498	Nema	78,4	144,3	86,4	24,9	40,5	18,8	12,1	4,1	2,0	131,9	13,8
R10	476 526	1 379 984	Farim	32,3	143,3	85,8	23,9	47,1	18,5	11,1	4,2	1,9	114,8	12,1
R11	467 479	1 379 940	Ufude	37,1	128,3	72,6	8,9	25,8	14,4	2,3	2,5	1,4	8,8	4,6
R12	467 098	1 381 200	Sandjal	36,0	129,4	72,2	10,0	24,7	14,2	1,9	2,4	1,4	6,4	4,4
R13	467 156	1 377 649	Cancenha	67,2	129,4	73,5	10,0	33,8	14,7	3,0	2,7	1,5	15,4	5,2
R14	475 929	1 376 653	Saliquenhedim (K3)	49,9	139,2	95,2	19,8	50,4	20,7	7,9	3,9	1,6	59,9	7,6
R15	474 211	1 383 392	Sara Loba	34,1	134,0	74,8	14,6	30,2	15,1	6,0	3,1	1,5	36,8	6,6
R16	472 140	1 384 558	Urqui (Seidi)	43,8	128,5	72,7	9,1	25,0	14,4	2,6	2,4	1,4	10,9	4,8
R17	478 600	1 384 226	Sancalanco	61,8	131,7	75,0	12,3	31,4	15,1	5,4	2,5	1,5	44,6	6,2
R18	479 054	1 381 010	Fafaco	29,0	136,8	78,2	17,4	38,4	16,2	6,9	3,0	1,6	62,7	7,7
R19	466 182	1 381 270	Tambandinto	29,2	126,9	71,9	7,5	24,2	14,1	1,6	2,0	1,4	4,7	4,2
R20	469 292	1 385 691	Sintchan Maudie	43,0	126,1	71,9	6,7	24,1	14,1	1,7	2,0	1,4	4,9	4,2
R21	480 633	1 384 258	Bolumbato	60,2	131,5	74,5	12,1	34,2	15,0	4,7	2,4	1,5	36,6	5,7
R22	473 104	1 375 236	Tungina	20,0	137,4	79,5	18,0	50,3	16,8	7,7	3,9	1,6	58,5	7,6

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(1/) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(2/) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:	PM_{10} and $PM_{2.5}$	SO_2 - 1 hour	SO_2 - 24 hours	SO_2 annual	NO_2	CO
	IT1	-	IT1	-	-	-
	IT2	-	IT2	-	-	-
	IT3	-	-	-	-	-
	Guideline	Guideline	Guideline	Guideline	Guideline	Guideline

Knight Piésold CONSULTING

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.3
Air quality forecast in discrete receptors - Scenario 3 (Year 15)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3			$PM_{2.5}$ µg/m^3			SO_2 µg/m^3			NO_2 µg/m^3	
				Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years average
R2	473 539	1 380 590	Bani	168,4	442,1	136,8	62,0	161,2	40,2	31,0	11,1	2,5	291,0	37,2
R7	471 451	1 384 269	Canico Tumanna	67,0	154,2	76,8	22,1	36,9	16,1	5,0	4,6	1,6	19,0	9,3
R8	475 307	1 381 393	Army Base (Nema)	118,8	245,8	101,1	43,3	75,5	25,7	20,3	6,8	2,1	188,8	25,7
R9	475 727	1 380 498	Nema	111,2	234,5	96,7	39,8	70,3	23,4	11,0	4,9	1,8	78,4	16,1
R10	476 526	1 379 984	Farim	96,2	211,0	89,7	32,9	59,4	20,6	6,1	3,2	1,6	36,0	10,6
R11	467 479	1 379 940	Ufude	59,5	176,7	77,1	19,3	45,5	16,1	2,9	2,9	1,5	15,6	6,7
R12	467 098	1 381 200	Sandjal	56,7	139,6	74,5	17,6	30,0	15,1	2,1	2,4	1,4	8,7	5,2
R13	467 156	1 377 649	Cancenha	67,6	237,5	84,7	20,8	69,2	19,0	5,7	3,4	1,5	35,7	8,6
R14	475 929	1 376 653	Saliquenhedim (K3)	59,2	204,3	84,8	18,1	55,2	18,0	3,1	2,3	1,5	21,4	8,1
R15	474 211	1 383 392	Sara Loba	131,1	215,4	94,9	51,5	63,5	23,7	28,1	8,6	2,6	322,1	40,8
R16	472 140	1 384 558	Urqui (Seidi)	69,8	156,5	76,9	24,3	36,9	16,2	6,5	4,3	1,6	21,7	9,9
R17	478 600	1 384 226	Sancalanco	80,0	179,5	81,0	28,9	45,6	17,7	9,8	3,4	1,7	84,8	12,6
R18	479 054	1 381 010	Fafaco	68,1	191,6	81,5	24,5	53,8	17,7	5,0	3,1	1,5	24,0	8,5
R19	466 182	1 381 270	Tambandinto	49,8	131,1	73,3	15,1	26,7	14,6	1,8	1,9	1,4	6,2	4,6
R20	469 292	1 385 691	Sintchan Maudie	44,3	145,4	73,5	14,7	32,0	14,7	2,0	2,8	1,4	6,5	5,7
R21	480 633	1 384 258	Bolumbato	67,9	163,7	78,3	23,7	39,8	16,6	6,5	3,0	1,6	48,8	9,1
R22	473 104	1 375 236	Tungina	45,9	182,8	77,9	12,8	46,3	16,2	2,5	2,5	1,5	16,2	6,0

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(1) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(2) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:	PM_{10} and $PM_{2.5}$	SO_2 - 1 hour	SO_2 - 24 hours	SO_2 annual	NO_2	CO
	IT1	-	IT1	-	-	-
	IT2	-	IT2	-	-	-
	IT3	-	-	-	-	-
	Guideline	Guideline	Guideline	Guideline	Guideline	Guideline

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.4
Air quality forecast in discrete receptors - Scenario 4 (Year 25)

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3			$PM_{2.5}$ µg/m^3			SO_2 µg/m^3			NO_2 µg/m^3	
				Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years average
R2	473 539	1 380 590	Bani	110,8	209,5	90,6	37,1	54,7	20,8	15,6	5,1	2,0	153,3	21,6
R7	471 451	1 384 269	Canico Tumanna	88,6	147,3	76,1	28,2	32,3	15,6	7,9	3,7	1,6	30,8	9,5
R8	475 307	1 381 393	Army Base (Nema)	83,8	170,4	82,9	26,5	42,5	17,9	10,7	4,1	1,7	92,1	14,2
R9	475 727	1 380 498	Nema	73,8	197,6	82,6	22,0	48,6	17,5	8,6	3,6	1,6	61,7	12,1
R10	476 526	1 379 984	Farim	72,6	179,3	80,4	20,2	44,8	16,8	6,0	3,3	1,6	33,8	9,5
R11	467 479	1 379 940	Ufude	87,7	245,1	82,8	27,9	67,3	18,0	16,3	6,6	1,8	65,3	17,1
R12	467 098	1 381 200	Sandjal	66,2	174,8	75,8	20,7	41,9	15,5	4,8	4,3	1,5	15,5	8,7
R13	467 156	1 377 649	Cancenha	46,8	288,2	86,4	14,4	82,7	19,3	16,3	6,0	1,8	125,1	17,2
R14	475 929	1 376 653	Saliquenhedim (K3)	51,3	170,6	81,5	12,9	40,1	16,7	2,6	2,2	1,5	17,4	7,3
R15	474 211	1 383 392	Sara Loba	64,9	197,7	80,2	20,3	50,1	17,1	11,4	4,2	1,7	95,6	13,9
R16	472 140	1 384 558	Urqui (Seidi)	82,1	151,2	76,3	25,7	33,7	15,6	8,5	3,7	1,6	39,5	9,9
R17	478 600	1 384 226	Sancalanco	61,4	150,2	76,1	18,7	32,8	15,5	6,1	2,8	1,5	42,7	8,4
R18	479 054	1 381 010	Fafaco	57,2	163,2	76,4	17,0	38,4	15,6	5,1	2,7	1,5	22,8	7,5
R19	466 182	1 381 270	Tambandinto	39,2	142,0	73,6	11,1	30,5	14,7	2,1	3,0	1,5	6,5	6,0
R20	469 292	1 385 691	Sintchan Maudie	42,1	127,6	73,0	11,8	25,4	14,5	2,0	2,4	1,4	5,7	5,5
R21	480 633	1 384 258	Bolumbato	41,4	142,2	74,6	12,1	30,7	15,0	4,7	2,3	1,5	26,0	6,8
R22	473 104	1 375 236	Tungina	29,6	180,2	74,6	7,6	44,2	15,0	2,4	2,2	1,4	13,2	5,6

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

(1) Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

(2) Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:	PM_{10} and $PM_{2.5}$	SO_2 - 1 hour	SO_2 - 24 hours	SO_2 annual	NO_2	CO
	IT1	-	IT1	-	-	-
	IT2	-	IT2	-	-	-
	IT3	-	-	-	-	-
	Guideline	Guideline	Guideline	Guideline	Guideline	Guideline

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.5
Air quality forecast in discrete receptors for Access Road and Port Site

Code	East - X (m)	North - Y (m)	Receptor	PM_{10} µg/m^3			$PM_{2.5}$ µg/m^3			SO_2 µg/m^3			NO_2 µg/m^3	
				Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	Wet season 24 hour 98th	Dry season 24 hour 98th	3 years average	3 years 1 hour 99th	3 years 24 hour 99th	3 years average	3 years 1 hour 98th	3 years average
R23	472 111	1 373 945	Mandinga	35,6	176,4	76,5	10,0	45,8	15,8	4,6	4,4	1,5	22,6	6,6
R24	476 318	1 373 422	Colimessen Cunda	36,7	156,3	75,7	10,0	13,9	15,2	2,4	2,6	1,5	11,0	5,2
R25	476 727	1 369 836	Djalicunda	25,9	140,8	74,1	5,9	6,4	14,7	1,8	2,0	1,4	7,0	4,4
R26	478 044	1 366 292	Bironqui	28,7	139,8	75,0	6,2	4,9	14,8	1,9	1,6	1,4	9,0	4,4
R27	479 863	1 363 349	Calingue Fula	25,0	134,7	73,5	5,3	3,2	14,5	1,6	1,5	1,4	5,7	4,1
R28	481 403	1 359 002	Mansaba	27,7	134,0	73,6	5,9	2,7	14,5	1,7	1,5	1,4	6,8	4,1
R29	481 019	1 357 093	Mansaba-Sutu	28,1	135,6	73,9	6,1	3,1	14,5	1,8	1,5	1,4	7,3	4,2
R30	480 274	1 355 429	Serraco	27,6	134,0	74,5	5,9	2,9	14,7	1,8	1,5	1,4	7,6	4,3
R31	478 415	1 353 750	Manbonco	25,7	132,0	73,8	5,5	2,4	14,5	1,8	1,5	1,4	7,6	4,2
R32	474 753	1 345 041	Cutia	23,0	128,8	72,7	4,8	1,4	14,2	1,7	1,5	1,4	5,7	4,0
R33	470 457	1 340 690	Querene	23,0	129,3	72,4	4,8	1,5	14,2	1,8	1,6	1,4	5,8	4,0
R34	470 122	1 340 110	Cureyni	24,4	130,8	72,5	5,1	1,9	14,2	1,8	1,6	1,4	6,1	4,0
R35	469 887	1 339 748	Cussac	27,6	131,4	72,8	5,9	2,0	14,3	1,9	1,6	1,4	6,7	4,0
R36	469 086	1 338 540	San Saunto	25,9	130,0	73,0	5,5	1,7	14,3	1,9	1,6	1,4	6,6	4,1
R37	465 535	1 334 500	Mansoa	24,2	129,8	73,7	5,1	1,6	14,5	2,1	1,8	1,4	7,6	4,3
R38	463 910	1 332 112	-	31,9	151,1	77,7	7,0	7,0	15,5	2,9	1,9	1,5	15,1	5,1
R39	463 997	1 331 985	-	27,1	139,0	75,7	5,8	3,9	15,0	2,5	1,9	1,5	10,7	4,7
R40	463 691	1 331 694	-	23,3	132,3	73,4	4,8	2,3	14,4	2,5	1,9	1,4	8,1	4,3
R41	462 525	1 330 718	-	24,2	130,0	72,5	5,1	1,7	14,2	2,6	2,0	1,4	7,7	4,1
R42	461 739	1 330 377	-	25,3	129,7	73,0	5,4	1,6	14,3	2,8	2,1	1,4	7,9	4,2
R43	458 118	1 328 830	Uaque	24,9	129,1	73,0	5,2	1,4	14,3	2,8	2,4	1,4	7,6	4,3
R44	454 657	1 327 513	-	24,8	131,7	72,8	5,2	2,1	14,3	2,1	2,4	1,4	6,7	4,2
R45	454 534	1 327 343	-	24,2	130,2	72,6	5,1	1,7	14,2	2,1	2,6	1,4	6,8	4,2
R46	454 145	1 327 269	-	26,2	129,4	72,5	5,6	1,5	14,2	2,0	2,6	1,4	6,5	4,2
R47	454 166	1 327 003	-	22,5	127,2	72,3	4,7	1,0	14,1	1,9	2,7	1,4	6,0	4,2
R48	453 322	1 326 752	-	28,5	133,8	73,6	6,2	2,6	14,5	2,1	2,7	1,4	8,1	4,3
R49	453 191	1 326 681	-	29,5	133,9	73,9	6,4	2,6	14,5	2,2	2,6	1,5	8,3	4,4
R50	453 100	1 326 631	-	30,9	133,2	74,3	6,8	2,5	14,6	2,2	2,5	1,5	8,7	4,5
R51	452 990	1 326 599	-	39,3	139,0	75,4	8,9	3,9	14,9	2,3	2,6	1,5	10,3	4,7
R52	452 798	1 326 487	-	30,4	143,2	77,0	6,6	5,0	15,3	2,3	2,6	1,5	12,8	5,0
R53	451 373	1 325 821	Dugal	23,0	128,8	72,0	4,8	1,4	14,1	1,7	2,9	1,4	5,1	4,1
R54	451 451	1 325 785	Dugal	23,8	129,8	72,4	5,0	1,6	14,2	1,8	3,0	1,4	5,6	4,1
R55	451 379	1 325 741	Dugal	23,4	129,1	72,2	4,9	1,5	14,1	1,8	3,0	1,4	5,3	4,1
R56	451 764	1 325 439	-	25,2	128,0	72,7	5,4	1,2	14,2	2,0	2,5	1,4	5,9	4,2
R57	451 724	1 325 217	-	23,2	127,0	72,6	4,9	0,9	14,2	1,9	2,6	1,4	5,8	4,2
R58	452 239	1 325 348	-	23,5	127,9	72,8	5,0	1,2	14,3	2,0	2,9	1,5	6,1	4,3
R59	451 954	1 324 457	-	23,4	127,6	72,8	4,9	1,1	14,2	2,8	3,4	1,5	6,5	4,4
R60	453 350	1 324 081	Cunteda	25,6	129,8	73,3	5,4	1,6	14,4	5,2	4,1	1,5	11,0	4,7
R61	453 361	1 323 771	Cunteda	29,9	133,7	74,0	6,6	2,6	14,6	6,1	4,3	1,6	15,4	4,9
R62	453 616	1 323 520	Cunteda	27,9	130,5	73,5	6,1	1,8	14,5	7,8	4,3	1,6	21,4	5,2
R63	453 272	1 323 441	Cunteda	28,6	130,7	74,1	6,3	1,9	14,6	7,4	4,7	1,6	17,9	5,2
R64	452 801	1 322 155	Arote	24,6	129,2	72,9	5,2	1,6	14,3	10,1	7,0	1,8	23,9	5,6
R65	452 894	1 322 028	Arote	25,6	130,3	73,4	5,5	1,9	14,4	10,2	6,7	1,8	30,7	5,9
R66	452 923	1 321 807	-	30,5	134,0	75,7	6,9	2,7	15,0	11,4	7,4	1,9	41,8	6,7
R67	452 421	1 321 384	-	24,4	130,1	72,6	5,4	1,8	14,3	12,6	7,9	1,9	25,1	5,9
R68	452 429	1 320 949	Ancone	26,5	131,9	73,7	5,8	2,4	14,5	19,2	10,4	2,0	45,1	6,9
R69	452 474	1 320 599	Village Chief	30,4	136,2	74,9	7,0	3,4	14,9	25,5	11,1	2,3	92,7	8,8
R70	452 716	1 320 121	Fishing Beach	27,9	130,1	74,3	6,6	2,6	15,0	64,3	23,0	6,1	236,2	58,1

Prepared by Knight Piésold Consultores.

Notes:

Concentrations has been determined at 2 m of ground height. Dust deposition was calculated for 0 m of groung height.

[1,2] Wet season was selected between 2014/05/01 00:00:00 to 2014/10/31 23:00:00.

[1,2] Dry season was selected between 2013/11/01 00:00:00 to 2014/04/30 23:00:00.

Legend:	PM_{10} and $PM_{2.5}$	SO_2 - 1 hour	SO_2 - 24 hours	SO_2 annual	NO_2	CO
	IT1	-	IT1	-	-	-
	IT2	-	IT2	-	-	-
	IT3	-	-	-	-	-
	Guideline	Guideline	Guideline	Guideline	Guideline	Guideline

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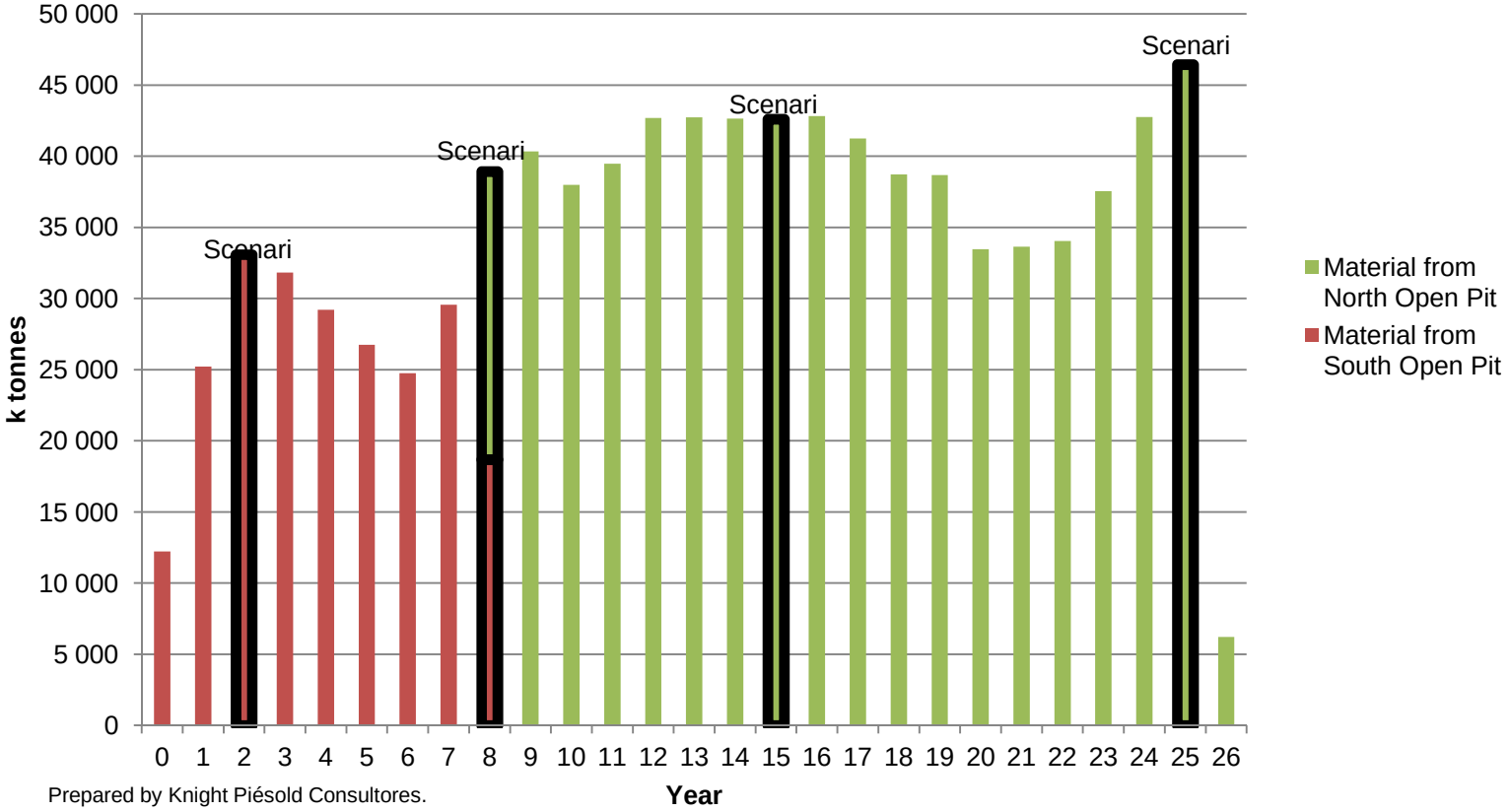
Graphs

GRAPH 4.1
Mining planning - Farim Phosphate Project



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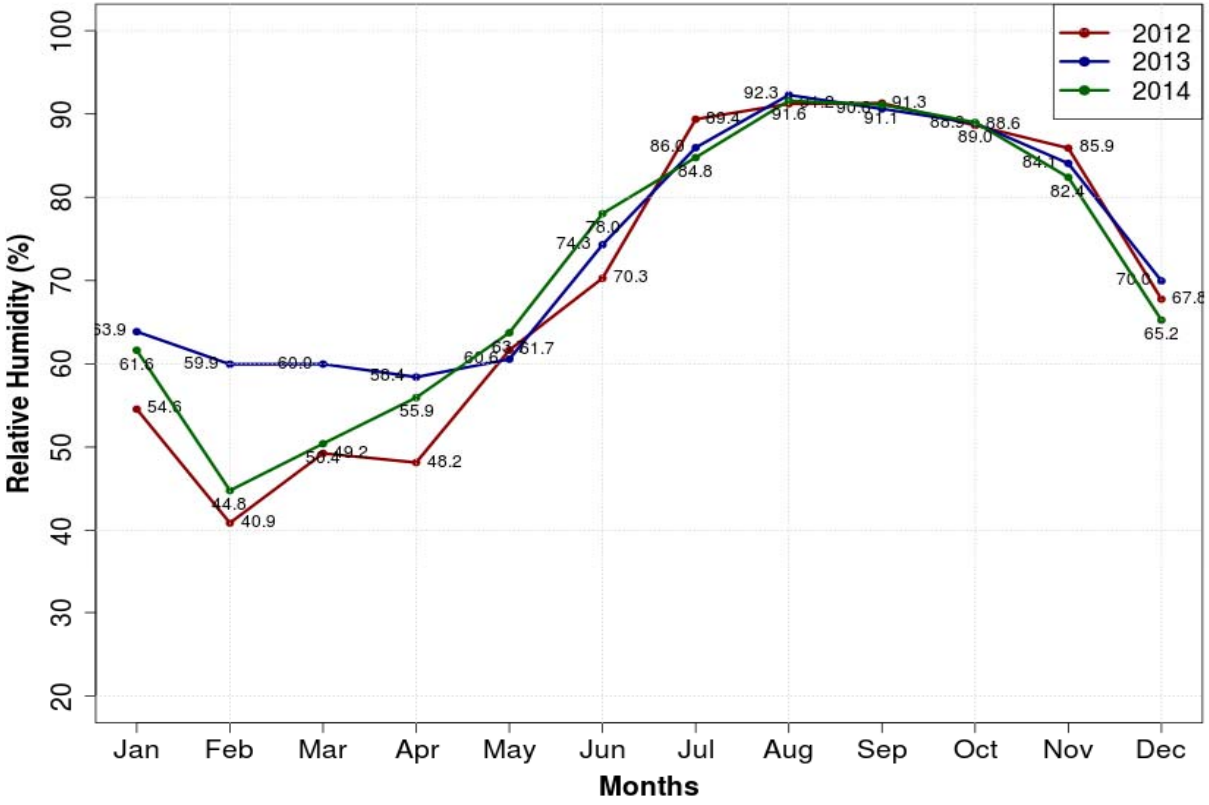
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.2
Relative humidity - Farim weather station



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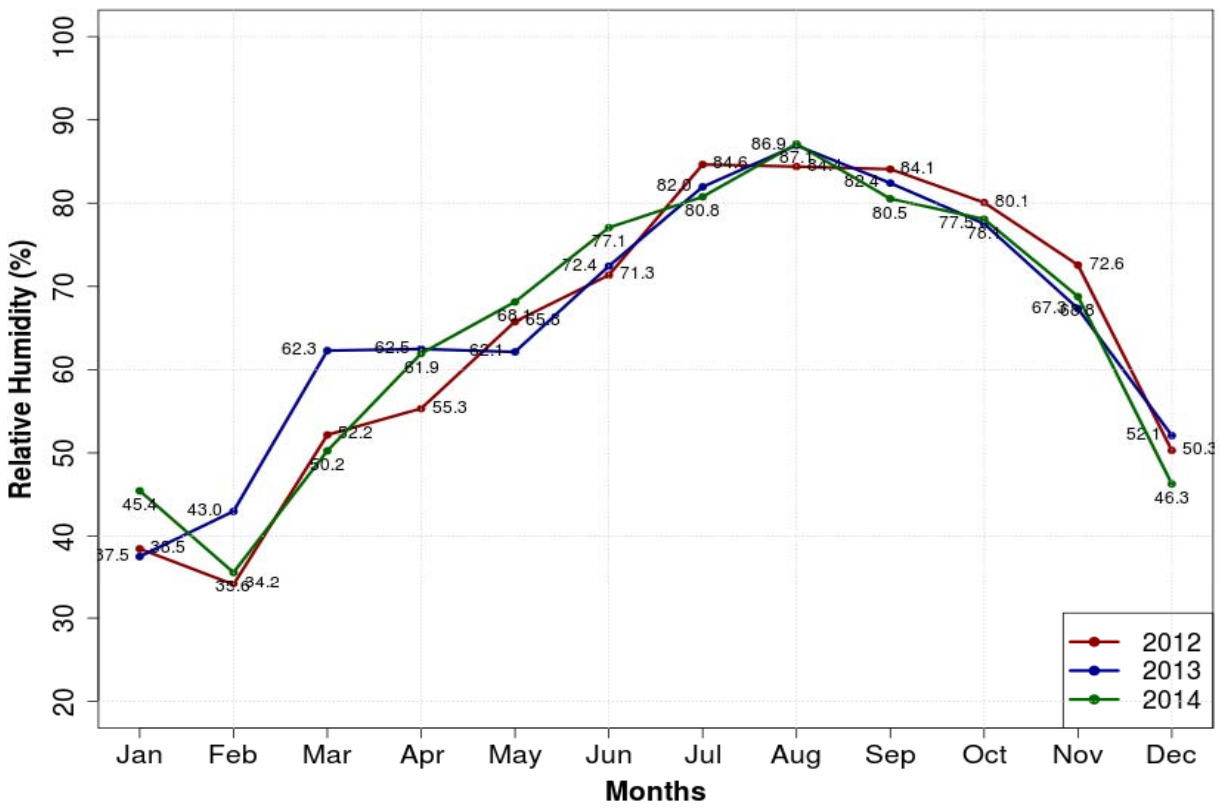
GRAPH 4.3
Relative humidity - GGOV weather station



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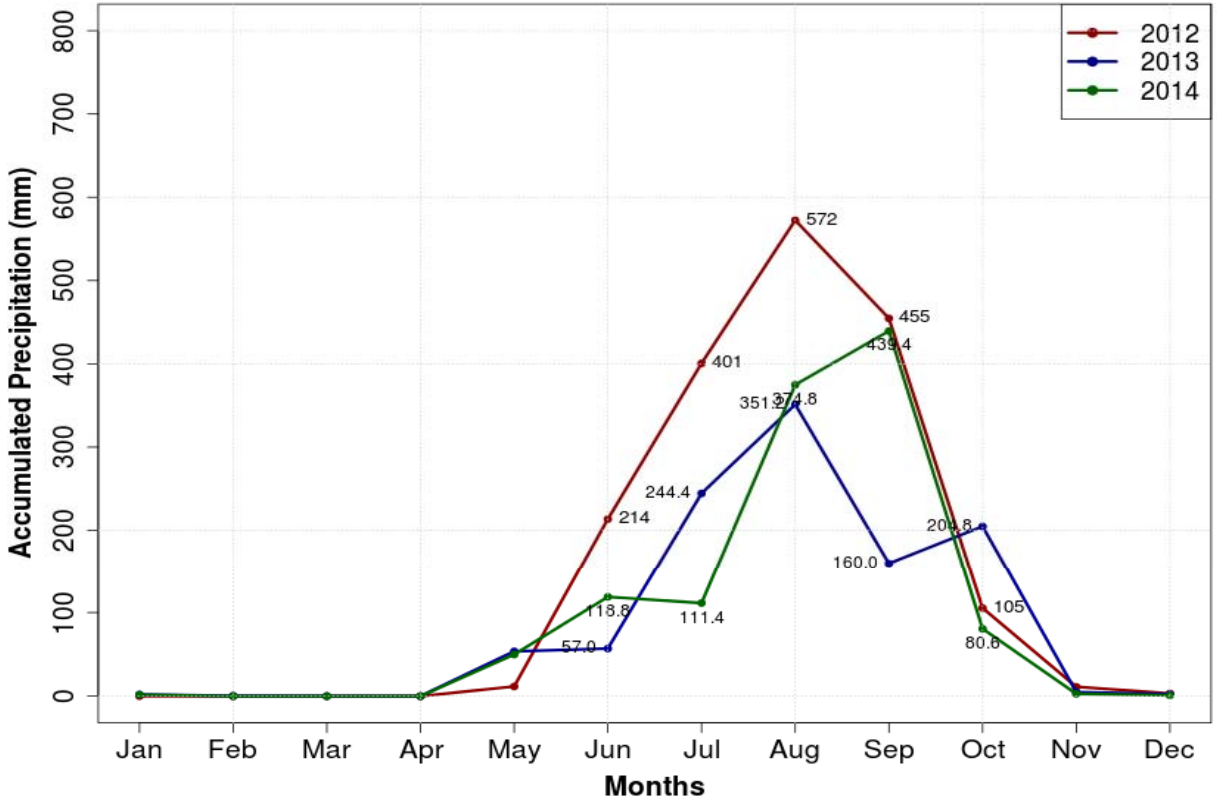
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.4
Rain rate - Farim weather station



Prepared by Knight Piésold Consultores.

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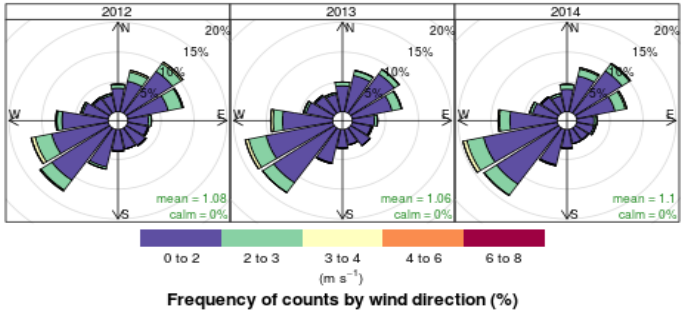
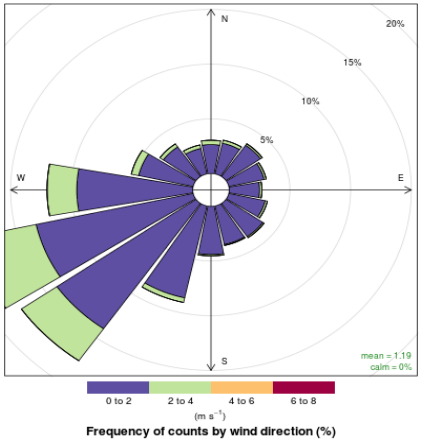
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

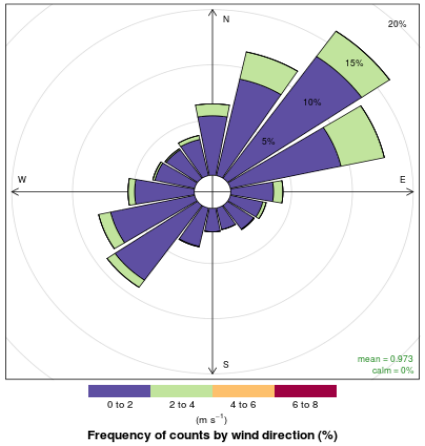
GRAPH 4.5
Wind speed and wind direction - Farim weather station



Wet season (May - Oct)



Dry season (Nov - Apr)



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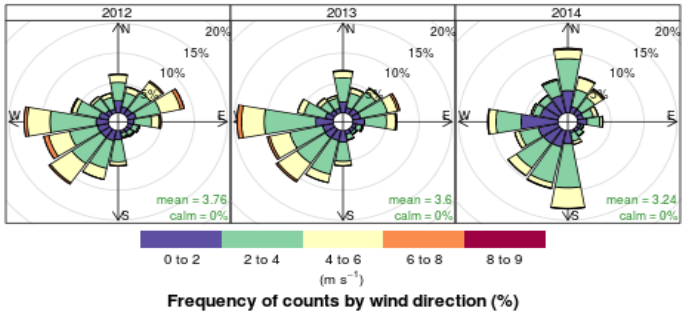
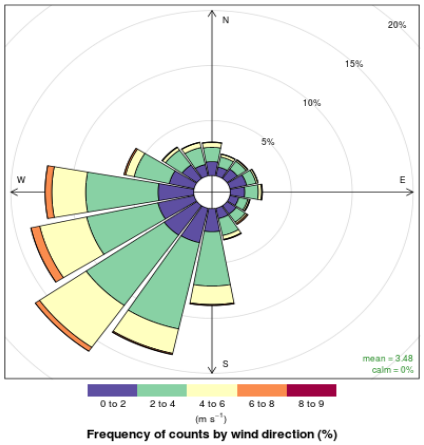
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

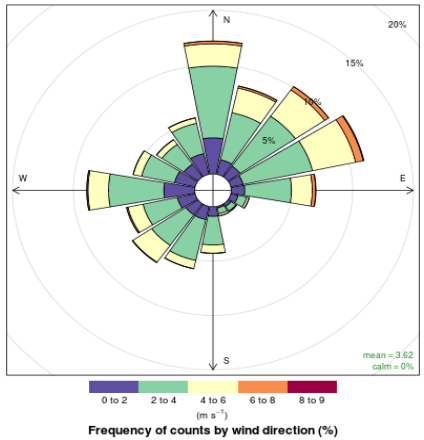
GRAPH 4.6
Wind speed and wind direction - GGOV weather station



Wet season (May - Oct)



Dry season (Nov - Apr)



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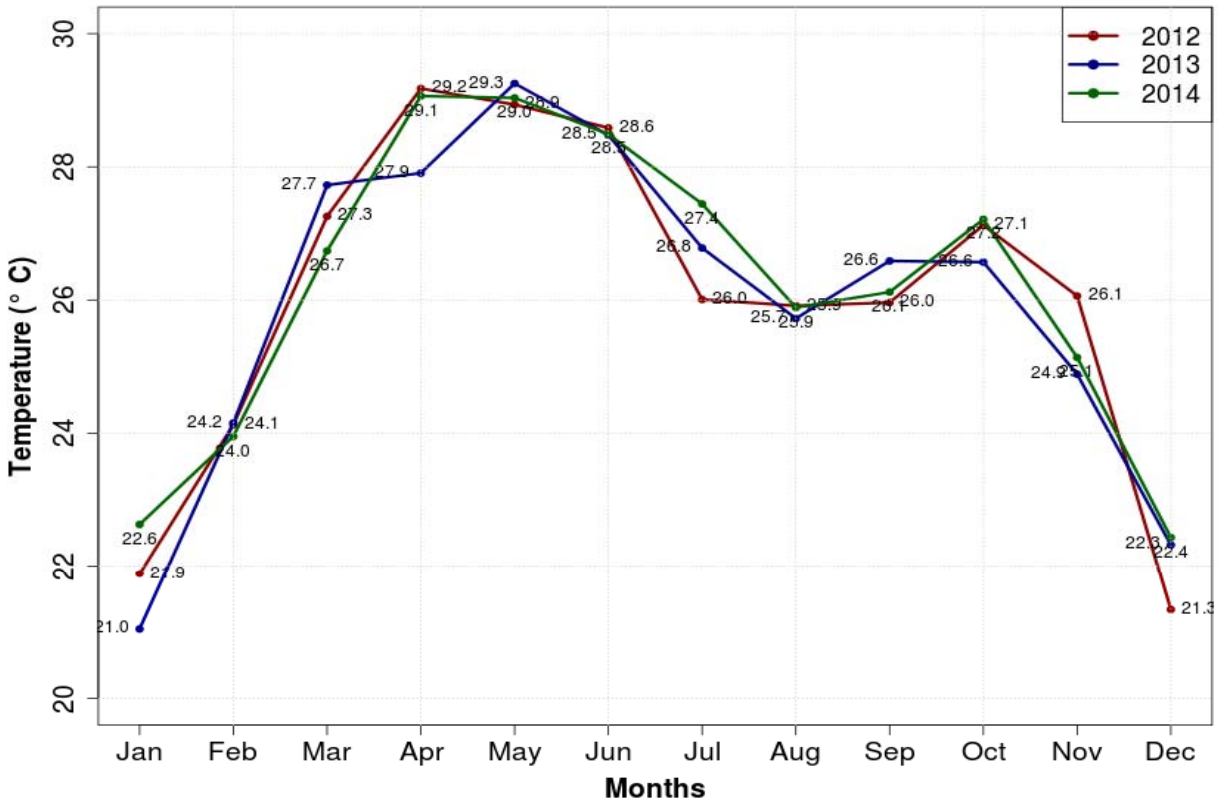
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.7
Temperature - Farim weather station



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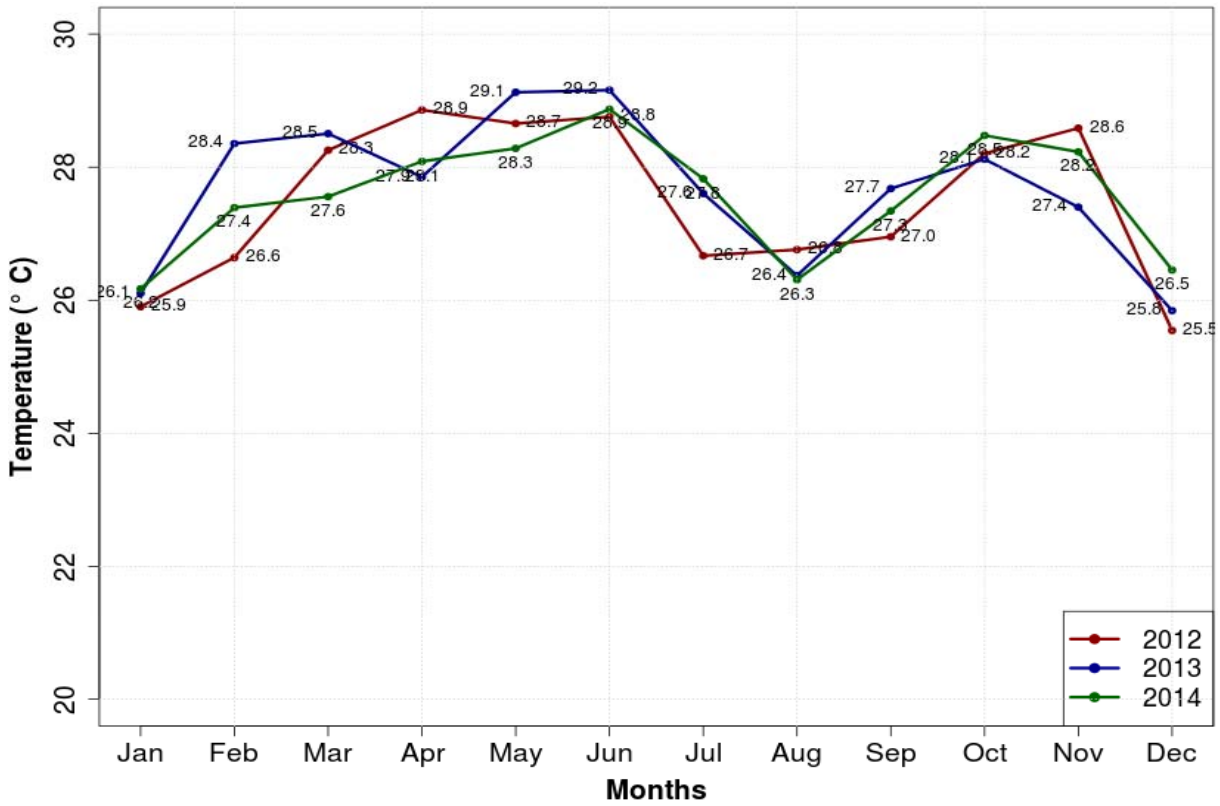
GRAPH 4.8
Temperature - GGOV weather station



Prepared by Knight Piésold Consultores.

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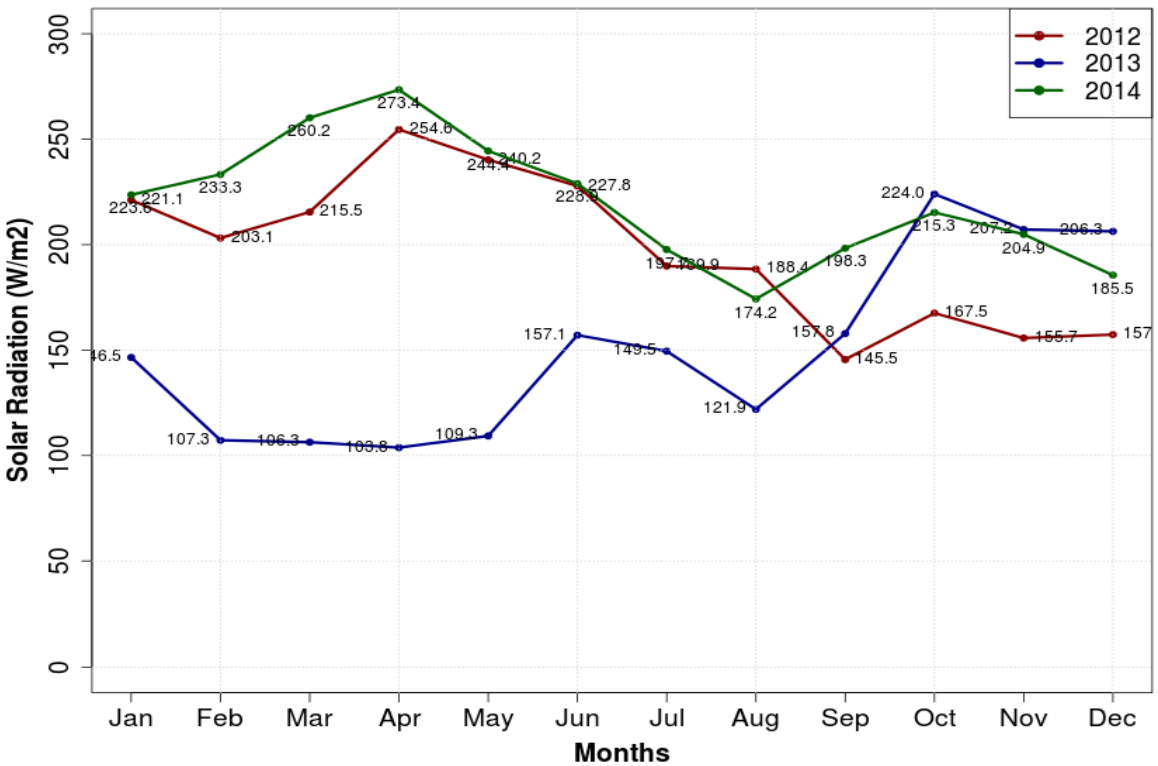
GRAPH 4.9
Solar radiation - GGOV weather station



Prepared by Knight Piésold Consultores.

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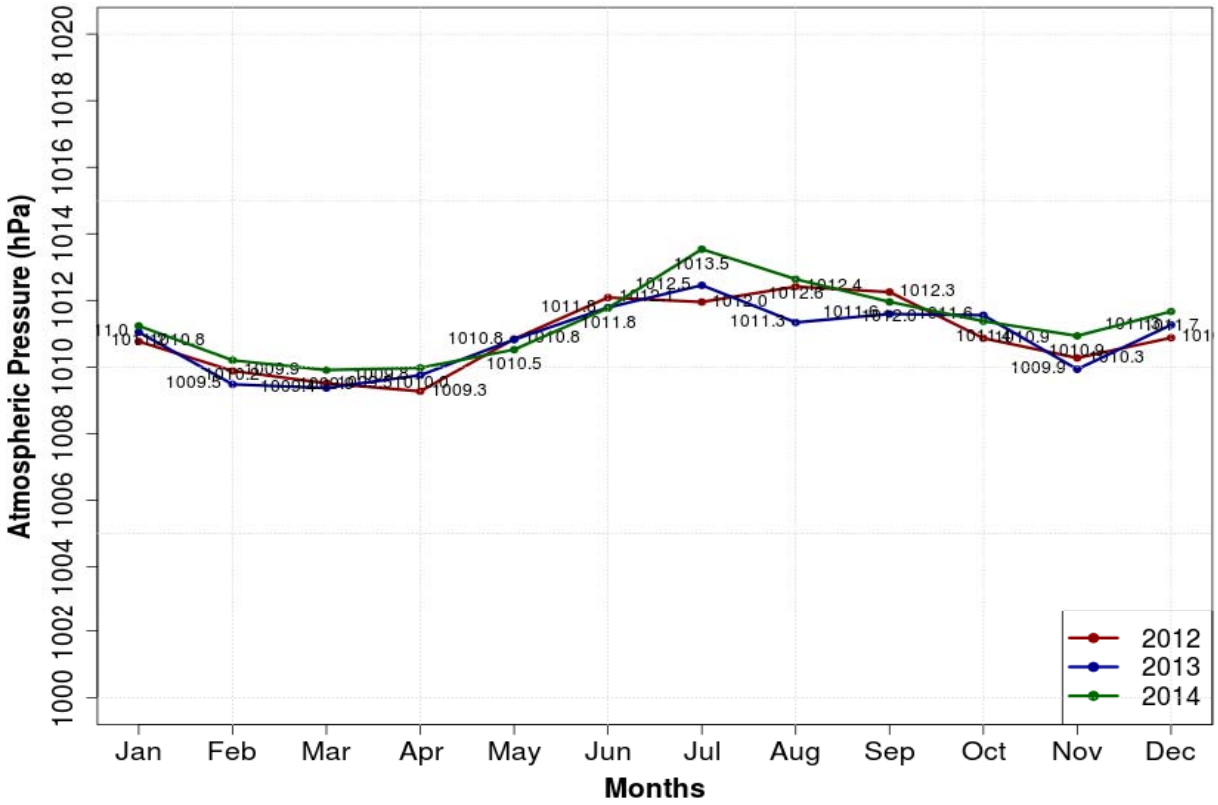
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.10
Atmospheric pressure - Farim weather station



Prepared by Knight Piésold Consultores.

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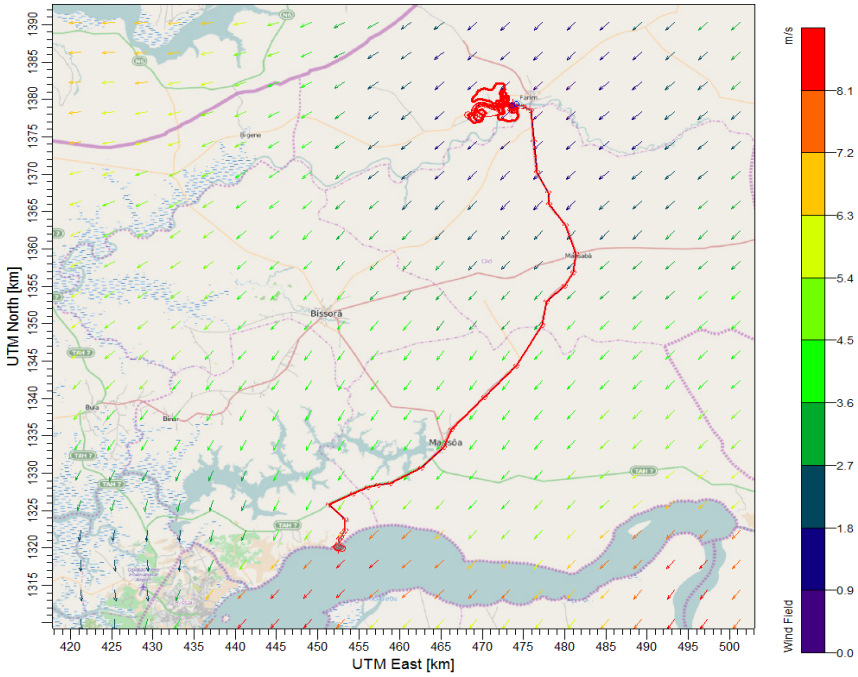
GRAPH 4.11
Wind field generated by CALMET – Dry season



Prepared by Knight Piésold Consultores.
Date: 2012/02/06 07:00:00.

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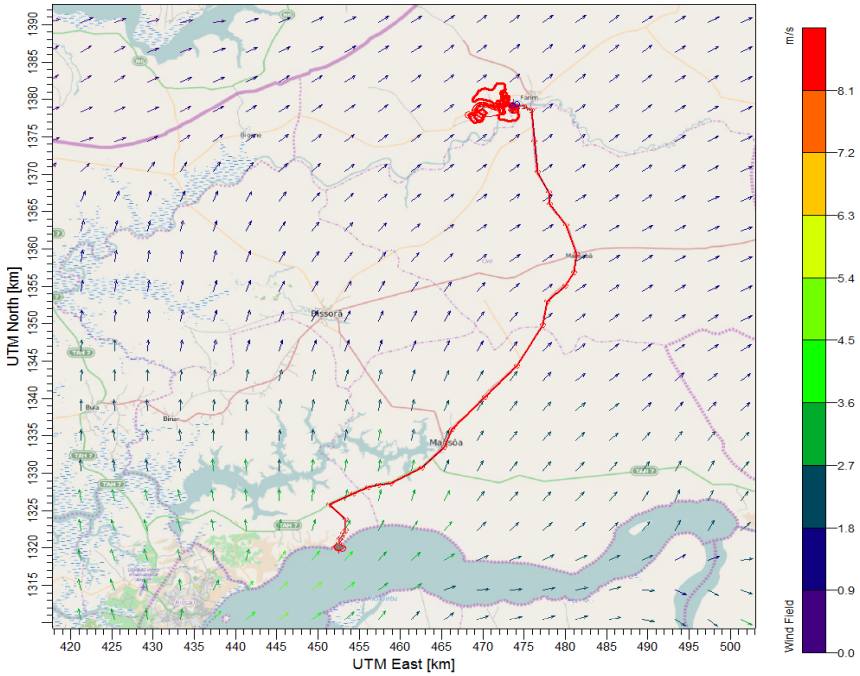
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.12
Wind field generated by CALMET – Wet season



Prepared by Knight Piésold Consultores.
Date: 2014/06/08 14:00:00.

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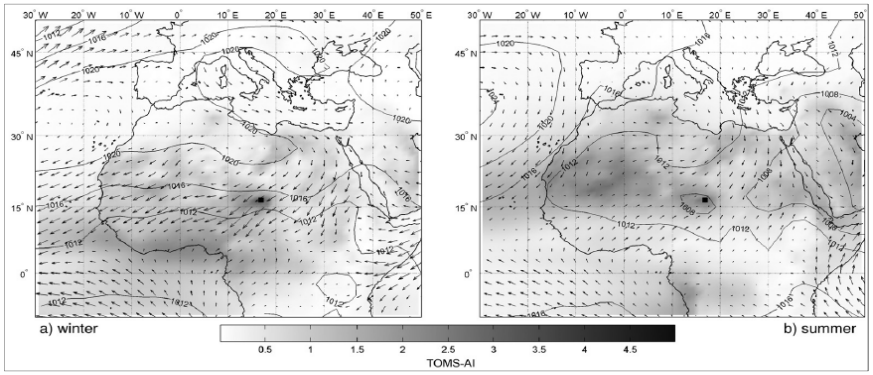
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.13
Particulate matter transportation during dry and wet season



Prepared by Knight Piésold Consultores.
Source: Schwanghart & Schütt (2008).
Notes:
Mean annual atmospheric mineral dust concentration quantified by TOMS aerosol index (dimensionless) and NCEP/NCAR horizontal wind vectors at 925 hPa during the years 1978 – 1993. The black square indicates the location of the Bodélé Depression.
a) December to February.
b) June to August.

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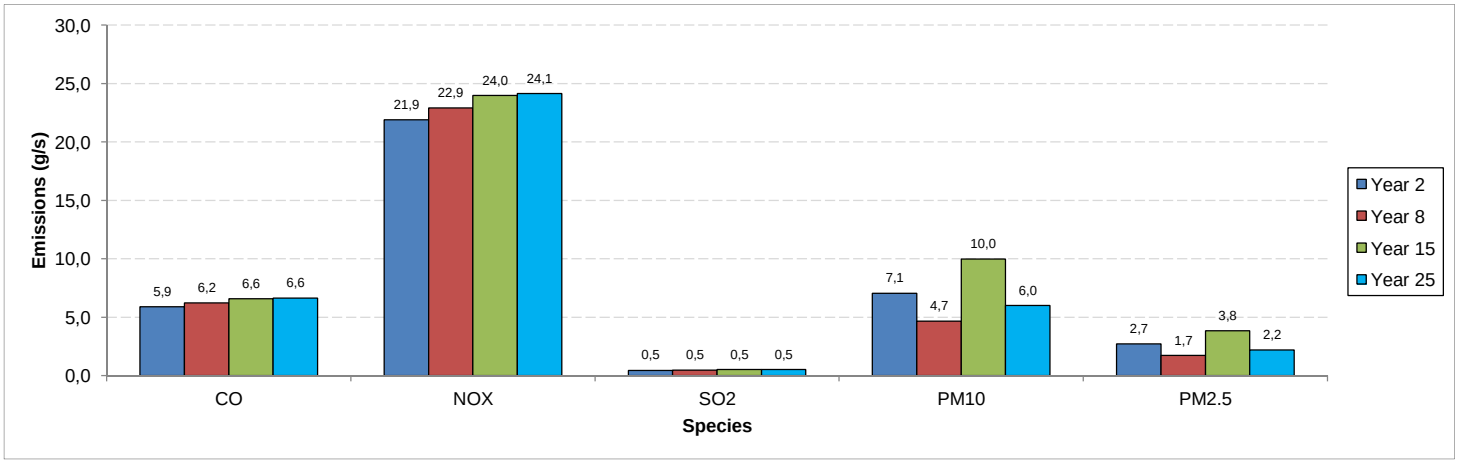
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.14
Emissions of particulate matter and gases - Mine Site
Farim Phosphate Project



Prepared by Knight Piésold Consultores.

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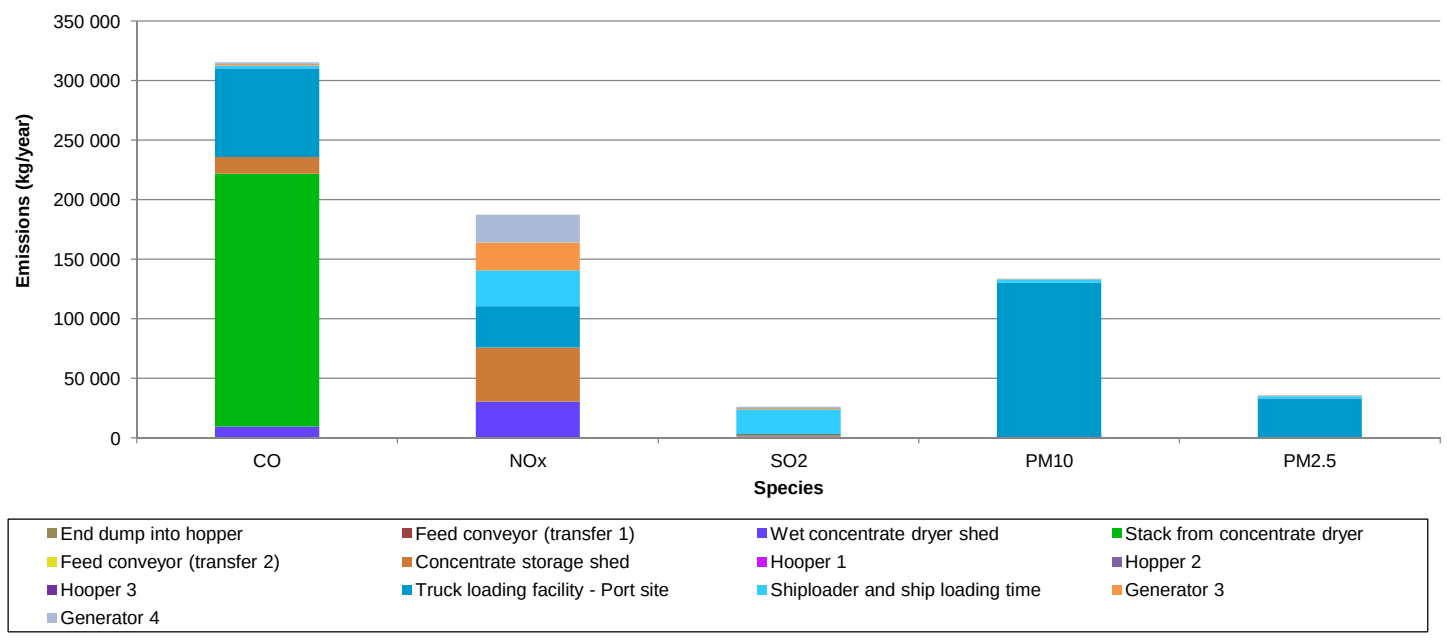
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.15
Emissions of particulate matter and gases - Port site facility and access road
Farim Phosphate Project



Prepared by Knight Piésold Consultores.

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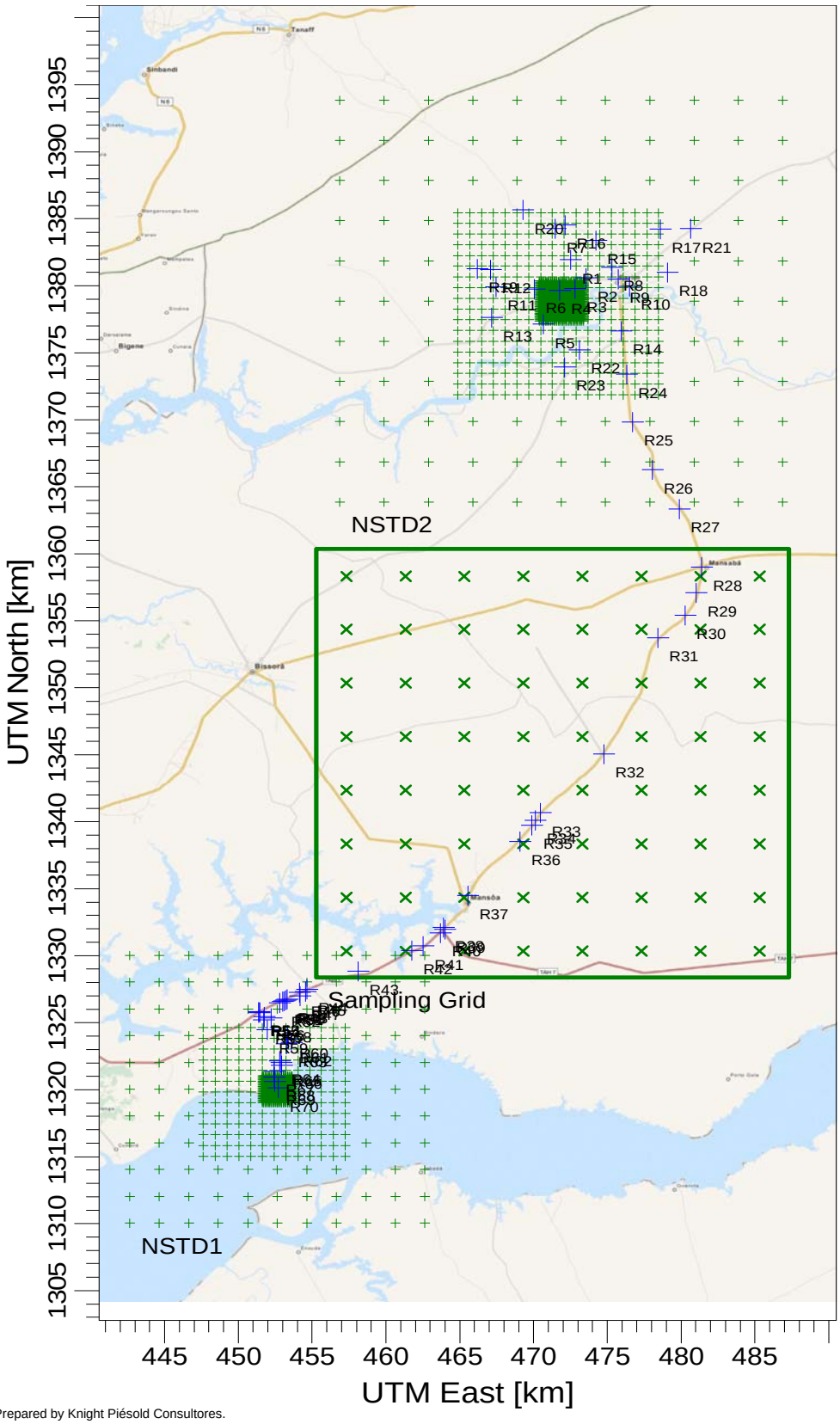
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.16
Nested, sampling and discrete receptors – Model domain in CALPUFF



Prepared by Knight Piésold Consultores.

Legend:

+ Discrete receptors
+ Nested grid
x Sampling grid

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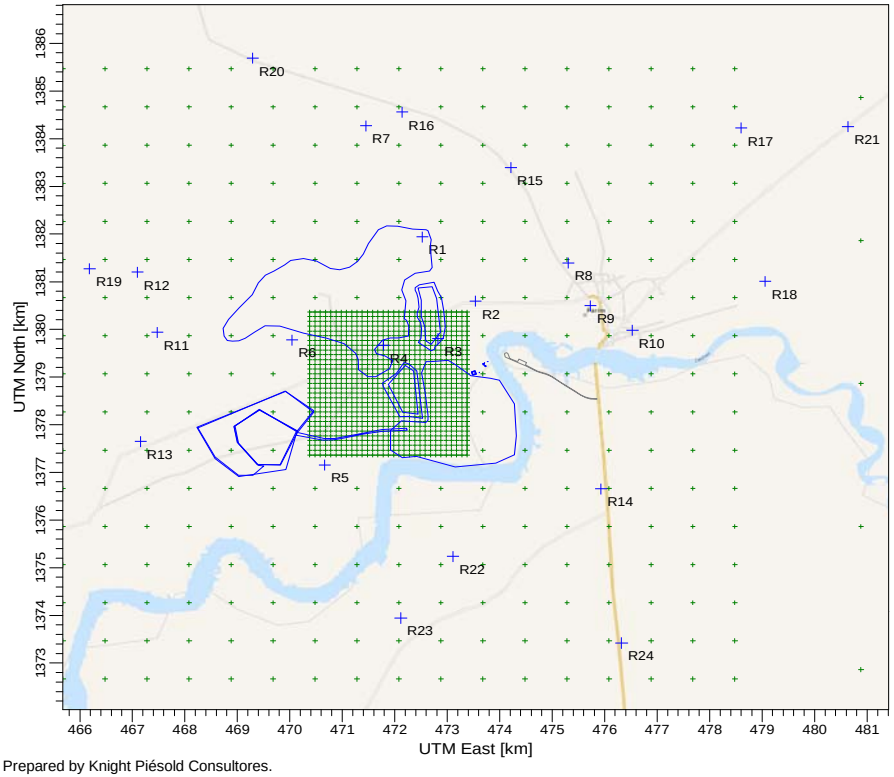
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.17
Receptors in Mine Site



Prepared by Knight Piésold Consultores.

Legend:

+ Discrete receptors

+ Nested grid

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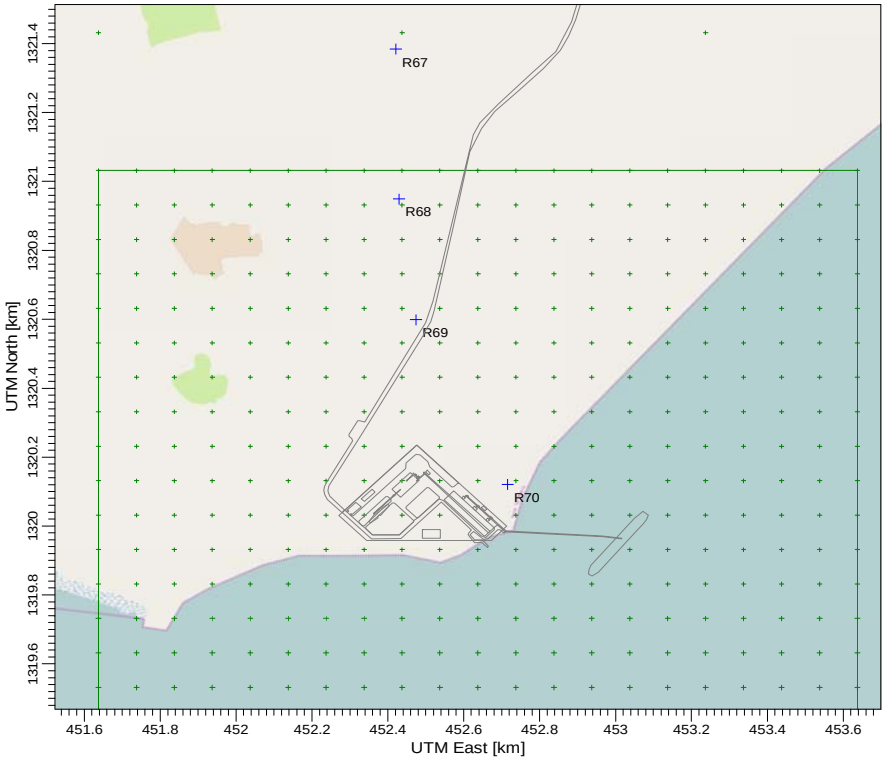
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.18
Receptors in Port Site



Prepared by Knight Piésold Consultores.

Legend:

+ Discrete receptors

+ Nested grid

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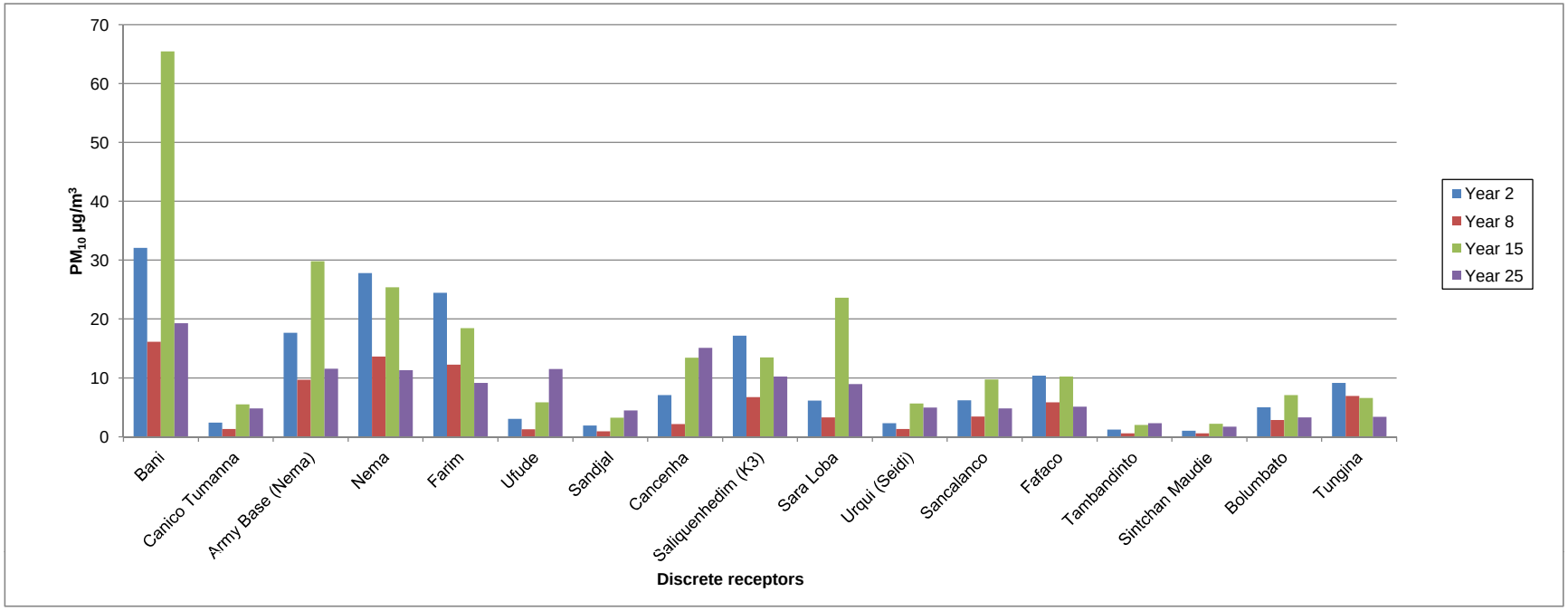
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 5.1
Dispersion modelling results for PM_{10} annual average concentration - Mine site



Prepared by Knight Piésold Consultores.

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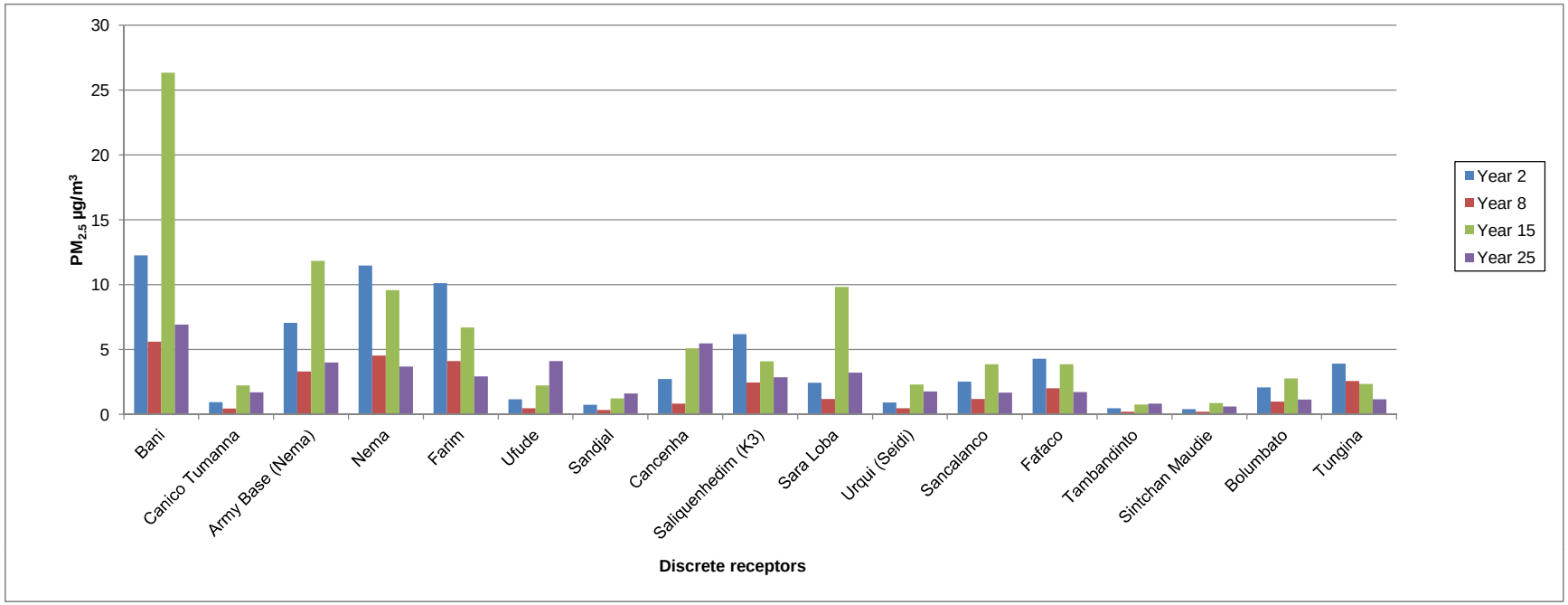
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 5.2
Dispersion modelling results for $PM_{2.5}$ annual average concentration - Mine site



Prepared by Knight Piésold Consultores.

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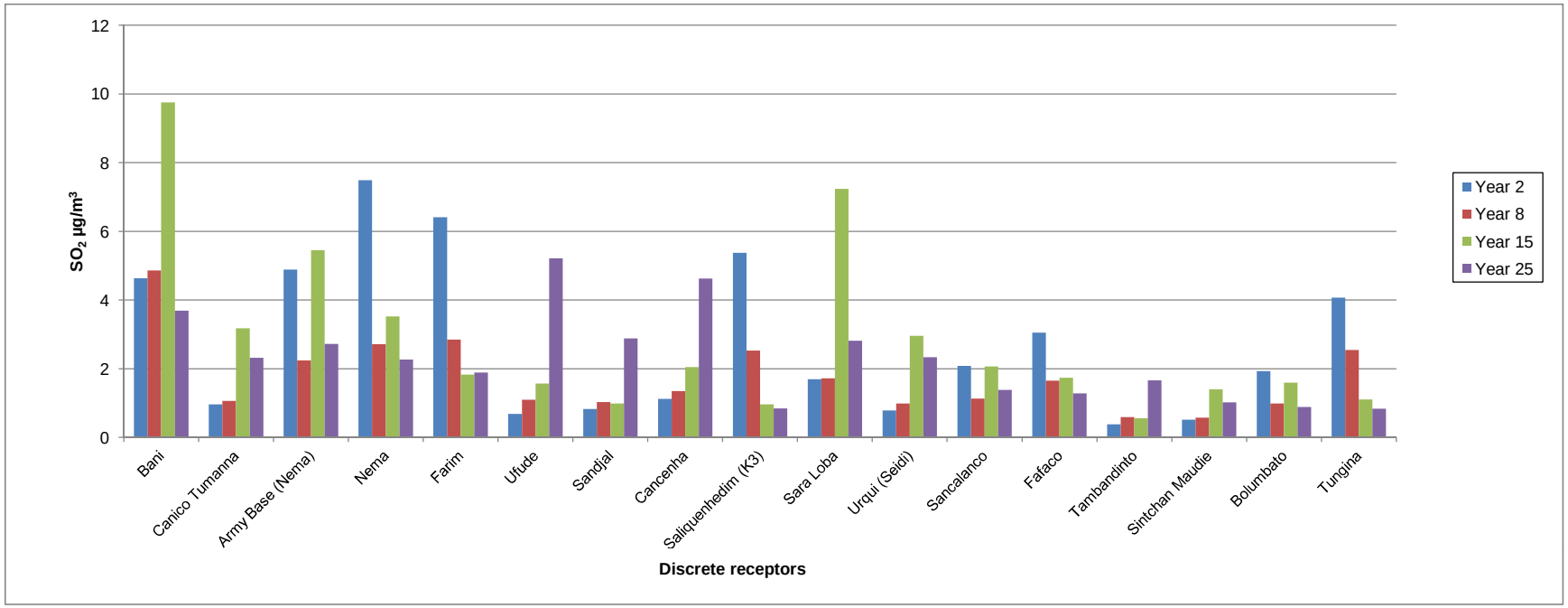
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 5.3
Dispersion modelling results for SO_2 based on 99th percentil of the 24 hour average of three years - Mine site



Prepared by Knight Piésold Consultores.

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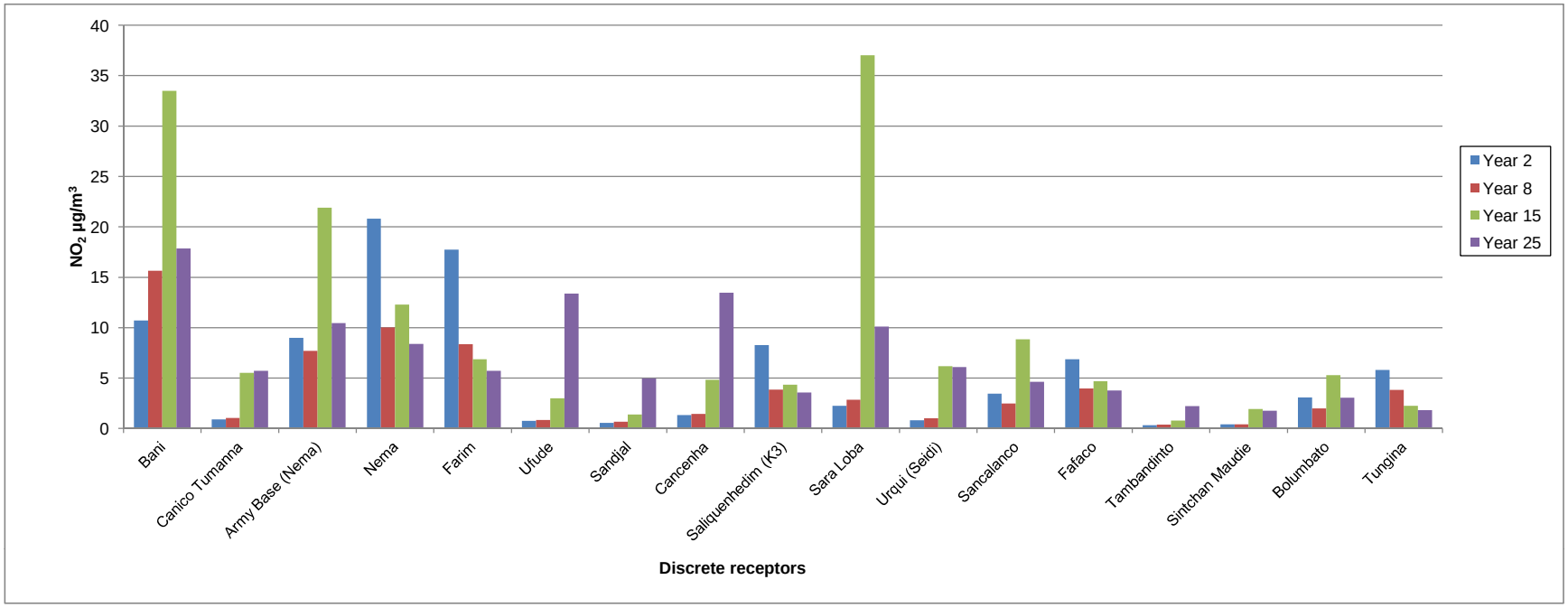
GRAPH 5.4
Dispersion modelling results for NO_2 annual average concentration - Mine site



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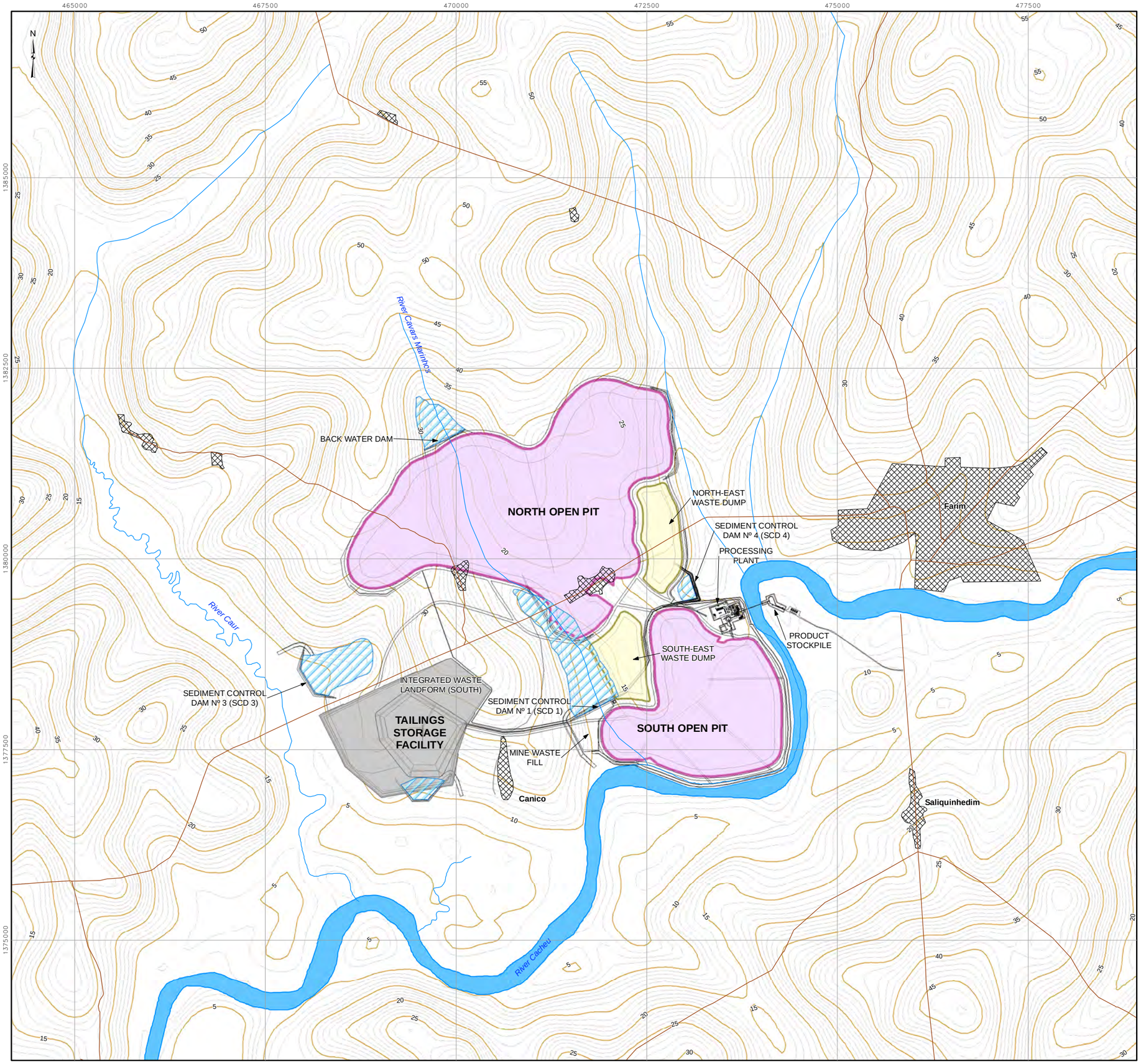
Figures



LEGEND

URBAN AREA
- EXISTING POPULATION

HYDROGRAPHY
- RIVER

TOPOGRAPHY
- PRINCIPAL CURVES
- SECONDARY CURVES

ROADS
- EXISTING ROAD

FACILITIES
- DAM WATER
- OPEN PIT
- WASTE DUMP
- STORAGE FACILITY

1 0 1 2 Km.

ESCALE = 1:50,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	GENERAL ARRANGEMENT PLAN – MINE SITE

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DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.1	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

09/06/2015 11:45:31 a.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.1.mxd

LEGEND

URBAN AREA

EXISTING POPULATION

ROADS

ACCESS ROAD FROM MINE SITE TO PONT CHUGUE PORT

5 0 5 10 Km.

ESCALE = 1:250,000

REFERENCE
-COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	ACCESS ROAD FROM MINE SITE TO PONT CHUGUE PORT

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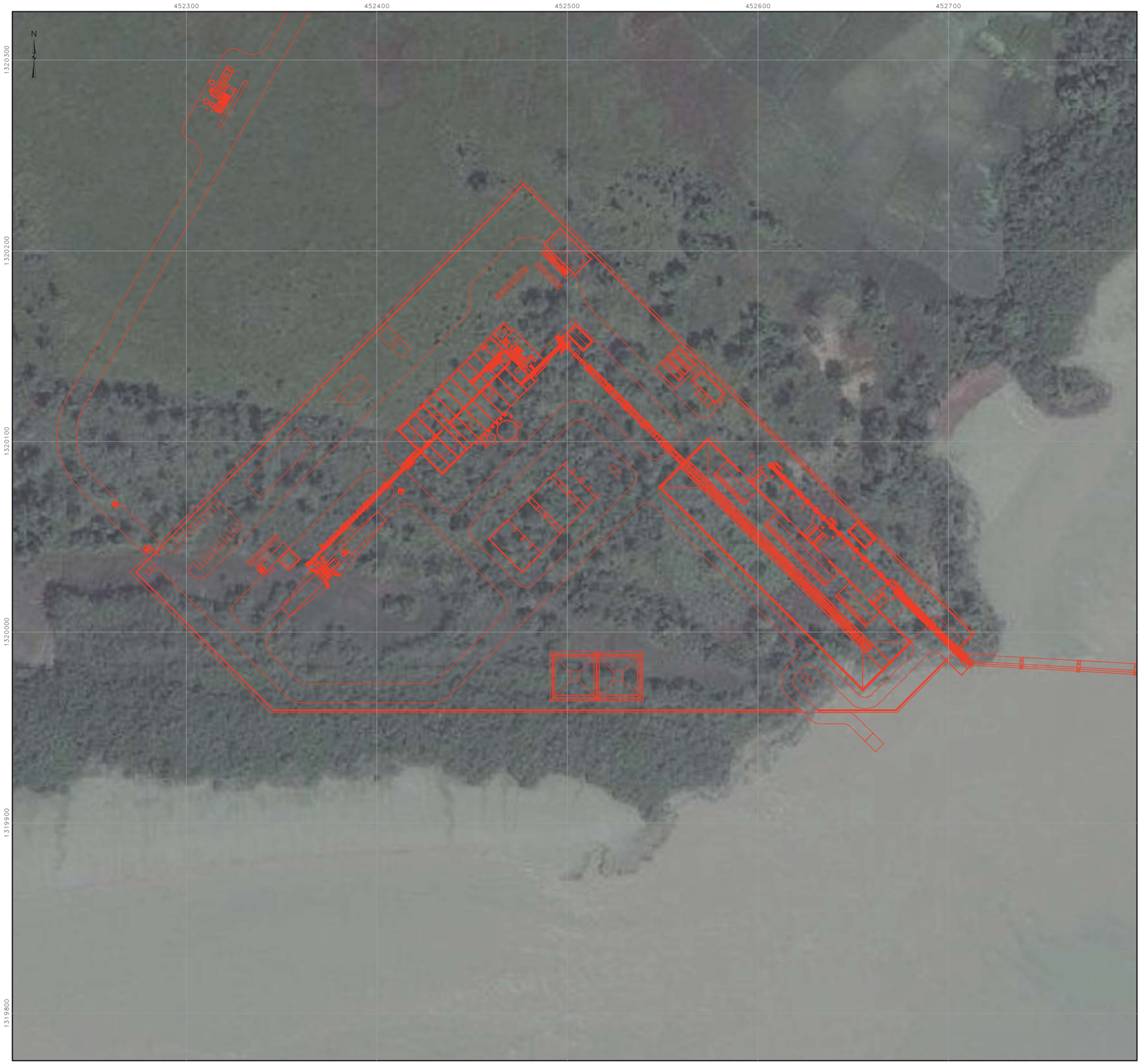
DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.2	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

12/06/2015 03:39:30 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.2.mxd



LEGEND

PONTA CHUGUE PORT FACILITY

50 0 50 100 Meters

ESCALE = 1:2,000

REFERENCE
-COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PONTA CHUGUE PORT FACILITY

Knight Piésold
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DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.3	REV. 0
DRAWN BY	GV	APPROVED BY		JUN 2015		

12/06/2015 03:58:21 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.3.mxd

467500 470000 472500 475000 477500

1385000 1382500 1380000 1377500 1375000

N

BACK WATER DAM

NORTH OPEN PIT

NORTH-EAST WASTE DUMP

NEWD

SEDIMENT CONTROL DAM Nº 4 (SCD 4)

PROCESSING PLANT

FARIM

SEDIMENT CONTROL DAM Nº 3 (SCD 3)

LINE1

LINE2

LINE3

LINE4

LINE5

SPC

CFD

RSC

COS

RST

G1

G2

TLF

SEWD

SOUTH-EAST WASTE DUMP

PRODUCT STOCKPILE

SOP

TSF

SEDIMENT CONTROL DAM Nº 1 (SCD 1)

SOUTH OPEN PIT

IWL

Canico

Saliquinhedim

RBG

MINE SITE

ESCALE = 1:50,000

LEGEND

URBAN AREA
- EXISTING POPULATION

HYDROGRAPHY
- RIVER

ROADS
- EXISTING ROAD

FACILITIES
- FACILITIES

EMISSION SOURCES
- LINE SOURCES
- AREA SOURCES
- POINT SOURCES

450000 460000 470000 480000

1390000 1380000 1370000 1360000 1350000 1340000 1330000 1320000 1310000

N

MINE SITE

PORT FACILITY

10 0 10 20 Km.

ESCALE = 1:480,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	MINE SITE EMISSION SOURCES – SCENARIO 1 (YEAR 2)

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.4	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

17/06/2015 02:35:01 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\mod_17062015\FIGURE 4.4.mxd

467500 470000 472500 475000 477500

1385000 1382500 1380000 1377500 1375000

N

BACK WATER DAM

NORTH OPEN PIT

NORTH-EAST WASTE DUMP

SEDIMENT CONTROL DAM Nº 4 (SCD 4)

PROCESSING PLANT

FARIM

LINE7

NOP

LINE9

COS

PST

SEDIMENT CONTROL DAM Nº 3 (SCD 3)

SOUTH-EAST WASTE DUMP

PRODUCT STOCKPILE

TSF

LINE4

SOUTH OPEN PIT

SEDIMENT CONTROL DAM Nº 1 (SCD 1)

SOP

LINE6

SPS

LINE2

Canico

Saliquinhedim

TLF

CPC

CFD

RSC

G1

G2

COS

RST

RBG

MINE SITE

ESCALE = 1:50,000

LEGEND

URBAN AREA
- EXISTING POPULATION

HYDROGRAPHY
- RIVER

ROADS
- EXISTING ROAD

FACILITIES
- FACILITIES

EMISSION SOURCES
- LINE SOURCES
- AREA SOURCES
- POINT SOURCES

450000 460000 470000 480000

1390000 1380000 1370000 1360000 1350000 1340000 1330000 1320000 1310000

MINE SITE

PORT FACILITY

10 0 10 20 Km.

ESCALE = 1:480,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	MINE SITE EMISSION SOURCES – SCENARIO 2 (Year 8)

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.5	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

17/06/2015 02:37:38 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\mod_17062015\FIGURE 4.5.mxd

467500 470000 472500 475000 477500

1385000 1382500 1380000 1377500 1375000

N

BACK WATER DAM

NOP

NPS

LINE7

LINE12

NORTH OPEN PIT

NORTH-EAST WASTE DUMP

SEDIMENT CONTROL DAM Nº 4 (SCD 4)

PROCESSING PLANT

FARIM

SEDIMENT CONTROL DAM Nº 3 (SCD 3)

LINE10

LINE9

COS

RST

SOUTH-EAST WASTE DUMP

PRODUCT STOCKPILE

LINE11

TSF

SPS

SOUTH OPEN PIT

SEDIMENT CONTROL DAM Nº 1 (SCD 1)

IWL

Canico

Saliquinhedim

TLF

SRC 10

CPC

CFD

RSC

G1

G2

COS

RST

RBG

LINE5

MINE SITE

ESCALE = 1:50,000

LEGEND

URBAN AREA
- EXISTING POPULATION

HYDROGRAPHY
- RIVER

ROADS
- EXISTING ROAD

FACILITIES
- FACILITIES

EMISSION SOURCES
- LINE SOURCES
- AREA SOURCES
- POINT SOURCES

450000 460000 470000 480000

1390000 1380000 1370000 1360000 1350000 1340000 1330000 1320000 1310000

N

MINE SITE

SRC 10

PORT FACILITY

10 0 10 20 Km.

ESCALE = 1:480,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	MINE SITE EMISSION SOURCES – SCENARIO 3 (YEAR 15)

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.6	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

17/06/2015 02:37:10 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\mod_17062015\FIGURE 4.6.mxd

467500 470000 472500 475000 477500 480000

1.385000 1.382500 1.380000 1.377500 1.375000

N

BACK WATER DAM

NORTH OPEN PIT

NORTH-EAST WASTE DUMP

FARIM

LINE7

NOP

SEDIMENT CONTROL DAM Nº 4 (SCD 4)

PROCESSING PLANT

LINE9

SEDIMENT CONTROL DAM Nº 3 (SCD 3)

COS

RST

SOUTH-EAST WASTE DUMP

PRODUCT STOCKPILE

TSF

SEDIMENT CONTROL DAM Nº 1 (SCD 1)

SOUTH OPEN PIT

Canico

Saliquinhedim

TLF

SRC 10

CPC

CFD

RSC

G1

G2

COS

RST

RBG

LINE9

LINE5

MINE SITE

ESCALE = 1:50,000

LEGEND

URBAN AREA
- EXISTING POPULATION

HYDROGRAPHY
- RIVER

ROADS
- EXISTING ROAD

FACILITIES
- FACILITIES

EMISSION SOURCES
- LINE SOURCES
- AREA SOURCES
- POINT SOURCES

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

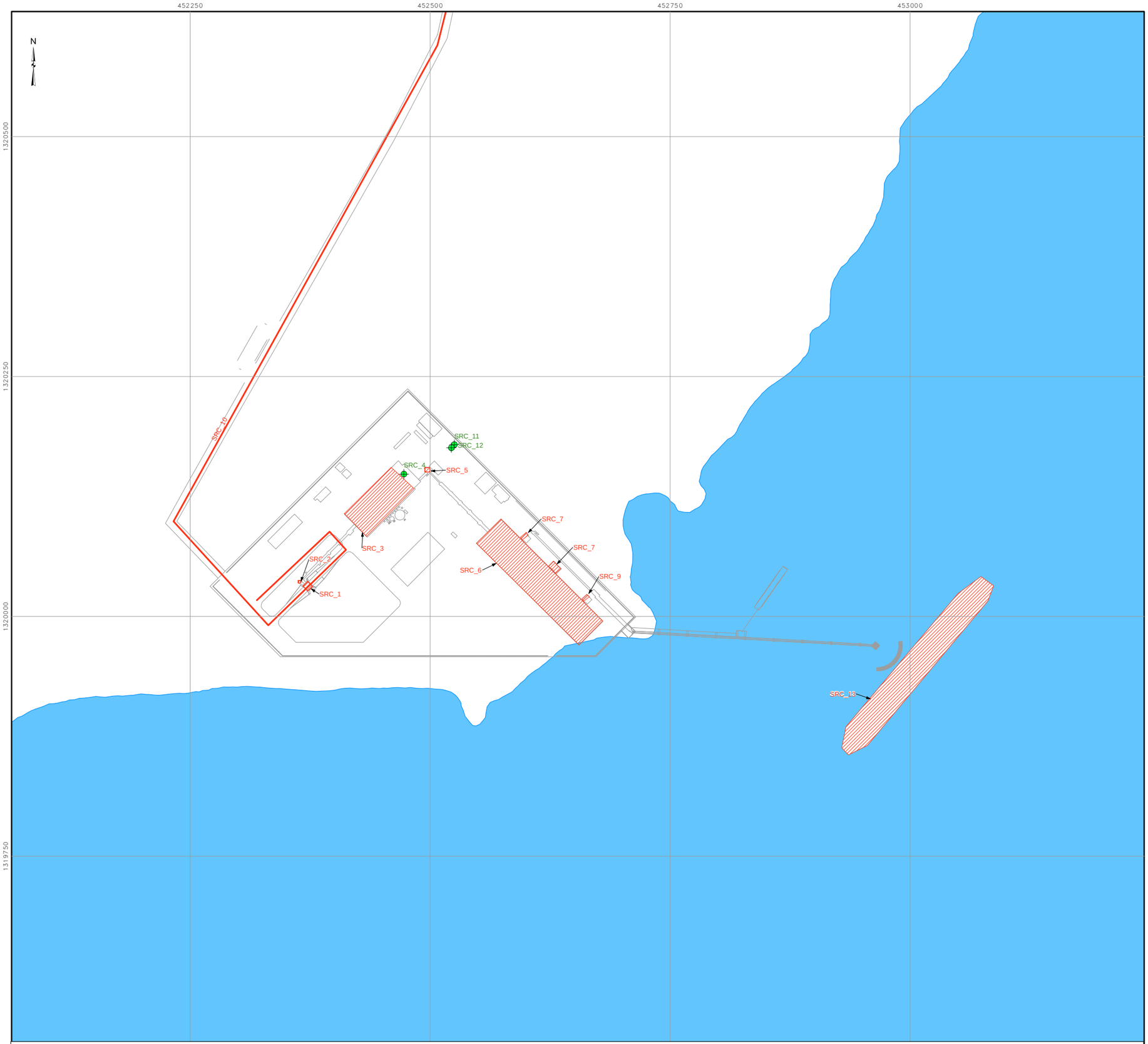
CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	MINE SITE EMISSION SOURCES – SCENARIO 4 (YEAR 25)

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.7	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

17/06/2015 02:50:01 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\mod_17062015\FIGURE 4.7.mxd



PORT FACILITY

ESCALE = 1:4,000

LEGEND

FACILITY

PONTA CHUGUE PORT FACILITY

EMISSION SOURCES

LINE SOURCES

AREA SOURCES

POINT SOURCES

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	EMISSION SOURCES AT ACCESS ROAD AND PORT SITE

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.8	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

17/06/2015 02:39:35 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\mod_17062015\FIGURE 4.8.mxd

LEGEND

URBAN AREA
- EXISTING POPULATION

POINT
- RECEPTORS

ROADS
- ACCESS ROAD FROM MINE SITE TO PONT CHUGUE PORT

5 0 5 10 Km.

ESCALE = 1:250,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

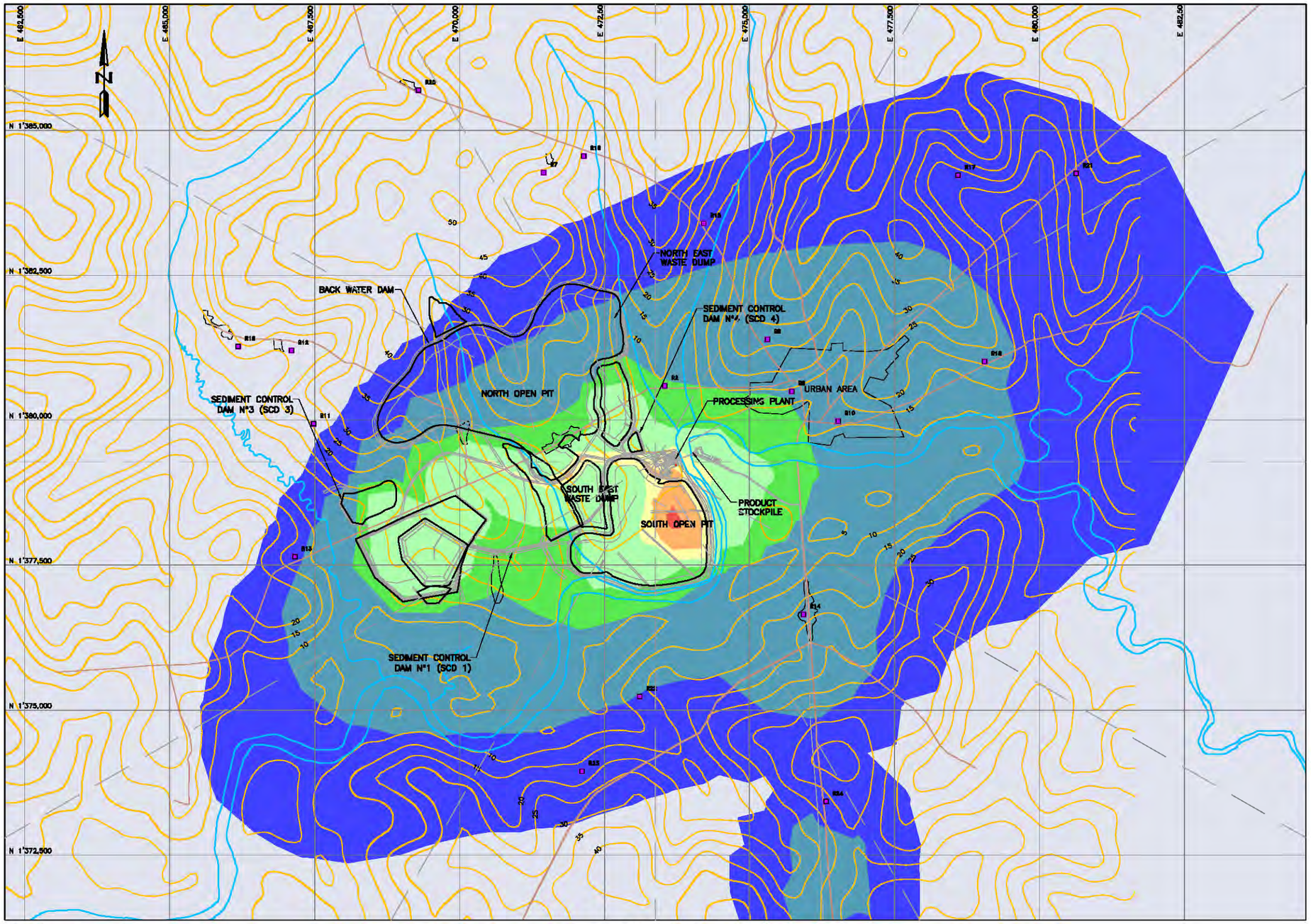
CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	LOCATION OF SENSITIVE RECEPTORS

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.9	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

11/06/2015 11:59:21 a.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.9.mxd



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

750 0 750 1500 METERS
1:75000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTORS
- BACKGROUND

VALUE RUN LENGTH AVERAGE CONCENTRATION (PM10)

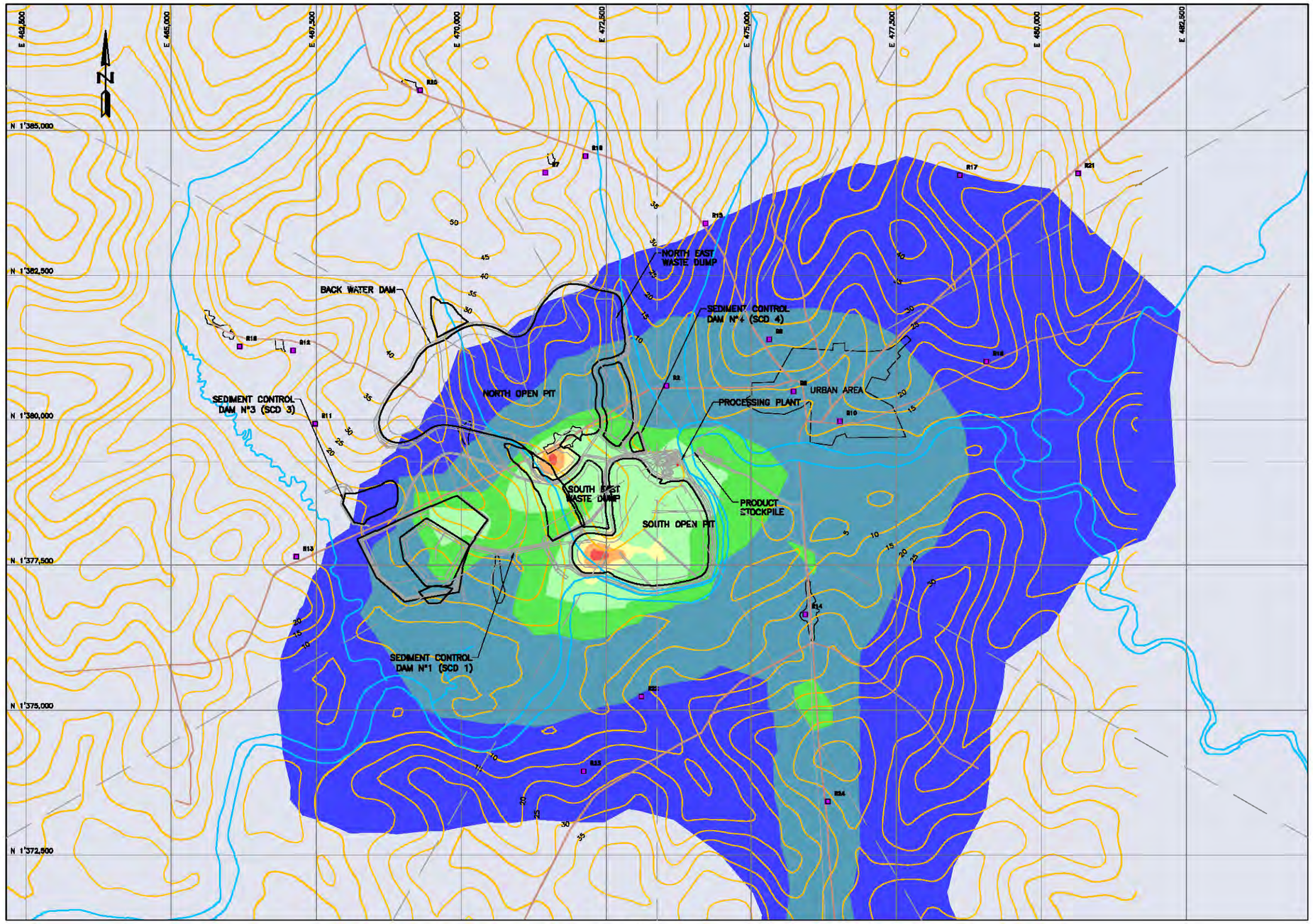
500
300
200
120
100
80
75
70

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PM10 CONCENTRATION FOR ANNUAL AVERAGE PERIOD AT MINE – SCENARIO 1

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 6.1	REV.
DRAWN BY	EA	APPROVED BY	–	05/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 6.1 A | XREF | M:\ProjectFiles\NB3D1-520\05A\Acad Files\FIGURE 6.1 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

750 0 750 1500 METERS
1:75000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTORS
- BACKGROUND

VALUE RUN LENGTH AVERAGE CONCENTRATION (PM10)

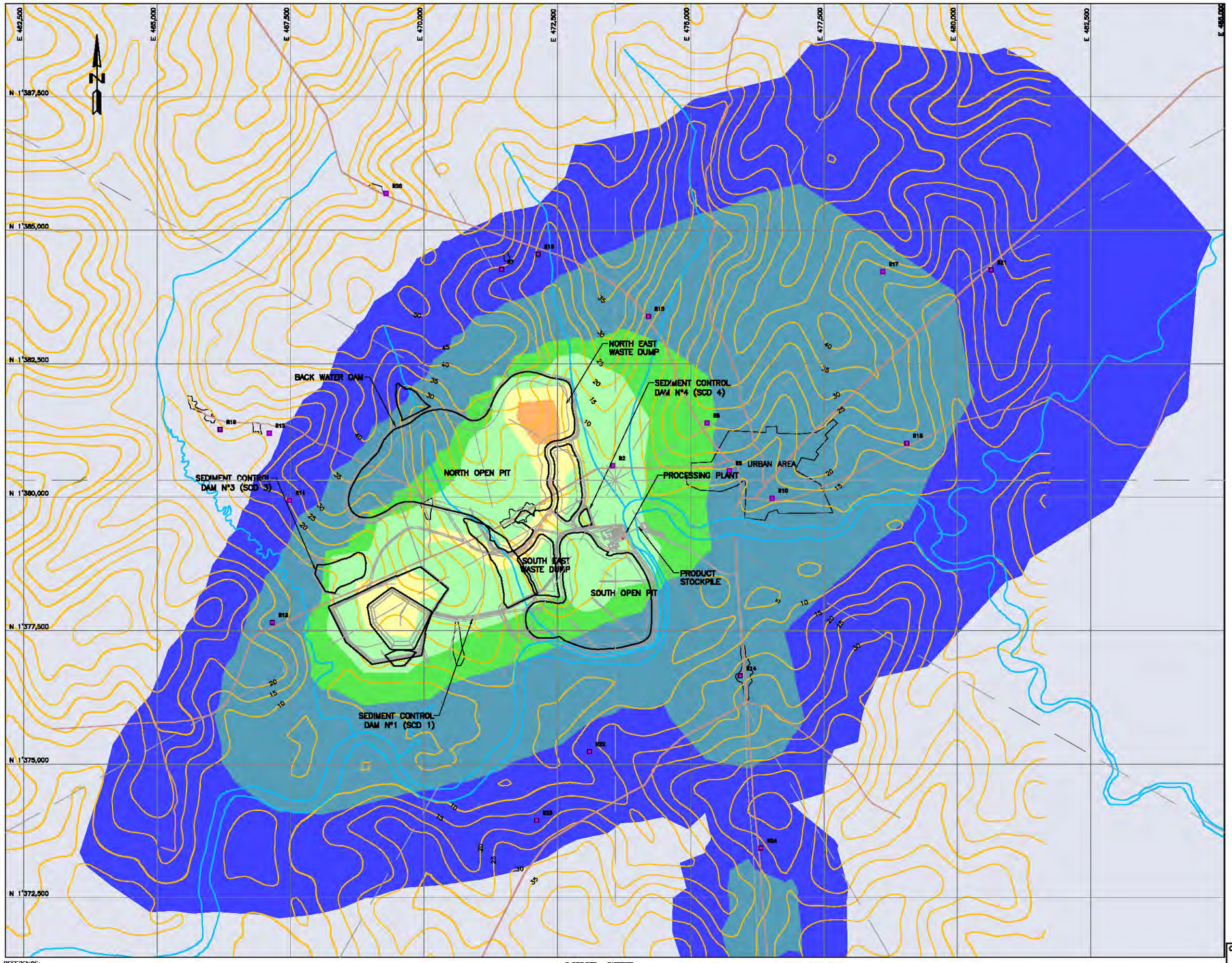
500
300
200
120
100
80
75
70

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PM10 CONCENTRATION FOR ANNUAL AVERAGE PERIOD AT MINE – SCENARIO 2

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 6.2	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 6.2 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 6.2 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

750 0 750 1500 METERS
1:75000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTORS
- BACKGROUND

VALUE RUN LENGTH AVERAGE CONCENTRATION (PM10)

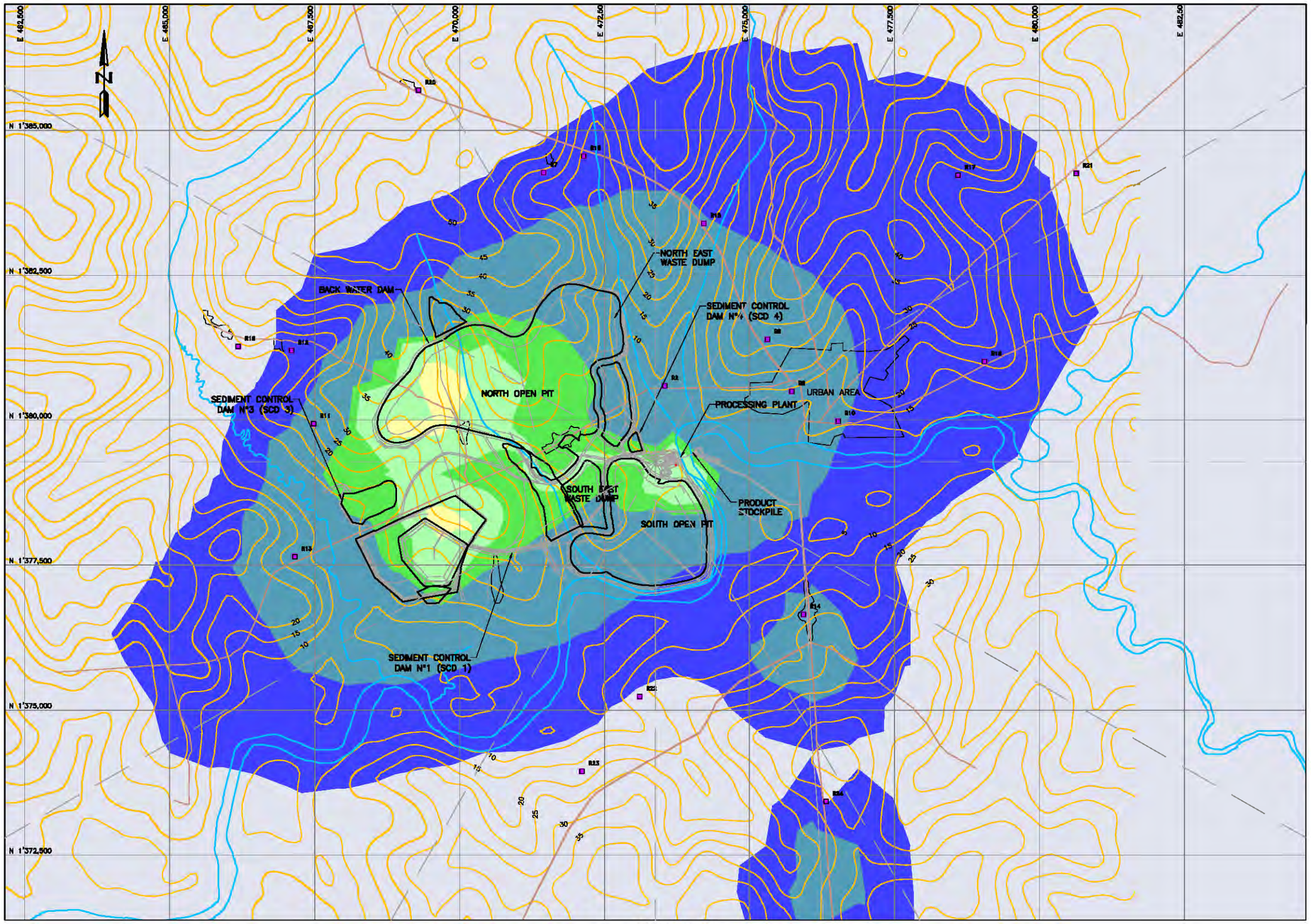
500
300
200
120
100
80
75
70

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PM10 CONCENTRATION FOR ANNUAL AVERAGE PERIOD AT MINE – SCENARIO 3

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 6.3	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 6.3 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 6.3 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

750 0 750 1500 METERS

1:75000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTORS
- BACKGROUND

VALUE RUN LENGTH AVERAGE CONCENTRATION (PM10)

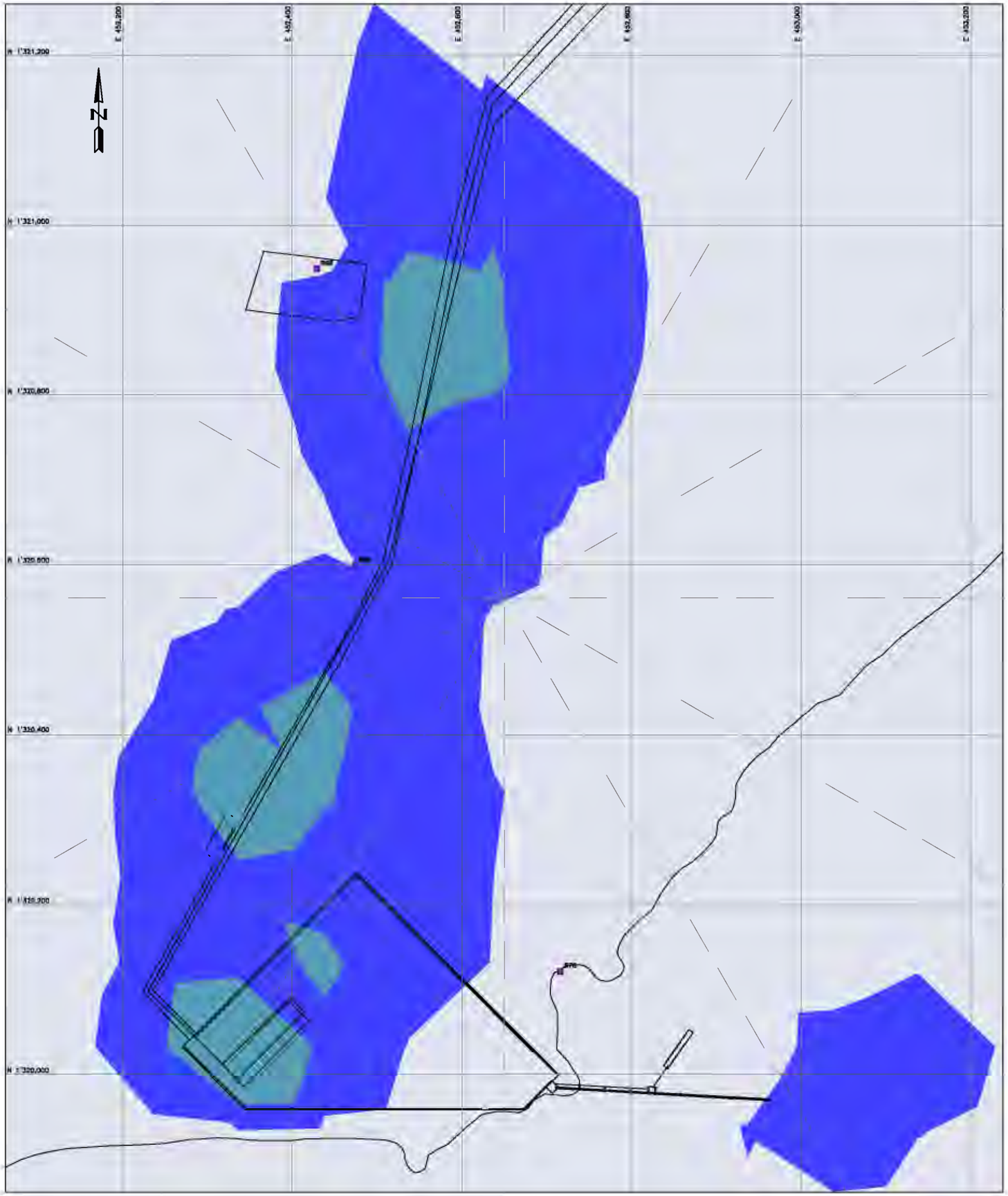
500
300
200
120
100
80
75
70

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PM10 CONCENTRATION FOR ANNUAL AVERAGE PERIOD AT MINE – SCENARIO 4

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 6.4	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 6.4 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 6.4 A.dwg



LEGEND:

- EXISTING ROAD
- FACILITIES
- RECEPTORS
- BACKGROUND

VALUE RUN LENGTH AVERAGE CONCENTRATION (PM10)

- 500
- 300
- 200
- 120
- 100
- 80
- 75
- 70

REFERENCE:
–COORDINATE SYSTEM UTM, DATUM WGS–84, ZONA 28N.

PORT FACILITY PLANT

100 0 100 200 METERS
SCALE = 1:5000

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PM10 CONCENTRATION FOR ANNUAL AVERAGE PERIOD AT PORT SITE

Knight Piésold CONSULTING

DESIGNED BY		CHECKED BY		DATE	FIGURE 6.5	REV. A
DRAWN BY		APPROVED BY				

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 6.5 A | XREF | M:\ProjectFiles\NB301–520\05A\Acad Files\FIGURE 6.5 A.dwg

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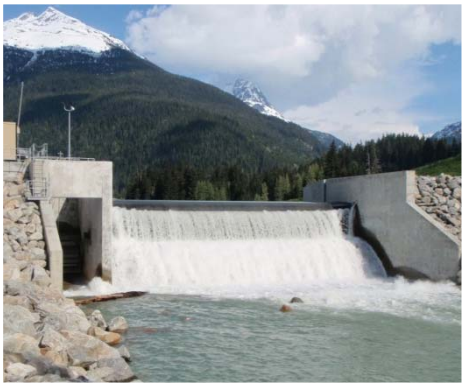
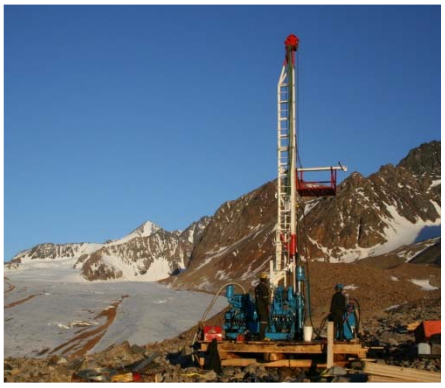
Appendix A

Atmospheric Emissions Inventory

LYCOPODIUM MINERLAS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT





AIR QUALITY MODELLING EMISSIONS INVENTORY

PREPARADO FOR:

Lycopodium Minerals Canada Ltd.
5060 Spectrum Way, Suite 400
Mississauga, Ontario
Canada, L4W 5N5

PREPARED BY:

Knight Piésold Consultores S.A.
Calle Aricota 106, 5° Piso, Santiago de Surco
Lima 33, Perú
t. +51.1.202.3777 • f. +51.1.202.3778

Knight Piésold
CONSULTING
www.knightpiesold.com

NB301-520/05A
Rev. A
June 26, 2015

ISO 9001
ISO 14001
OHSAS 18001
BUREAU VERITAS
Certification
Nº BR233186, BR233187, BR233188

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Lycopodium Minerals Canada Ltd. Environmental and Social Impact Assessment for the Farim Phosphate Project
Air Quality Modelling

Emissions Inventory

June 2015

Rev. No.	Date	Description	KP Perú	KP North Bay
0			Alejandro Delgado	Richard Cook
A	June 26, 2015	Issued for review	Alejandro Delgado	Richard Cook

ISO 9001
ISO 14001
OHSAS 18001
BUREAU VERITAS
Certification
N° BR233186, BR233187, BR233188

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Lycopodium Minerals Canada Ltd.
Environmental and Social Impact Assessment for the Farim Phosphate Project
Air Quality Modelling

Emissions Inventory

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Lycopodium Minerals Canada Ltd.
Environmental and Social Impact Assessment for the Farim Phosphate Project
Air Quality Modelling

Emissions Inventory

1.0 Introduction

The present atmospheric emissions inventory of particulate matter and gases pertains to mining operation activities, concentrate transport, storage and shipping of phosphate concentrate in the Farim Phosphate Project. The emissions inventory calculations are based on emission factors (EF) prepared by international environmental agencies (i.e., USEPA Guideline AP-42, NPI Guideline of the Australian Government, and Mineral Handling and Processing Industries of the Mojave Desert Air Quality Management District - MDAQMD), as well as on emission factors suggested by the technical data sheets of the equipment (CAT, 2011a, 2011b).

The emissions inventory considers mining operation years 2, 8, 15 and 25, and presents a list of emission sources for air pollutants such as particulate matter (PM) smaller than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). These sources were classified as specific (stacks), linear, area and volumetric sources. The following sections describe the development of the emissions inventory.

2.0 Atmospheric Emissions Inventory

The quantification of PM_{10} y $PM_{2.5}$ particulate matter emissions, as well as CO, NO_x and SO_2 gas emissions are based on emission factors from following international environmental guidelines:

- *AP 42 Manual, Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources:*
    - *11.9 Western Surface Coal Mining*(USEPA, 1998)
    - *13.2 Fugitive Dust Sources*
        - *13.2.1 Paved Roads* (USEPA, 2011)
        - *13.2.2 Unpaved Roads*(USEPA, 2006a)
        - *13.2.4 Aggregate Handling And Storage Piles*(USEPA, 2006b)
        - *13.2.5 Industrial Wind Erosion*(USEPA, 2006c)
    - *11.19 Introduction to Construction and Aggregate Processing*
        - *11.19.2 Crushed Stone Processing and Pulverized Mineral Processing*
    - *11.21 Phosphate Rock Processing* (USEPA, 1995)

- NPI Guidelines of the Australian Government:
    - *Emission Estimation Technique Manual for Mining* (NPI, 2012b)
    - *Emission Estimation Technique Manual for Combustion Engines*(NPI, 2008)
    - *Estimation Technique Manual for Maritime operations* (NPI, 2012a)

- *Emissions Inventory Guidance – Mineral Handling and Processing Industries*(MDAQMD, 2000 Rev. 2013)

- Technique sheet of Diesel Generators (CAT, 2011a, 2011b)

These guidelines suggest emission factors based on the nature of the mining activity. In general, estimation of emissions is carried out using the following equation[1].

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

Where *E* is the emission rate of substance *i* (in mass/time units, g/s or kg/year), *A* is the activity level (e.g., fuel consumption per year), *EF* is the substance's emission factor (e.g., substance grams/fuel consumption amount) and *ER* reduction efficiency rate due to application of technologies for atmospheric emissions.

[1] Available at http://www.epa.gov/ttnchie1/ap42/

2.1 Farim Phosphate Mine

The quantification results for the emissions inventory according to source and year are shown in Table 2.1. The methodology used for estimation of emissions according to activity type is described below.

2.1.1 Earthmoving

2.1.1.1 Bulldozing

Earthmoving emissions occur in pit areas and overburden piles due to material collection and arrangement. The main piece of equipment involved in this activity is usually dozers and motorgraders. Calculation of particulate matter emissions from the use of dozers was based on Manual AP-42, section 11.9, Western Surface Coal Mining (USEPA, 1998).

$$EF_{PM_{10}} = k \times 0.45 \times {s^{1.5}}/{M^{1.4}}$$
$$EF_{PM_{2.5}} = k \times 2.6 \times {s^{1.2}}/{M^{1.3}}$$
$$E = EF \times T$$

Where:

- *E* = particle emission rate,
- *EF* = emission factor in kg/h-eq,
- *k* = escalation factor according to size of emitted particles (0.75 for PM_{10} and 0.105 for $PM_{2.5}$),
- *s* = fines content (%)
- *M* = material moisture percentage (%), and
- *T* = equipment operation hours per year (h-eq/year).

Data from the soil characterization study (Golder Associates, 2013) regarding fines content and soil moisture was used to estimate the emission factors, providing values of 13% and 20%, respectively.

$$EF = 0.75 \times 0.45 \times {13^{1.5}}/{20^{1.4}} = 0.239 \frac{kg\ PM_{10}}{h - eq}$$
$$EF = 0.105 \times 2.6 \times {13^{1.2}}/{20^{1.3}} = 0.121 \frac{kg\ PM_{2.5}}{h - eq}$$

Approximate machinery operation hours per year according to source location, as well as calculated emissions resulting from earthmoving are shown in Table 2.2. By multiplying the activity rate by the emission factor, one finds that this activity may generate from 0.361 g/s to 0.451 g/s of PM_{10}, and from 0.182 g/s to 0.228 g/s of $PM_{2.5}$.

2.1.1.2 Vehicle exhaust from heavy equipment

Use of heavy machinery will generate gases and fine particle emissions due to diesel combustion. These emissions were estimated using the *Emission Estimation Technique Manual for Combustion Engines*, prepared by the National Pollutant Inventory of the Australian Government (NPI, 2008). As there is no detailed data on heavy equipment fuel consumption available, emissions were estimated based on the number of machinery operation hours and engine power (kW), according to manufacturer data (technical sheets).

$$E = P \times LF \times T \times EF$$

Where:

- *E* = gases and particle emission rate,
- *P* = machinery power (kW),
- *LF* = load factor used in operation of facilities by type of equipment,
- *T* = machinery operation hours (h-eq/year),
- *EF* = emission factor given due to engine type and diesel fuel (kg/kWh)

Table 2.3 shows results of particle and gas emissions from use of heavy machinery; machinery engine power, machinery use factor, and machinery operation hours per year are also shown. CO emissions range from 3.107 g/s to 3.933 g/s. NO_x emissions range from 9.285 g/s to 11.738 g/s. SO_2 emissions range from 0.297 g/s to 0.371 g/s. PM_{10} emissions range from 0.734 g/s to 0.945 g/s. $PM_{2.5}$ emissions range from 0.681 g/s to 0.875 g/s.

2.1.2 Loading of material and handling

Emissions caused by material loading and handling for stockpiling were estimated using the equation proposed by Manual AP-42, Section 13.2.4, *Aggregate Handling and Storage Piles* (USEPA, 2006b).

$$EF = k \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1,3} \Big/ \left(\frac{M}{2}\right)^{1,4}$$

$$E = EF \times Q$$

Where:

- *E* = particulate emission rate,
- *EF* = emission factor in kg/t,
- *k* = scaling factor according to size of emitted particles (0.35 for PM_{10} and 0.053 for $PM_{2.5}$),
- *U* = average wind speed (m/s),
- *M* = material moisture percentage (%),
- *Q* = loading material amount (t/year)

An average wind velocity of 1.06 m/s is considered, in accordance with meteorological data from the Farim automatic station. Moisture content to be considered depends on type of handled material and its stage in the process; moisture content may be 20% for overburden (Golder Associates, 2013) and 27% for phosphate ore (Lycopodium, 2014).

The estimation of emission factor and results from estimates of particulate matter emissions (PM_{10} y $PM_{2.5}$) resulting from loading of material on trucks and handling of stockpiles are shown in Table 2.4. Based on operation years analyzed, PM_{10}, emissions range from 0.0091 g/s to 0.0131 g/s. $PM_{2.5}$ emissions were much lower due to the nature of activities, ranging from 0.0014 g/s to 0.0020 g/s.

2.1.3 Unloading of material, handling and screening

The calculation of emissions from concentrate handling during unloading was based on Section 13.2.4 *Aggregate Handling and Storage Piles* in Manual AP-42 (USEPA, 2006b).

$$EF = k \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \Big/ \left(\frac{M}{2}\right)^{1.4}$$

$$E = EF \times Q$$

Where:

- *E* = particulate emission rate,
- *EF* = emission factor in kg/t,
- *k*= escalation factor according to size of emitted particulate (0.35 for PM_{10} and 0.053 for $PM_{2.5}$),
- *U* = average wind speed (m/s),
- *M* = material moisture percentage (%), and
- *Q* = unloaded amount (t/year)

According to the NPI manual (2012b), dumping of material from truck hoppers is represented by the following equation:

$$EF = k \times 0.012$$
$$E = EF \times Q$$

Where:

- *EF* = emission factor in kg/t,
- *k*= scaling factor according to size of emitted particulate (0.355 for PM_{10} and 0.053 for $PM_{2.5}$), and
- *Q* = transferred amount (t/year)

The calculation of emissions from handling due to material transfer using the conveyor belt system with control measures (water spray) was based on Section 11.19.2 *Crushed Stone Processing and Pulverized Mineral* of Manual AP-42 (USEPA, 2004).

$$EF = k \times 0.00007$$
$$E = EF \times Q$$

Where:

EF = emission factor in kg/t,

k= scaling factor according to size of emitted particulate (0.33 for PM_{10} and 0.093 for $PM_{2.5}$), and

Q = transferred amount (t/year)

Emissions from material screening were calculated based on Section 11.19.2 *Crushed Stone Processing and Pulverized Mineral* in Manual AP-42 (USEPA, 2004).

$$EF = k \times 0.15$$
$$E = EF \times Q$$

Where:

EF = emission factor in kg/t,

k= escalation factor according to size of emitted particulate (0.36 for PM_{10} and 0.0024 for $PM_{2.5}$), and

Q = transferred amount (t/year)

As a mitigation measure, it is considered to use covered conveyor belts, as well as sprinkler irrigation during screening activities. Emissions inventory manuals present control efficiency values according to the cover level of a transfer zone, such as belts or unloading areas:

- Covered conveyor belt (MDAQMD, 2000) = 85%
- Three-quarter covered conveyor belt (MDAQMD, 2000) = 70%

The application of dust suppression systems using sprinkler irrigation during material transfer from truck hoppers is considered as a control measure. According to the NPI manual (NPI, 2012b), this control measure represents a reduction efficiency of 70%.

Based on Manual AP-42, Section 11.19.2 *Crushed Stone Processing and Pulverized Mineral* (USEPA, 2004), the reduction efficiency of dust suppression systems using sprinkler irrigation during screening activities is 99%.

The formula used for calculation of emissions taking into consideration these emission reduction efficiencies is as follows:

$$E_c = E \times (100\% - C)$$

Where:

E_c = controlled emissions of particulate matter
E = uncontrolled emissions
C = control efficiency (%)

The amount of handled material, emission factor values, emission control efficiency, and emission rates are shown in Table 2.5. Fugitive emissions of particulate matter due to the aforementioned activities are estimated to be from 1.5714 g/s to 2.1127 g/s for PM_{10} and from 0.0262 g /s to 0.0343 g /s for $PM_{2.5}$.

2.1.4 Material haulage

2.1.4.1 Suspension of particulate matter from truck traffic

Particulate matter emissions from material haulage are based on the AP-42 Manual.

$$EF = k \times \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W}{3}\right)^{0.45} \times 0.2819 \times \left(\frac{365 - P}{365}\right)$$
$$E = EF \times VKT$$

Where:

EF = emission factor in kg/VKT,
k= scaling factor according to size of emitted particulate (1.5 for PM_{10} and 0.15 for $PM_{2.5}$),
s= road fines percentage (%),
W = average vehicle weight (t),
P = days per year with at least 0.254 mm precipitation, and
VKT = kilometers traveled by vehicle fleet

Emission factors and kilometers travelled by the vehicle fleet were estimated based on vehicle features, mainly truck and front-end loader capacities, travelled distances, number of trips, as well as access road characteristics (fines content estimated at 13%), as shown in Table 2.6.

Regarding the emission factor for material haulage over unpaved roads, it includes a correction factor as suggested by Watson & Chow (2000), since particulate emissions on roads can be reduced by 75% due to the influence of gravity on the coarse fraction of PM_{10} on haulage roads. As indicated by Watson & Chow (2000), this coarse fraction remains suspended at 1 to 2 m height above ground level; subsequently, particles settle on the

surface or drop on nearby structures after a few minutes of suspension. It should be noted that the main source of particulate matter for this activity results from suspension, which is caused mainly by friction between the tires and the road surface, as well as by the turbulence created by the vehicle. Emissions coming from the hoppers are considered negligible, given the fact that the speed at which the trucks move very rarely is strong enough to cause materials to be blown away (Cecala et. al., 2012).

The use of two water tank trucks for watering of haulage roads is considered as a control measure. The reduction efficiency of this measure is estimated at 87% according to USEPA methodology (USEPA, 2006a).

According to operation years analyzed, PM_{10} emissions range from 1.0190 g/s to 5.5101 g/s. $PM_{2.5}$ emissions seem to range from 0.4076 g/s to 2.2041 g/s.

2.1.4.2 Fuel consumption by trucks

Calculation of gas and particulate emissions from diesel fuel consumption corresponding to vehicle traffic for concentrate transport are based on emission factors from *Emission estimation technique manual for Combustion engines* (NPI, 2008).

$$EF = 8.51\frac{kg\ CO}{kL} \quad EF = 22.30\frac{kg\ NO_x}{kL} \quad EF = 0.84\frac{kg\ SO_2}{kL} \quad EF = 1.17\frac{kg\ PM_{10}}{kL}$$
$$EF = 1.12\frac{kg\ PM_{2.5}}{kL}$$

It is deemed that trucks have fuel consumption equal to 24.8 L D2/100 km.

The results of particulate and gas emissions due to fuel consumption are shown in Table 2.7. CO emissions range from 0.0453 g/s to 0.2023 g/s. NO_x emissions range from 0.1188 g/s to 0.5301 g/s. SO_2 emissions range from 0.0044 g/s to 0.0199 g/s. PM_{10} emissions range from 0.0062 g/s to 0.0278 g/s. $PM_{2.5}$ emissions range from 0.0060 g/s to 0.0266 g/s.

2.1.5 Diesel generators

Particulate and gas emissions were determined based on data from the technical specifications for model CAT 3512B TA generator sets. The technical sheets for the equipment show fuel consumption rate, emission exit temperature, gas flow rate (m^3/min), and stack diameter as well as emission factors in mg/Nm^3. For estimation of emissions, the project considers operation of 2 diesel generator sets around the clock for 365 days in an average year; note that this condition is the most unfavorable one under a conservative scenario.

The results of particulate and gas emissions from diesel generator operation are shown in Table 2.8. CO emissions are estimated at 2.6347 g/s. NO_x emissions are estimated at 12.2369 g/s. SO_2 emissions are estimated at 0.1453 g/s. PM_{10} and $PM_{2.5}$ emissions are estimated at 0.1207 g/s.

2.1.6 Wind erosion

Wind erosion due to project activities corresponds to stockpiles, waste dumps and tailings storage facility.

2.1.6.1 Stockpiles

Emissions from wind erosion of stockpiles were estimated with the following equation included in *Emissions Inventory Guidance - Mineral Handling and Processing Industries* (MDAQMD, 2000).

$$EF = J \times 1{,}7 \times \frac{sL}{1{,}5} \times \frac{(365 - P)}{235} \times \frac{I}{15} \times \frac{365}{200}$$
$$E = EF \times A$$

Where:

EF = emission factor, in tons/acre.year,
A= exposed surface area, in acres,
J= aerodynamic factor according to particle size (0.5 for PM_{10} and 0.2 for $PM_{2.5}$)
sL= percentage of fines content in stockpile (%),
P = days per year with at least 0.254 mm precipitation, and
I = percentage of winds faster than 5.36 m/s.

According to the geometric configuration of the ROM Stockpile and Coarse Ore Stockpile, exposed surface areas are estimated at 4.40 and 0.11 acres, respectively. Based on meteorological and project data, emission factors estimated for PM_{10} and $PM_{2.5}$ are 0.013 tons/acre.year and 0.005 tons/acre.year, respectively.

The emission results for particulate matter (PM_{10} and $PM_{2,5}$) from wind erosion of stockpiles are shown in Table 2.9; emissions are estimated at 57.67 kg/year for PM_{10} and 23.07 kg/year for $PM_{2.5}$.

2.1.6.2 Open areas in waste dump and tailings storage facility

Emissions resulting from wind erosion in open spaces of disturbed areas (waste dumps and tailings storage facilities) were estimated by the equation indicated in the Emissions Inventory Guidance - Mineral Handling and Processing Industries (MDAQMD, 2000).

$$EF = k \times 2.814 \times (1 - v) \times \left(\frac{u}{u_t}\right)^3 \times C(x)$$

$$u_t = u_t^* \times u^*$$

$$x = 0.886 \times \frac{u_t}{u}$$

$$E = EF \times A$$

Where:

EF = emission factor in tons per acre and year,
k = particulate aerodynamic factor (0.5 for PM_{10} and 0.2 for $PM_{2.5}$),
A = disturbed area in acres,
v = amount of vegetative cover as a fraction,
u = mean wind speed in meters per second,
u_t = threshold value of wind speed in meters per second,
C(x) = correction factor,
u_t^* = threshold friction velocity in meters per second,
u^* = ratio of wind speed to friction velocity

The emission factors were determined considering meteorological data recorded by the Farim station, as well as the kind of disturbed area, either waste dump or tailings storage facility. The correction factor, which depends on the value calculated for parameter x is shown in Chart 2.1.

Chart 2.1
Correction factor

x	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
C(x)	1.91	1.90	1.89	1.86	1.83	1.77	1.70	1.60	1.48	1.33	1.20	1.05	0.90	0.78	0.62	0.5	0.4	0.29

Prepared by Knight Piésold Consultores
Source: (MDAQMD, 2000)

The estimated disturbed areas, emission factors, and particulate matter emissions are shown in Table 2.10. PM_{10} emissions vary between 0.2575 g/s and 1.0510 g/s. $PM_{2.5}$ emissions vary between 0.1030 g/s and 0.4204 g/s.

2.2 Ponta Chugue port facilities and paved access road

Phosphate concentrate will be taken to the port site by truck, which will unload the concentrate by means of a conveyor belt system. The phosphate concentrate will be transferred to a storage pile, where a front-end loader will feed the concentrate into the drying system to reduce its moisture content from 8% to 3%. Finally, the 3%-moisture concentrate will be dumped into a pile inside a closed warehouse for its subsequent transfer to the ship by means of a conveyor system that feeds the ship's hoppers.

The results of the quantification of particle and gas emissions, calculated using the emission factor method, were classified into emission sources for each air pollutant; air pollutants were CO (carbon monoxide), NO_x (nitrogen oxides), SO_2 (sulfur dioxide), PM_{10} (particulate matter under 10 microns), and $PM_{2.5}$ (particulate matter under 2.5 microns). The emission results for each air pollutant, in kilos per year and grams per second are shown in Table 2.11. It can be observed that not all activities produce gas emissions.

Activities identified as potential emission sources of particles and gases during the operation stage are as follows:

- concentrate handling,
- concentrate drying,
- front-end loader fuel consumption,
- truck circulation on paved roads,
- truck fuel consumption, and
- ship fuel consumption during the time it takes to load concentrate

In the following sections, the emission factors used for calculating the emissions inventory based on type of activity are presented.

2.2.1 Phosphate concentrate handling

Emissions during concentrate handling are produced due to unloading (hoppers and storage piles) and concentrate transfer (conveyor belts). It should be noted that this type of activity releases particulate matter emissions only. Thus, in order to estimate emissions, each point at which concentrate is handled must be considered, both for unloading and during its transfer.

Calculation of emissions resulting from concentrate handling while unloading are based on Section 13.2.4 Aggregate Handling And Storage Piles of Manual AP-42 (USEPA, 2006b).

$$EF = k \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \Big/ \left(\frac{M}{2}\right)^{1.4}$$

$$E = EF \times Q$$

Where:

EF = emission factor in kg/t,

k = scaling factor, depending on size of particles emitted (0.35 for PM_{10} and 0.053 for $PM_{2.5}$),

U = mean wind speed (m/s),

M = material moisture percentage (%), and
Q = quantity unloaded (t/year)

Moreover, calculation of emissions resulting from handling by transferring concentrate using conveyor belt system with control measures was based on Section 11.19.2 Crushed Stone Processing and Pulverized Mineral of Manual AP-42 (USEPA, 2004).

$$EF = k \times 0.00007$$
$$E = EF \times Q$$

Where:

EF = emission factor in kg/t,
k = scaling factor, depending on size of particles emitted (0.33 for PM_{10} and 0.093 for $PM_{2.5}$), and
Q = quantity transferred (t/year)

A mean speed of 3.28 m/s is considered, according to meteorological data from the Osvaldo Vieira International Airport (ICAO code: GGOV) station. The moisture content considered depends on the type of concentrate handled and on its stage in the process: It can be 8% before the drying process and 3% at its end.

Below, calculation of emission factors for air pollutants PM_{10} and $PM_{2.5}$ is presented, both for unloading and transfer of material.

- Unloading of concentrate at 8% moisture

$$EF\ PM_{10} = 0.35 \times 0.0016 \times \left(\frac{3.28}{2.2}\right)^{1.3} \Big/ \left(\frac{8}{2}\right)^{1.4} = 1.35E-04$$

$$EF\ PM_{2.5} = 0.053 \times 0.0016 \times \left(\frac{3.28}{2.2}\right)^{1.3} \Big/ \left(\frac{8}{2}\right)^{1.4} = 2.05E-05$$

- Unloading of concentrate at 3% moisture

$$EF\ PM_{10} = 0.35 \times 0.0016 \times \left(\frac{3.28}{2.2}\right)^{1.3} \Big/ \left(\frac{3}{2}\right)^{1.4} = 5.34E-04$$

$$EF\ PM_{2.5} = 0.053 \times 0.0016 \times \left(\frac{3.28}{2.2}\right)^{1.3} \Big/ \left(\frac{3}{2}\right)^{1.4} = 8.08E-05$$

- Transfer of concentrate between conveyor belts (controlled)

$$EF\ PM_{10} = 0.33 \times 0.00007 = 2.31E - 05$$
$$EF\ PM_{2.5} = 0.093 \times 0.00007 = 6.51E - 06$$

As mitigation measure, the use of covered conveyor belts is considered. Emissions inventory guides present control efficiency values based on the cover level of a transfer zone, such as conveyor belts or unloading areas:

- Total enclosure for unloading on storage piles (NPI, 2012b) = 99%
- Covered conveyor belt (MDAQMD, 2000) = 85%
- Three-quarter-covered conveyor belt (MDAQMD, 2000) = 70%

The formula used for calculating emissions taking into account these efficiencies is as follows:

$$E_c = E \times (100\% - C)$$

Where:

E_c = controlled particulate matter emissions
E = uncontrolled emissions
C = control efficiency (%)

The quantity of handled material, emission factor values, emission control efficiency, and emission rates are shown in Table 2.12. Fugitive emissions of particulate matter due to concentrate handling seem to generate PM_{10} and $PM_{2.5}$ emission totals equal to 0.0271 g/s and 0.0017 g/s, respectively.

2.2.2 Phosphate concentrate drying

According to Manual AP-42, Section 11.21, Phosphate Rock Processing (USEPA, 1995), phosphate concentrate drying produces mainly CO, PM_{10} and $PM_{2.5}$ emissions.

$$EF = k \times 2.9\ \frac{kg\ PM_i}{t}$$
$$EF = 0.17 \frac{kg\ CO}{t}$$
$$E = EF \times Q$$

Where:

EF = emission factor in kg/t,
k = scaling factor, depending on size of particles emitted (0.82 for PM_{10} and 0.27 for $PM_{2.5}$), and

Q = quantity of material (t/year).

Below, calculation of emission factors for the air pollutants PM_{10} and $PM_{2.5}$ is presented.

$$EF = 0.82 \times 2.9 = 2.38 \frac{kg\ PM_{10}}{t}$$
$$EF = 0.27 \times 2.9 = 0.78 \frac{kg\ PM_{2.5}}{t}$$

The project (Lycopodium, 2014) considers installation of a dust collector followed by a wet scrubber, as control measure. Emission reduction efficiencies of these devices were calculated based on emission factors depending on the control measure or without the control measure (USEPA, 1995):

- Dryer without control

$$EF = 2.9 \frac{kg\ PM}{t}$$

- Dryer with scrubber

$$EF_1 = 0.035 \frac{kg\ PM}{t}$$

- Dryer with dust collector (electrostatic precipitator)

$$EF_2 = 0.016 \frac{kg\ PM}{t}$$

Considering this information, reduction efficiencies were calculated in order to be able to determine total reduction efficiency (C_T), which is equal to 99.99%.

$$C_1 = \frac{(EF - EF_1)}{EF} = \frac{2.9 - 0.035}{2.9} \times 100 = 98.79\%$$
$$C_2 = \frac{(EF - EF_2)}{EF} = \frac{2.9 - 0.016}{2.9} \times 100 = 99.45\%$$
$$C_T = 1 - (1 - C_1)(1 - C_2) = 99.993\%$$

According to project data (Lycopodium, 2014), the dryer will emit 120°C-hot gases to the atmosphere, through the chimney. The parameters that characterize the emissions released through the chimney are given below:

- Exit temperature (Lycopodium, 2014) = 393.15 K
- Chimney diameter (estimated) = 2 m
- Chimney area (estimated) = 3.14 m^2
- Chimney height (approximate) = 10 m
- Flow under normal conditions (25 ºC, 1 atm) (USEPA, 1995) = 45 Nm^3/s

- Flow at chimney exit (120 ºC, 101.1 kPa[2]) = 59.47 m^3/s
- Gas exit speed (120ºC, 101.1 kPa) = 18.9 m/s

The concentrate quantity that will be placed in the dryer, emission factor values, emission control efficiency, and emission rates is shown in Table 2.13. Fugitive emissions of particulate matter for PM_{10} are equal to 0.006 g/s and for $PM_{2.5}$, are equal to 0.002 g/s. CO emissions are estimated at 6.738 g/s.

2.2.3 Heavy machinery

Quantification of emissions due to use of heavy machinery (FEL) was based on the Emission Estimation Technique Manual for Combustion Engines (NPI, 2008).

$$E = P \times T \times LF \times EF$$

Where:

E = gas and particle emission rate,
P = average machinery power (kW),
T = hours of machinery operation (h-eq/year),
LF = loading factor used in installation operations based on type of device,
EF = emission factor based on the type of engine and diesel fuel (kg/kWh).

Five front-end loaders (FEL) are considered, which will be used around the clock. Furthermore, according to technical specifications, the nominal power of CAT 980H front-end loaders is equal to 293 kW, and they have a load factor of 0.5 according to the recommendations in the above mentioned manual (NPI, 2008).

Table 2.14 shows the number of pieces of machinery to be used, the values in kWh/year, emission factor values for gases and particles, and emission estimates; the latter are shown below:

- CO emissions = 0.739 g/s
- NO_x emissions = 2.401 g/s
- SO_2 emissions = 0.076 g/s
- PM_{10} emissions = 0.015 g/s
- $PM_{2.5}$ emissions = 0.013 g/s

2.2.4 Vehicle circulation on paved access road

Particle and gas emissions are produced by circulation of trucks transporting the phosphate concentrate along the route connecting the truck loading facilities at Farim with the Ponta

[2] Mean value of atmospheric pressure according to GGOV station records

Chugue Port facilities. The main emission sources will result from suspension of particulate matter that had settled on the paved road, as well as from fuel consumption by the vehicle fleet. It is important to point out that truck circulation will be restricted to the time between 6:00 a.m. and 8:00 p.m. (Lycopodium, 2014).

It should be noted that the main source of particulate matter for this activity results from resuspension, which is caused mainly by friction between the tires and the road surface, as well as by the turbulence created by the vehicle. Emissions coming from the hoppers are considered negligible, given the fact that the speed at which the trucks move very rarely is strong enough to cause materials to be blown away (Cecala et. al., 2012).

2.2.4.1 Suspension of particulate matter due to truck circulation

Quantification of emissions due to suspension of particulate matter that had settled on the road was based on Manual AP-42, Section 13.2.1, Paved Roads (USEPA, 2011).

$$EF = k \times (sL)^{0.91} \times (W)^{1.02} \times \left(1 - \frac{P}{4N}\right)$$

$$E = EF \times Q$$

Where:

- *E* = gas and particle emission rate,
- *k* = scaling factor, depending on size of particles emitted (0.62 g/VKT for PM_{10} and 0.15 g/VKT for $PM_{2.5}$),
- *sL*= fine particulate matter load on surface (g/m^2),
- *W* = average weight (tons) of vehicles circulating on road,
- *P* = number of days of period with at least 0.254 mm of precipitation,
- *N* = number of days of period

For calculation of emission factor for heavy vehicles, the fine particulate matter load is considered to be 0.6 g/m^2, because the projected traffic volume is less than 500 vehicles per day (USEPA, 2011). The average weight is calculated taking the weight of the empty and loaded vehicle as reference, which gives approximately 51.5 tons, a value that represents trucks with 31-ton cargo capacity (Lycopodium, 2014). The number of precipitation days per year with at least 0.254 mm is considered to be 101, according to meteorological data (Golder Associates, 2014). Furthermore, the project considers using 12 light vehicles (pickup trucks), which – under a conservative scenario – are estimated to be used for daily transfer between the mine site and the port area.

Based on this information, calculation of emission factors for air pollutants PM_{10} and $PM_{2.5}$ corresponding to heavy vehicles is presented below:

$$EF = 0.62 \times (0.6)^{0.91} \times (51.5)^{1.02} \times \left(1 - \frac{101}{4 \times 365}\right) \frac{g\ PM_{10}}{VKT} \times \frac{1\ kg}{1000\ g} = 0.020 \frac{kg\ PM_{10}}{VKT}$$

$$EF = 0.15 \times (0.6)^{0.91} \times (51.5)^{1.02} \times \left(1 - \frac{101}{4 \times 365}\right) \frac{g\ PM_{2.5}}{VKT} \times \frac{1\ kg}{1000\ g} = 4.89E - 03 \frac{kg\ PM_{2.5}}{VKT}$$

Calculation of emission factors for air pollutants PM_{10} and $PM_{2.5}$ corresponding to light vehicles is as follows:

$$EF = 0.62 \times (0.6)^{0.91} \times (3)^{1.02} \times \left(1 - \frac{101}{4 \times 365}\right) \frac{g\ PM_{10}}{VKT} \times \frac{1\ kg}{1000\ g} = 0.001 \frac{kg\ PM_{10}}{VKT}$$

$$EF = 0.15 \times (0.6)^{0.91} \times (3)^{1.02} \times \left(1 - \frac{101}{4 \times 365}\right) \frac{g\ PM_{2.5}}{VKT} \times \frac{1\ kg}{1000\ g} = 2.69E - 04 \frac{kg\ PM_{2.5}}{VKT}$$

Maximum daily requirement for haulage of phosphate concentrate per year is estimated at 1.25 million tons. Truck cargo capacity is 31 tons (Lycopodium, 2014), while the distance traveled by the trucks is about 78 km. Based on this information, daily vehicle traffic and the kilometers travelled by the vehicles (VKT) are calculated.

$$\frac{truck}{year} = \frac{1.25\ Mt}{31\ t} \times \frac{10^6 t}{1\ Mt} \times 2\ (round\ trip) = 80{,}645$$

$$\frac{VKT}{year} = 80{,}645 \times \frac{78.23\ km}{year} = 6{,}309{,}032$$

For the case of light vehicles, it is estimated at 61,320 for one trip of the 12 light vehicles every hour during the 365 days of the year, as a rather conservative condition.

Table 2.15 shows calculated emissions resulting from particle suspension due to vehicle traffic, being the emission total 7.219 g/s for PM_{10} and 1.746 g/s for $PM_{2.5}$.

2.2.4.2 Fuel consumption by heavy and light vehicles

Gas and particle emissions due to diesel and gasoline fuel (petrol) consumption corresponding to vehicle circulation for concentrate transport, as well as to light vehicles were based on emission factors from the Emission Estimation Technique Manual for Combustion Engines (NPI, 2008).

- Emission factors for diesel fuel consumption:

$$EF = 8.51 \frac{kg\ CO}{kL} \quad EF = 22.30 \frac{kg\ NO_x}{kL} \quad EF = 0.84 \frac{kg\ SO_2}{kL} \quad EF = 1.17 \frac{kg\ PM_{10}}{kL}$$

$$EF = 1.12 \frac{kg\ PM_{2.5}}{kL}$$

- Emission factors for gasoline or petrol fuel consumption:

$$EF = 86.80\frac{kg\ CO}{kL} \quad EF = 11.00\frac{kg\ NO_x}{kL} \quad EF = 0.084\frac{kg\ SO_2}{kL} \quad EF = 0.072\frac{kg\ PM_{10}}{kL}$$
$$EF = 0.067\frac{kg\ PM_{2.5}}{kL}$$

Trucks were considered to present a (diesel) fuel consumption equal to 24.8 L D2/100 km, which – based on the quantity of kilometers traveled (VKT) – gives an estimated annual fuel consumption of approximately 1,454 kL. Regarding the (petrol) fuel consumption by light vehicles, the consumption rate was based on that of the Toyota pickup model Tacoma 4WD[3] (2014 model), which is equal to 14.7 L petrol/100 km.

Table 2.16 shows calculated emissions resulting from fuel consumption, which are given below:

- CO emissions = 4.050 g/s
- NO_x emissions = 2.315 g/s
- SO_2 emissions = 0.074 g/s
- PM_{10} emissions = 0.102 g/s
- $PM_{2.5}$ emissions = 0.098 g/s

Therefore, the main emissions for this activity correspond to CO and NO_x, of which 82% of CO emissions result from petrol consumption by light vehicles, and 81% of NO_x result from diesel consumption by heavy vehicles.

Although it is true that diesel is an important source of particulate matter (it represents 97% of PM emissions), it emits a larger quantity of NO_x. Yanowitz, Mccormick, & Graboski (2000), point out that altitude and humidity may influence diesel emissions, e.g., at high altitude, larger quantities of PM, CO and hydrocarbons are produced. On the other hand, at high humidity values, NO_x concentrations coming from emissions may decrease. Finally, they mention that control measures have been more effective at mitigating PM emissions than those of NO_x (Yanowitz et al., 2000).

2.2.5 Diesel generators

Particle and gas emissions were determined based on information from technical specifications for generators model CAT 3412C TA. The specification sheet for the devices presents the fuel consumption rate, emission exit temperature, gas flow rate (m^3/min), chimney diameter, as well as emission factors in mg/Nm^3. For emission estimation, the

[3] Toyota pickup Tacoma 4WD, based on 2014 (https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/tools/fuelratings/FCG2014print_e.pdf)

project considers operating 2 diesel generators 24 hours a day and 365 days a year for an average year; being this condition the most unfavorable condition under a conservative scenario.

Particle and gas emission results due to diesel generator operation are shown in Table 2.17. CO emissions are estimated at 0.0909 g/s. NO_x emissions are estimated at 1.4818 g/s. SO_2 emissions are estimated at 0.0683 g/s. And PM_{10} and $PM_{2.5}$ emissions are estimated at 0.0227 g/s.

2.2.6 Ship operation during phosphate concentrate loading

Estimation of emissions produced by the ship during concentrate loading, due to fuel consumption from engine operation was based on the Estimation Technique Manual for Maritime Operation (NPI, 2012a).

$$E_i = N \times EF_i \times P \times TIW$$

Where:

Ei =	emissions by auxiliary power engines	(kg/year)
N =	number of ships docking every year	(ships/year)
EF_i =	emission factor of substance i from auxiliary engines	(kg/kWh)
P =	auxiliary power (assumed at 600 kW, according to manual)	(kW)
TIW =	average waiting time per ship	(hours/ship)

For emission quantification, a standard nominal power of 600 kW is considered for auxiliary engine operation. According to the design criterion (Lycopodium, 2014), it will take 48 hours to load the concentrates onto the ship, considering 33 loading operations per year.

Table 2.18 shows the calculated emissions resulting from simultaneous operation of 2 auxiliary engines, which gives the daily average emission total for this activity, as shown below:

- NO_x emissions = 0.9534 g/s
- $PM_{2.5}$ emissions = 0.0565 g/s
- PM_{10} emissions = 0.0658 g/s
- SO_2 emissions = 0.6378 g/s
- CO emissions = 0.0723 g/s

3.0 Bibliography

CAT. (2011a). Diesel Generator Set - CAT 3412C.

CAT. (2011b). Diesel Generator Set - CAT 3512B.

Cecala, A. B., O'Brien, A. D., Schall, J., Colinet, J. F., Fox, W. R., Franta, R. J., … Schultz, M. J. (2012). Dust Control Handbook for Industrial Minerals Mining and Processing. Pittsburgh, PA.: Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health.

Golder Associates. (2013). 2012 Ground Characterisation - Factual Report. London, UK.

Golder Associates. (2014). Appendix C1 Air Dispersion Modelling (ADM). In *Mine Component Environmental and Social Impact Assessment* (p. 842). London, UK: Golder Associates (UK) LTD.

Lycopodium. (2014). *Farim Phosphate Project - Process Design Criteria*.

MDAQMD. (2000). Emissions Inventory Guidance Mineral Handling and Processing Industries. Mojave Desert Air Quality Management District. Antelope Valley Air Pollution Control District. Revised during 2013.

NPI. (2008). *Emission estimation technique manual for Combustion engines* (version 3.). Canberra-Australia: Department of the Environment, Water, Heritage and the Arts. Retrieved from http://www.npi.gov.au/reporting/industry-reporting-materials/emission-estimation-technique-manuals

NPI. (2012a). *Emission estimation technique manual for Maritime operations Version 2.1*. Canberra: Australia Government. Department of Sustainability, Environment, Water, Population and Communities.

NPI. (2012b). EMISSION ESTIMATION TECHNIQUE MANUAL FOR MINING VERSION 3 . 1. Camberra: Australia Government. Department of Sustainability, Environment, Water, Population and Communities.

USEPA. (1995). 11.21 Phosphate Rock Processing. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42 Fifth Edition* (Fifth Edit., Vol. 1, pp. 1–10). NC: U. S. Environmental Protection Agency.

USEPA. (1998). 11.9 Western Surface Coal Mining. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–14). NC: U. S. Environmental Protection Agency.

USEPA. (2004). 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–17). NC: U. S. Environmental Protection Agency.

USEPA. (2006a). 13.2.2 Unpaved Roads. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–20). NC: U. S. Environmental Protection Agency.

USEPA. (2006b). 13.2.4 Aggregate Handling And Storage Piles. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–6). NC: U. S. Environmental Protection Agency.

USEPA. (2006c). 13.2.5 Industrial Wind Erosion. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (Fifth Edit., pp. 1–15). NC: U. S. Environmental Protection Agency.

USEPA. (2011). 13.2.1 Paved Roads. In *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42*.

Watson, J. G., & Chow, J. C. (2000). *Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research* (No. DRI Document No. 6110.4F). Nevada: Desert Research Institute. Retrieved from http://www.epa.gov/ttn/chief/efdocs/fugitivedust.pdf

Yanowitz, J., Mccormick, R. L., & Graboski, M. S. (2000). In-use emissions from heavy-duty diesel vehicles. *Environmental Science and Technology*. doi:10.1021/es990903w

Knight Piésold Consultores S.A.

Prepared by: _____
Alejandro Delgado
Environmental Engineer KP Peru

Revised by: _____
Edgardo Enríquez
Project Management KP Peru

Approved by: _____
Claudia Sandoval
Environmental Management KP Peru

Tables

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT
AIR QUALITY MODELLING

TABLE 2.1
Particulate matter and gases emissions by source
Mine site

Scenario	Source	Type of source	Code of source	CO emissions		NO_x emissions		SO_2 emissions		PM_{10} emissions		$PM_{2.5}$ emissions	
				E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s
Year 2	South Open Pit	Volume	SOP	75 804	2,4037	231 293	7,3343	7 487	0,2374	47 921	1,5196	21 428	0,6795
	Integrated Waste Landform (IWL)	Areal	IWL	4 076	0,1293	18 938	0,6005	741	0,0235	22 394	0,7101	4 491	0,1424
	South-East Waste Dump	Areal	SEWD	-	-	-	-	-	-	224	0,0071	90	0,0028
	North-East Waste Dump	Areal	NEWD	1 356	0,0430	6 299	0,1997	247	0,0078	7 719	0,2448	2 109	0,0669
	Truck loading facility	Volume	TLF	-	-	-	-	-	-	46	0,0015	7	0,0002
	ROM Stockpile	Areal	RST	-	-	-	-	-	-	7 521	0,2385	135	0,0043
	ROM bin grizzly / ROM belt feeder	Areal	RBG	-	-	-	-	-	-	91	0,0029	24	0,0008
	Coarse ore stockpile	Areal	COS	-	-	-	-	-	-	21	0,0007	4	0,0001
	Reject screen 1 and 2	Volume	RSC	-	-	-	-	-	-	1 890	0,0599	13	0,0004
	Concentrate filter discharge conveyor	Volume	CFD	-	-	-	-	-	-	7	0,0002	33	0,0010
	Concentrate pipe conveyor feed bin	Volume	CPC	-	-	-	-	-	-	9	0,0003	39	0,0012
	Tailing Storage Facility	Areal	TSF	16 750	0,5311	36 277	1,1503	886	0,0281	4 711	0,1494	3 006	0,0953
	Generator 1	Point	G1	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	Generator 2	Point	G2	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	South Open Pit - IWL	Lineal	Line1	3 539	0,1122	9 274	0,2941	347	0,0110	100 981	3,2021	40 664	1,2894
	South Open Pit - South Open Pit	Lineal	Line2	293	0,0093	767	0,0243	29	0,0009	8 347	0,2647	3 361	0,1066
	South Open Pit - NEWD	Lineal	Line3	394	0,0125	1 033	0,0328	39	0,0012	11 252	0,3568	4 531	0,1437
	South Open Pit - ROM Stockpile	Lineal	Line4	230	0,0073	602	0,0191	23	0,0007	4 298	0,1363	1 737	0,0551
	ROM Stockpile - ROM bin grizzly	Lineal	Line5	96	0,0030	251	0,0080	9	0,0003	1 402	0,0445	568	0,0180
	Total			**185 627**	**5,8862**	**690 637**	**21,9000**	**14 389**	**0,4563**	**222 641**	**7,0599**	**86 045**	**2,7285**
Year 8	South Open Pit	Volume	SOP	37 785	1,1982	117 194	3,7162	3 809	0,1208	32 148	1,0194	11 414	0,3619
	North Open Pit	Volume	NOP	47 432	1,5040	145 821	4,6240	4 713	0,1495	41 743	1,3236	13 697	0,4343
	South Pit SOS	Volume	SPS	7 055	0,2237	27 077	0,8586	965	0,0306	14 739	0,4674	6 021	0,1909
	Truck loading facility	Volume	TLF	-	-	-	-	-	-	46	0,0015	7	0,0002
	ROM Stockpile	Areal	RST	-	-	-	-	-	-	7 521	0,2385	135	0,0043
	ROM bin grizzly / ROM belt feeder	Areal	RBG	-	-	-	-	-	-	91	0,0029	24	0,0008
	Coarse ore stockpile	Areal	COS	-	-	-	-	-	-	21	0,0007	4	0,0001
	Reject screen 1 and 2	Volume	RSC	-	-	-	-	-	-	1 890	0,0599	13	0,0004
	Concentrate filter discharge conveyor	Volume	CFD	-	-	-	-	-	-	7	0,0002	33	0,0010
	Concentrate pipe conveyor feed bin	Volume	CPC	-	-	-	-	-	-	9	0,0003	39	0,0012
	Tailing Storage Facility	Areal	TSF	19 541	0,6196	42 323	1,3421	1 034	0,0328	12 672	0,4018	6 377	0,2022
	Generator 1	Point	G1	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	Generator 2	Point	G2	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	South Open Pit - South Open Pit	Lineal	Line2	243	0,0077	637	0,0202	24	0,0008	6 935	0,2199	2 793	0,0886
	South Open Pit - ROM Stockpile	Lineal	Line4	593	0,0188	1 553	0,0492	58	0,0018	11 093	0,3518	4 483	0,1421
	ROM Stockpile - ROM bin grizzly	Lineal	Line5	96	0,0030	251	0,0080	9	0,0003	1 402	0,0445	568	0,0180
	South Open Pit - SPS	Lineal	Line6	148	0,0047	387	0,0123	14	0,0005	4 216	0,1337	1 698	0,0538
	North Open Pit - North Open Pit	Lineal	Line7	216	0,0068	566	0,0179	21	0,0007	6 160	0,1953	2 481	0,0787
	North Open Pit - ROM Stockpile	Lineal	Line9	135	0,0043	353	0,0112	13	0,0004	2 525	0,0801	1 020	0,0324
	Total			**196 332**	**6,2256**	**722 066**	**22,8966**	**15 244**	**0,4834**	**147 024**	**4,6621**	**54 612**	**1,7317**
Year 15	North Open Pit	Areal	NOP	91 779	2,9103	284 348	9,0166	9 200	0,2917	60 038	1,9038	26 684	0,8462
	Integrated Waste Landform (IWL)	Areal	IWL	2 850	0,0904	10 389	0,3294	359	0,0114	31 780	1,0077	4 743	0,1504
	South Pit SOS	Volume	SPS	2 850	0,0904	10 389	0,3294	359	0,0114	5 529	0,1753	2 388	0,0757
	North Pit SOS	Volume	NPS	1 356	0,0430	6299,2	0,1997	246,5	0,0078	8 122	0,2576	3 234	0,1026
	Truck loading facility	Volume	TLF	-	-	-	-	-	-	46	0,0015	7	0,0002
	ROM Stockpile	Areal	RST	-	-	-	-	-	-	7 521	0,2385	135	0,0043
	ROM bin grizzly / ROM belt feeder	Areal	RBG	-	-	-	-	-	-	91	0,0029	24	0,0008
	Coarse ore stockpile	Areal	COS	-	-	-	-	-	-	21	0,0007	4	0,0001
	Reject screen 1 and 2	Volume	RSC	-	-	-	-	-	-	1 890	0,0599	13	0,0004
	Concentrate filter discharge conveyor	Volume	CFD	-	-	-	-	-	-	7	0,0002	33	0,0010
	Concentrate pipe conveyor feed bin	Volume	CPC	-	-	-	-	-	-	9	0,0003	39	0,0012
	Tailing Storage Facility	Areal	TSF	19 541	0,6196	42 323	1,3421	1 034	0,0328	21 551	0,6834	9 929	0,3148
	Generator 1	Point	G1	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	Generator 2	Point	G2	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	ROM Stockpile - ROM bin grizzly	Lineal	Line5	96	0,0030	251	0,0080	9	0,0003	1 402	0,0445	568	0,0180
	North Open Pit - North Open Pit	Lineal	Line7	365	0,0116	958	0,0304	36	0,0011	10 427	0,3306	4 199	0,1331
	North Open Pit - ROM Stockpile	Lineal	Line9	617	0,0196	1 618	0,0513	61	0,0019	11 557	0,3665	4 670	0,1481
	North Open Pit - IWL	Lineal	Line10	5 144	0,1631	13 479	0,4274	505	0,0160	146 757	4,6536	59 097	1,8740
	North Open Pit - SPS	Lineal	Line11	136	0,0043	356	0,0113	13	0,0004	3 876	0,1229	1 561	0,0495
	North Open Pit - NPS	Lineal	Line12	22	0,0007	58	0,0018	2	0,0001	626	0,0199	252	0,0080
	Total			**207 844**	**6,5907**	**756 370**	**23,9843**	**16 407**	**0,5203**	**315 057**	**9,9904**	**121 386**	**3,8491**
Year 25	North Open Pit	Volume	NOP	101 684	3,2244	321 814	10,2047	10 524	0,3337	98 638	3,1278	33 048	1,0479
	Truck loading facility	Volume	TLF	-	-	-	-	-	-	46	0,0015	7	0,0002
	ROM Stockpile	Areal	RST	-	-	-	-	-	-	7 521	0,2385	135	0,0043
	ROM bin grizzly / ROM belt feeder	Areal	RBG	-	-	-	-	-	-	91	0,0029	24	0,0008
	Coarse ore stockpile	Areal	COS	-	-	-	-	-	-	21	0,0007	4	0,0001
	Reject screen 1 and 2	Volume	RSC	-	-	-	-	-	-	1 890	0,0599	13	0,0004
	Concentrate filter discharge conveyor	Volume	CFD	-	-	-	-	-	-	7	0,0002	33	0,0010
	Concentrate pipe conveyor feed bin	Volume	CPC	-	-	-	-	-	-	9	0,0003	39	0,0012
	Tailing Storage Facility	Areal	TSF	22 333	0,7082	48369,2	1,5338	1181,6	0,0375	34 622	1,0979	15 344	0,4866
	Generator 1	Point	G1	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	Generator 2	Point	G2	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	ROM Stockpile - ROM bin grizzly	Lineal	Line5	96	0,0030	251	0,0080	9	0,0003	1 402	0,0445	568	0,0180
	North Open Pit - North Open Pit	Lineal	Line7	758	0,0240	1 986	0,0630	74	0,0024	21 623	0,6857	8 707	0,2761
	North Open Pit - ROM Stockpile	Lineal	Line9	1 046	0,0332	2 742	0,0870	103	0,0033	19 592	0,6213	7 917	0,2510
	Total			**209 006**	**6,6275**	**761 066**	**24,1333**	**16 474**	**0,5224**	**189 269**	**6,0017**	**69 646**	**2,2085**

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT
AIR QUALITY MODELLING

TABLE 2.2
Particulate matter emissions - Bulldozing
Mine site

Scenario	Source	Activity rate (hour of equipment operation) (1)			EF- PM_{10} (2)	EF - $PM_{2.5}$ (2)	PM_{10} emissions		$PM_{2.5}$ emissions	
		# Heavy equipment/day	hours-eq/day	Total hours/year	kg/hour-eq	kg/hour-eq	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s
Year 2	South Open Pit	5	16,32	29 784	0,239	0,121	7 108	0,225	3 594	0,114
	Integrated Waste Landform (IWL)	2	16,32	11 914	0,239	0,121	2 843	0,090	1 437	0,046
	North-East Waste Dump	1	16,32	5 957	0,239	0,121	1 422	0,045	719	0,023
	Total						**11 372**	**0,361**	**5 750**	**0,182**
Year 8	South Open Pit	3	16,32	17 870	0,239	0,121	4 265	0,135	2 156	0,068
	North Open Pit	3	16,32	17 870	0,239	0,121	4 265	0,135	2 156	0,068
	South Pit SOS	3	16,32	17 870	0,239	0,121	4 265	0,135	2 156	0,068
	Total						**12 794**	**0,406**	**6 469**	**0,205**
Year 15	North Open Pit	6	16,32	35 741	0,239	0,121	8 529	0,270	4 312	0,137
	Integrated Waste Landform (IWL)	1	16,32	5 957	0,239	0,121	1 422	0,045	719	0,023
	South Pit SOS	1	16,32	5 957	0,239	0,121	1 422	0,045	719	0,023
	North Pit SOS	1	16,32	5 957	0,239	0,121	1 422	0,045	719	0,023
	Total						**12 794**	**0,406**	**6 469**	**0,205**
Year 25	North Open Pit	10	16,32	59 568	0,239	0,121	14 215	0,451	7 187	0,228
	Total						**14 215**	**0,451**	**7 187**	**0,228**

Prepared by Knight Piésold Consultores.

Notes

(1) Source: GB Minerals. This procedure applies to the bulldozing, scraping and grading of topsoil, overburden, waste material, and ore through the use of heavy equipment such as bulldozers, graders, scrapers.

(2) Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995).

Data:

Material silt content - s (%) =	13	Source: Golder (2013) - Ground Characterisation - Factual Report.
Material moisture content - M (%) =	20	Source: Golder (2013) - Ground Characterisation - Factual Report.
Control efficiency using wind screen - C (%) =	0	Source: MDAQMD (2013) - Mineral Handling and Processing Industries.

Emission factor equation (US EPA - AP 42):

$$\llbracket EF \rrbracket\_(\llbracket PM \rrbracket\_10\ ) = k \times 0.45 \times s\text{^}1.5/$$

k - PM_{10} = 0.75

$$\llbracket EF \rrbracket\_(\llbracket PM \rrbracket\_2.5\ ) = k \times 2.6 \times s\text{^}1.2/M$$

k - $PM_{2.5}$ = 0.105

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT
AIR QUALITY MODELLING

TABLE 2.3
Particulate matter and gases emissions - Use of heavy equipment (vehicle exhaust)
Mine site

Scenario	Source	Type of heavy equipment [1]	Average power - P (kW) [2]	Load factor (LF) [3]	Number of equipment [1]	Hours of equipment per day	Total hours used - T	EF - CO [3]	EF - NO_x [3]	EF - SO_2 [3,4]	EF - PM_{10} [3]	EF - $PM_{2,5}$ [3]	CO emissions		NO_x emissions		SO_2 emissions		PM_{10} emissions		$PM_{2,5}$ emissions	
						h-eq/day	h-eq/year	kg/kWh	kg/kWh	kg/kWh	kg/kWh	kg/kWh	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s
Year 2	South Open Pit	CAT 374DL - Excavator	355	1,00	3	16,32	17 870	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	21 189	0,672	50 118	1,589	1 561	0,049	2 703	0,086	2 639	0,084
		CAT 336DL - Excavator	200	1,00	1	16,32	5 957	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	3 979	0,126	9 412	0,298	293	0,009	508	0,016	496	0,016
		CAT 992K - Wheel Loader	607	0,50	6	16,32	35 741	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	39 376	1,249	127 999	4,059	4 062	0,129	11 715	0,371	10 782	0,342
		CAT D9R - Dozer	302	0,55	3	16,32	17 870	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	8 549	0,271	31 167	0,988	1 077	0,034	2 755	0,087	2 535	0,080
		CAT 16M - Motor Grader	221	0,50	2	16,32	11 914	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	2 712	0,086	12 598	0,399	493	0,016	1 103	0,035	1 015	0,032
	Integrated Waste Landform (IWL)	CAT D9R - Dozer	302	0,55	2	16,32	11 914	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	4 076	0,129	18 938	0,601	741	0,023	1 658	0,053	1 526	0,048
	North-East Waste Dump	CAT 16M - Motor Grader	221	0,50	1	16,32	5 957	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	1 356	0,043	6 299	0,200	247	0,008	552	0,017	507	0,016
	Tailing Storage Facility	CAT CS-56 - Compactor	116	0,50	6	16,32	35 741	8,08E-03	1,75E-02	4,28E-04	1,04E-03	9,57E-04	16 750	0,531	36 277	1,150	886	0,028	2 156	0,068	1 984	0,063
					Total								**97 986**	**3,107**	**292 807**	**9,285**	**9 360**	**0,297**	**23 149**	**0,734**	**21 484**	**0,681**
Year 8	South Open Pit	CAT 374DL - Excavator	355	1,00	1	16,32	5 957	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	7 063	0,224	16 706	0,530	520	0,016	901	0,029	880	0,028
		CAT 336DL - Excavator	200	1,00	1	16,32	5 957	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	3 979	0,126	9 412	0,298	293	0,009	508	0,016	496	0,016
		CAT 992K - Wheel Loader	607	0,50	3	16,32	17 870	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	19 688	0,624	63 999	2,029	2 031	0,064	5 858	0,186	5 391	0,171
		CAT D9R - Dozer	302	0,55	2	16,32	11 914	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	5 699	0,181	20 778	0,659	718	0,023	1 836	0,058	1 690	0,054
		CAT 16M - Motor Grader	221	0,50	1	16,32	5 957	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	1 356	0,043	6 299	0,200	247	0,008	552	0,017	507	0,016
	North Open Pit	CAT 374DL - Excavator	355	1,00	2	16,32	11 914	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	14 126	0,448	33 412	1,059	1 040	0,033	1 802	0,057	1 759	0,056
		CAT 336DL - Excavator	200	1,00	0	16,32	0	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
		CAT 992K - Wheel Loader	607	0,50	4	16,32	23 827	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	26 251	0,832	85 332	2,706	2 708	0,086	7 810	0,248	7 188	0,228
		CAT D9R - Dozer	302	0,55	2	16,32	11 914	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	5 699	0,181	20 778	0,659	718	0,023	1 836	0,058	1 690	0,054
		CAT 16M - Motor Grader	221	0,50	1	16,32	5 957	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	1 356	0,043	6 299	0,200	247	0,008	552	0,017	507	0,016
	South Pit SOS	CAT D9R - Dozer	302	0,55	2	16,32	11 914	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	5 699	0,181	20 778	0,659	718	0,023	1 836	0,058	1 690	0,054
		CAT 16M - Motor Grader	221	0,50	1	16,32	5 957	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	1 356	0,043	6 299	0,200	247	0,008	552	0,017	507	0,016
	Tailing Storage Facility	CAT CS-56 - Compactor	116	0,50	7	16,32	41 698	8,08E-03	1,75E-02	4,28E-04	1,04E-03	9,57E-04	19 541	0,620	42 323	1,342	1 034	0,033	2 515	0,080	2 314	0,073
					Total								**111 813**	**3,546**	**332 415**	**10,541**	**10 521**	**0,334**	**26 557**	**0,842**	**24 621**	**0,781**
Year 15	North Open Pit	CAT 374DL - Excavator	355	1,00	3	16,32	17 870	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	21 189	0,672	50 118	1,589	1 561	0,049	2 703	0,086	2 639	0,084
		CAT 336DL - Excavator	200	1,00	1	16,32	5 957	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	3 979	0,126	9 412	0,298	293	0,009	508	0,016	496	0,016
		CAT 992K - Wheel Loader	607	0,50	8	16,32	47 654	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	52 501	1,665	170 665	5,412	5 416	0,172	15 620	0,495	14 376	0,456
		CAT D9R - Dozer	302	0,55	4	16,32	23 827	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	11 398	0,361	41 556	1,318	1 437	0,046	3 673	0,116	3 380	0,107
		CAT 16M - Motor Grader	221	0,50	2	16,32	11 914	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	2 712	0,086	12 598	0,399	493	0,016	1 103	0,035	1 015	0,032
	Integrated Waste Landform (IWL)	CAT D9R - Dozer	302	0,55	1	16,32	5 957	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	2 850	0,090	10 389	0,329	359	0,011	918	0,029	845	0,027
	South Pit SOS	CAT D9R - Dozer	302	0,55	1	16,32	5 957	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	2 850	0,090	10 389	0,329	359	0,011	918	0,029	845	0,027
	North Pit SOS	CAT 16M - Motor Grader	221	0,50	1	16,32	5 957	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	1 356	0,043	6 299	0,200	247	0,008	552	0,017	507	0,016
	Tailing Storage Facility	CAT CS-56 - Compactor	116	0,50	7	16,32	41 698	8,08E-03	1,75E-02	4,28E-04	1,04E-03	9,57E-04	19 541	0,620	42 323	1,342	1 034	0,033	2 515	0,080	2 314	0,073
					Total								**118 375**	**3,754**	**353 748**	**11,217**	**11 199**	**0,355**	**28 509**	**0,904**	**26 418**	**0,838**
Year 25	North Open Pit	CAT 374DL - Excavator	355	1,00	3	16,32	17 870	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	21 189	0,672	50 118	1,589	1 561	0,049	2 703	0,086	2 639	0,084
		CAT 336DL - Excavator	200	1,00	1	16,32	5 957	3,34E-03	7,90E-03	2,46E-04	4,26E-04	4,16E-04	3 979	0,126	9 412	0,298	293	0,009	508	0,016	496	0,016
		CAT 992K - Wheel Loader	607	0,50	8	16,32	47 654	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	52 501	1,665	170 665	5,412	5 416	0,172	15 620	0,495	14 376	0,456
		CAT D9R - Dozer	302	0,55	7	16,32	41 698	2,88E-03	1,05E-02	3,63E-04	9,28E-04	8,54E-04	19 947	0,633	72 723	2,306	2 514	0,080	6 427	0,204	5 915	0,188
		CAT 16M - Motor Grader	221	0,50	3	16,32	17 870	2,06E-03	9,57E-03	3,75E-04	8,38E-04	7,71E-04	4 068	0,129	18 898	0,599	740	0,023	1 655	0,052	1 522	0,048
	Tailing Storage Facility	CAT CS-56 - Compactor	116	0,50	8	16,32	47 654	8,08E-03	1,75E-02	4,28E-04	1,04E-03	9,57E-04	22 333	0,708	48 369	1,534	1 182	0,037	2 875	0,091	2 645	0,084
					Total								**124 017**	**3,933**	**370 184**	**11,738**	**11 705**	**0,371**	**29 787**	**0,945**	**27 593**	**0,875**

Prepared by Knight Piésold Consultores.

Notes:

[1] Source: GB Minerals.

[2] Source: Technique sheets

[3] Source: National Pollutant Inventory, Emission Estimation Technique Manual for Combustion Engines (NPI, 2008).

[4] Sulphur content of 500 ppm (0.05%).

$$E = P \times LF \times T \times EF$$

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TABLE 2.4
Particulate matter emissions - Loading of material in trucks and handling by Front-End-Loader
Mine site

Scenario	Source	Type of material	Maximum material (Q) (1)	EF- PM_{10} (2)	EF - $PM_{2,5}$ (2)	PM_{10} emissions		$PM_{2.5}$ emissions	
			Mt/year	kg/t	kg/t	E - kg/year	E - g/s	E - kg/year	E - g/s
Year 2	South Open Pit	Overburden	31,34	8,61E-06	1,30E-06	269,91	0,0086	40,87	0,0013
		Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	ROM Stockpile	Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	Truck loading facility	Phosphate concentrate	1,25	5,66E-06	8,57E-07	7,07	0,0002	1,07	3,40E-05
	Total					**296,8**	**0,0094**	**44,9**	**0,0014**
Year 8	South Open Pit	Overburden	17,33	8,61E-06	1,30E-06	149,24	0,0047	22,60	0,0007
		Matrix phosphate	1,36	5,66E-06	8,57E-07	7,70	0,0002	1,17	3,70E-05
	North Open Pit	Overburden	19,85	5,66E-06	8,57E-07	112,31	0,0036	17,01	0,0005
		Matrix phosphate	0,39	5,66E-06	8,57E-07	2,20	0,0001	0,33	1,06E-05
	ROM Stockpile	Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	Truck loading facility	Phosphate concentrate	1,25	5,66E-06	8,57E-07	7,07	0,0002	1,07	3,40E-05
	Total					**288,43**	**0,0091**	**43,68**	**0,0014**
Year 15	North Open Pit	Overburden	40,85	8,61E-06	1,30E-06	351,91	0,0112	53,29	0,0017
		Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	ROM Stockpile	Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	Truck loading facility	Phosphate concentrate	1,25	5,66E-06	8,57E-07	7,07	0,0002	1,07	3,40E-05
	Total					**378,8**	**0,0120**	**57,4**	**0,0018**
Year 25	North Open Pit	Overburden	44,69	8,61E-06	1,30E-06	384,96	0,0122	58,29	0,0018
		Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	ROM Stockpile	Matrix phosphate	1,75	5,66E-06	8,57E-07	9,90	0,0003	1,50	4,76E-05
	Truck loading facility	Phosphate concentrate	1,25	5,66E-06	8,57E-07	7,07	0,0002	1,07	3,40E-05
	Total					**411,8**	**0,0131**	**62,4**	**0,0020**

Prepared by Knight Piésold Consultores.

Notes

(1) Mine Plan Production Statistics (Lycopodium Minerals Canada Ltd, 2015).

(2) Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995).

Data:

Anual mean wind speed - U (m/s) =	1,06	Source: Farim weather met station (December 18th 2012 to March 5th 2015)
Overburden moisture content - M (%) =	20	Source: Golder (2013) - Ground Characterisation - Factual Report.
Matrix moisture content - M (%) =	27	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria

Emission factor equation (US EPA - AP 42):

$EF=k\times0.0016\times(U/2.2)$^$1.3/(M/2)$^$1.4$

k - PM_{10} = 0.35

k - $PM_{2.5}$ = 0.053

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TABLE 2.5
Particulate matter emissions - Unloading of material and handling (overburden, matrix phosphate, and phosphate rock concentrate)
Mine site

Scenario	Source	Type of material	Material (Q) [1]	EF- PM_{10} [2]	EF - $PM_{2.5}$ [2]	Emissions control [3] [4]	PM_{10} emissions		$PM_{2.5}$ emissions	
			Mt/year	kg/t	kg/t	%	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s
Year 2	Integrated Waste Landform (IWL)	Overburden	11,44	4,26E-03	6,36E-05	70%	14 619,0	0,4636	218,3	0,00692
	South Open Pit	Overburden	17,02	4,26E-03	6,36E-05	70%	21 750,6	0,6897	324,7	0,01030
	North-East Waste Dump	Overburden	2,88	4,26E-03	6,36E-05	70%	3 677,0	0,1166	54,9	0,00174
	ROM Stockpile	Matrix phosphate	1,75	4,26E-03	6,36E-05	0%	7 455,0	0,2364	111,3	0,00353
	ROM bin grizzly	Matrix phosphate	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,00005
	ROM belt feeder / Feed conveyor	Matrix phosphate	1,75	4,62E-05	1,30E-05	0%	80,9	0,0026	22,8	0,00072
	Coarse ore stockpile	Matrix phosphate (unloading)	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,00005
	Coarse ore stockpile	Matrix phosphate handling by FEL	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,00005
	Reject screen 1 [5]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,00020
	Reject screen 2 [6]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,00020
	Concentrate filter discharge conveyor	Phosphate concentrate	1,25	2,31E-05	1,04E-04	75%	7,2	0,0002	32,6	0,00103
	Concentrate pipe conveyor feed bin	Phosphate concentrate	1,25	2,31E-05	1,04E-04	70%	8,7	0,0003	39,1	0,00124
	Truck loading facility	Phosphate concentrate unloading from conveyor	1,25	3,11E-05	4,70E-06	0%	38,8	0,0012	5,9	0,00019
	Total						**49 557**	**1,5714**	**827**	**0,0262**
Year 8	South Pit SOS	Overburden	3,19	4,26E-03	6,36E-05	70%	4 070,8	0,1291	60,8	0,0019
	South Open Pit	Overburden	14,14	4,26E-03	6,36E-05	70%	18 072,1	0,5731	269,8	0,0086
	North Open Pit	Overburden	19,85	4,26E-03	6,36E-05	70%	25 363,6	0,8043	378,7	0,0120
	ROM Stockpile	Matrix phosphate	1,75	4,26E-03	6,36E-05	0%	7 455,0	0,2364	111,3	0,0035
	ROM bin grizzly	Matrix phosphate	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,00005
	ROM belt feeder / Feed conveyor	Matrix phosphate	1,75	4,62E-05	1,30E-05	0%	80,9	0,0026	22,8	0,00072
	Coarse ore stockpile	Matrix phosphate (unloading)	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,00005
	Coarse ore stockpile	Matrix phosphate handling by FEL	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,00005
	Reject screen 1 [5]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,00020
	Reject screen 2 [6]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,00020
	Concentrate filter discharge conveyor	Phosphate concentrate	1,25	2,31E-05	1,04E-04	75%	7,2	0,0002	32,6	0,00103
	Concentrate pipe conveyor feed bin	Phosphate concentrate	1,25	2,31E-05	1,04E-04	70%	8,7	0,0003	39,1	0,00124
	Truck loading facility	Phosphate concentrate unloading from conveyor	1,25	3,11E-05	4,70E-06	0%	38,8	0,0012	5,9	0,00019
	Total						**57 017**	**1,8080**	**938**	**0,0297**

Prepared by Knight Piésold Consultores.

Notes

[1] Mine Plan Production Statistics (Lycopodium Minerals Canada Ltd, 2015).
[2] Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995). NPI Mining (2012).
[3] Source: National Pollutant Inventory (2012). Water spray as mitigation control of PM emissions on loading stockpiles and unloading trucks has an emission control of 50% and 70%, respectively.
[4] The emission reduction percentaje using different control techniques is as follows (MDAQMD, 2000; revision 2013):
Water spray for material handling (conveying) = 75%
Conveyor with full cover = 85%
Conveyor with three quarter = 70%
[5] Aperture of 5 mm = 100% passing. Control efficiency estimated using wet supression = 99.0%
[6] Aperture of 1 mm = 95.36% passing. Control efficiency estimated using wet supression = 99.0%

Data:

Anual mean wind speed - U (m/s) =	1,06	Source: Farim weather met station (December 18th 2012 to March 5th 2015).
Overburden moisture content - M (%) =	20	Source: Golder (2013b).
Matrix moisture content - M (%) =	27	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Phosphate concentrate moisture content - M (%) =	8	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.

Emission factor equation (US EPA - AP 42, NPI)

$EF=k\times0.0016\times(U/2.2)$^1.3/(M/2)^1.4
(Material handling and stockpile)
k - PM_{10} = 0.35
k - $PM_{2.5}$ = 0.053

$EF=k\times0.012$
(dumping overburden by trucks)
k - PM_{10} = 0.355
k - $PM_{2.5}$ = 0.053

$EF=k\times0.15$
(Fines screening)
k - PM_{10} = 0.36
k - $PM_{2.5}$ = 0.0024

$EF=k\times n\times0.00007$
(material transfer using conveyors)
k - PM_{10} = 0.33
k - $PM_{2.5}$ = 0.093

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TABLE 2.5 (Cont.)
Particulate matter emissions - Unloading of material and handling (overburden, matrix phosphate, and phosphate rock concentrate)

Scenario	Source	Type of material	Material (Q) [1]	EF- PM_{10} [2]	EF - $PM_{2,5}$ [2]	Emissions control [3] [4]	PM_{10} emissions		$PM_{2,5}$ emissions	
			Mt/year	kg/t	kg/t	%	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s
Year 15	Integrated Waste Landform (IWL)	Overburden	17,47	4,26E-03	6,36E-05	70%	22 325,2	0,7079	333,3	0,0106
	South Pit SOS	Overburden	0,92	4,26E-03	6,36E-05	70%	1 172,7	0,0372	17,5	0,0006
	North Pit SOS	Overburden	0,92	4,26E-03	6,36E-05	70%	1 172,7	0,0372	17,5	0,0006
	North Open Pit	Overburden	21,55	4,26E-03	6,36E-05	70%	27 540,9	0,8733	411,2	0,0130
	ROM Stockpile	Matrix phosphate	1,75	4,26E-03	6,36E-05	0%	7 455,0	0,2364	111,3	0,0035
	ROM bin grizzly	Matrix phosphate	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	4,76E-05
	ROM belt feeder / Feed conveyor	Matrix phosphate	1,75	4,62E-05	1,30E-05	0%	80,9	0,0026	22,8	0,0007
	Coarse ore stockpile	Matrix phosphate (unloading)	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	4,76E-05
	Coarse ore stockpile	Matrix phosphate handling by FEL	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	4,76E-05
	Reject screen 1 [5]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,0002
	Reject screen 2 [6]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,0002
	Concentrate filter discharge conveyor	Phosphate concentrate	1,25	2,31E-05	1,04E-04	75%	7,2	0,0002	32,6	0,0010
	Concentrate pipe conveyor feed bin	Phosphate concentrate	1,25	2,31E-05	1,04E-04	70%	8,7	0,0003	39,1	0,0012
	Truck loading facility	Phosphate concentrate unloading from conveyor	1,25	3,11E-05	4,70E-06	0%	38,8	0,0012	5,9	0,0002
	Total						**61 722**	**1,9572**	**1 008**	**0,0320**
Year 25	North Open Pit	Overburden	44,69	4,26E-03	6,36E-05	70%	57 115,5	1,8111	852,7	0,0270
	ROM Stockpile	Matrix phosphate	1,75	4,26E-03	6,36E-05	0%	7 455,0	0,2364	111,3	0,0035
	ROM bin grizzly	Matrix phosphate	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	0,0000
	ROM belt feeder / Feed conveyor	Matrix phosphate	1,75	4,62E-05	1,30E-05	0%	80,9	0,0026	22,8	0,0007
	Coarse ore stockpile	Matrix phosphate (unloading)	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	4,76E-05
	Coarse ore stockpile	Matrix phosphate handling by FEL	1,75	5,66E-06	8,57E-07	0%	9,9	0,0003	1,5	4,76E-05
	Reject screen 1 [5]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,0002
	Reject screen 2 [6]	Matrix phosphate	1,75	5,40E-02	3,60E-04	99%	945,0	0,0300	6,3	0,0002
	Concentrate filter discharge conveyor	Phosphate concentrate	1,25	2,31E-05	1,04E-04	75%	7,2	0,0002	32,6	0,0010
	Concentrate pipe conveyor feed bin	Phosphate concentrate	1,25	2,31E-05	1,04E-04	70%	8,7	0,0003	39,1	0,0012
	Truck loading facility	Phosphate concentrate unloading from conveyor	1,25	3,11E-05	4,70E-06	0%	38,8	0,0012	5,9	0,0002
	Total						**66 626**	**2,1127**	**1 081**	**0,0343**

Prepared by Knight Piésold Consultores.

Notes

[1] Mine Plan Production Statistics (Lycopodium Minerals Canada Ltd, 2015).
[2] Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995). NPI Mining (2012).
[3] Source: National Pollutant Inventory (2012). Water spray as mitigation control of PM emissions on loading stockpiles and unloading trucks has an emission control of 50% and 70%, respectively.
[4] The emission reduction percentaje using different control techniques is as follows (MDAQMD, 2000; revision 2013):
Water spray for material handling (conveying and stockpile) = 75%
Conveyor with full cover = 85%
Conveyor with three quarter = 70%
[5] Aperture of 5 mm = 100% passing. Control efficiency estimated using wet supression = 99.0%
[6] Aperture of 1 mm = 95.36% passing. Control efficiency estimated using wet supression = 99.0%

Data:

Anual mean wind speed - U (m/s) =	1,06	Source: Farim weather met station (December 18th 2012 to March 5th 2015).
Overburden moisture content (%) =	20	Source: Golder (2013b).
Matrix moisture content (%) =	27	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Phosphate concentrate moisture content (%) =	8	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.

Emission factor equation (US EPA - AP 42, NPI)

$EF=k\times0.0016\times(U/2.2)$^$1.3/(M/2)$^$1.4$
(Material handling and stockpile)
k - PM_{10} = 0.35
k - $PM_{2.5}$ = 0.053

$EF=k\times0.012$
(dumping overburden by trucks)
k - PM_{10} = 0.355
k - $PM_{2.5}$ = 0.053

$EF=k\times0.15$
(Fines screening)
k - PM_{10} = 0.36
k - $PM_{2.5}$ = 0.0024

$EF=k\times n\times0.00007$
(material transfer using conveyors)
k - PM_{10} = 0.33
k - $PM_{2.5}$ = 0.093

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TABLE 2.6
Particulate matter emissions - Haul road (unpaved roads)
Mine site

Scenario	Lineal source		Maximum material to be transfer (Q) [1]	Truck traffic (veh/year)	Distance of the road	Vehicle kilometer traveled - A	EF- PM_{10} [2]	EF - $PM_{2.5}$ [2]	PM_{10} emissions		$PM_{2.5}$ emissions	
	From	To	Mt/year	Vehicle per annum	km	VKT per annum	kg/VKT	kg/VKT	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s
Year 2	South Open Pit	Integrated Waste Landform (IWL)	11,44	235 855	7,11	1 676 977	0,461	0,184	100 494,35	3,18665	40 197,74	1,27466
		South Open Pit	17,02	350 913	0,395	138 611	0,461	0,184	8 306,36	0,26339	3 322,55	0,10536
		North-East Waste Dump	2,88	59 323	3,15	186 868	0,461	0,184	11 198,26	0,35509	4 479,30	0,14204
		ROM Stockpile	1,75	97 222	1,12	108 763	0,302	0,121	4 265,98	0,13527	1 706,39	0,05411
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	0,235	0,094	1 388,84	0,04404	555,54	0,01762
	Total								**125 653,8**	**3,9845**	**50 261,51**	**1,5938**
Year 8	South Open Pit	South Pit SOS	3,19	65 675	1,07	70 010	0,461	0,184	4 195,41	0,13304	1 678,16	0,05321
		South Open Pit	14,14	291 566	0,395	115 169	0,461	0,184	6 901,58	0,21885	2760,63	0,08754
		ROM Stockpile	1,36	75 611	3,71	280 744	0,302	0,121	11 011,57	0,34917	4404,63	0,13967
	North Open Pit	North Open Pit	19,85	409 203	0,25	102 301	0,461	0,184	6 130,47	0,19440	2 452,19	0,07776
		ROM Stockpile	0,39	21 611	2,96	63 913	0,302	0,121	2 506,85	0,07949	1 002,74	0,03180
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	0,235	0,094	1 388,84	0,04404	555,54	0,01762
	Total								**32 134,7**	**1,0190**	**12 853,89**	**0,4076**
Year 15	North Open Pit	Integrated Waste Landform (IWL)	17,47	360 183	6,77	2 437 176	0,461	0,184	146 049,93	4,63121	58 419,97	1,85249
		North Open Pit	21,55	444 329	0,390	173 155	0,461	0,184	10 376,48	0,32904	4 150,59	0,13161
		South Pit SOS	0,92	18 920	3,40	64 367	0,461	0,184	3 857,23	0,12231	1 542,89	0,04892
		North Pit SOS	0,92	18 920	0,55	10 402	0,461	0,184	623,37	0,01977	249,35	0,00791
		ROM Stockpile	1,75	97 222	3,01	292 483	0,302	0,121	11 472,03	0,36378	4 588,81	0,14551
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	0,235	0,094	1 388,84	0,04404	555,54	0,01762
	Total								**173 767,9**	**5,5101**	**69 507,2**	**2,2041**
Year 25	North Open Pit	North Open Pit	44,69	921 471	0,390	359 097	0,461	0,184	21 519,21	0,68237	8 607,69	0,27295
		ROM Stockpile	1,75	97 222	5,10	495 833	0,302	0,121	19 448,00	0,61669	7 779,20	0,24668
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	0,235	0,094	1 388,84	0,04404	555,54	0,01762
	Total								**42 356,1**	**1,3431**	**16 942,4**	**0,5372**

Prepared by Knight Piésold Consultores.

Notes

[1] Mine Plan Production Statistics (Lycopodium Minerals Canada Ltd, 2015).

[2] Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995).

Data:

Mining dump truck capacity (Tonne) =	97	Source: Golder's information. GB Minerals for overburden haul roads.
Mining dump truck capacity (Tonne) =	36	Source: Golder's information .GB Minerals for matrix haul roads.
Front End Loader capacity (Tonne) =	7,7	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Truck capacity for concentrate (Tonne) =	31	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Mean vehicle weight (W) =	138,5	Source: Golder's information. GB Minerals for overburden haul roads.
Mean vehicle weight (W) =	54	Source: Golder's information. GB Minerals for matrix haul roads.
Mean vehicle weight for FEL(W) =	31	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Surface material silt content (s) =	13	Source: Golder (2013) - Ground Characterisation - Factual Report.
Moisture content uncontrolled road (%) =	10	Source: Golder (2013) - Ground Characterisation - Factual Report.
Days in a year with <0.254 mm of precipitation (P) =	101	Source: Golder (2013) - Technical Memorandum Assessment of Dewatered Phosphate Matrix Moisture Content.
Correction of emission factor - C =	0,75	Source: Watson and Chow (2000).
Moisture ratio: %M watered road/%M uncontrolled road =	4	Source: US EPA AP-42, Section 13.2.2 Unpaved Roads. Figure 13.2.2-2 Watering control effectiveness.
Eficiency control - ER (%) =	87	Source: US EPA AP-42 (Section 13.2.2 Figura 13.2.2-2) or equivalent mitigation control.

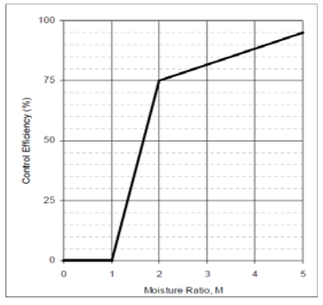

Figure 13.2.2-2 from US EPA Emissions Guideline AP-42.

Emission factor equation (US EPA - AP 42):

$$EF=k\times(s/12)^{0.9}\times(W/3)^{0.45}\times0.2819\times((365-P)/365)\times C$$

k - PM_{10} = 1.5

k - $PM_{2.5}$ = 0.15

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

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TABLE 2.7
Particulate matter and gases emissions - Vehicle exhaust by fuel consumption
Mine site

Scenario	Lineal source		Maximum material to be transfer (Q) (1)	Truck traffic (veh/year)	Average distance traveled (L)	Vehicle kilometer traveled (VKT)	Diesel fuel consumption - A	EF - CO (2)	EF - NO_x (2)	EF - SO_2 (2,3)	EF - PM_{10} (2)	EF - $PM_{2,5}$ (2)	CO emissions		NO_x emissions		SO_2 emissions		PM_{10} emissions		$PM_{2.5}$ emissions	
	From	To	Mt/year	Truck per annum	km	VKT per annum	kL/year	kg/kL	kg/kL	kg/kL	kg/kL	kg/kL	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s
Year 2	South Open Pit	Integrated Waste Landform (IWL)	11,44	235 855	7,11	1 676 977	415,9	8,51	22,30	0,84	1,17	1,12	3 539,2	0,1122	9 274,4	0,2941	347,3	0,011	486,6	0,015	465,8	0,015
		South Open Pit	17,02	350 913	0,40	138 611	34,4						292,5	0,0093	766,6	0,0243	28,7	0,001	40,2	0,001	38,5	0,001
		North-East Waste Dump	2,88	59 323	3,15	186 868	46,3						394,4	0,0125	1 033,5	0,0328	38,7	0,001	54,2	0,002	51,9	0,002
		ROM Stockpile	1,75	97 222	1,12	108 763	27,0						229,5	0,0073	601,5	0,0191	22,5	0,0007	31,6	0,0010	30,2	0,0010
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	11,3						95,9	0,0030	251,4	0,0080	9,4	0,0003	13,2	0,0004	12,6	0,0004
	Total												**4 551,6**	**0,1443**	**11 927,3**	**0,3782**	**446,6**	**0,0142**	**625,8**	**0,0198**	**599,0**	**0,0190**
Year 8	South Open Pit	South Pit SOS	3,19	65 675	1,07	70 010	17,4	8,51	22,30	0,84	1,17	1,12	147,8	0,0047	387,2	0,0123	14,5	0,000	20,3	0,001	19,4	0,001
		South Open Pit	14,14	291 566	0,40	115 169	28,6						243,1	0,0077	636,9	0,0202	23,8	0,0008	33,4	0,0011	32,0	0,0010
		ROM Stockpile	1,36	75 611	3,71	280 744	69,6						592,5	0,0188	1 552,6	0,0492	58,1	0,0018	81,5	0,0026	78,0	0,0025
	North Open Pit	North Open Pit	19,85	409 203	0,25	102 301	25,4						215,9	0,0068	565,8	0,0179	21,2	0,0007	29,7	0,0009	28,4	0,0009
		ROM Stockpile	0,39	21 611	2,96	63 913	15,9						134,9	0,0043	353,5	0,0112	13,2	0,0004	18,5	0,0006	17,8	0,0006
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	11,3						95,9	0,0030	251,4	0,0080	9,4	0,0003	13,2	0,0004	12,6	0,0004
	Total												**1 430,0**	**0,0453**	**3 747,3**	**0,1188**	**140,3**	**0,0044**	**196,6**	**0,0062**	**188,2**	**0,0060**
Year 15	North Open Pit	Integrated Waste Landform (IWL)	17,47	360 183	6,77	2 437 176	604,4	8,51	22,30	0,84	1,17	1,12	5 143,6	0,1631	13 478,6	0,4274	504,7	0,016	707,2	0,022	676,9	0,021
		North Open Pit	21,55	444 329	0,39	173 155	42,9						365,4	0,0116	957,6	0,0304	35,9	0,001	50,2	0,002	48,1	0,002
		South Pit SOS	0,92	18 920	3,40	64 367	16,0						135,8	0,0043	356,0	0,0113	13,3	0,000	18,7	0,001	17,9	0,001
		North Pit SOS	0,92	18 920	0,55	10 402	2,6						22,0	0,0007	57,5	0,0018	2,2	0,000	3,0	0,000	2,9	0,000
		ROM Stockpile	1,75	97 222	3,01	292 483	72,5						617,3	0,0196	1 617,5	0,0513	60,6	0,0019	84,9	0,0027	81,2	0,0026
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	11,3						95,9	0,0030	251,4	0,0080	9,4	0,0003	13,2	0,0004	12,6	0,0004
	Total												**6 380,1**	**0,2023**	**16 718,6**	**0,5301**	**626,0**	**0,0199**	**877,2**	**0,0278**	**839,7**	**0,0266**
Year 25	North Open Pit	North Open Pit	44,69	921 471	0,39	359 097	89,1	8,51	22,30	0,84	1,17	1,12	757,9	0,0240	1 986,0	0,0630	74,4	0,002	104,2	0,003	99,7	0,003
		ROM Stockpile	1,75	97 222	5,10	495 833	123,0						1 046,4	0,0332	2 742,2	0,0870	102,7	0,0033	143,9	0,0046	137,7	0,0044
	ROM Stockpile	ROM bin grizzly	1,75	454 545	0,10	45 455	11,3						95,9	0,0030	251,4	0,0080	9,4	0,0003	13,2	0,0004	12,6	0,0004
	Total												**1 900,2**	**0,0603**	**4 979,5**	**0,1579**	**186,5**	**0,0059**	**261,3**	**0,0083**	**250,1**	**0,0079**

Prepared by Knight Piésold Consultores.

Notes

(1) Mine Plan Production Statistics (Lycopodium Minerals Canada Ltd, 2015).

(3) Source: National Pollutant Inventory, Emission Estimation Technique Manual for Combustion Engines (NPI, 2008).

Data:

Mining dump truck capacity (Tonne) =	97	Source: Golder's information. GB Minerals for overburden haul roads.
Mining dump truck capacity (Tonne) =	36	Source: Golder's information .GB Minerals for matrix haul roads.
Fuel consumption of Diesel for truck - highway (L D2/100 km) =	24,8	Source: Value assumed, based on 2014 Vehicle technologies - Chapter 3 Market Report (http://cta.ornl.gov/vtmarketreport/pdf/chapter3_heavy_trucks.pdf)

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TABLE 2.8
Particulate matter and gases emissions - Diesel generators
Mine site

Scenario	Source	Hours of operation [1]	Fuel consumption (diesel) @ 100% load	Exhaust gas flow rate	Emission factor [2]					Emissions									
					CO	NO_x	SO_2 [3]	PM_{10}	$PM_{2.5}$	CO		NO_x		SO_2		PM_{10}		$PM_{2.5}$	
		hrs-eq/year	kL per annun	Nm^3/year	mg/Nm^3	mg/Nm^3	kg/kL	mg/Nm^3	mg/Nm^3	kg/year	g/s	kg/year	g/s	kg/year	g/s	kg/year	g/s	kg/year	g/s
Years 1 - 25	Generator 1	8 760	2 705	59 485 036	698,4	3 243,7	0,847	32	32	41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	Generator 2	8 760	2 705	59 485 036						41 544	1,3174	192 952	6,1185	2 291	0,0727	1 904	0,0604	1 904	0,0604
	Total									**83 089**	**2,6347**	**385 903**	**12,2369**	**4 582**	**0,1453**	**3 807**	**0,1207**	**3 807**	**0,1207**

Prepared by Knight Piésold Consultores.

Notes

[1] GB Minerals.
[2] Source: Technical sheet of Diesel Generator Set CAT 3512B TA.
[3] Source: Emissions estimation technique manual for Combustion engines Version 3.0 (NPI, 2008).

Data:

Fuel density (kg/kL) =	847	Source: http://www.engen.co.za/common/downloads/product_information/product_handbook/fuels/engen_diesel_0.05.pdf
Fuel consumption rate (L/h) =	308,8	Source: Technical sheet of Diesel Generator Set CAT 3512B TA Diesel Engine.
Sulfur content in fuel (%) =	0,05	Source: Golder's information (Appendix C1 - Air Dispersion Modelling)
Temperature at normal conditions (K) =	298,15	Source: USEPA. Standard atmospheric conditions.
Pressure at normal conditions (kPa) =	101,325	Source: USEPA. Standard atmospheric conditions.
Atmospheric pressure (kPa) =	101,1	Source: Meteorological station of GGOV (2012-2014).
Exhaust gas flow rate (m^3/min) =	253,2	Source: Technical sheet of Diesel Generator Set CAT 3512B TA Diesel Engine.
Source type =	Point	Source: Technical sheet of Diesel Generator Set CAT 3512B TA Diesel Engine.
Stack height (m) =	3	Source: Golder's information (Appendix C1 - Air Dispersion Modelling)
Stack diameter (m) =	0,2032	Source: Technical sheet of Diesel Generator Set CAT 3512B TA Diesel Engine.
Exit temperature (K) =	665,6	Source: Technical sheet of Diesel Generator Set CAT 3512B TA Diesel Engine.
Exit velocity (m/s) =	130,13	Source: Calculated.

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TABLE 2.9
Particulate matter emissions - Wind erosion from Stockpiles
Mine site

Scenario	Source	Disturbed area [1]			EF - PM_{10} [2]	EF - $PM_{2.5}$ [2]	PM_{10} emissions		$PM_{2.5}$ emissions	
		ha	km^2	Acre	ton/acre.year	ton/acre.year	E - kg/year	E - g/s	E - kg/year	E - g/s
Years 2 - 25	ROM Stockpile	1,7818	0,0178	4,40	0,013	0,005	56,3	0,0018	22,5	0,0007
	Coarse ore stockpile	0,0431	0,0004	0,11	0,013	0,005	1,4	4,32E-05	0,5	1,73E-05
	Total						**57,67**	**1,83E-03**	**23,07**	**7,31E-04**

Prepared by Knight Piésold Consultores.

Notes:

[1] Source: Knight Piésold Consultores.

[2] Source: Emissions Inventory Guidance - Mineral Handling and Processing Industries - Mojave Desert Air Quality Management District (MDAQMD,2000).

Data:

Anual mean wind speed (m/s) =	1,06	Source: Farim weather met station (December 18th 2012 to March 5th 2015)
Silt loading for matrix phosphate - s (%) =	31,70	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Days in a year with <0.254 mm of precipitation (P) =	101	Source: Golder (2013) - Technical Memorandum Assessment of Dewatered Phosphate Matrix Moisture Content.
Number of days in the year (N) =	365	Days of year.
Number of hours greater than 5.36 m/s =	12	Source: Farim weather met station (December 18th 2012 to March 5th 2015)
Number of hours of the registered period # =	31830	Source: Farim weather met station (December 18th 2012 to March 5th 2015)
Percentaje of time for winds >5,36 m/s - I (%) =	0,04	Calculated.
Angle of coarse ore stockpile (º) =	45,00	Assumed.
Capacity of coarse ore stockpile (tonnes) =	2000	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Radius of coarse ore stockpile - r (m) =	9,85	Calculated.
Height of coarse ore stockpile - h (m) =	9,85	Calculated.
Capacity of ROM stockpile (tonnes) =	450000	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.

Emission factor equation (MDAQMD, 2013):

$$EF=k\times1.7\times sL/1.5\times((365-P))/235\times I$$

k - PM_{10} = 0.5

k - $PM_{2.5}$ = 0.2

Cone volume for coarse ore stockpile:

$$V=(\pi\times r\text{^}2\times h)/3$$

Cone lateral area:

$$A\_L=\pi\times r\times g$$

Pyramidal frustum volume for Rom Stockpile:

$$V=h/3\times(A\_1+A\_2+\sqrt{(A\_1\times A\_2)})$$

Disturbed area of pyramidal frustrum volume:

$$AL=4\times h\times((B+b)/2)+b\text{^}2$$

A_1 = 5000 m^2

A2 = 3000 m^2

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TABLE 2.10
Particulate matter emissions - Wind erosion in open areas (WRD and TMF)
Mine site

Scenario	Source	Disturbed area (1)			EF - PM_{10} (2)	EF - $PM_{2.5}$ (2)	PM_{10} emissions		$PM_{2.5}$ emissions	
		ha	km^2	Acre	ton/acre.year	ton/acre.year	E - kg/year	E - g/s	E - kg/year	E - g/s
Year 2	Integrated Waste Landform (IWL)	52,2	0,52	129,0	25,37	10,15	3 274	0,1038	1 309	0,0415
	South-East Waste Dump	35,8	0,36	88,5	2,54	1,01	224	0,0071	90	0,0028
	North-East Waste Dump	33,0	0,33	81,5	25,37	10,15	2 069	0,0656	828	0,0262
	Tailing Storage Facility	7,1	0,07	17,6	145,23	58,09	2 555	0,0810	1 022	0,0324
	Total						**8 122**	**0,2575**	**3 249**	**0,1030**
Year 8	South Pit SOS	64,1	0,64	158,3	25,37	10,15	4 015	0,1273	1 606	0,0509
	Tailing Storage Facility	28,3	0,28	69,9	145,23	58,09	10 157	0,3221	4 063	0,1288
	Total						**14 172**	**0,4494**	**5 669**	**0,1798**
Year 15	Integrated Waste Landform (IWL)	113,5	1,13	280,4	25,37	10,15	7 115	0,2256	2 846	0,0902
	South Pit SOS	321,7	3,22	794,8	2,54	1,01	2 017	0,0639	807	0,0256
	North Pit SOS	396,9	3,97	980,8	5,07	2,03	4 977	0,1578	1 991	0,0631
	Tailing Storage Facility	53,0	0,53	131,1	145,23	58,09	19 036	0,6036	7 614	0,2414
	Total						**33 144**	**1,0510**	**13 257**	**0,4204**
Year 25	Tailing Storage Facility	88,5	0,88	218,6	145,23	58,09	31 747	1,0067	12 699	0,4027
	Total						**31 747**	**1,0067**	**12 699**	**0,4027**

Prepared by Knight Piésold Consultores.

Notes:

(1) Source: GB Minerals.

(2) Source: Emissions Inventory Guidance - Mineral Handling and Processing Industries - Mojave Desert Air Quality Management District (MDAQMD,2000).

Data:

Anual mean wind speed - u (m/s) =	1,06	Source: Farim weather met station (December 18th 2012 to March 5th 2015)
Threshold value of wind speed for tailings - u_t (m/s) =	0,28	Source: MDAQMD (2013).
Threshold value of wind speed for overburden - u_t (m/s) =	0,50	Source: MDAQMD (2013).
Value for correction factor - x =	0,23	Source: MDAQMD (2013). Representative value for tailings.
Value for correction factor - x =	0,42	Source: MDAQMD (2013). Representative value for overburden.
Correction factor - C(x) =	1,91	Source: MDAQMD (2013). Representative value for tailings.
Correction factor - C(x) =	1,90	Source: MDAQMD (2013). Representative value for overburden.
Amount of vegetative covers as a fraction - v =	0,9	Vegetation cover in South-East Waste Dump for year 2 (assumed).
Amount of vegetative covers as a fraction - v =	0,9	Vegetation cover in South Open Pit for year 15 (assumed).
Amount of vegetative covers as a fraction - v =	0,8	Vegetation cover in North Open Pit for year 15 (assumed).
Amount of vegetative covers as a fraction - v =	1	Vegetation cover in North Open Pit for SOS in year 25 (assumed).
Threshold friction velocity - u^*_t (m/s)	0,25	Source: MDAQMD (2013), value representative of overburden (abandoned agricultural land).
Threshold friction velocity - u^*_t (m/s)	0,14	Source: MDAQMD (2013), value representative of mine tailings.
Ratio of wind speed to friction velocity u* =	2	Source: MDAQMD (2013), value representative of open space.

Emission factor equation (MDAQMD, 2013):

$$EF=k\times 2.814\times(1-v)\times(u/u\_t\ )\text{^}3\times C(x)$$

k - PM_{10} = 0.5

k - $PM_{2.5}$ = 0.2

$$u\_t=u\_t\text{^}*\times u$$

$$x=0.886\times u\_t/u$$

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TABLE 2.11
Particulate matter and gases emissions by source
Ponta Chugue Port Facility

Scenario	Source			CO emissions		NO_x emissions		SO_2 emissions		PM_{10} emissions		$PM_{2.5}$ emissions	
	Description	Type	Code	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s	E - kg/year	E - g/s
Years 1 to 25	End dump into hopper	Area	SRC_1	-	-	-	-	-	-	51	0,002	8	2,43E-04
	Feed conveyor (transfer 1)	Area	SRC_2	-	-	-	-	-	-	4	1,37E-04	1	3,87E-05
	Wet concentrate dryer shed	Area	SRC_3	9 317	0,295	30 287	0,960	961	0,030	443	0,014	387	0,012
	Stack from concentrate dryer	Point	SRC_4	212 500	6,738	-	-	-	-	198	0,006	65	0,002
	Feed conveyor (transfer 2)	Area	SRC_5	-	-	-	-	-	-	4	1,37E-04	1	3,87E-05
	Concentrate storage shed	Area	SRC_6	13 976	0,443	45 430	1,441	1 442	0,046	42	0,001	38	0,001
	Hooper 1	Area	SRC_7	-	-	-	-	-	-	25	0,001	4	1,20E-04
	Hopper 2	Area	SRC_8	-	-	-	-	-	-	50	0,002	8	2,40E-04
	Hooper 3	Area	SRC_9	-	-	-	-	-	-	25	0,001	4	1,20E-04
	Truck loading facility - Port site	Lineal	SRC_10	74 503	4,050	34 833	2,315	1 364	0,074	129 341	7,031	32 634	1,774
	Generator 3	Point	SRC_11	1 433	0,045	23 365	0,741	1 077	0,034	359	0,011	359	0,011
	Generator 4	Point	SRC_12	1 433	0,045	23 365	0,741	1 077	0,034	359	0,011	359	0,011
	Shiploader and ship loading time	Area	SRC_13	2 281	0,072	30 067	0,953	20 114	0,638	2 740	0,087	1 809	0,057
	Total			**315 442**	**11,690**	**187 347**	**7,151**	**26 034**	**0,856**	**133 640**	**7,167**	**35 676**	**1,870**

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TABLE 2.12
Particulate matter emissions - Unloading of material and handling
Ponta Chugue Port Facility

Scenario	Source	Maximum material (Q) (1)	EF- PM_{10} (2)	EF - $PM_{2.5}$ (2)	Emissions control (3)	PM_{10} emissions		$PM_{2.5}$ emissions	
		MT/year	kg/t	kg/t	%	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s
Years 1 to 25	End dump into hopper	1,25	1,35E-04	2,05E-05	70%	50,7	0,0016	7,7	0,00024
	Feed conveyor (transfer 1)	1,25	2,31E-05	6,51E-06	85%	4,3	0,0001	1,2	0,00004
	Wet concentrate dryer shed /stockpile	1,25	1,35E-04	2,05E-05	99%	1,7	0,0001	0,3	0,00001
	Wet concentrate dryer shed /unloading by FEL	1,25	1,35E-04	2,05E-05	85%	25,3	0,0008	3,8	0,00012
	Feed conveyor (transfer 2)	1,250	2,31E-05	6,51E-06	85%	4,3	0,0001	1,2	0,00004
	Hooper 1	0,313	5,34E-04	8,08E-05	85%	25,0	0,0008	3,8	0,00012
	Hopper 2	0,625	5,34E-04	8,08E-05	85%	50,0	0,0016	7,6	0,00024
	Hooper 3	0,313	5,34E-04	8,08E-05	85%	25,0	0,0008	3,8	0,00012
	Shiploader	1,25	5,34E-04	2,05E-05	0%	666,9	0,0211	25,6	0,00081
	Total					**853,30**	**0,0271**	**54,9**	**0,0017**

Prepared by Knight Piésold Consultores.

Notes:

(1) Handling 1.25 million tonnes of product per year.

(2) Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995)
- Section 13.2.4 Aggregate Handling And Storage Piles
- Section 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing

(3) Control techniques for particulate matter emissions (MDAQMD, 2000; revision 2013; NPI, 2012):
Total enclosure for loading stockpiles (NPI, 2012) = 99%
Conveyor with full cover (MDAQMD, 2013) = 85%
Water spray for material handling (conveying and stockpile) (MDAQM, 2013) = 75%
Conveyor with three quarter (MDAQMD, 2013) = 70%

Data:

Anual mean wind speed - U (m/s) =	3,28	Source: Guinea-Bissau (GGOV) met station (January 2012 - December 2014).
Overburden moisture content - M (%) =	20	Source: Golder (2013b).
Matrix moisture content - M (%) =	27	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Phosphate concentrate moisture content - M (%) =	8	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
moisture product dried (%) =	3	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.

Emission factor equation (US EPA - AP 42)

$EF=k\times0.0016\times(U/2.2)$^$1.3/(M/2)$^$1.4$

k - PM_{10} = 0.35
k - $PM_{2.5}$ = 0.053

$EF=k\times0.00007$ (material transfer using conveyors)

k - PM_{10} = 0.33
k - $PM_{2.5}$ = 0.093

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TABLE 2.13
Particulate matter emissions - Dryer of phosphate concentrate
Ponta Chugue Port Facility

Scenario	Source	Maximum material (Q) (1)	EF- CO (2)	EF- PM_{10} (2)	EF - $PM_{2.5}$ (2)	Emissions control efficiency (3)	Emissions					
							CO		PM_{10}		$PM_{2.5}$	
		MT/year	kg/t	kg/t	kg/t	%	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s	Ec - kg/year	Ec - g/s
Years 1 to 25	Wet concentrate dryer shed	1,25	0,17	2,38	0,78	99,99%	212 500	6,738	198	0,006	65	0,002
	Total						**212 500**	**6,738**	**198**	**0,006**	**65**	**0,002**

Prepared by Knight Piésold Consultores.

Notes:

(1) Handling 1.25 million tonnes of product per year.

(2) Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995):
- Section 11.21 Phosphate Rock Processing.

(3) Control technique of particulate emissions (GB Minerals, 2014), estimated from Table 11.21-3, section 11.21 Phosphate Rock Processing (USEPA AP-42, 1993):

Dust collector (electrostatic precipitator) =	99,45%
Concentrate dryer scrubber =	98,79%
Total control efficiency =	99,99%

Emission factor equation (US EPA - AP 42)

$EF = k \times 2.9$ k - PM_{10} = 0.82

k - $PM_{2.5}$ = 0.27

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TABLE 2.14
Particulate matter and gases emissions - Use of heavy equipment (vehicle exhaust)
Ponta Chugue Port Facility

Scenario	Source	Heavy equipment	Number of equipment (1)	Hours of equipment per day (1)	Activity rate - A	EF - CO (2)	EF - NO_x (2)	EF - SO_2 (2)	EF - PM_{10} (2)	EF - $PM_{2.5}$ (2)	CO emissions		NO_x emissions		SO_2 emissions		PM_{10} emissions (3)		$PM_{2.5}$ emissions (3)	
				h-eq/year	kWh/year	kg/kWh	kg/kWh	kg/kWh	kg/kWh	kg/kWh	E - kg/y	E - g/s	E - kg/y	E - g/s	E - kg/y	E - g/s	E - kg/y	E - g/s	E - kg/y	E - g/s
Years 1 to 25	Wet concentrate dryer shed	Front end loader	2	24	2 566 680	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	9 317	0,295	30 287	0,960	961	0,030	416	0,013	383	0,012
	Concentrate storage shed	Front end loader	3	24	3 850 020	3,63E-03	1,18E-02	3,75E-04	1,08E-03	9,94E-04	13 976	0,443	45 430	1,441	1 442	0,046	42	0,001	38	0,001
	Total										**23 293**	**0,739**	**75 717**	**2,401**	**2 403**	**0,076**	**457**	**0,015**	**421**	**0,013**

Prepared by Knight Piésold Consultores.

Notes:

(1) Source: GB Minerals.

(2) Source: National Pollutant Inventory, Emission Estimation Technique Manual for Combustion Engines (NPI, 2008).

(3) Control techniques for particulate matter emissions (MDAQMD, 2000; revision 2013; NPI, 2012):

Total enclosure for loading stockpiles (NPI, 2012) = 99%

Conveyor with full cover (MDAQMD, 2013) = 85%

Data:

Average power (kW) = 293 Source: Technique sheets, model CAT 980H.

Load Factor (LF) = 0,5 Source: National Pollutant Inventory, Emission Estimation Technique Manual for Combustion Engines (NPI, 2008).

Emission equation (US EPA - AP 42)

$$E\_i = EF \times A$$

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TABLE 2.15
Particulate matter emissions - Phosphate concentrate transportation from mine to port (paved road)
Mine site to Ponta Chugue Port Facility

Scenario	Lineal source		Type of vehicle	Maximum material to be transfer (Q) (1)	Anual traffic (veh/year) (1)	Distance of the road	Vehicle kilometer traveled	EF- PM_{10} (2)	EF - $PM_{2.5}$ (2)	PM_{10} emissions		$PM_{2.5}$ emissions	
	From	To		Mt/year	Vehicle per annum	km	VKT per annum	kg/VKT	kg/VKT	E - kg/year	E - g/s	E - kg/year	E - g/s
Years 1 to 25	Truck loading facility	Port site	Heavy	1,25	80 645	78,23	6 309 032	0,020	4,89E-03	127 462,4	6,929	30 837,7	1,676
			Light	-	61 320	78,23	4 797 186	0,001	2,69E-04	5 333,7	0,290	1 290,4	0,070
	Total									**132 796,1**	**7,219**	**32 128,1**	**1,746**

Prepared by Knight Piésold Consultores.

Notes:

(1) Source: GB Minerals, Lycopodium - Farim Phosphate Project.

(2) Source: Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors (USEPA, 1995).

Data:

Operating time =	6:00 to 20:00 h	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Operating hours per day =	14	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Truck capacity for concentrate (Tonne) =	31	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Mean vehicle weight in tonnes (W) =	51,5	Source: Data estimated from truck capacity.
Mean vehicle weight in tonnes (W) =	3	Source: Weight in tonnes for pickup vehicles.
Surface material silt loading in g/m^2 (sL) =	0,6	Source: US EPA AP-42, Section 13.2.1 Paved Roads. Average daily traffic (ADT) less than 500 vehicles.
Days in a year with <0.254 mm of precipitation (P) =	101	Source: Golder (2014) - Appendix C1 Air Dispersion Modelling (ADM)
Number of days in the year (N) =	365	

Emission factor equation (US EPA - AP 42):

$$EF = k \times (sL)\text{^}0.91 \times (W)\text{^}1.02 \times (1 - P/4N)$$

k - PM_{10} = 0.62 g/VKT

k - $PM_{2.5}$ = 0.15 g/VKT

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TABLE 2.16
Particulate matter and gases emissions - Vehicle exhaust by fuel consumption
Mine site to Ponta Chugue Port Facility

Scenario	Lineal source		Type of vehicle	Truck traffic (veh/year)	Vehicle kilometer traveled (VKT)	Fuel consumption (calculated)	Emission factor (EF) [3]					Emissions									
							CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO		NO_x		SO_2		PM_{10}		$PM_{2.5}$	
	From	To		Truck per annum	VKT per annum	kL/year	kg/kL	kg/kL	kg/kL	kg/kL	kg/kL	kg/y	g/s	kg/y	g/s	kg/y	g/s	kg/y	g/s	kg/y	g/s
Years 1 to 25	Truck loading facility	Port site	Heavy [1]	80 645	6 308 871	1 562	8,51	22,30	0,84	1,17	1,12	13 292,7	0,723	34 832,9	1,894	1 304,3	0,071	1827,556	0,099	1749,5	0,095
			Light [2]	61 320	4 797 186	705	86,80	11,00	0,084	0,072	0,067	61 210,2	3,327	7 757,1	0,422	59,2	0,003	50,77342	0,003	47,2	0,003
	Total											**74 502,9**	**4,050**	**42 589,9**	**2,315**	**1 363,5**	**0,074**	**1 878,3**	**0,102**	**1 796,7**	**0,098**

Prepared by Knight Piésold Consultores.

Notes:

[1] Fuel consumption of Diesel

[2] Fuel consumption of Petrol.

[3] Source: Emission estimation technique manual for Combustion engines (NPI, 2008).

Data:

Operating time =	6:00 to 20:00 h	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Operating hours per day =	14	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Maximum material to be transfer - Q (Mt/year) =	1,25	Source: GB Minerals, Lycopodium - Farim Phosphate Project.
Averade distance traveled L (km) =	78,23	Source: Calculated.
Truck capacity for concentrate (Tonne) =	31	Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.
Economy fuel consumption rate (L D2/100 km) =	24,8	Source: Value assumed, based on 2014 Vehicle technologies - Chapter 3 Market Report (http://cta.ornl.gov/vtmarketreport/pdf/chapter3_heavy_trucks.pdf)
Economy fuel consumption rate (L F/100 km) =	14,7	Source: Toyota pickup Tacoma 4WD, based on 2014 (https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/tools/fuelratings/FCG2014print_e.pdf)

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TABLE 2.17
Particulate matter and gases emissions - Diesel generators
Ponta Chugue Port Facility

Scenario	Source	Hours of operation [1]	Fuel consumption (diesel) @ 100% load	Exhaust gas flow rate	Emission factor [2]					Emissions									
					CO	NO_x	SO_2 [3]	PM_{10}	$PM_{2.5}$	CO		NO_x		SO_2		PM_{10}		$PM_{2.5}$	
		hrs-eq/year	kL per annun	Nm^3/year	mg/Nm^3	mg/Nm^3	kg/kL	mg/Nm^3	mg/Nm^3	kg/year	g/s	kg/year	g/s	kg/year	g/s	kg/year	g/s	kg/year	g/s
Years 1 - 25	Generator 3	8 760	1 271	8 058 469	177,8	2 899,4	0,847	44,5	44,5	1 433	0,0454	23 365	0,7409	1 077	0,0341	359	0,0114	359	0,0114
	Generator 4	8 760	1 271	8 058 469						1 433	0,0454	23 365	0,7409	1 077	0,0341	359	0,0114	359	0,0114
	Total									**2 866**	**0,0909**	**46 729**	**1,4818**	**2 153**	**0,0683**	**717**	**0,0227**	**717**	**0,0227**

Prepared by Knight Piésold Consultores.

Notes

[1] GB Minerals.

[2] Source: Technical sheet of Diesel Generator Set CAT 3412C TA.

[3] Source: Emissions estimation technique manual for Combustion engines Version 3.0 (NPI, 2008).

Data:

Fuel density (kg/kL) =	847	Source: http://www.engen.co.za/common/downloads/product_information/product_handbook/fuels/engen_diesel_0.05.pdf
Fuel consumption rate (L/h) =	145,1	Source: Technical sheet of Diesel Generator Set CAT 3412C TA Diesel Engine.
Sulfur content in fuel (%) =	0,05	Source: Golder's information (Appendix C1 - Air Dispersion Modelling)
Temperature at normal conditions (K) =	298,15	Source: USEPA. Standard atmospheric conditions.
Pressure at normal conditions (kPa) =	101,325	Source: USEPA. Standard atmospheric conditions.
Atmospheric pressure (kPa) =	101,1	Source: Meteorological station of GGOV (2012-2014).
Exhaust gas flow rate (m^3/min) =	41,3	Source: Technical sheet of Diesel Generator Set CAT 3412C TA Diesel Engine.
Source type =	Point	Source: Technical sheet of Diesel Generator Set CAT 3412C TA Diesel Engine.
Stack height (m) =	3	Source: Golder's information (Appendix C1 - Air Dispersion Modelling)
Stack diameter (m) =	0,2032	Source: Technical sheet of Diesel Generator Set CAT 3412C TA Diesel Engine.
Exit temperature (K) =	801,4	Source: Technical sheet of Diesel Generator Set CAT 3412C TA Diesel Engine.
Exit velocity (m/s) =	21,23	Source: Calculated.

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TABLE 2.18
Particulate matter and gases emissions - Ship loading time
Ponta Chugue Port Facility

Auxiliary engine power (standard)	600,0	kW
Number of auxiliary engine	2,0	engines
Number of visits in the year [1]	36	visits/year
Ship loading time [1]	48,0	hr/visits
Transit time in the year	1728	hr/year

Parameter	Emission factor - (kg/kWh) [2]	Emissions		
		kg/year	tonne/year	g/s [3]
NO_x	1,45E-02	30 067	30,1	0,9534
$PM_{2.5}$	8,60E-04	1 783	1,8	0,0565
PM_{10}	1,00E-03	2 074	2,1	0,0658
SO_2	9,70E-03	20 114	20,1	0,6378
CO	1,10E-03	2 281	2,3	0,0723

Prepared by Knight Piésold Consultores.

Notes:

[1] Source: Lycopodium (2014) - Farim Phosphate Project - Process Design Criteria.

[2] Estimation Technique Manual for Maritime operations (NPI, 2012).

[3] Constant emission rates (average).

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Appendix B

Air Dispersion Results

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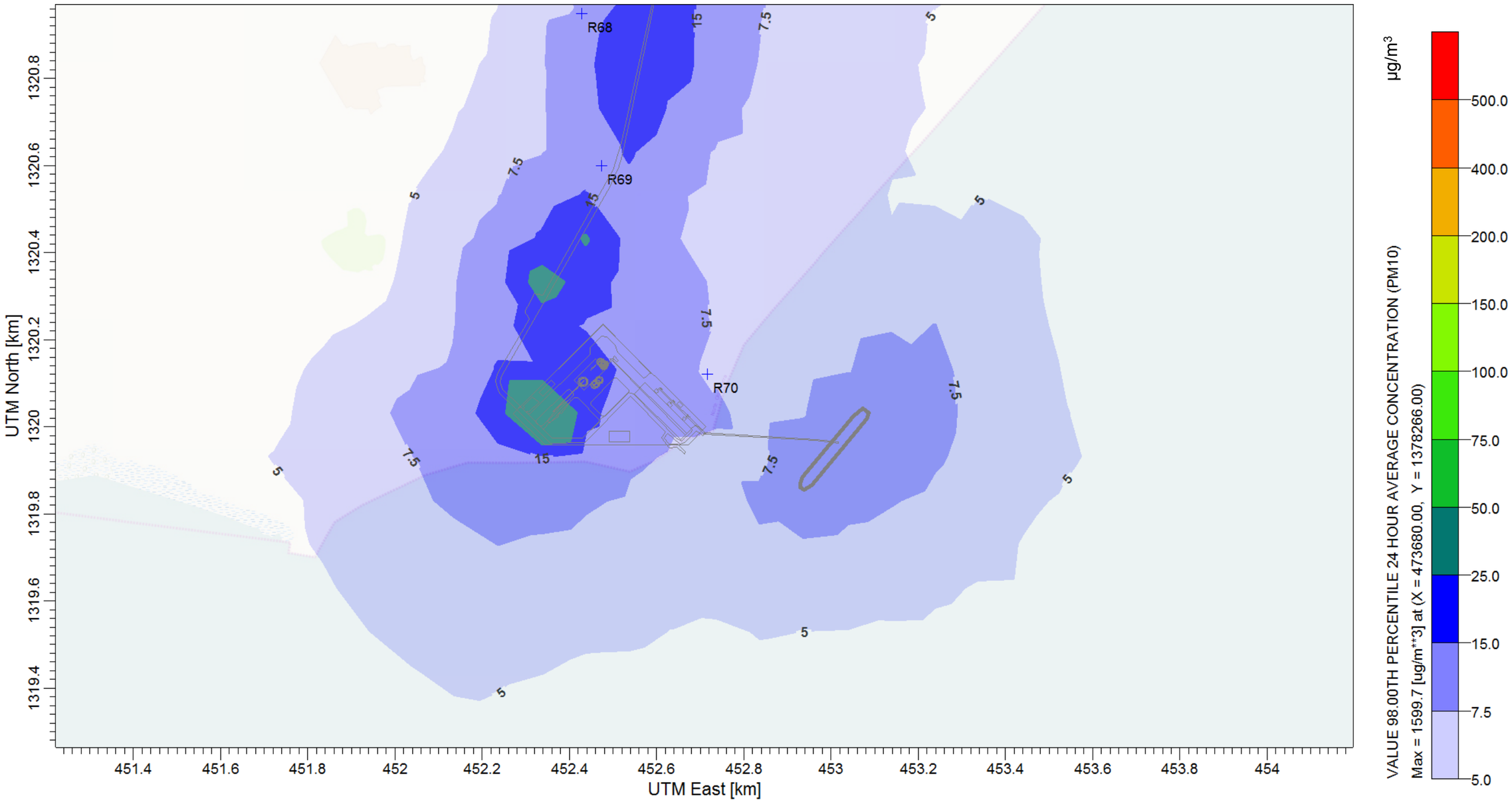
Appendix B-1

Ponta Chugue Port Facility



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN PORT SITE**

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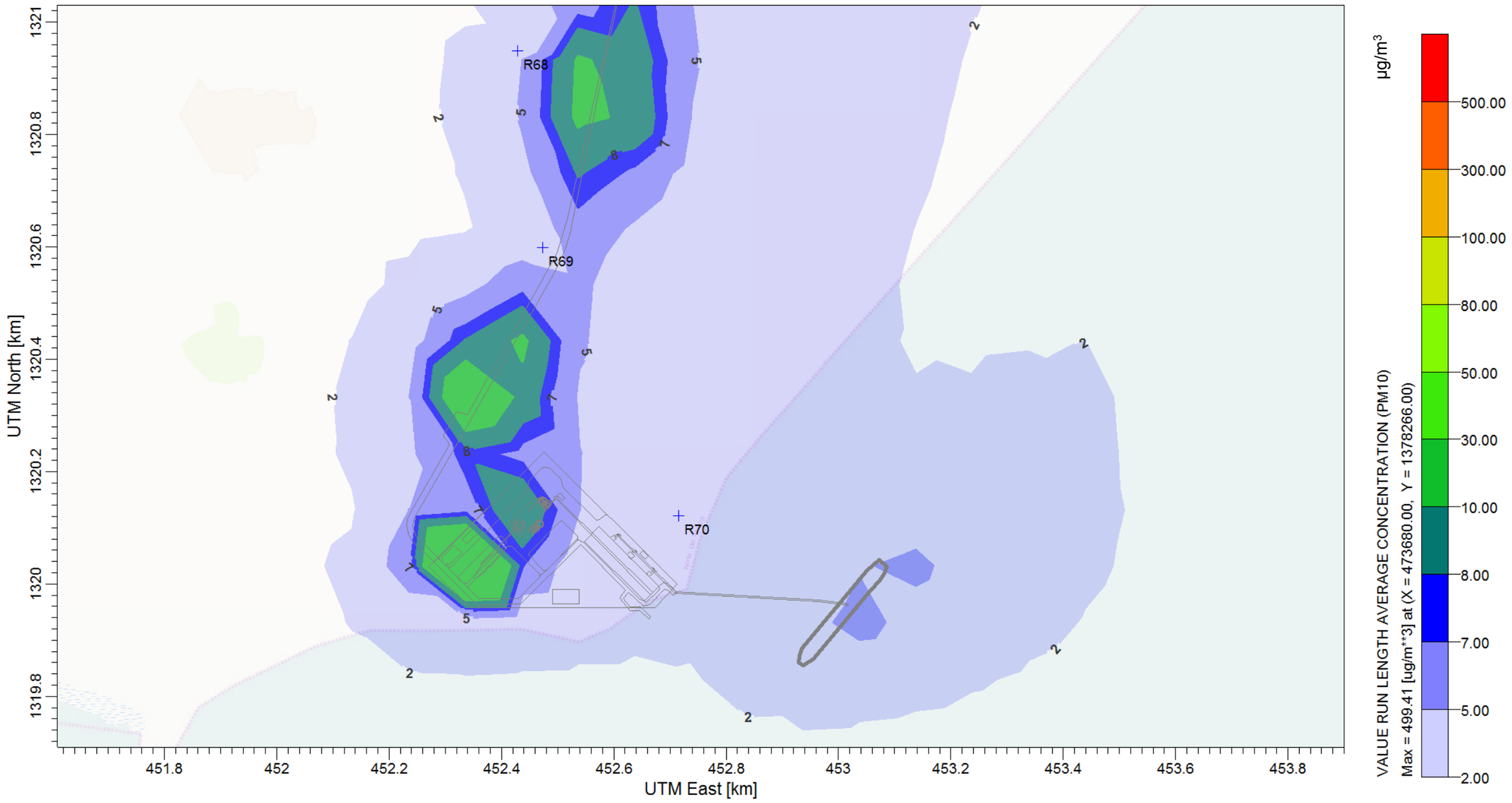
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.1**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION FOR ANNUAL AVERAGE PERIOD IN PORT SITE**

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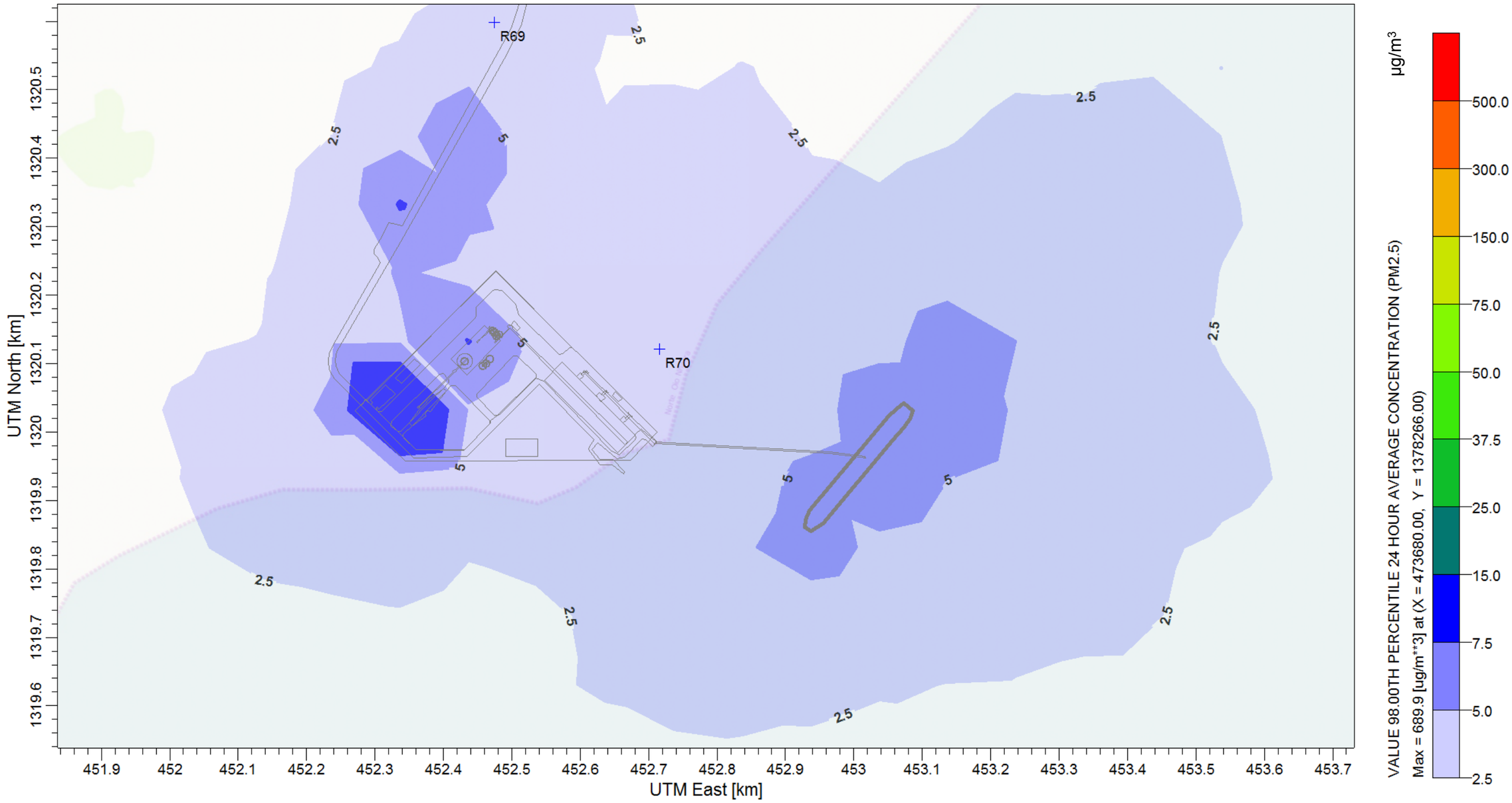
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.2**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN PORT SITE**

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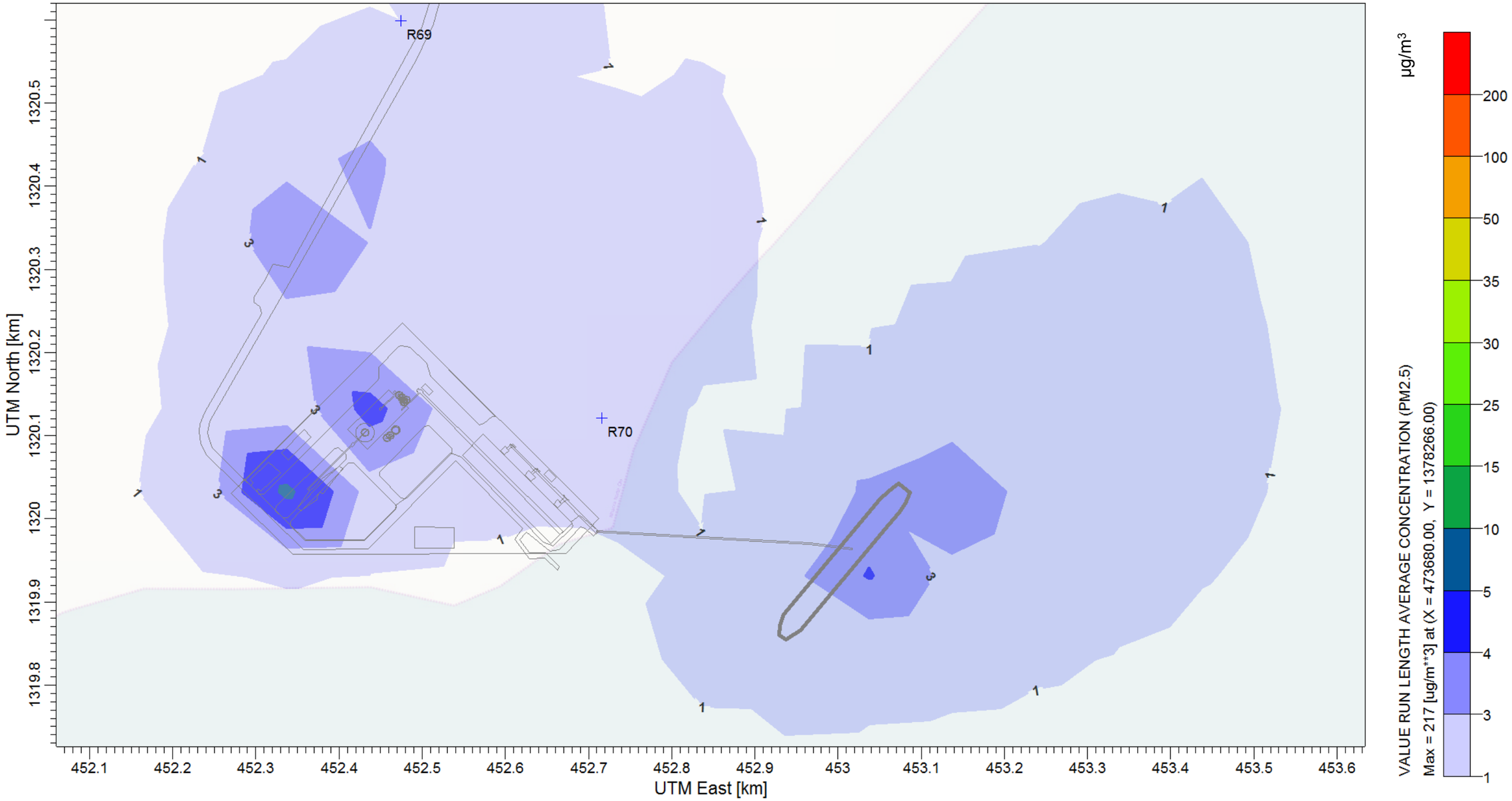
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.3**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION ANNUAL AVERAGE PERIOD IN PORT SITE**

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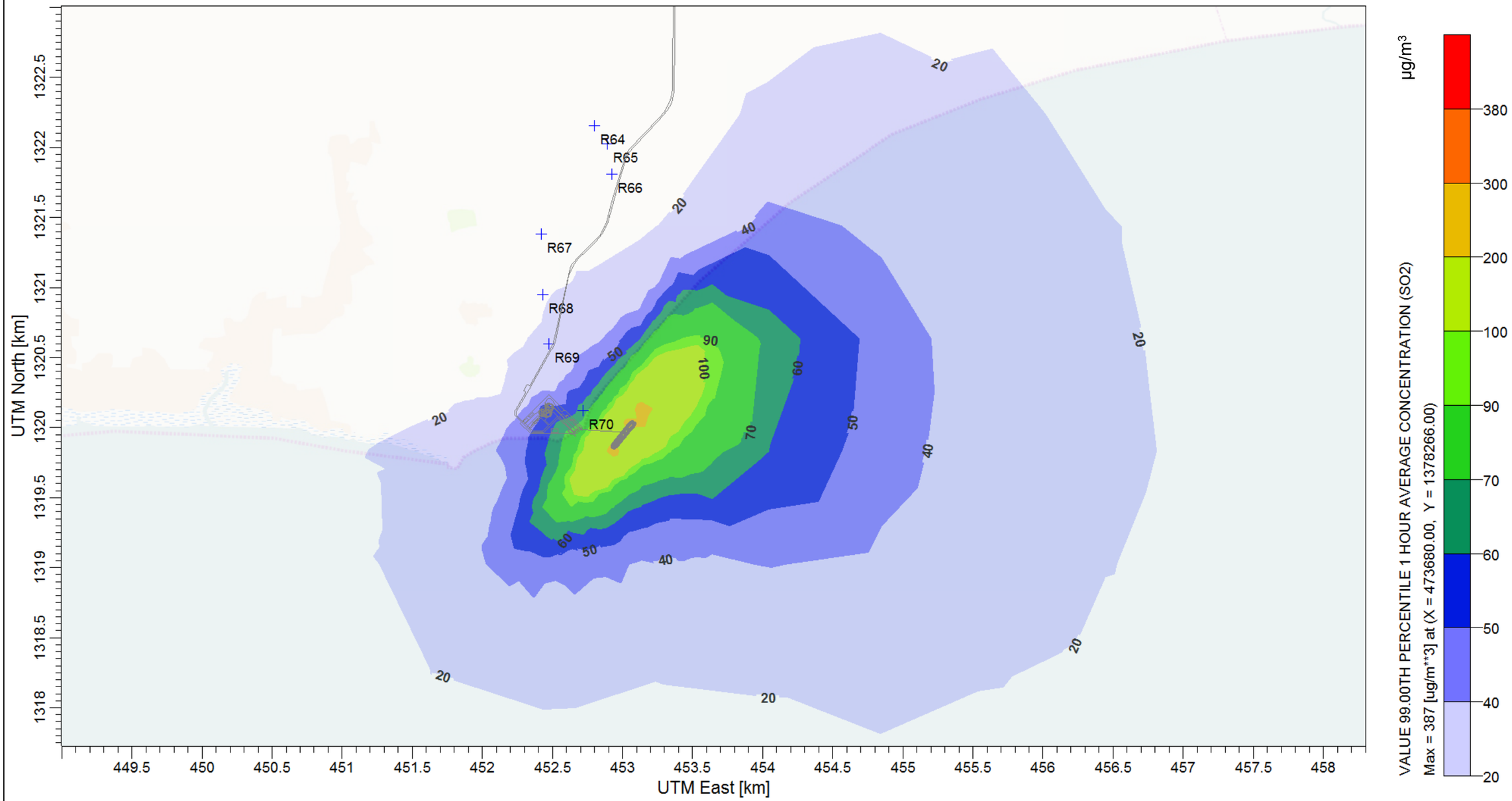
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.4**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN PORT SITE**

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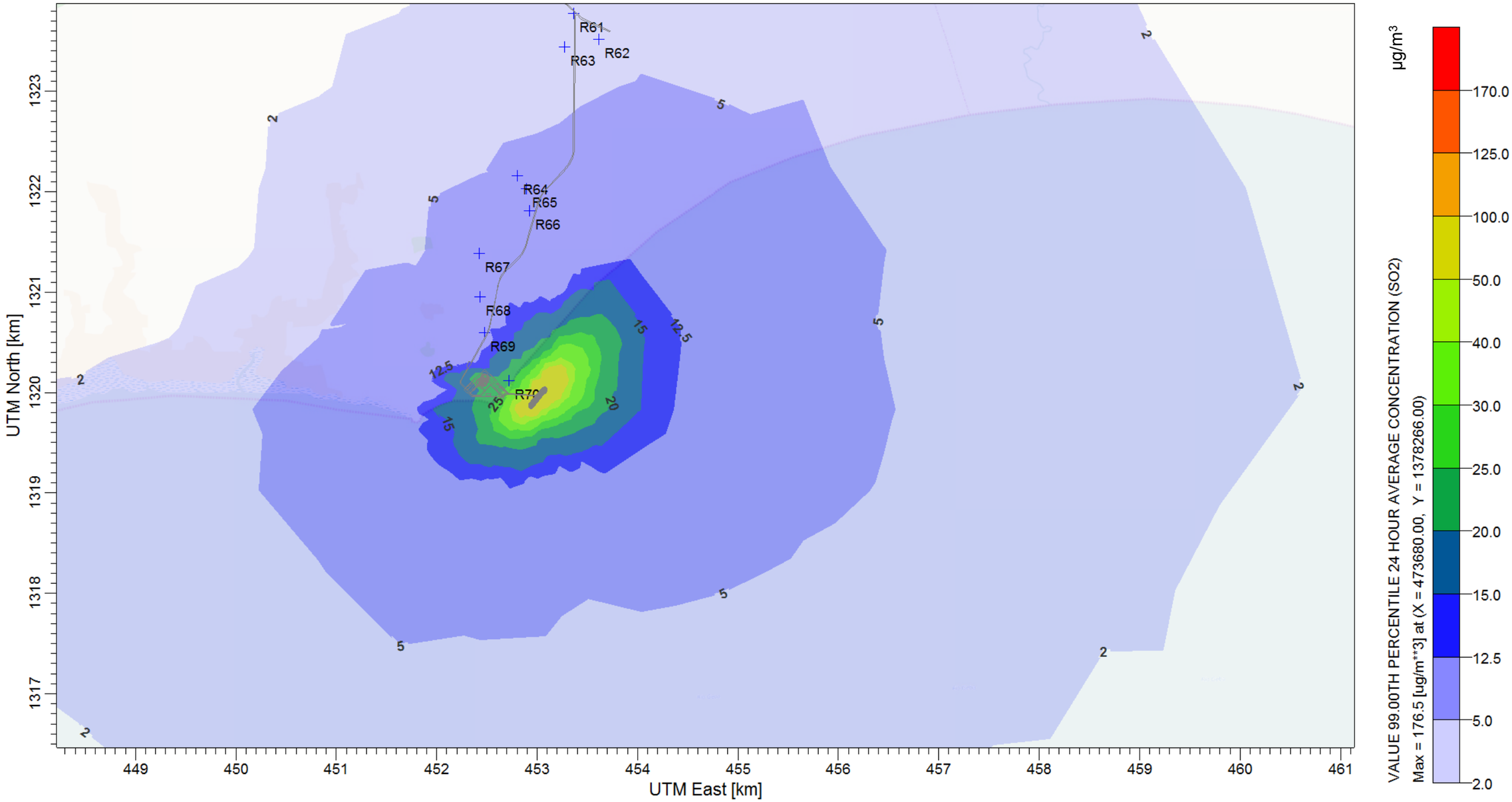
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.5**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN PORT SITE**

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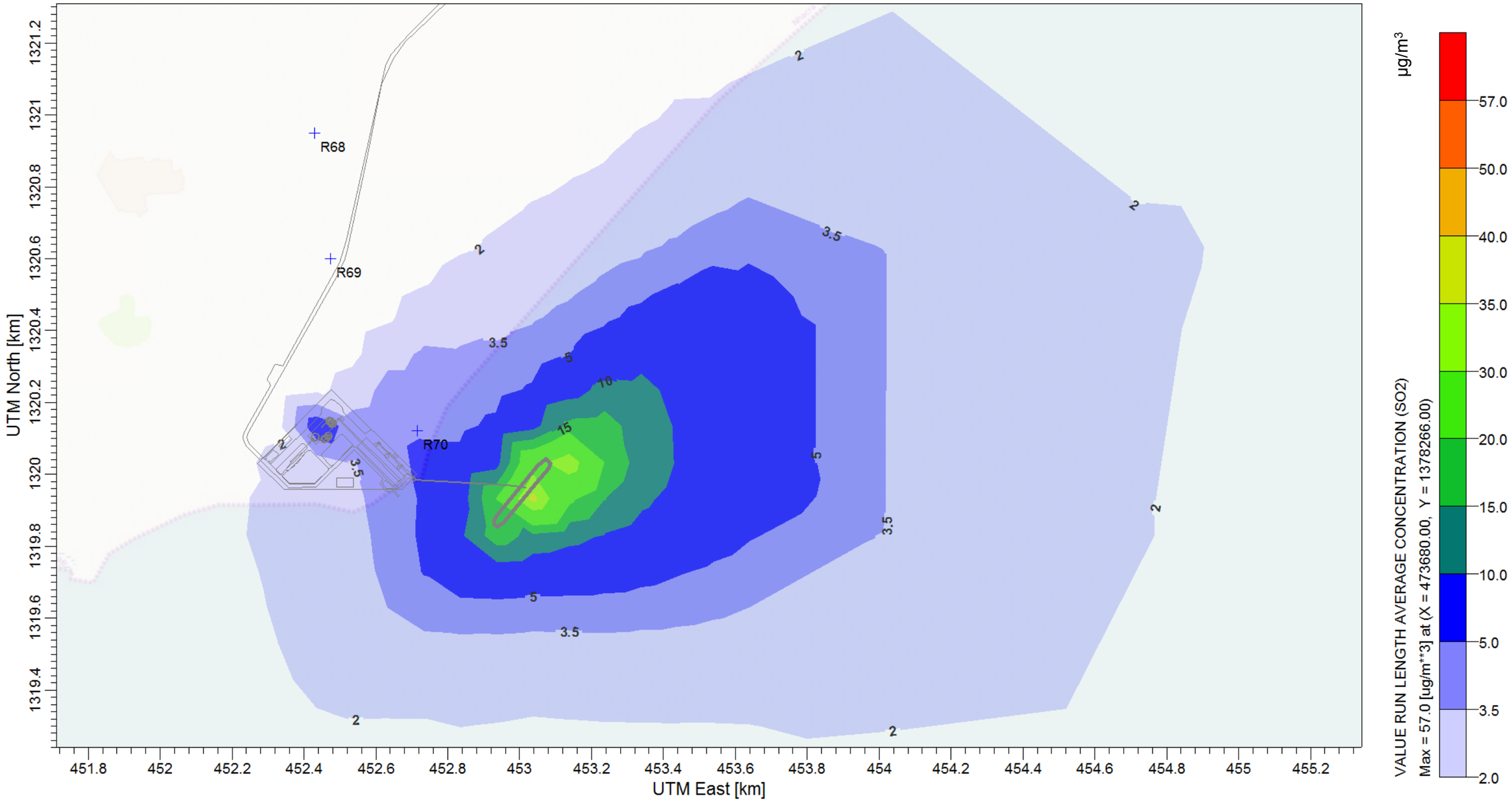
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.6**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION ANNUAL AVERAGE PERIOD IN PORT SITE**

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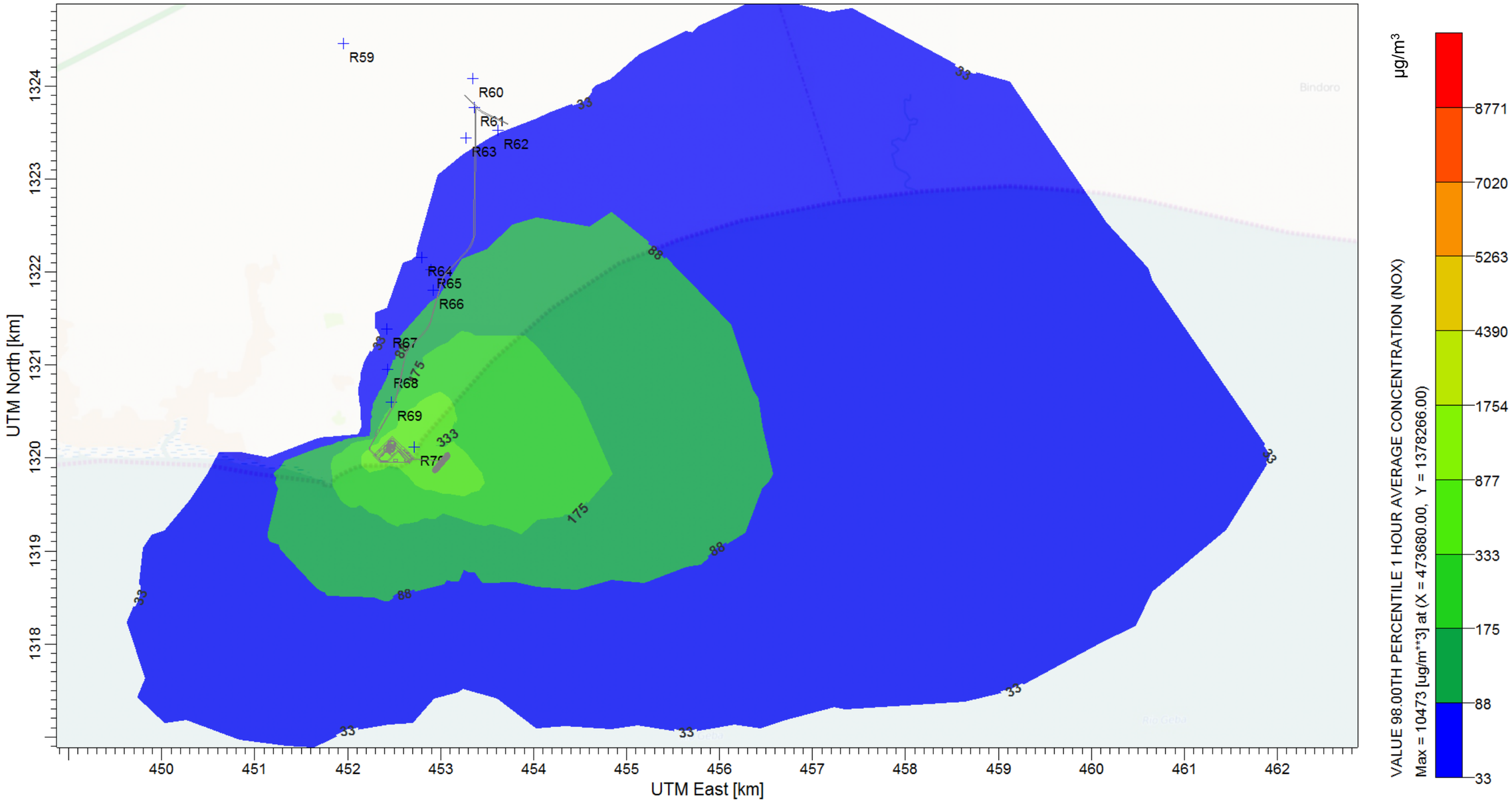
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-1.7	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_X DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN PORT SITE**

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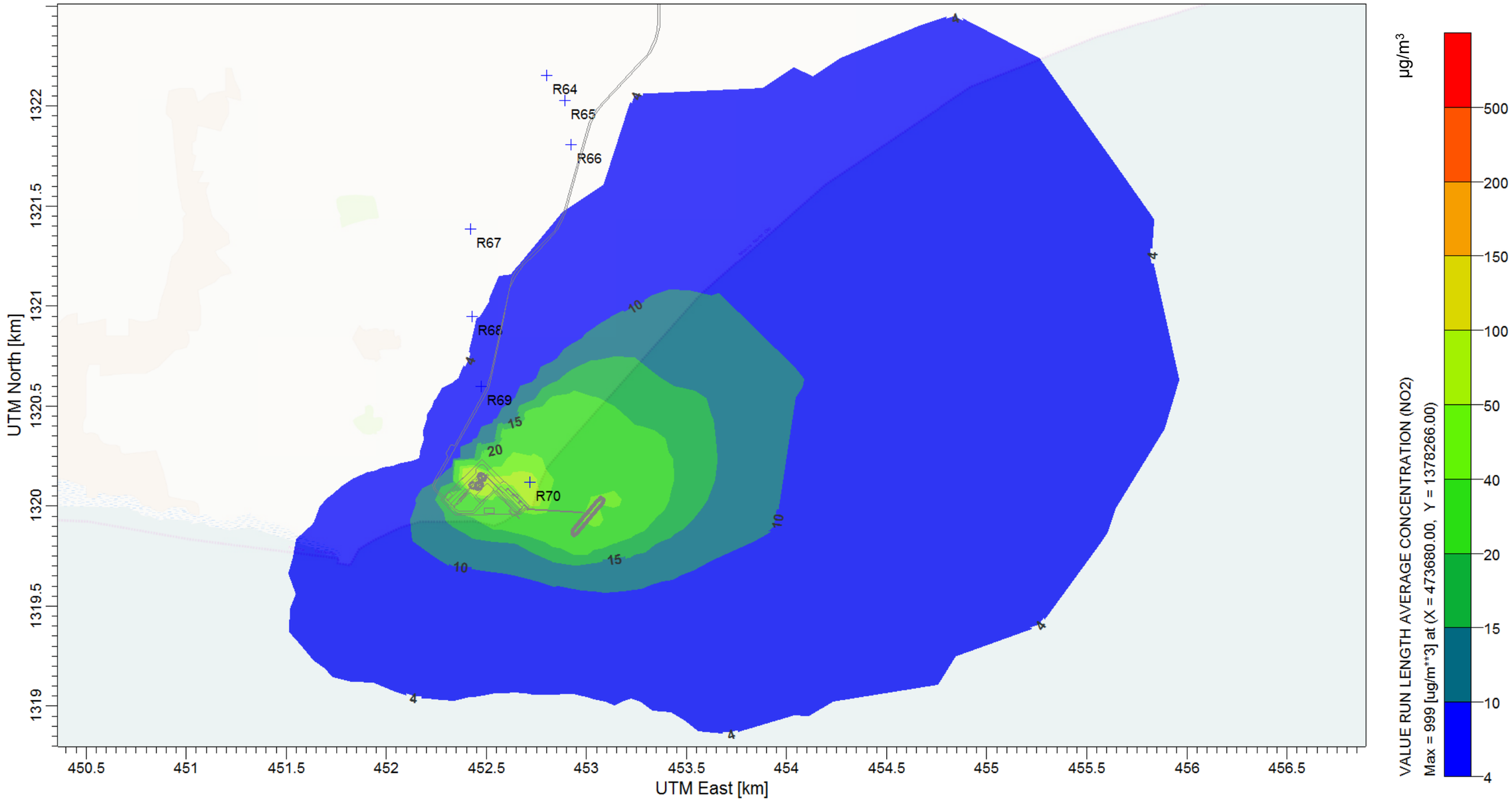
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.8**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_2 DISPERSION ANNUAL AVERAGE PERIOD IN PORT SITE**

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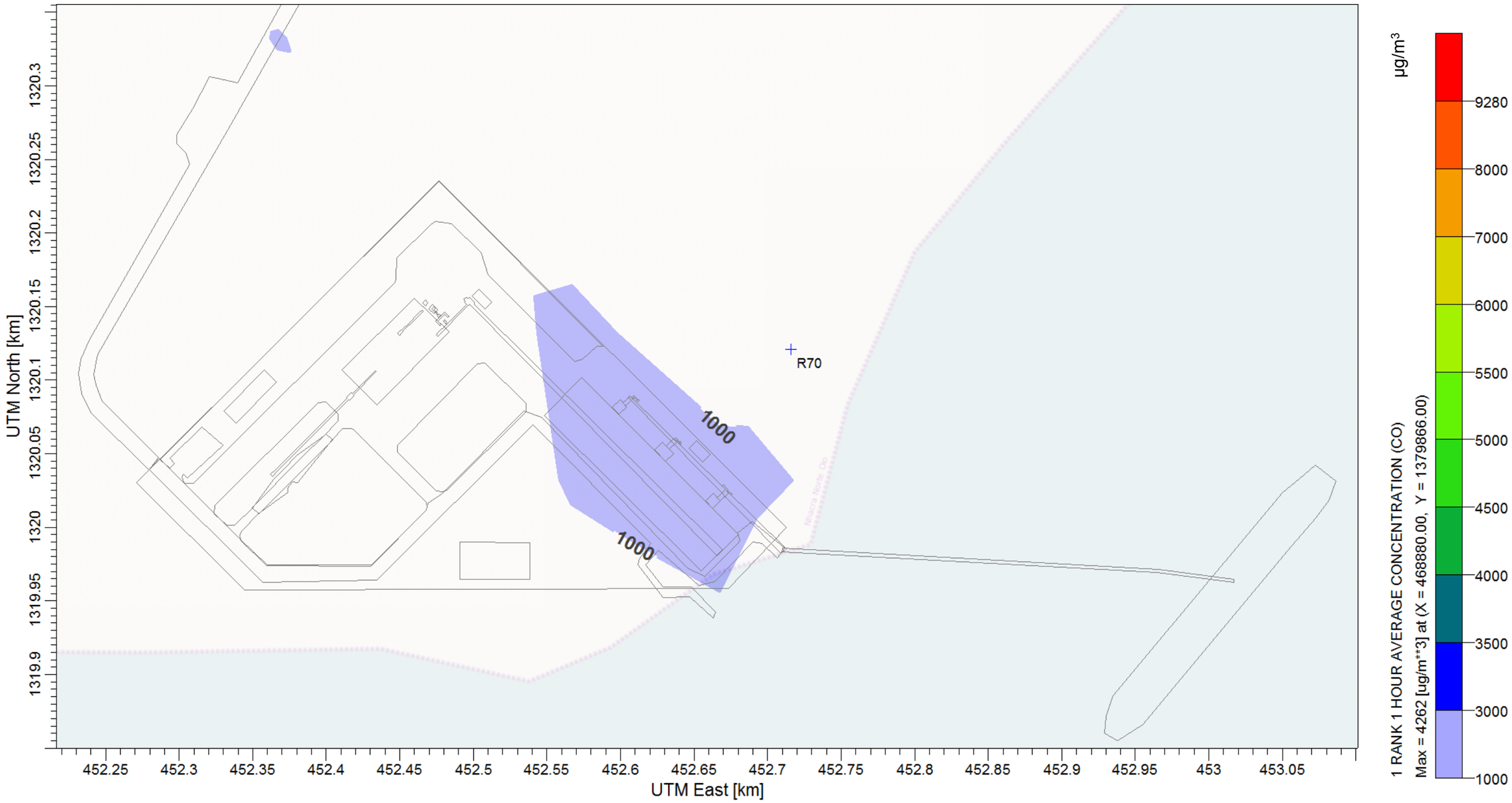
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.9**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 1 HOUR AVERAGE PERIOD IN PORT SITE**

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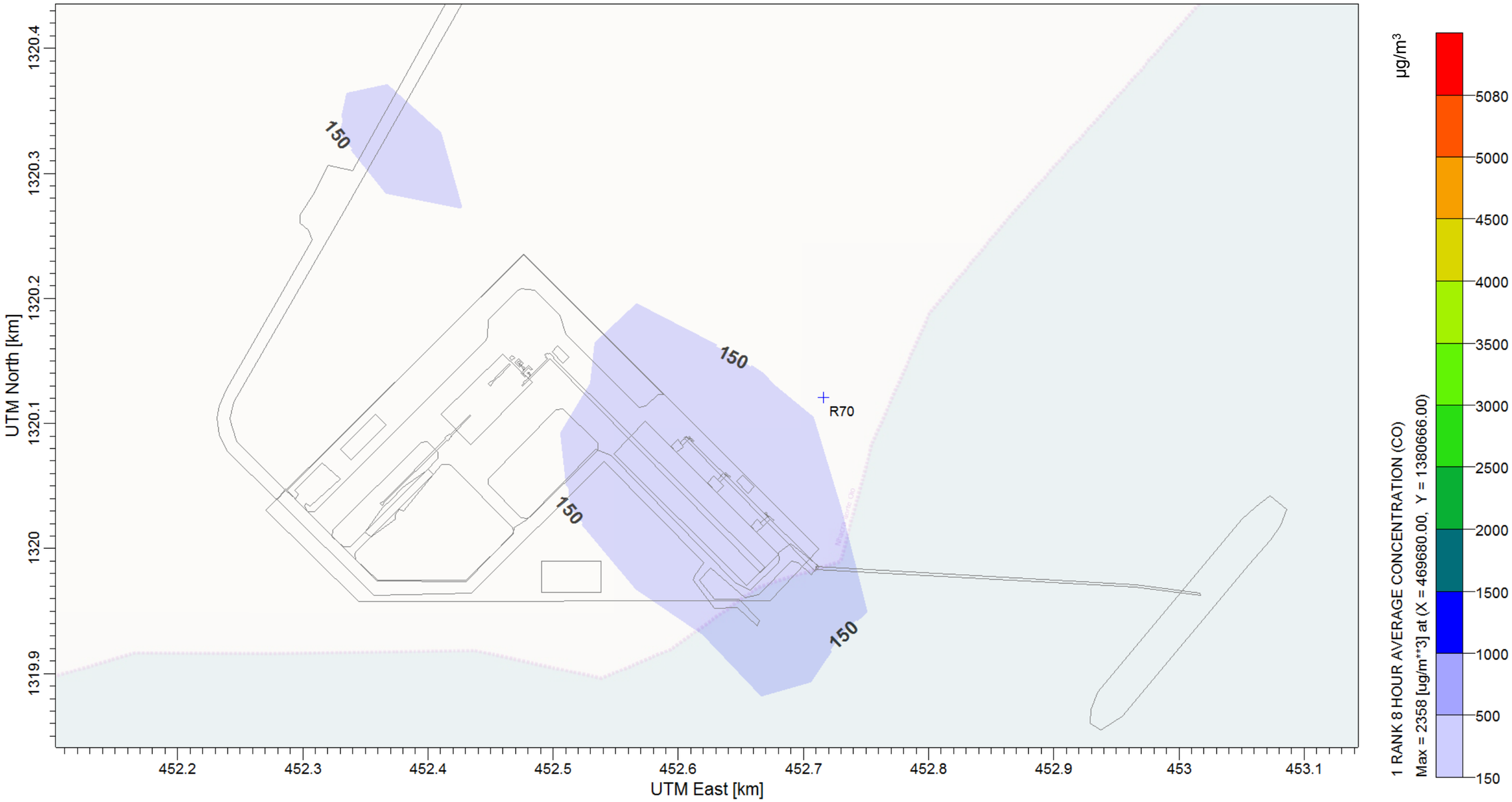
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-1.10**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 8 HOUR AVERAGE PERIOD IN PORT SITE**

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DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-1.11	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

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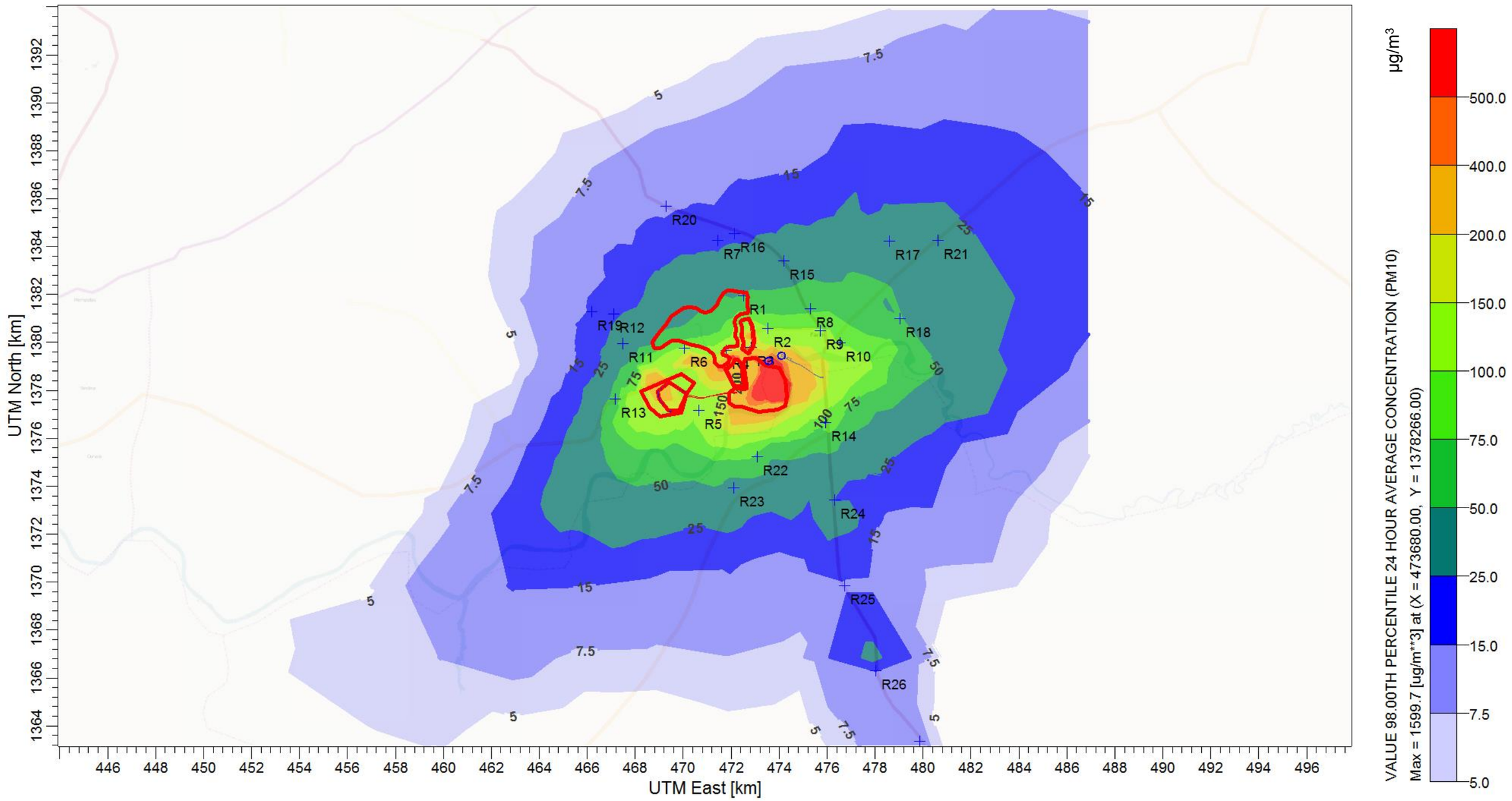
Appendix B-2

Mine Site – Scenario 1 (Year 2)



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

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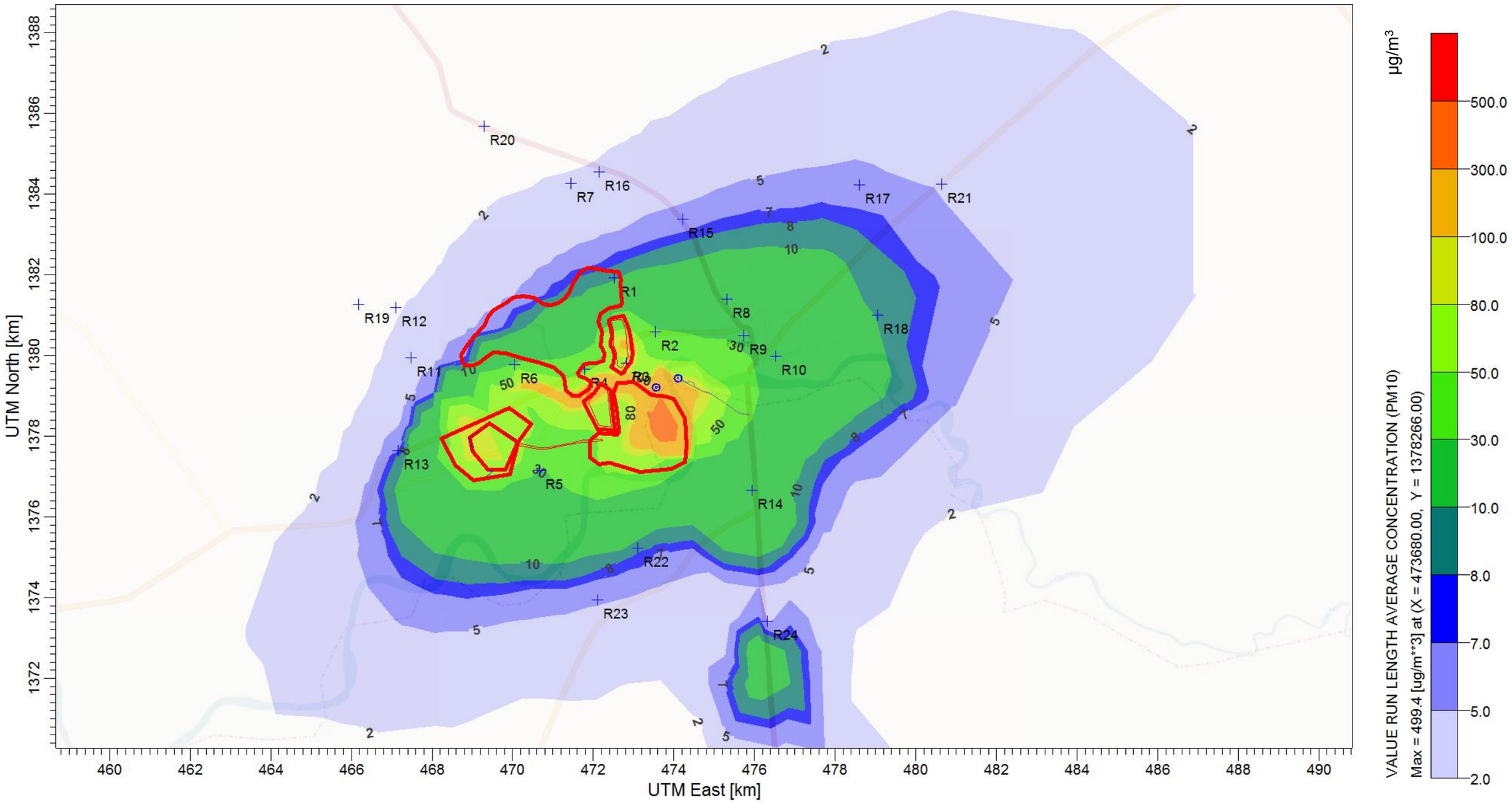
DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-2.1	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION FOR ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

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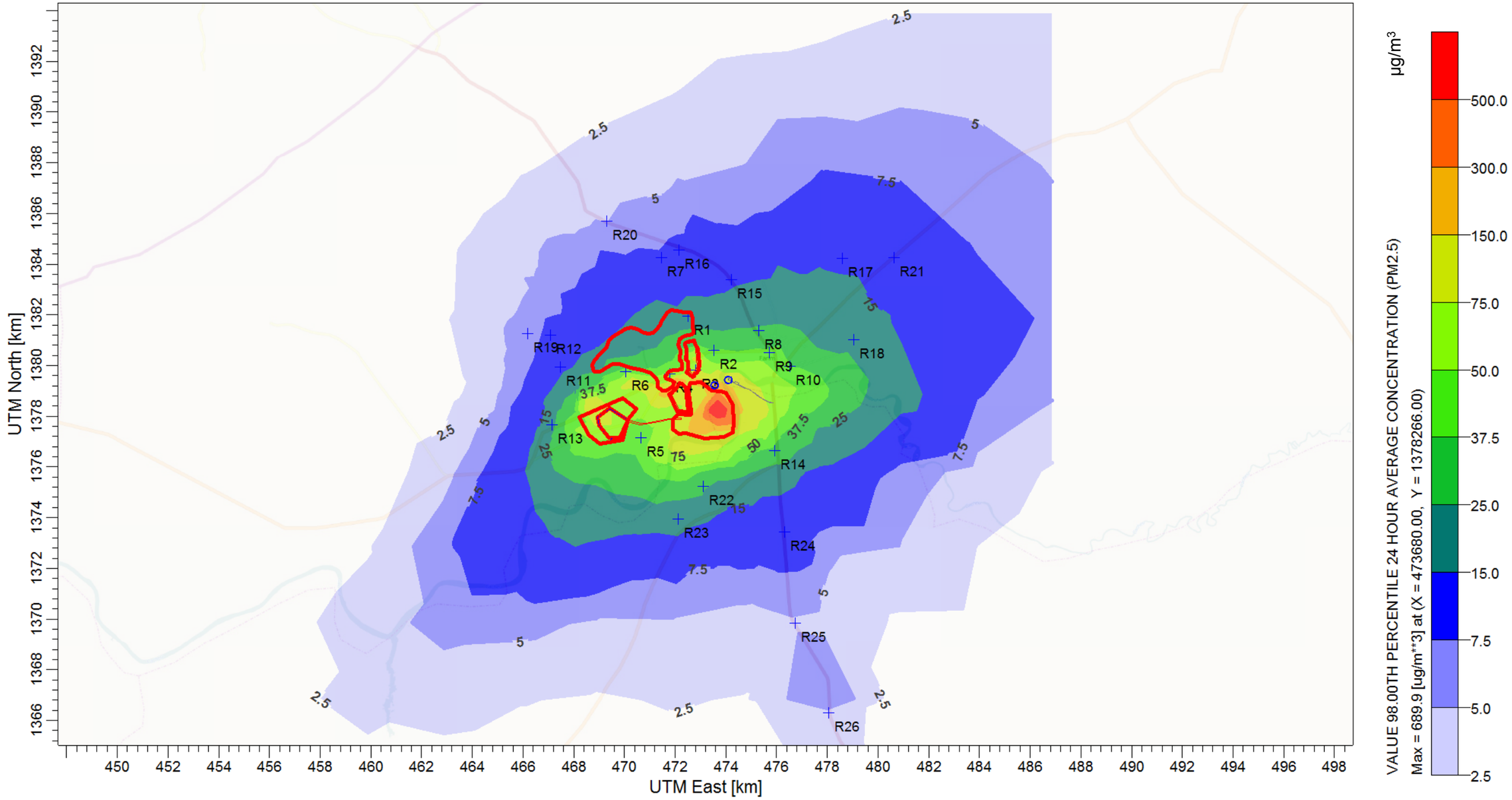
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.2**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

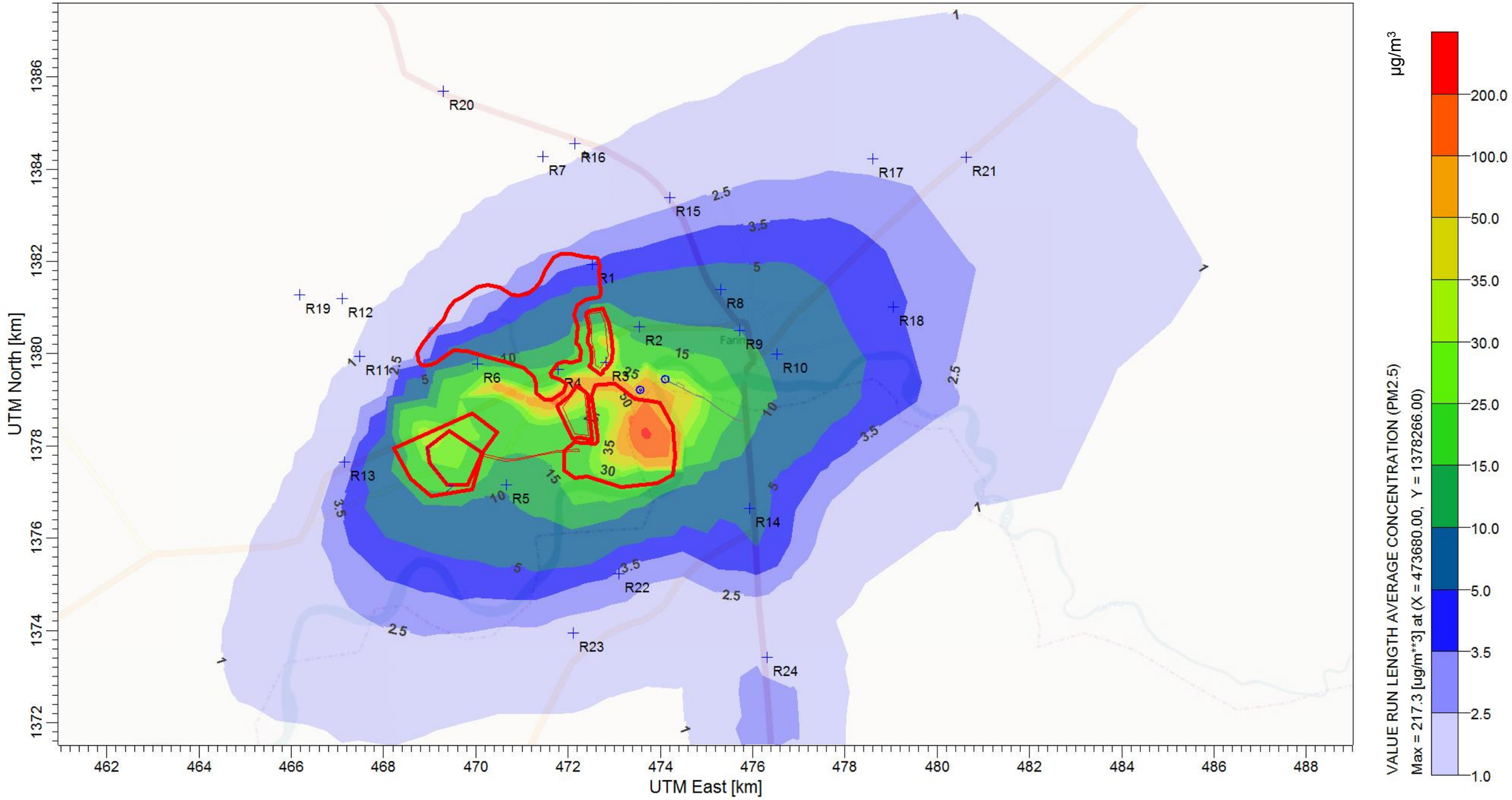


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-2.3	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

Knight Piésold
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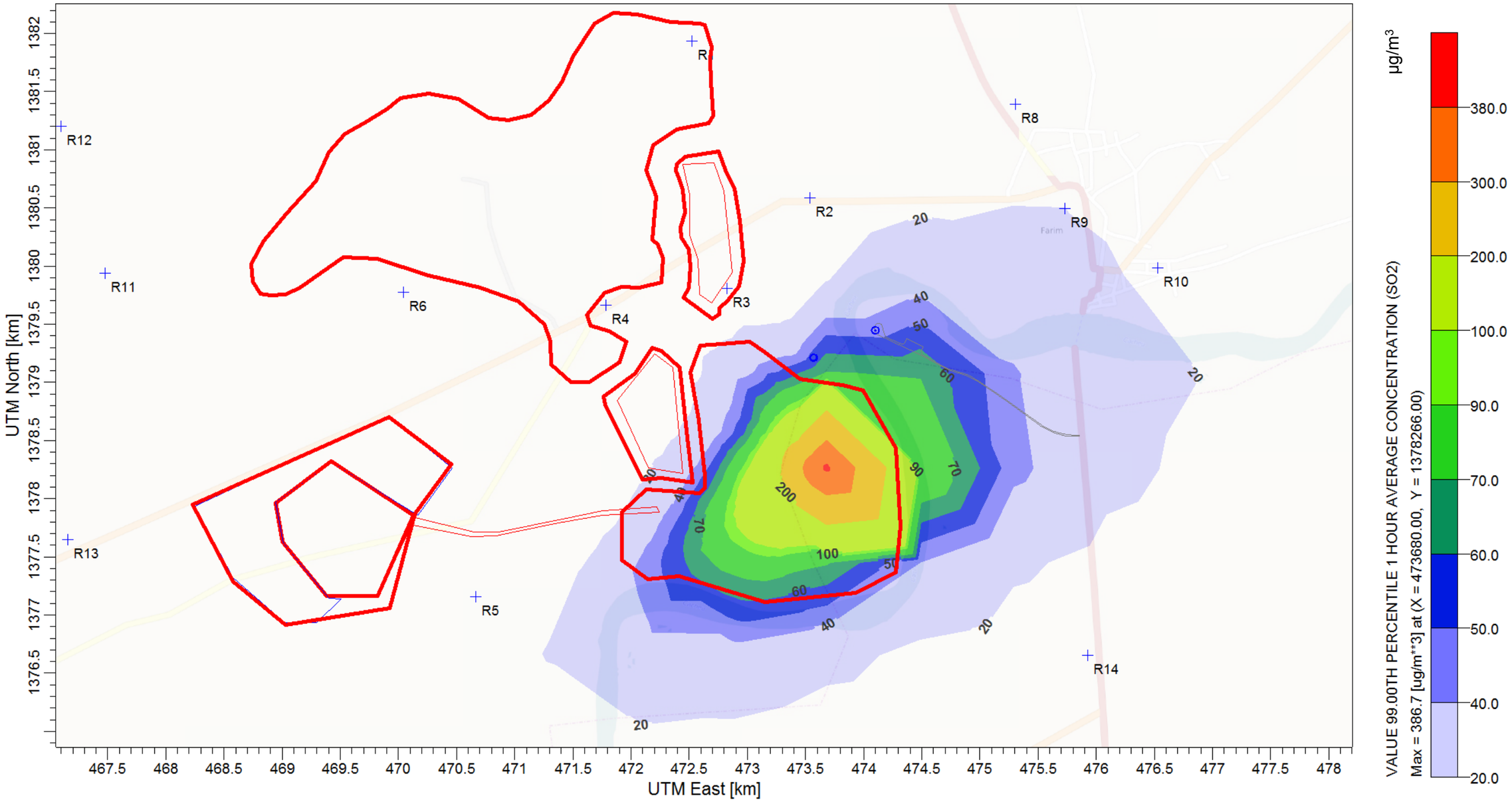
DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-2.4	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

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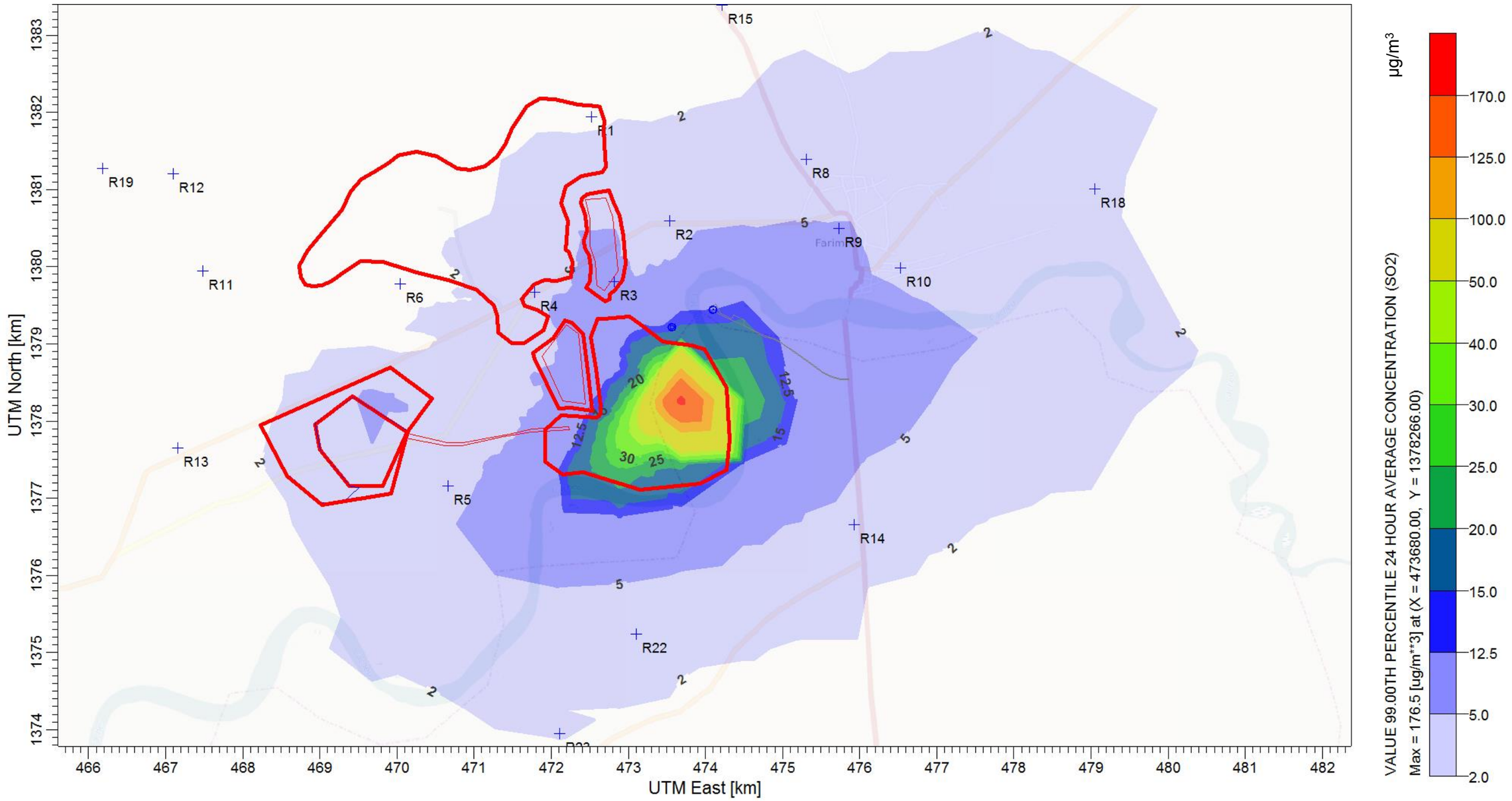
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.5**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

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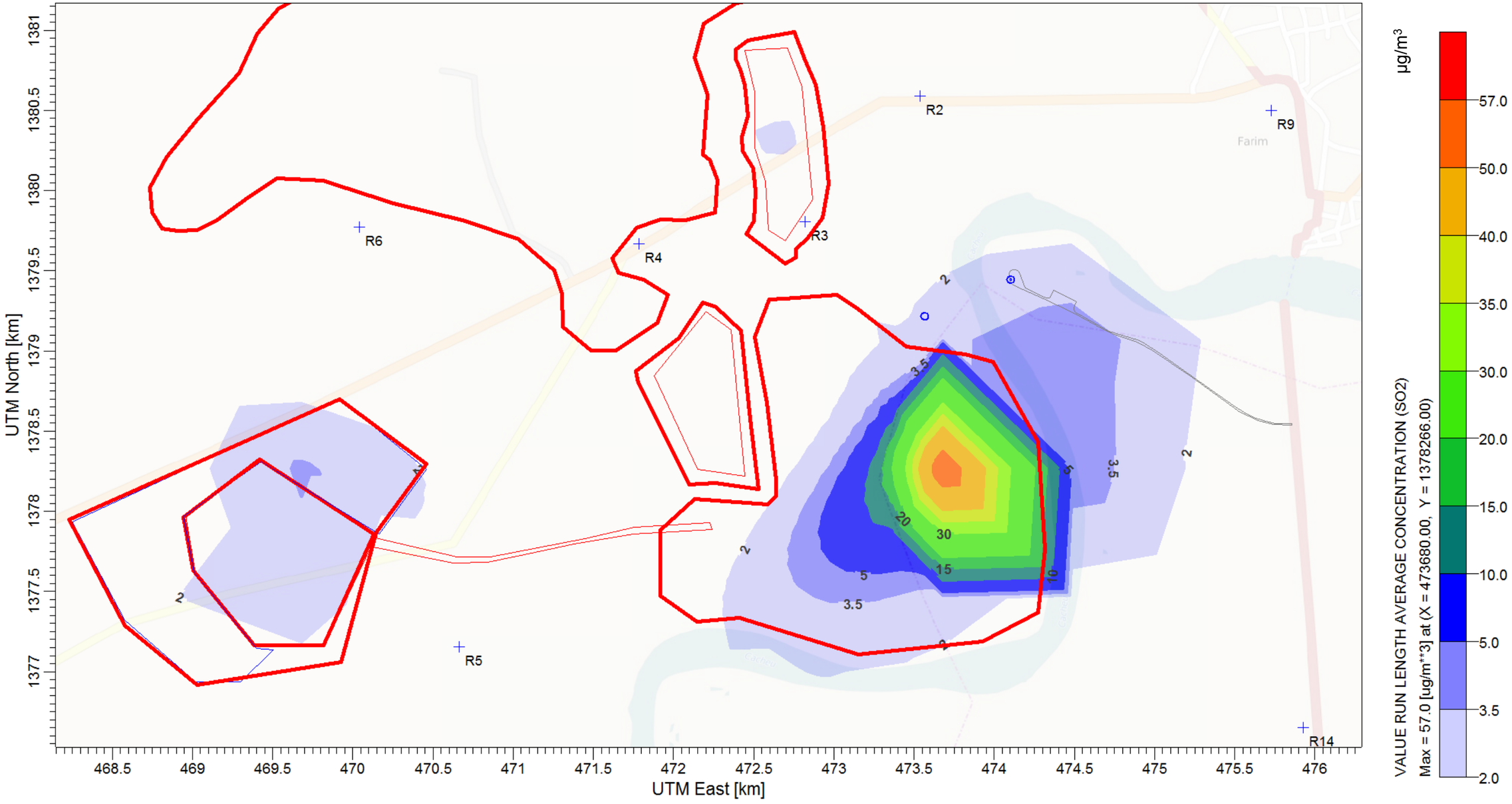
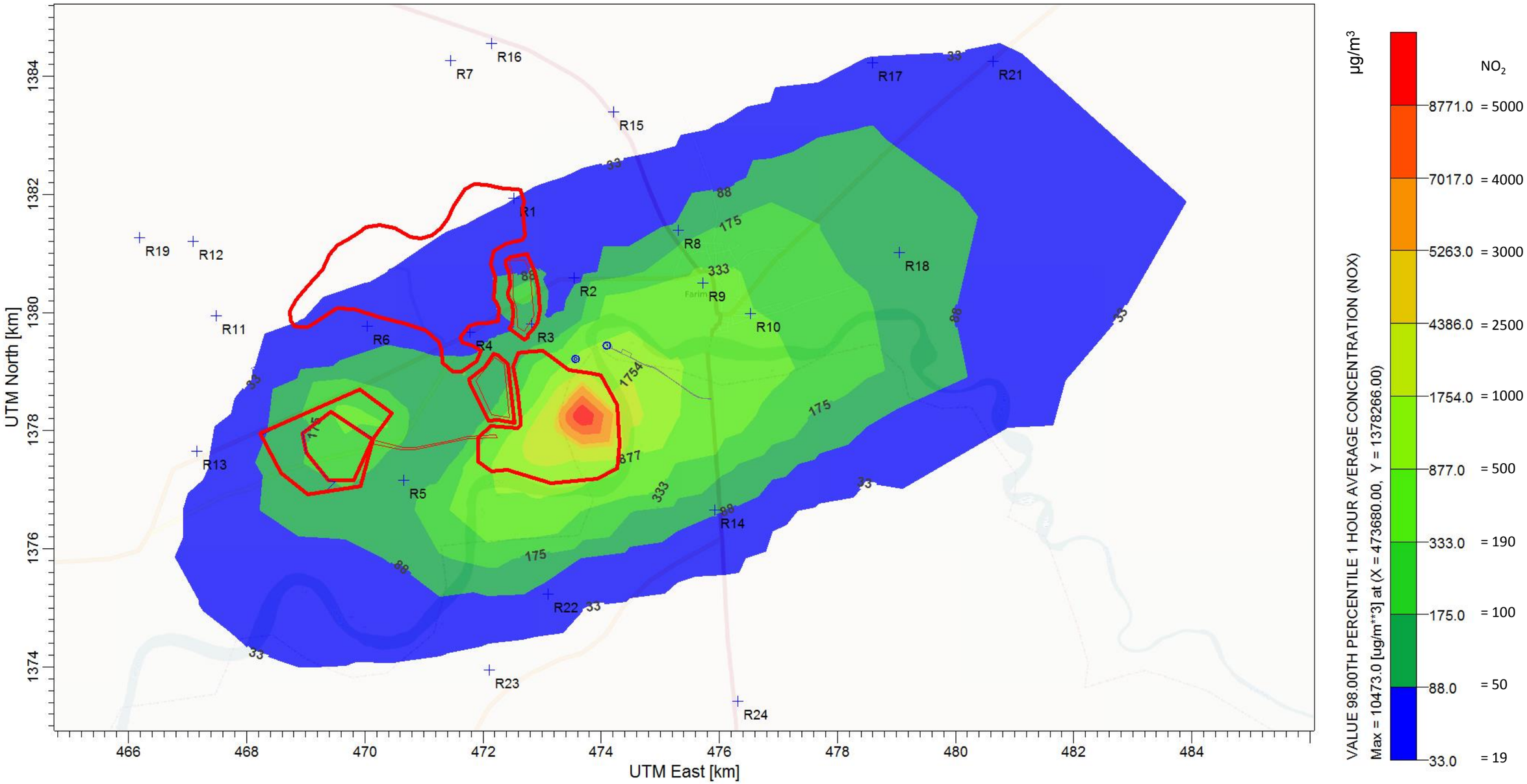
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.6**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**SO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 1**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.7**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



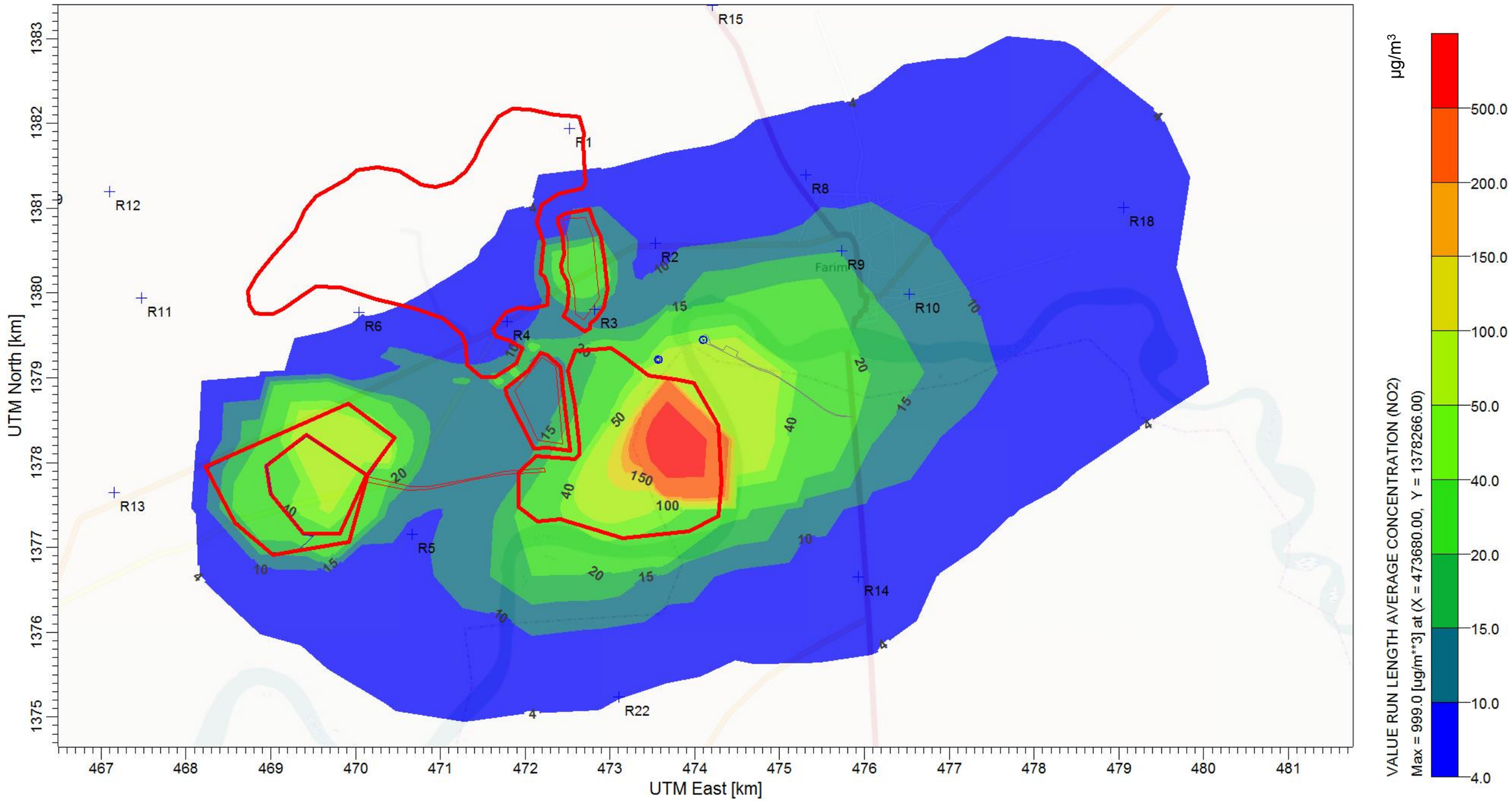
NOTES:
NO_2/NO_x= 0.57

REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_X DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

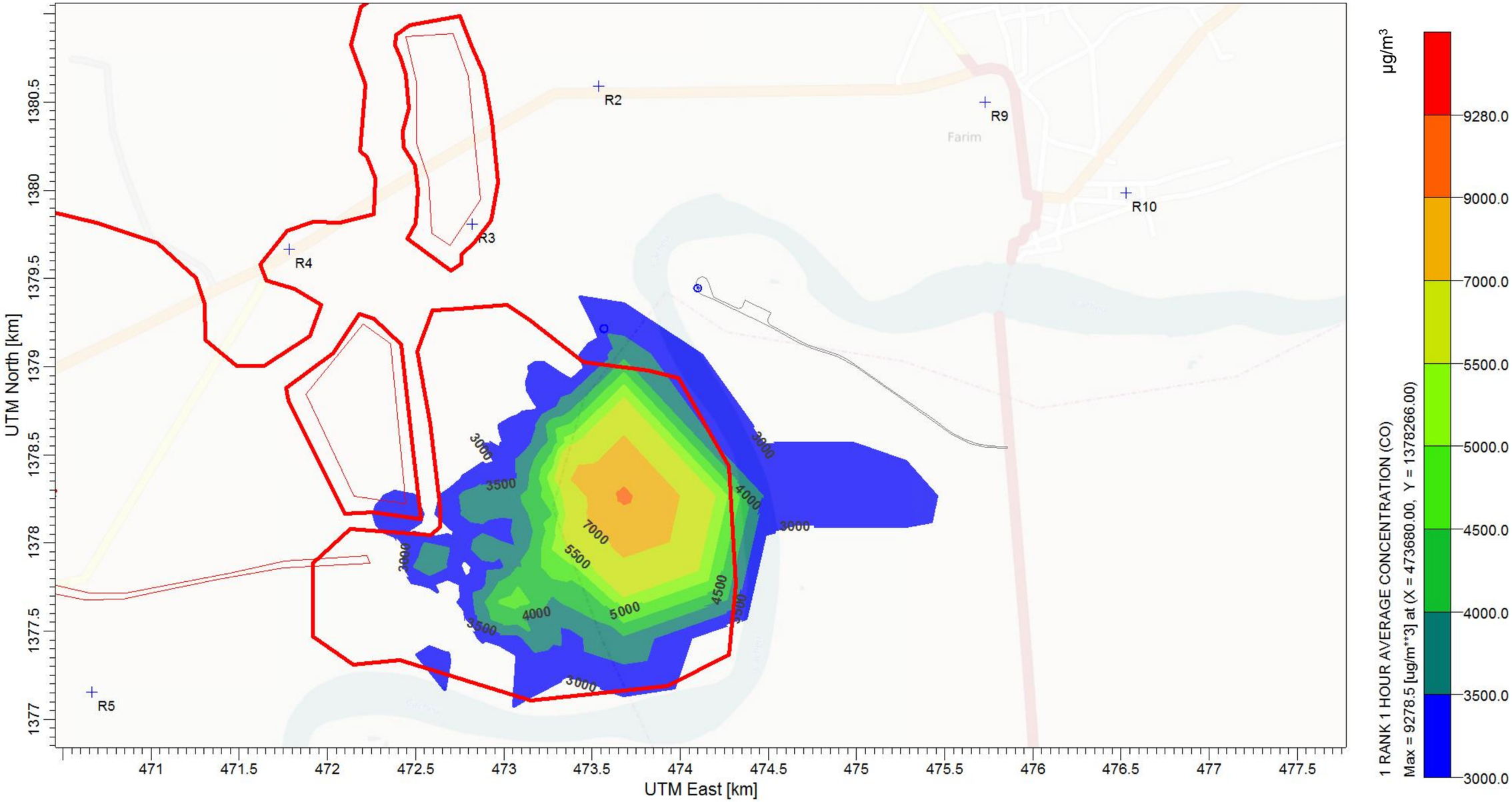
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-2.8	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**NO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 1**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.9**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

Knight Piésold
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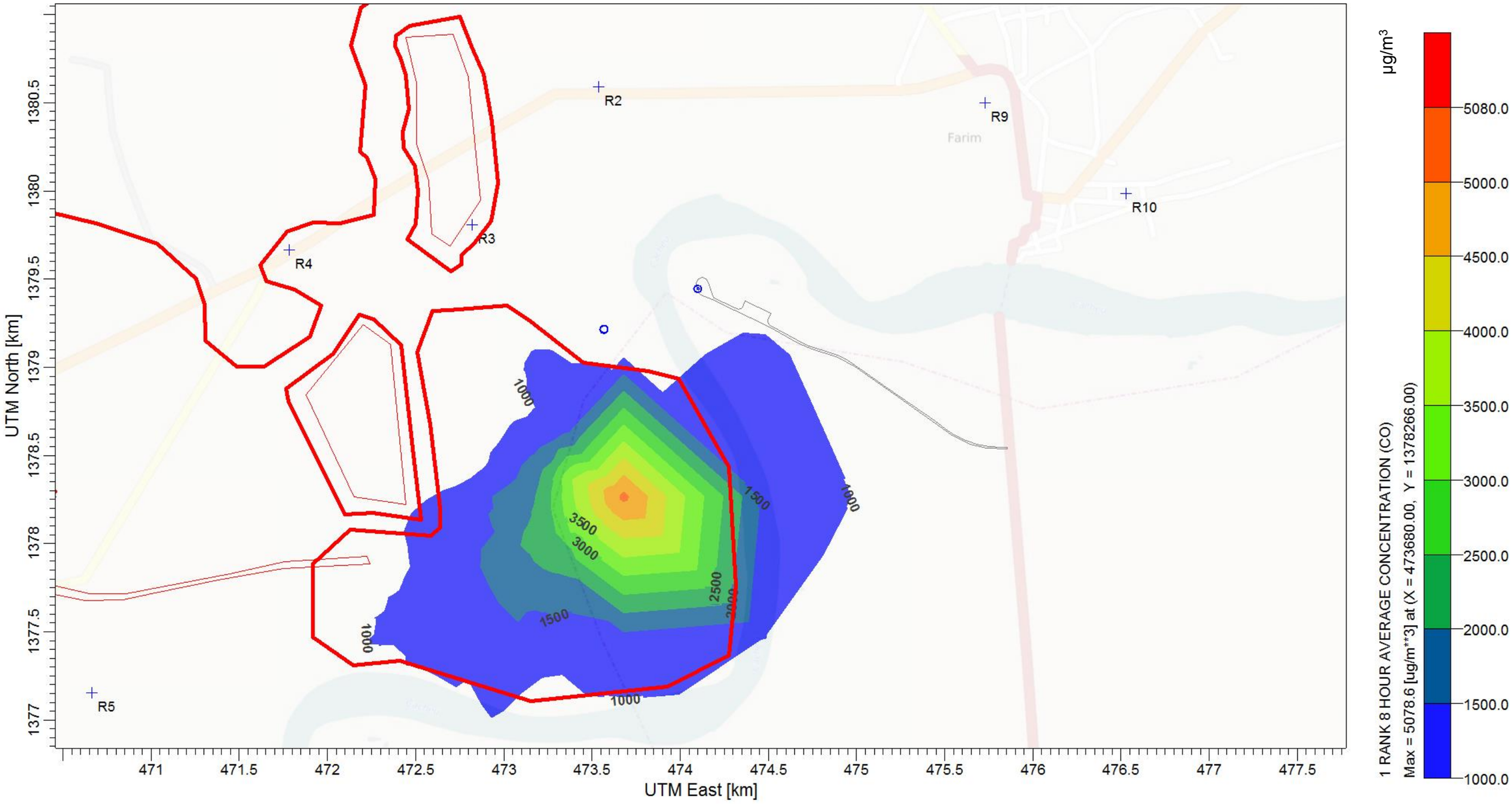
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.10**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 8 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 1**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-2.11**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

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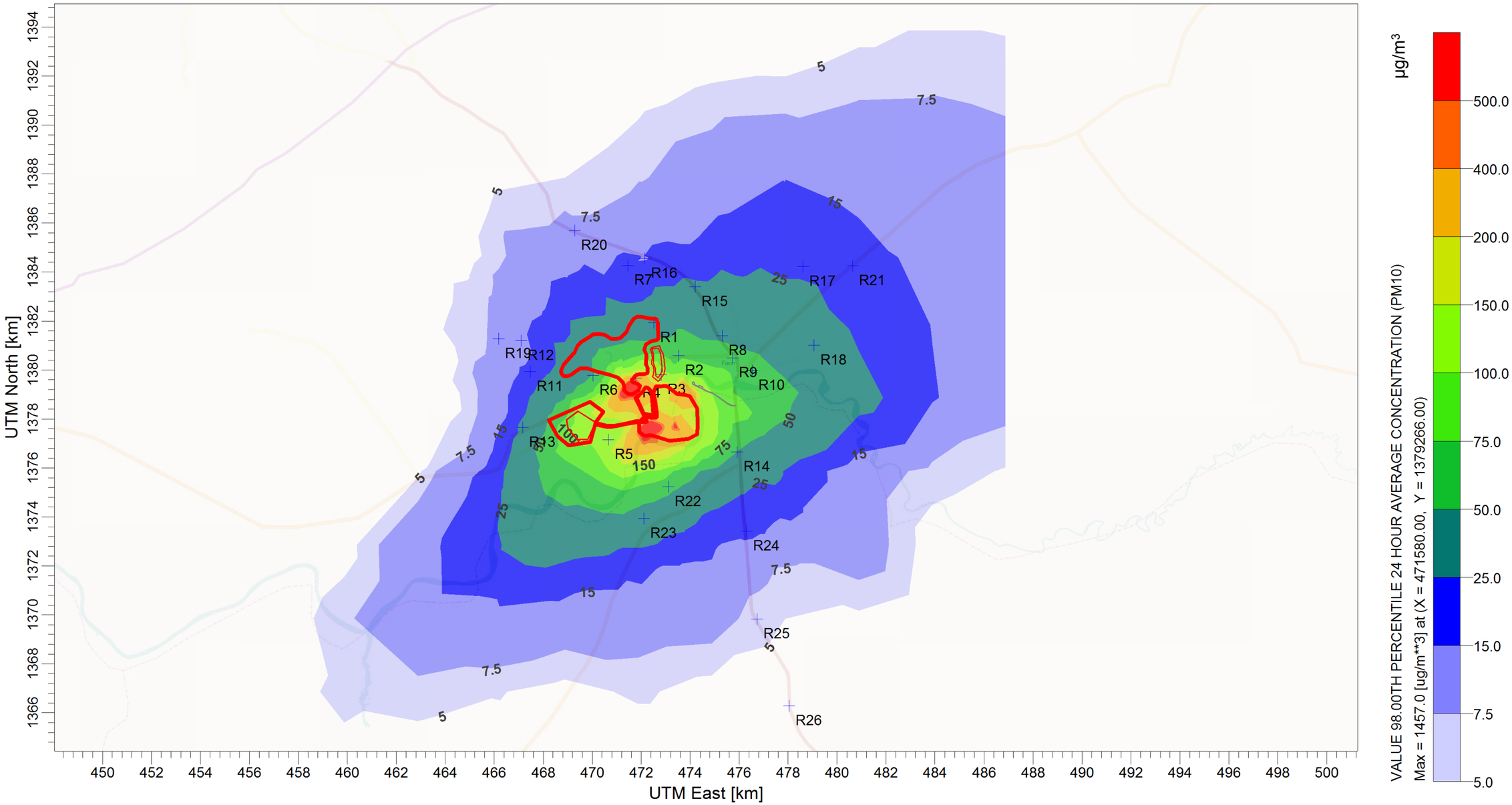
Appendix B-3

Mine Site – Scenario 2 (Year 8)

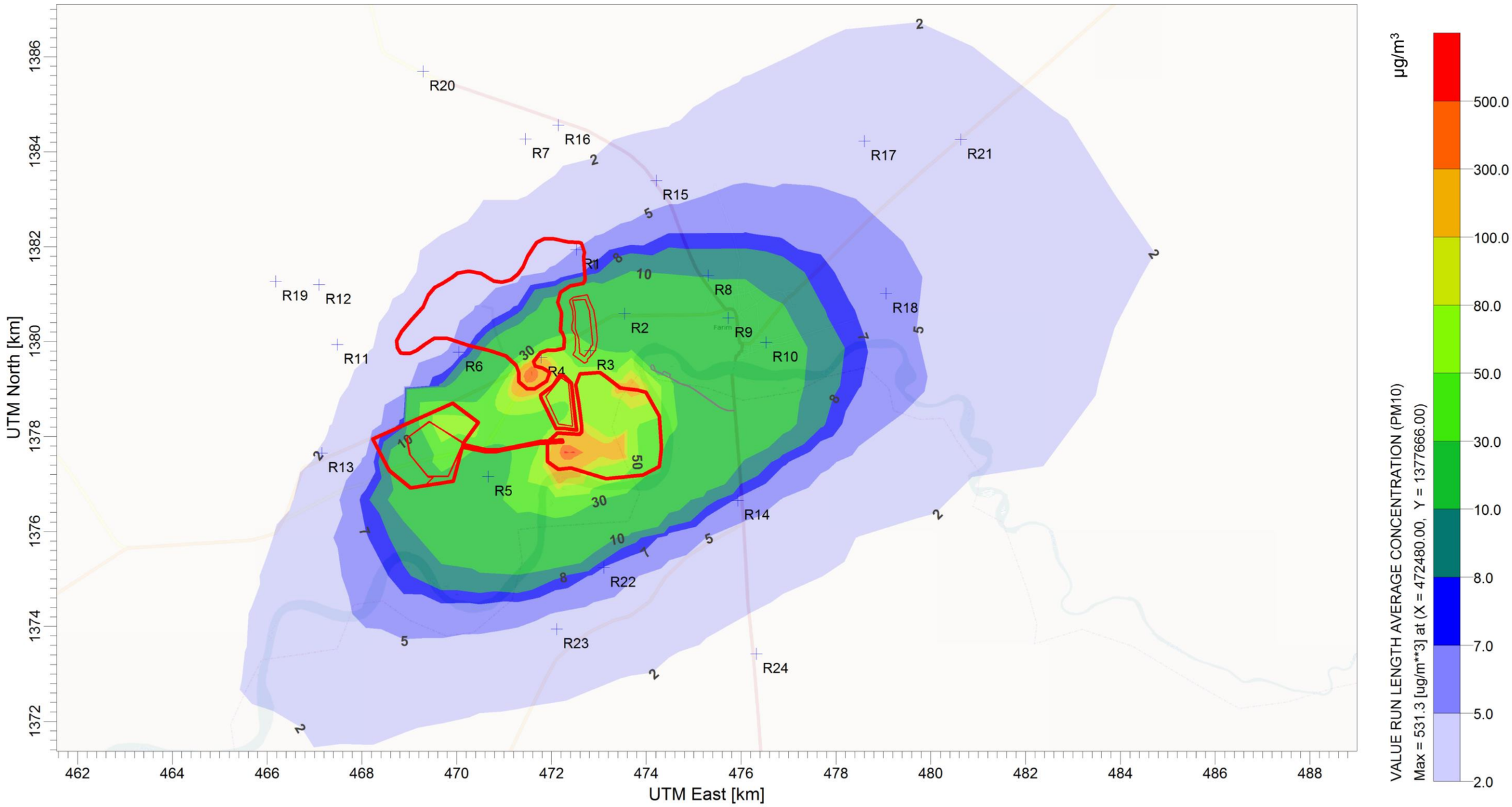


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-3.1	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

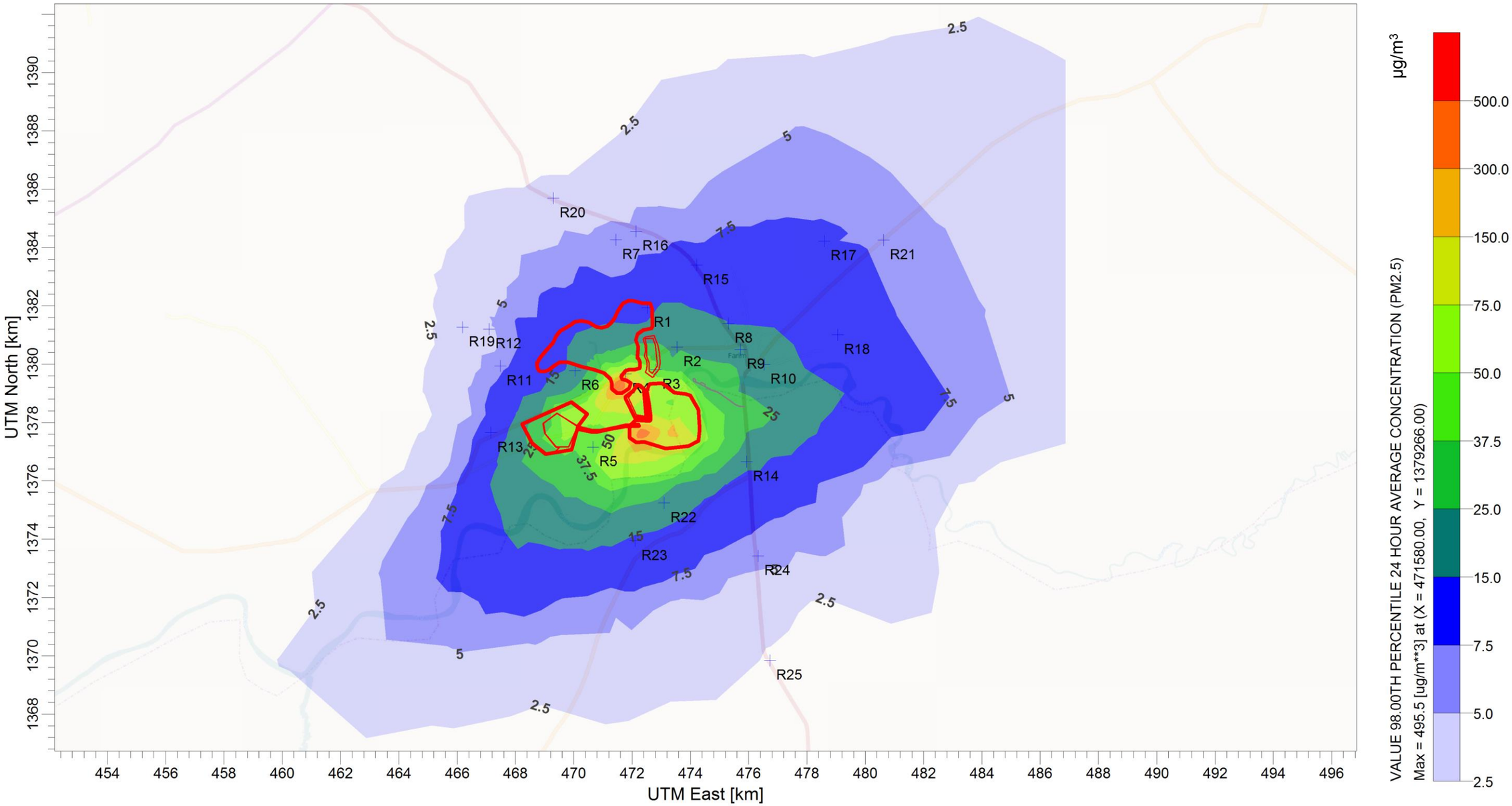


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION FOR ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-3.2	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

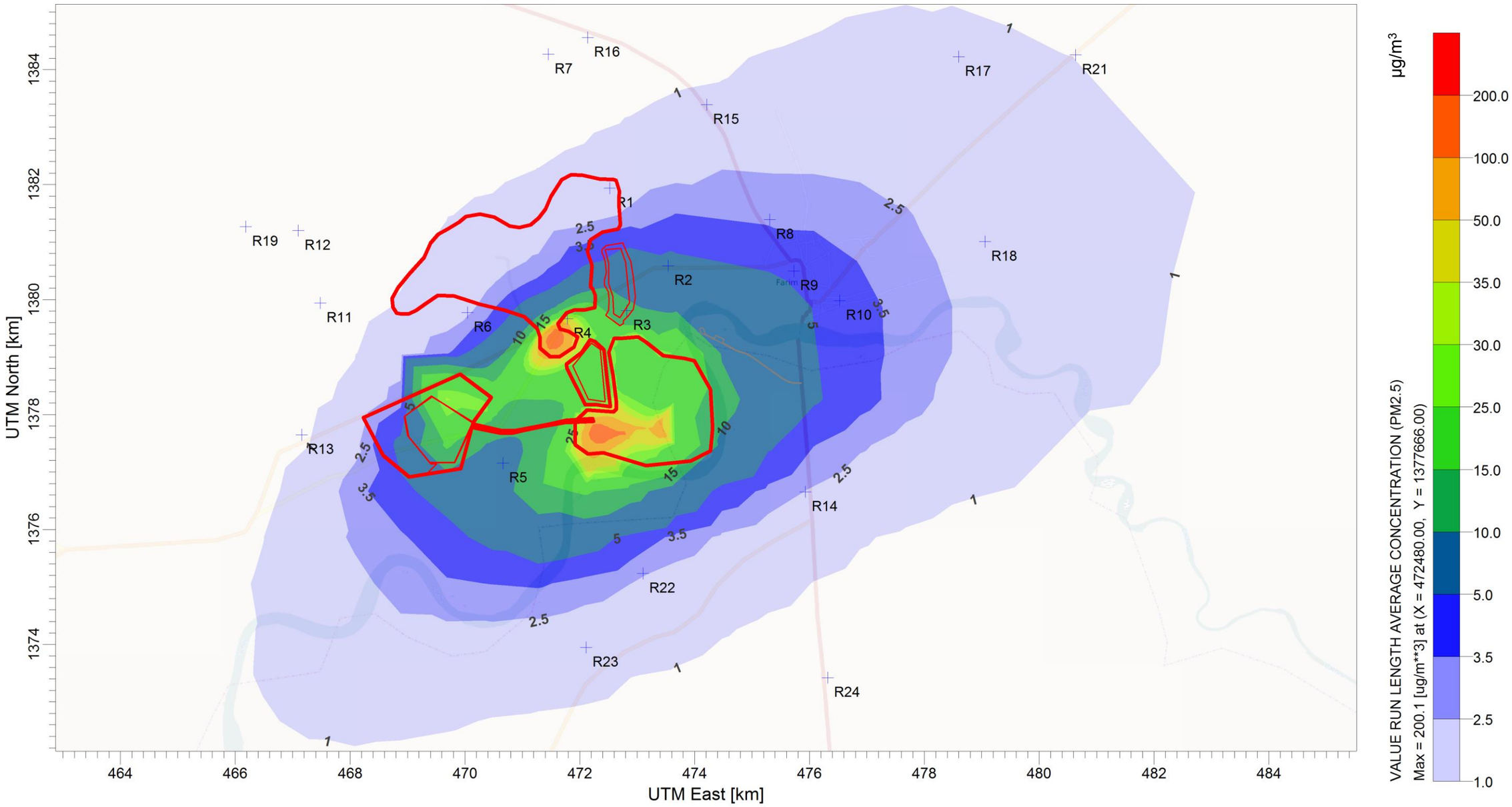


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-3.3	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

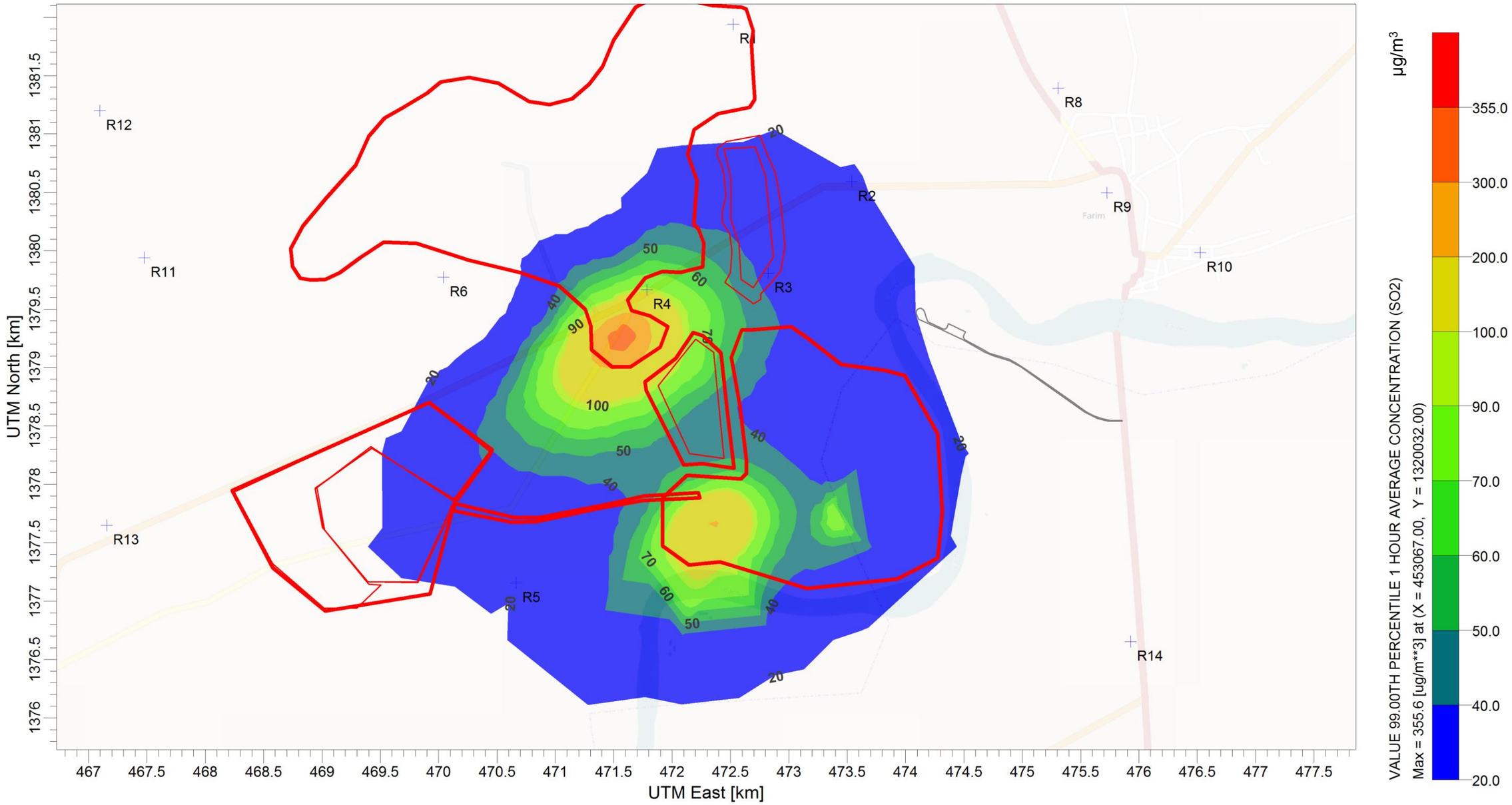


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-3.4**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

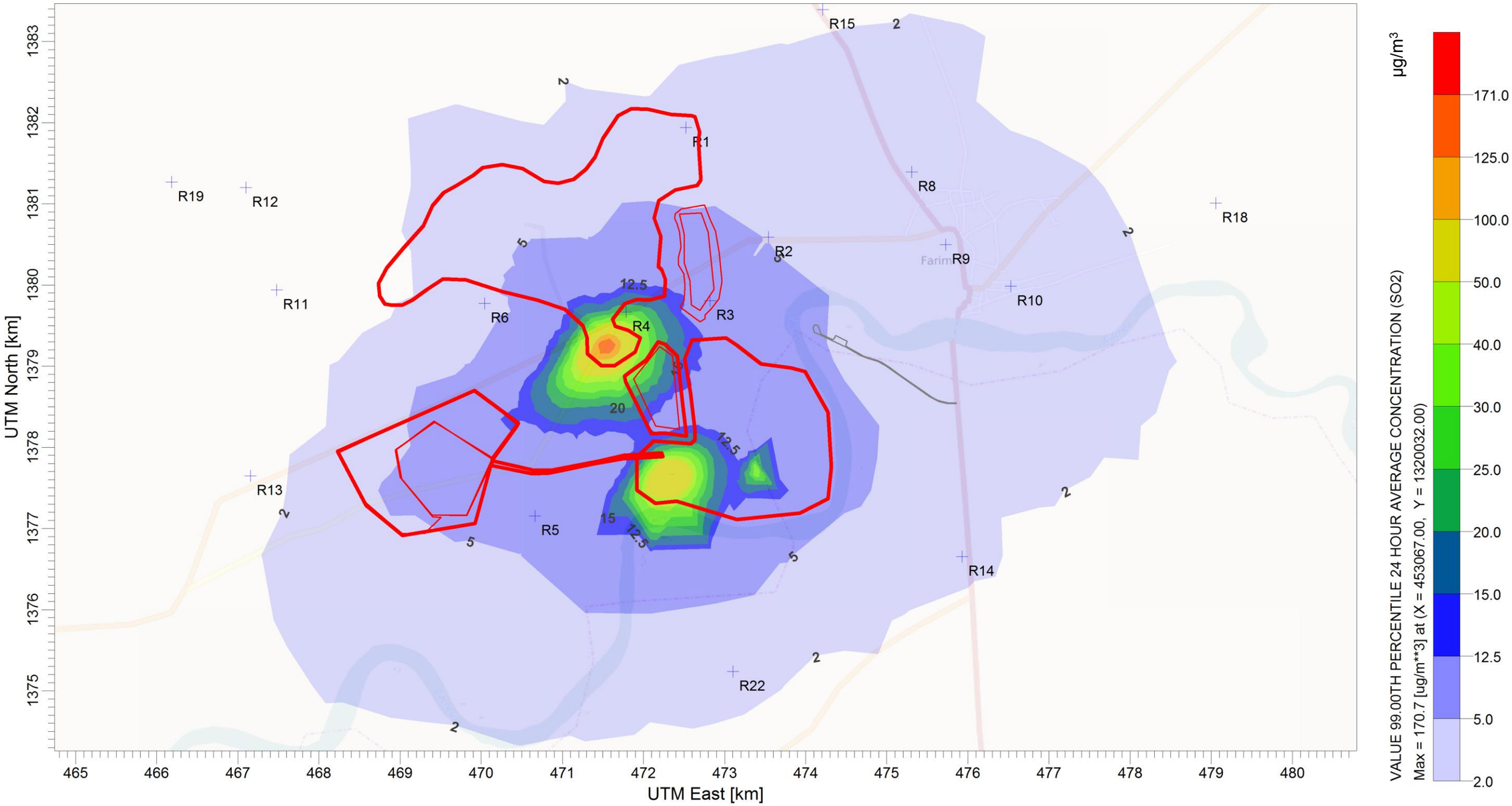


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-3.5	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

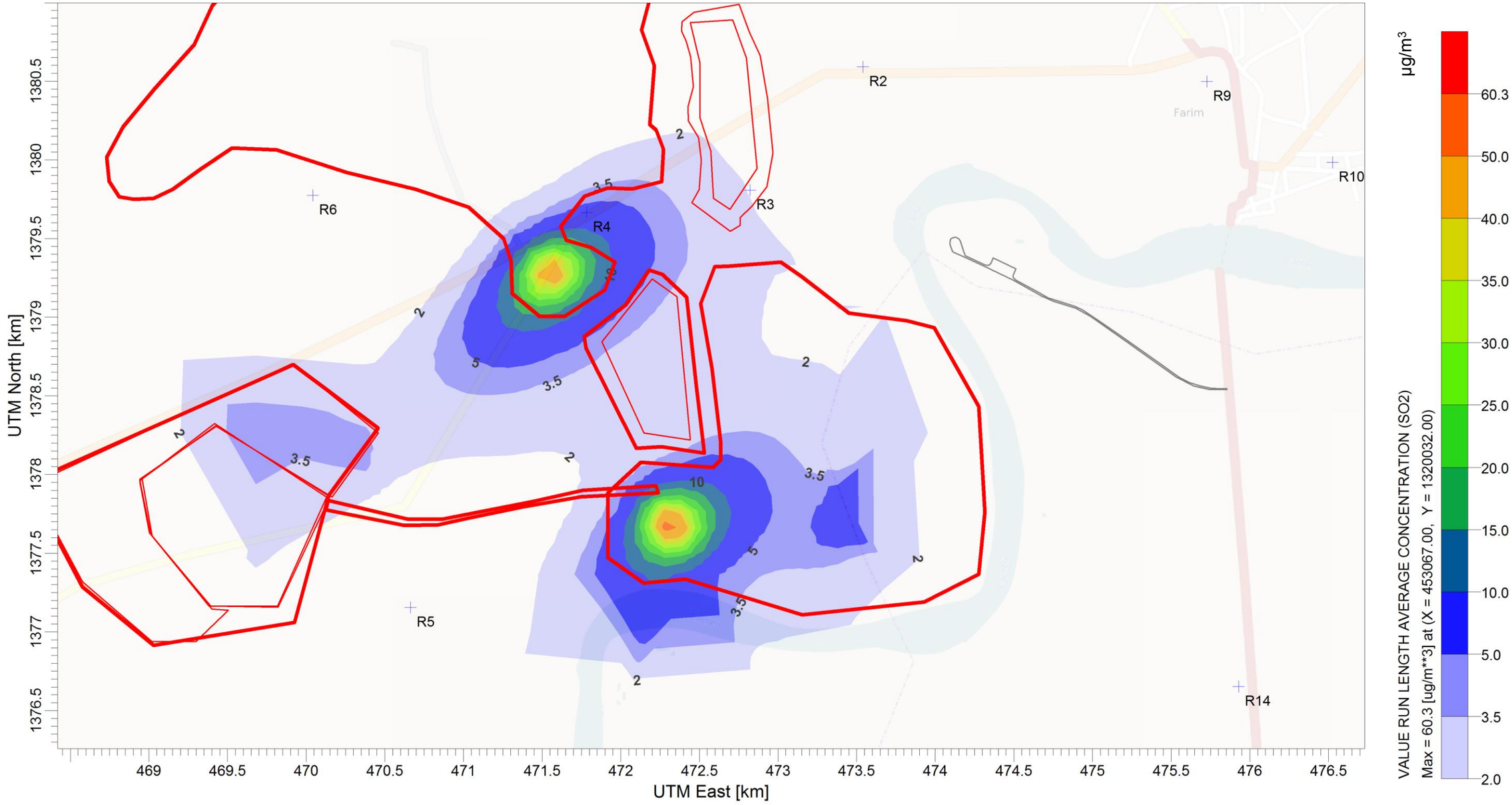


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

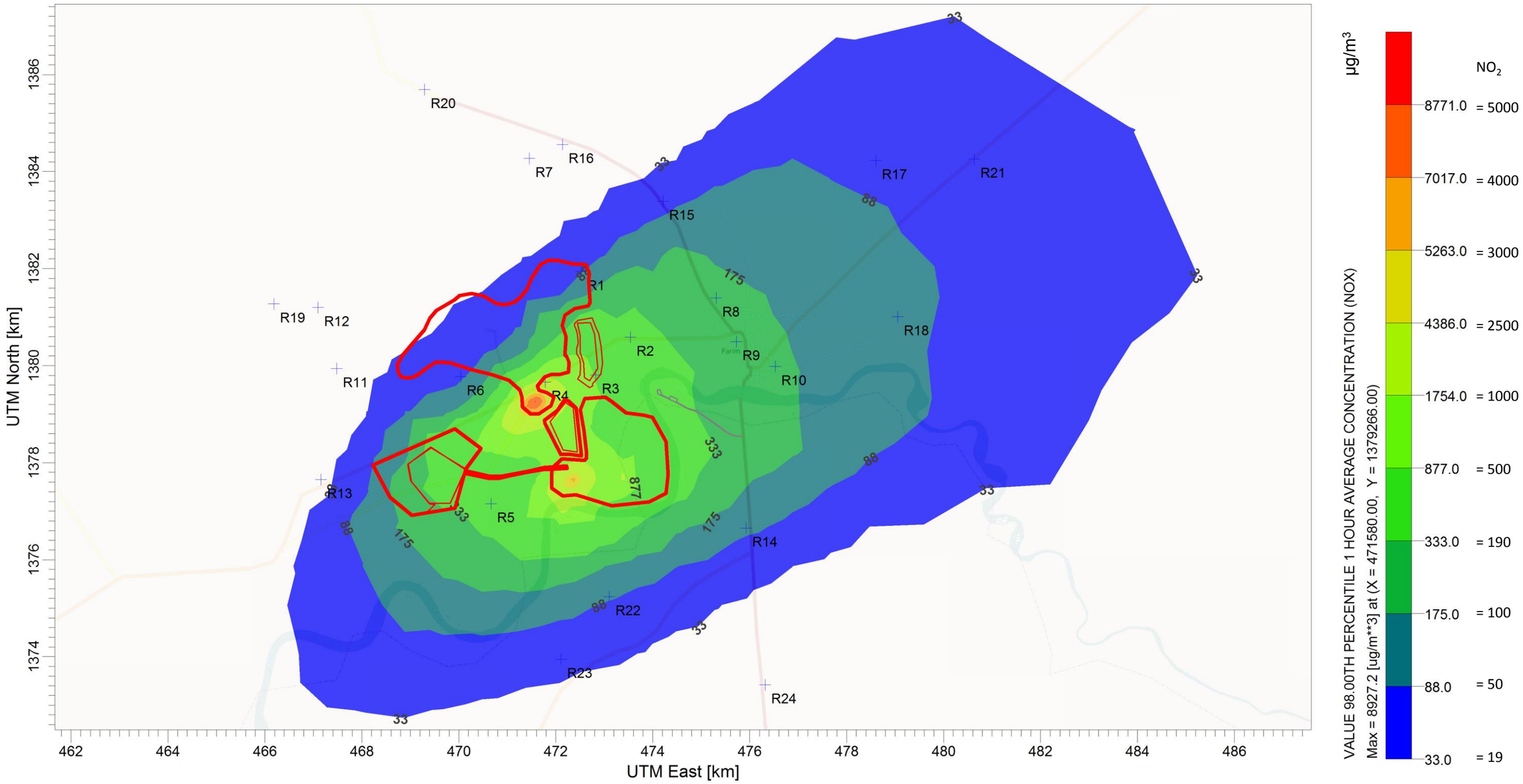
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-3.6**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**SO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 2**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-3.7**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



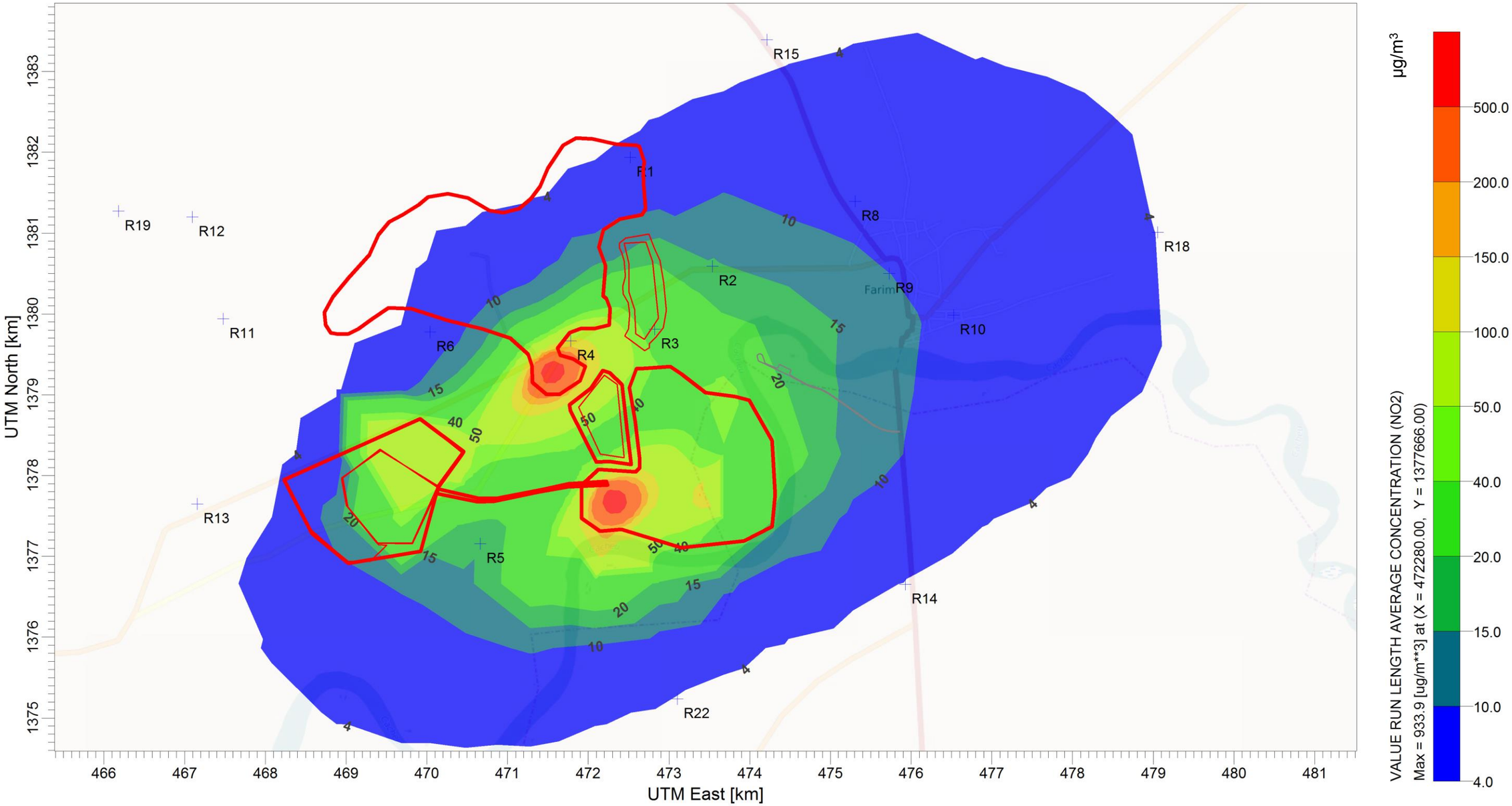
NOTES:
NO_2/NO_x = 0.57

REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_X DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-3.8**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

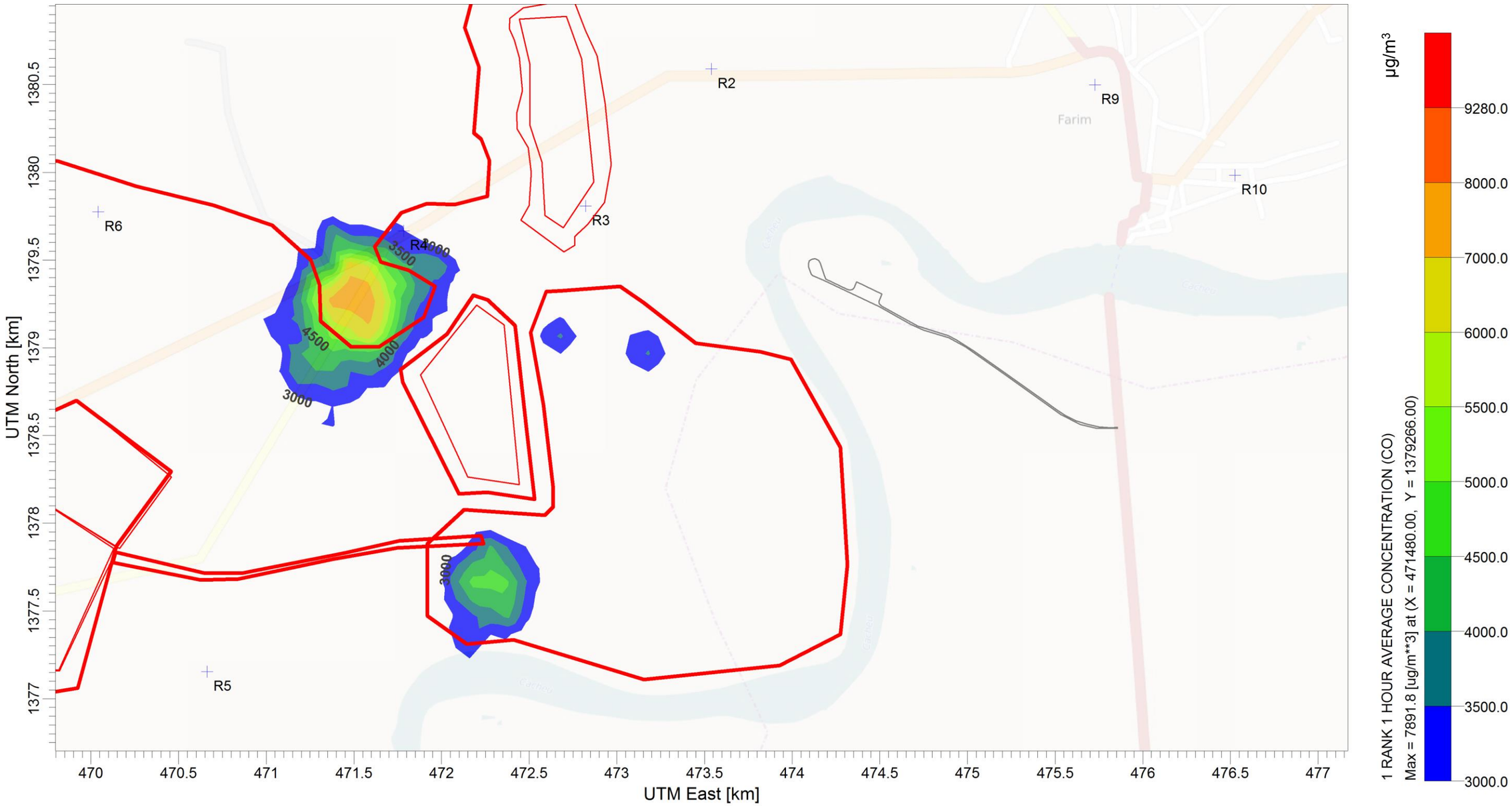


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

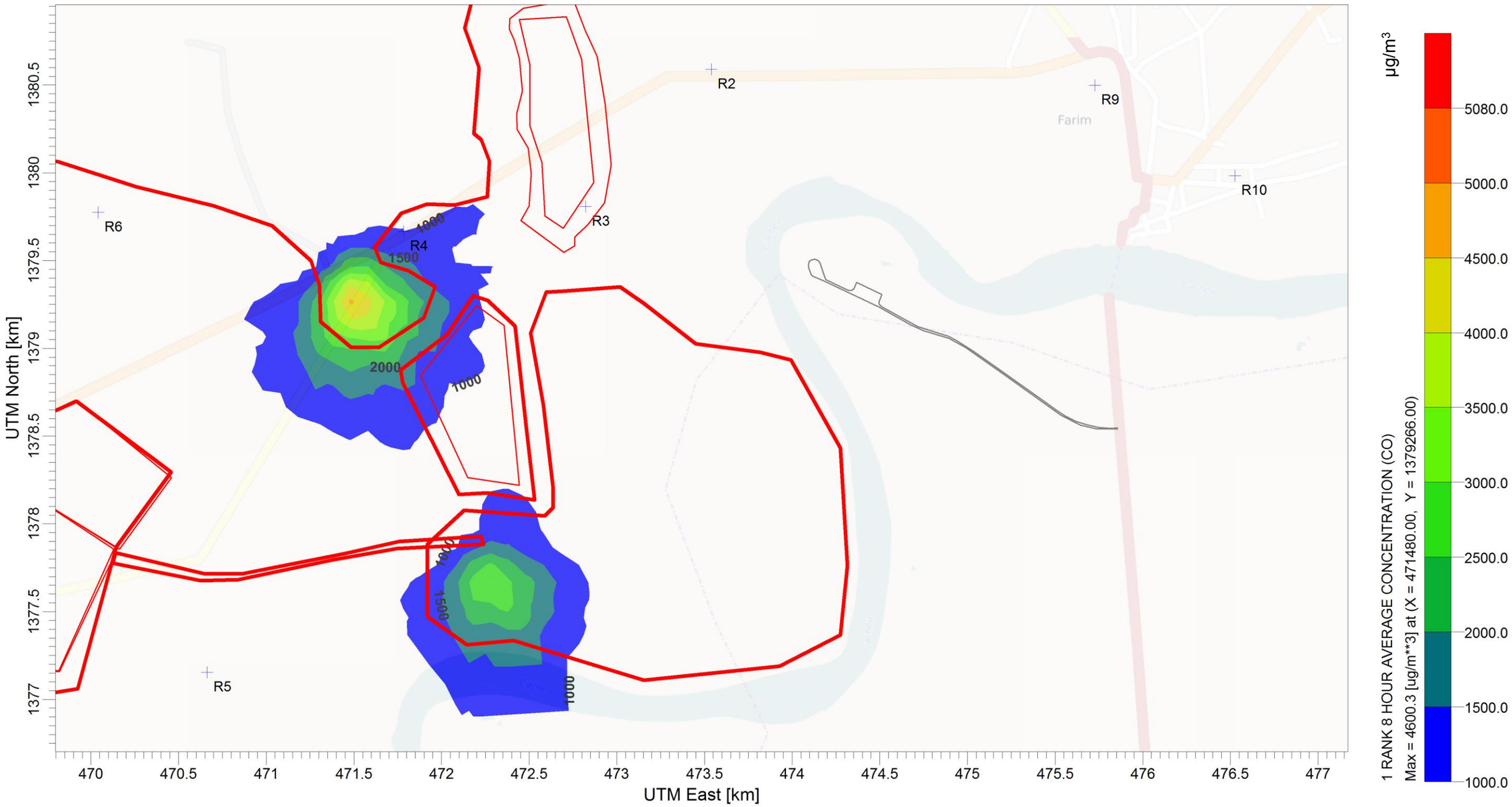
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-3.9	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**CO DISPERSION (RANK 1) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-3.10**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 8 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 2**

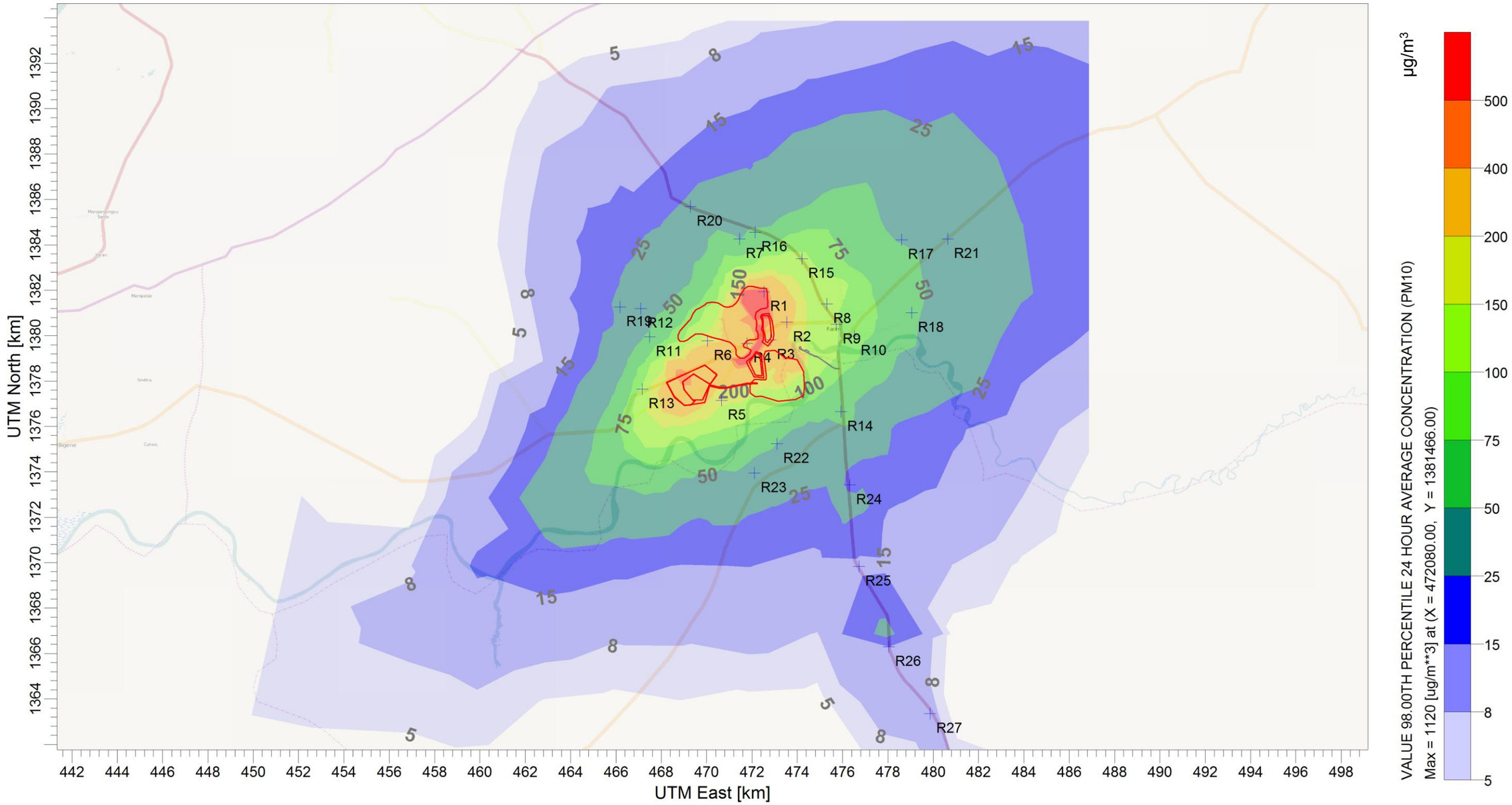
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-3.11**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

Knight Piésold CONSULTING

Appendix B-4

Mine Site – Scenario 3 (Year 15)

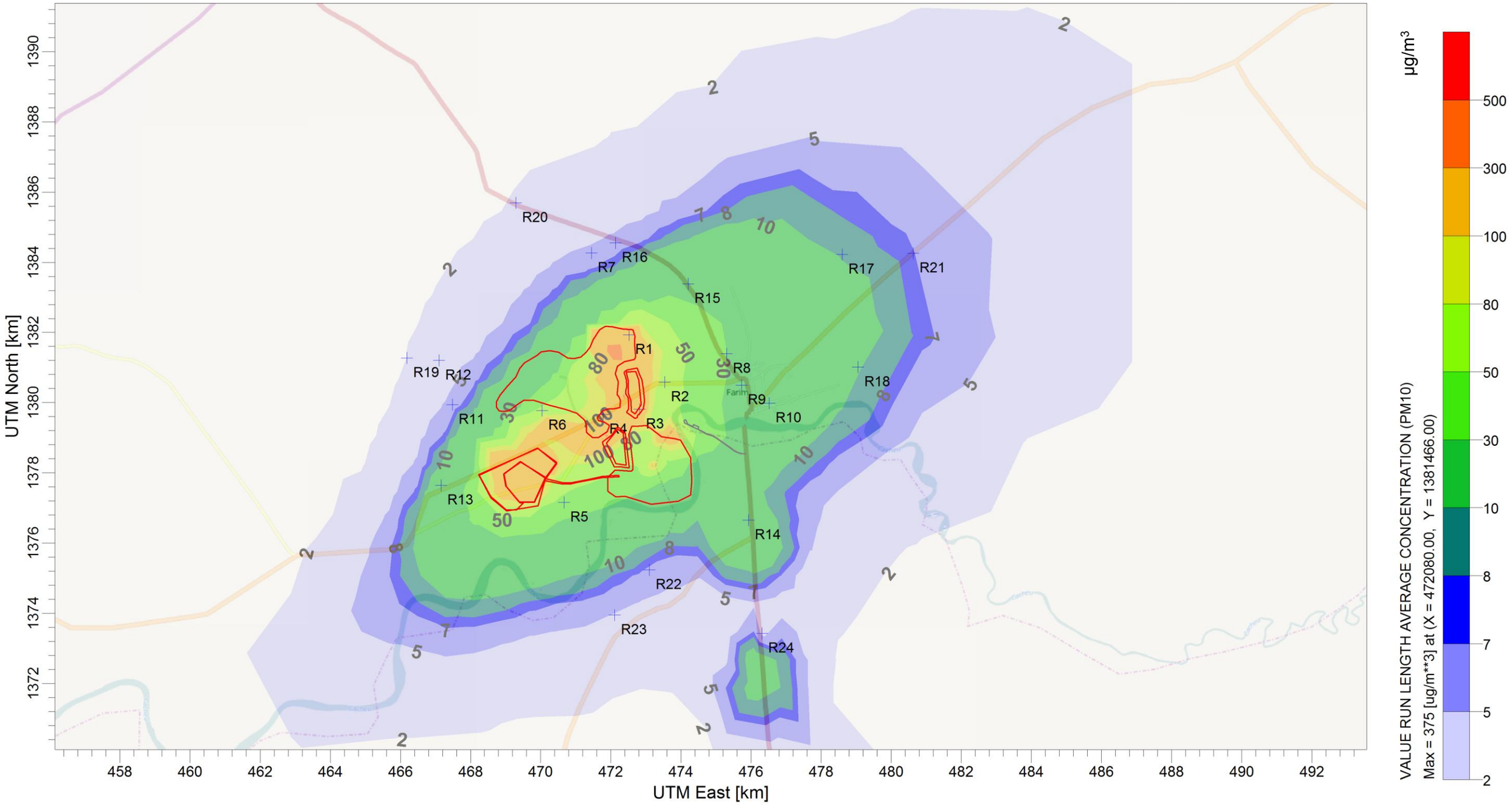


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-4.1**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

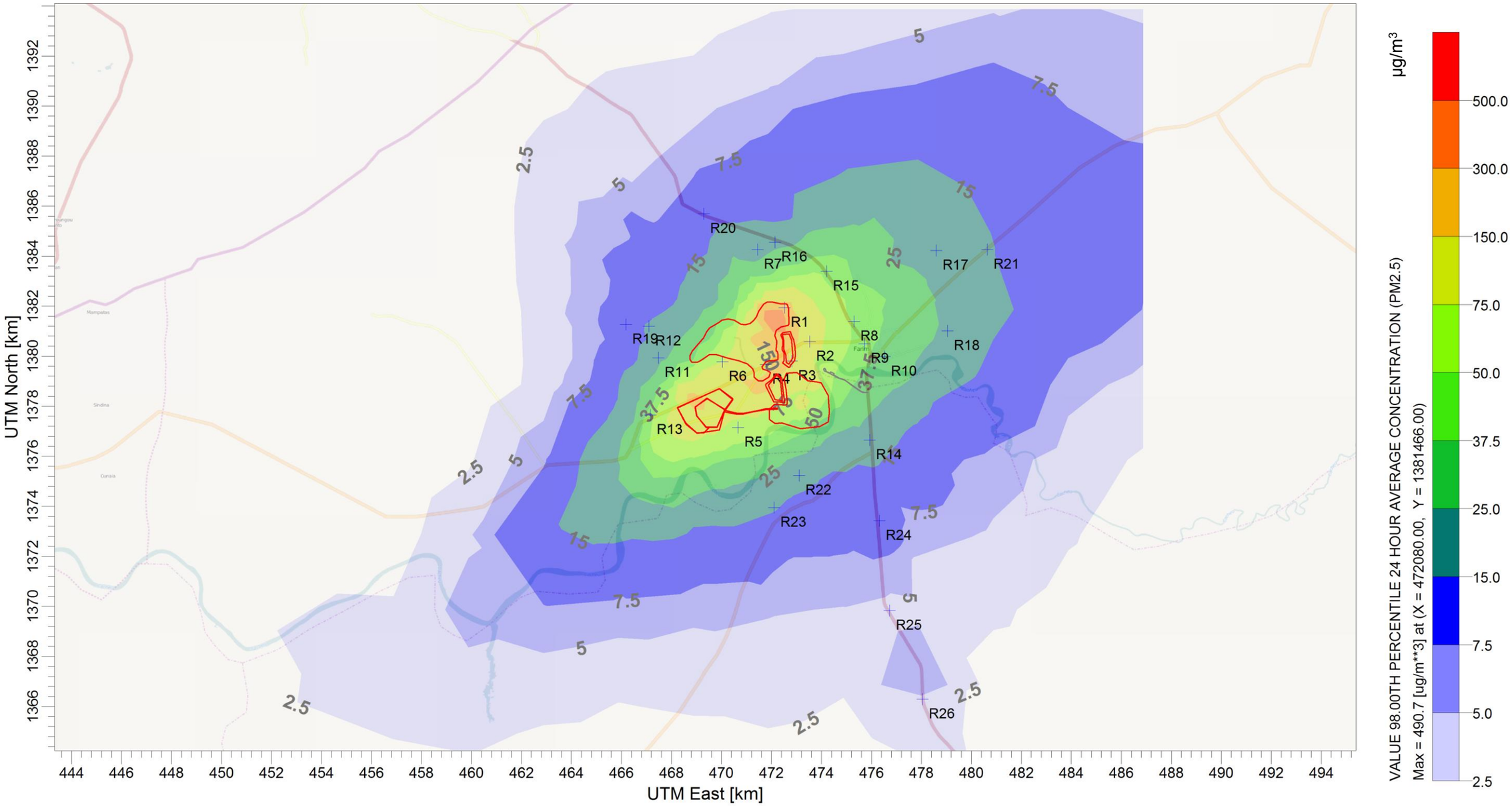


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION FOR ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.2	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

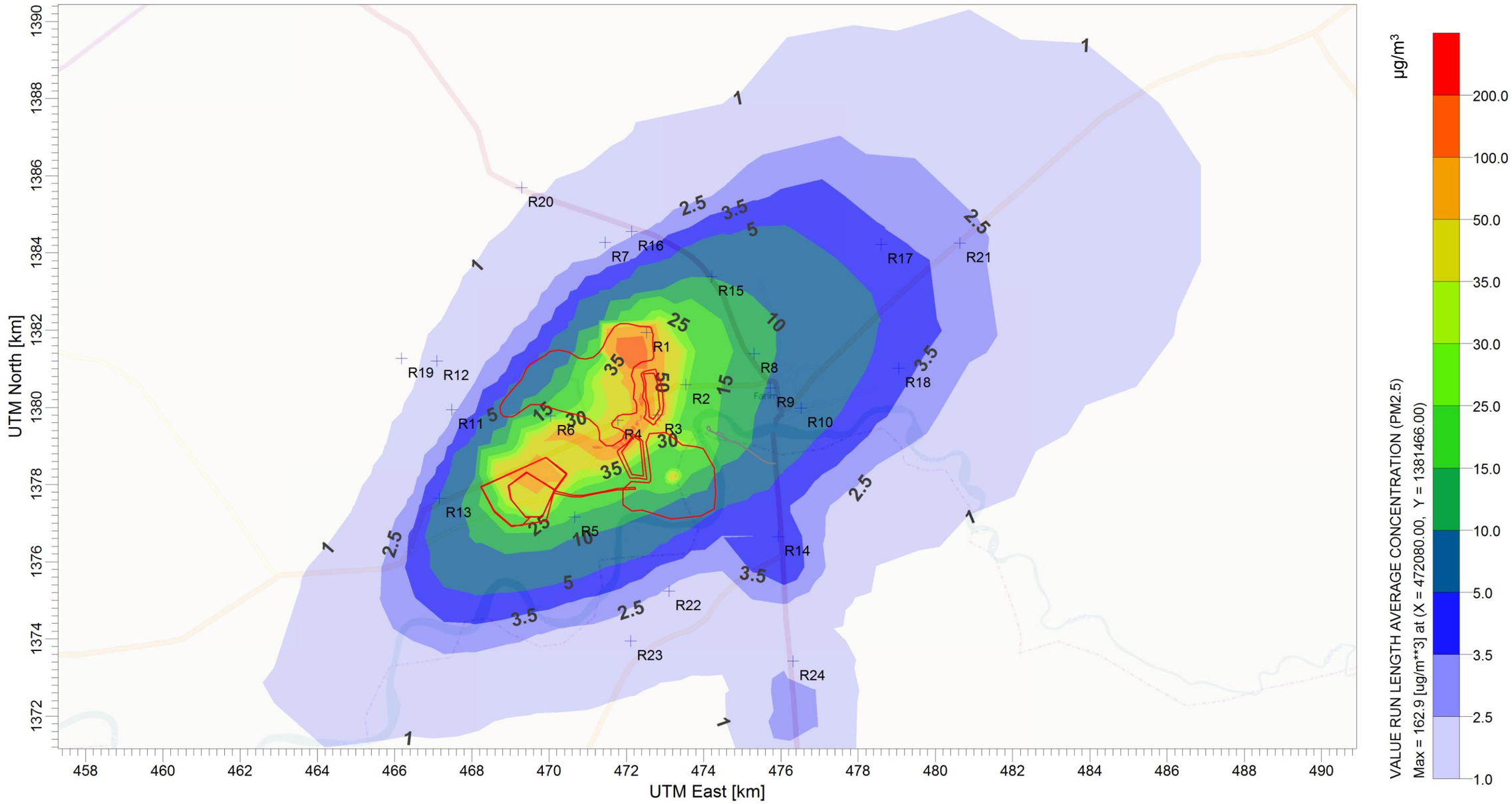


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.3	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

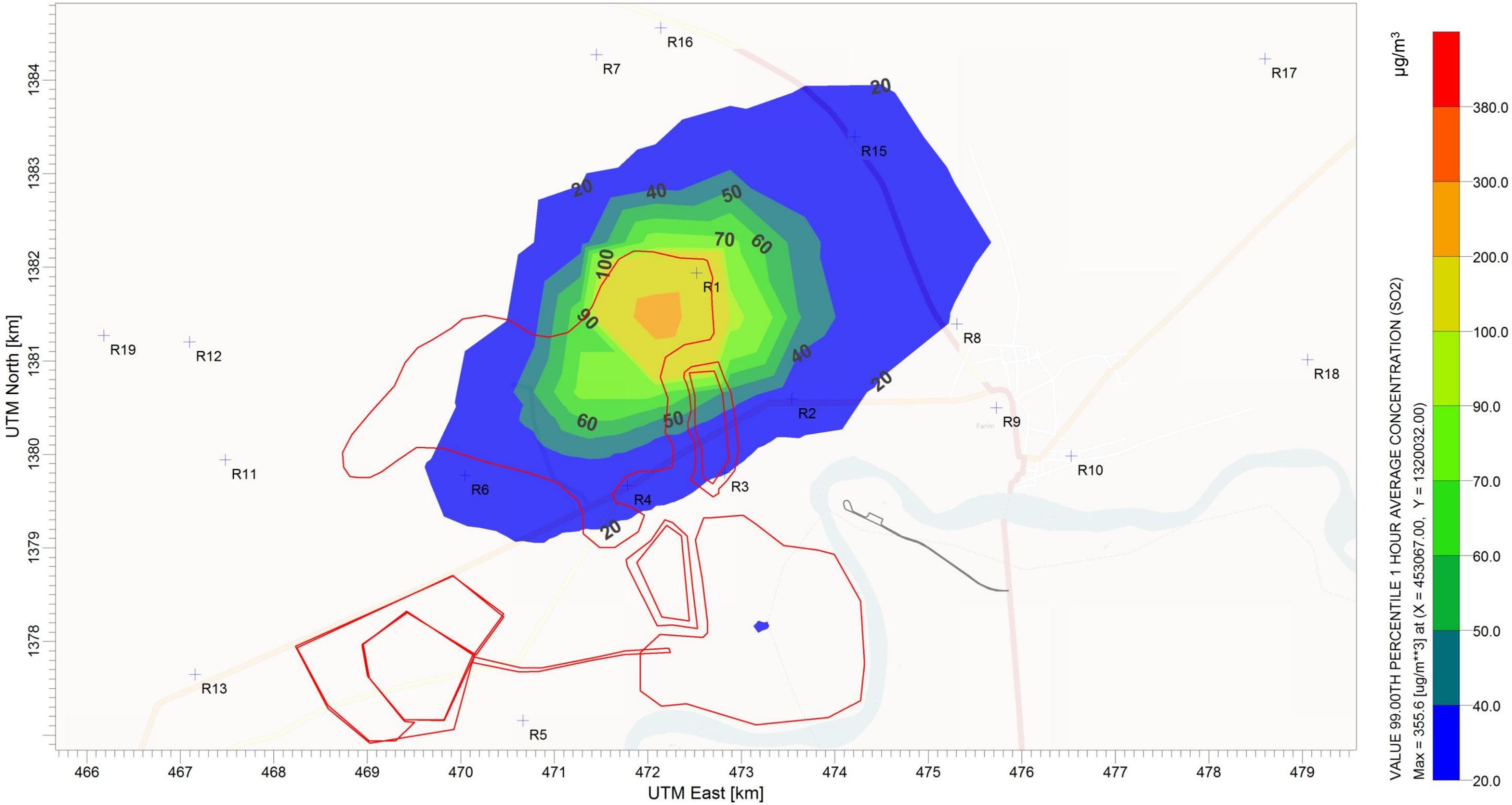


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

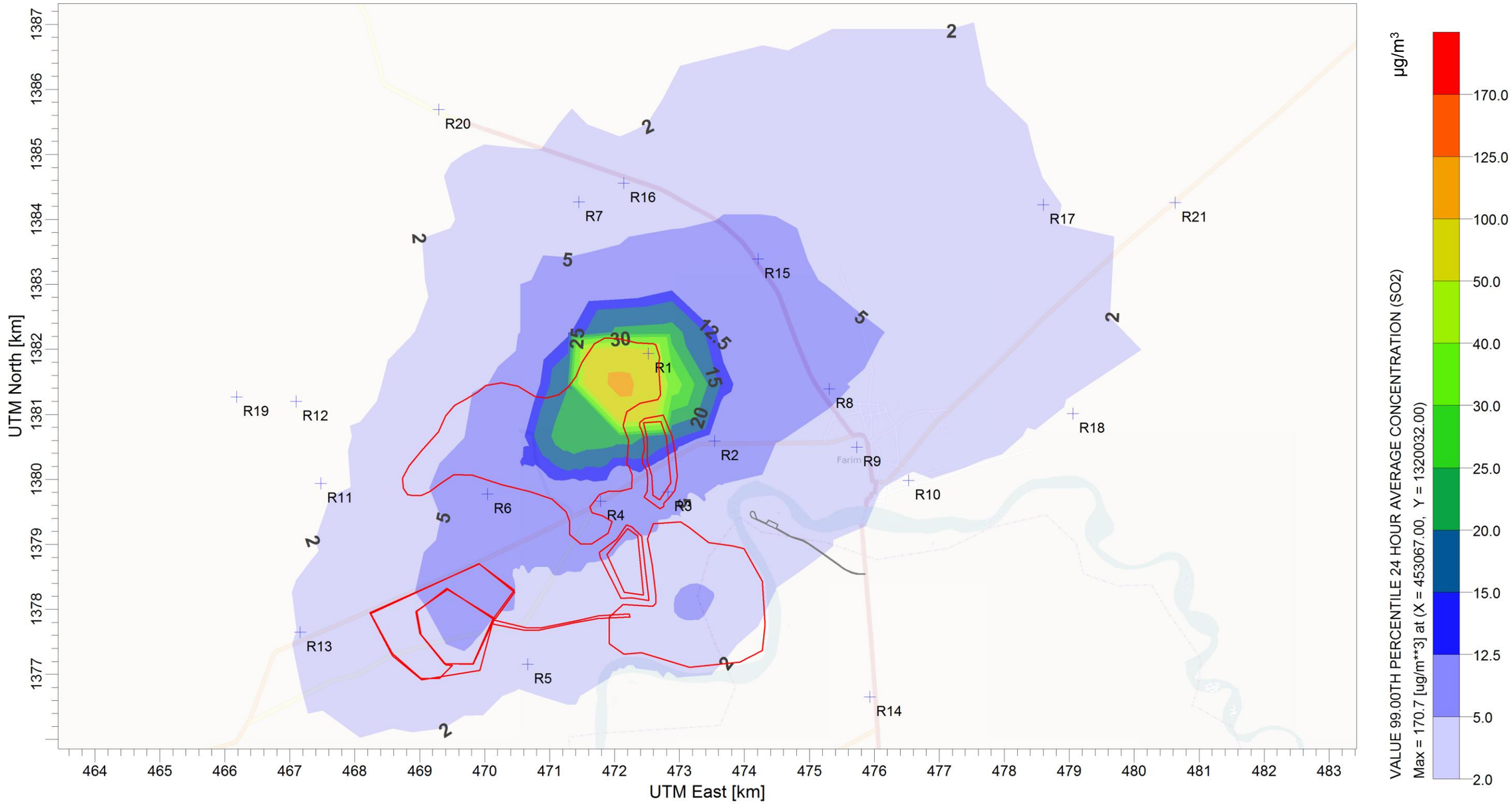
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.4	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-4.5**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

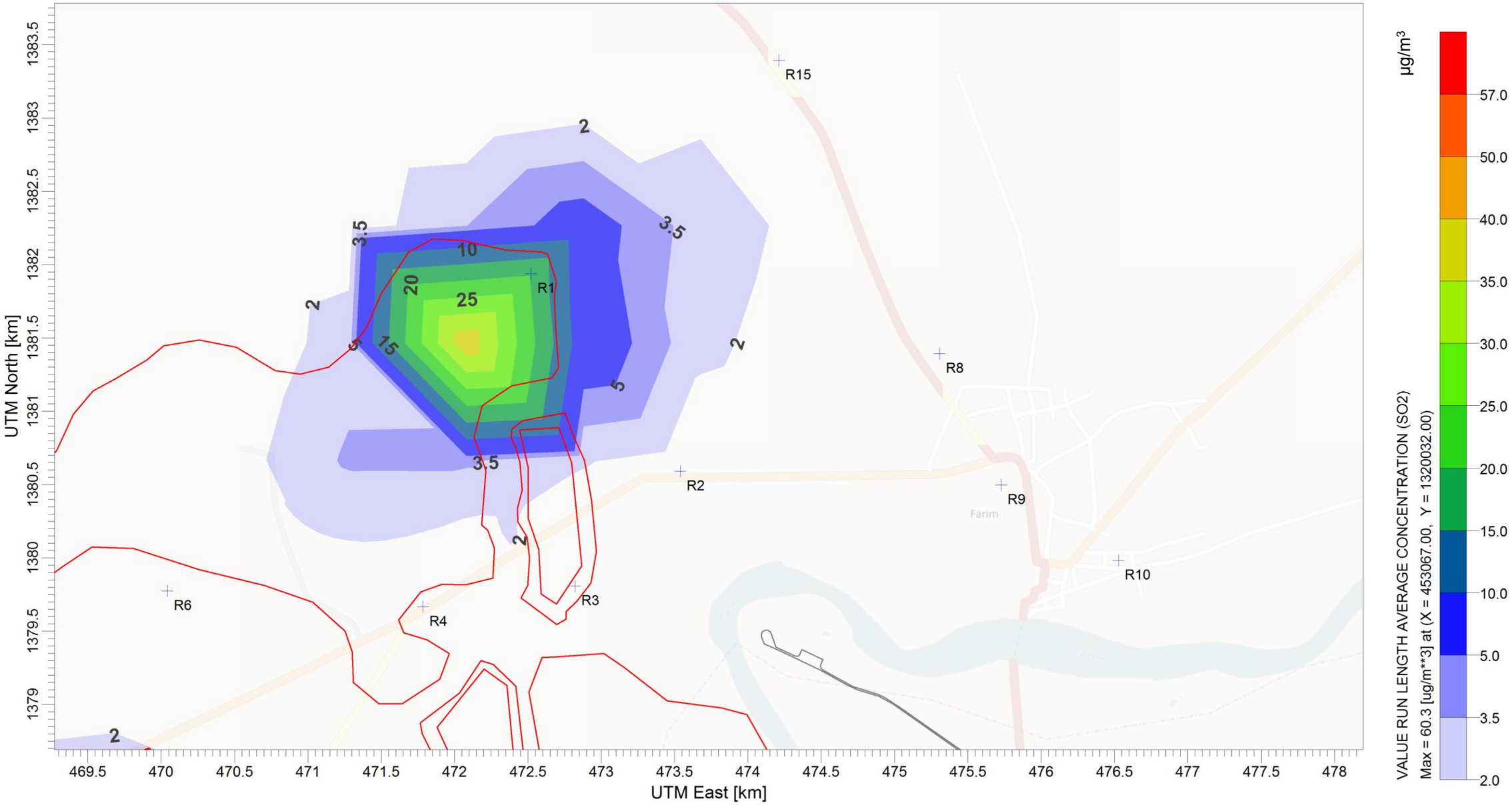


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.6	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

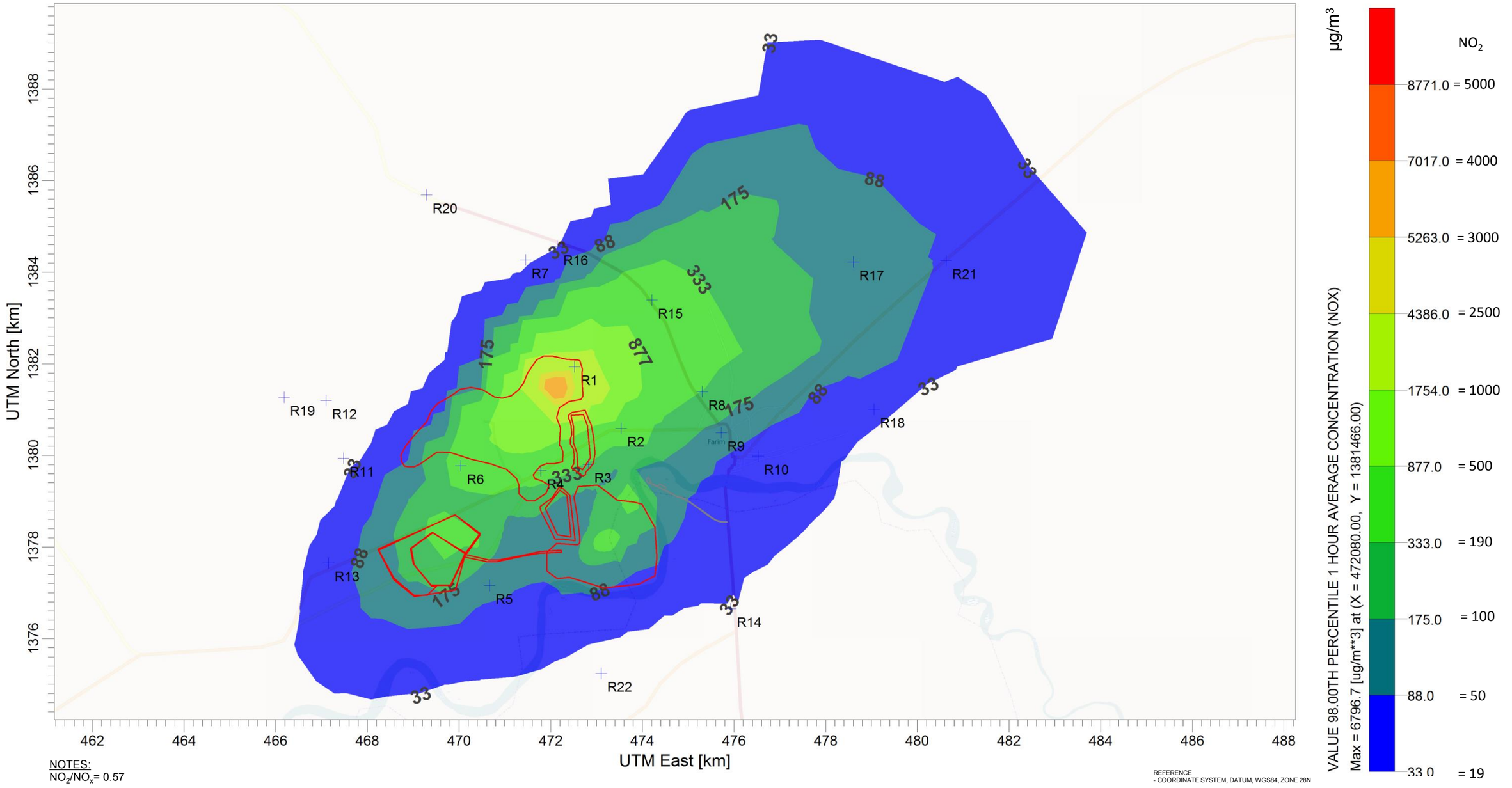


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.7	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



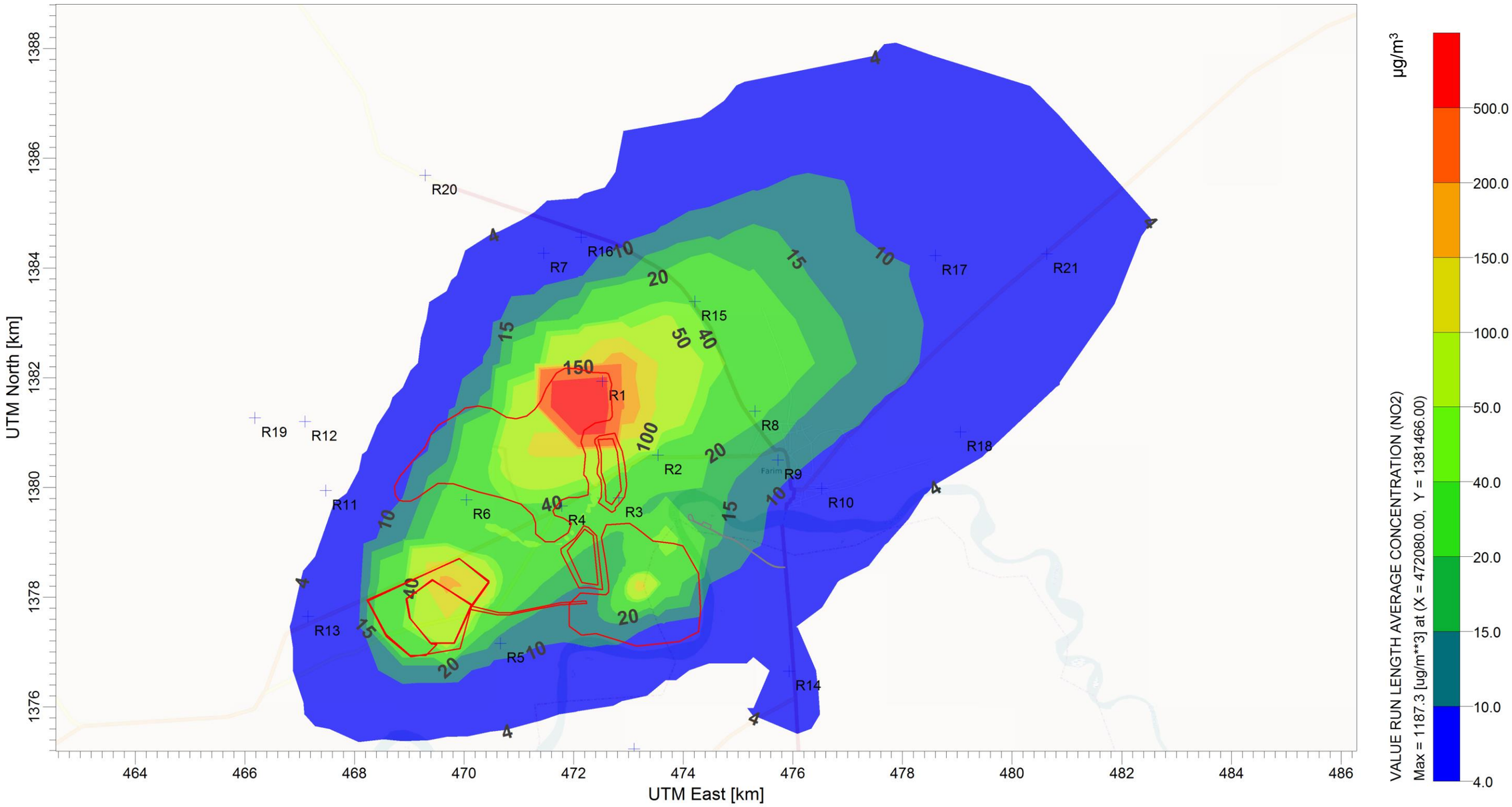
NOTES:
NO_2/NO_x= 0.57

REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_X DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.8	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

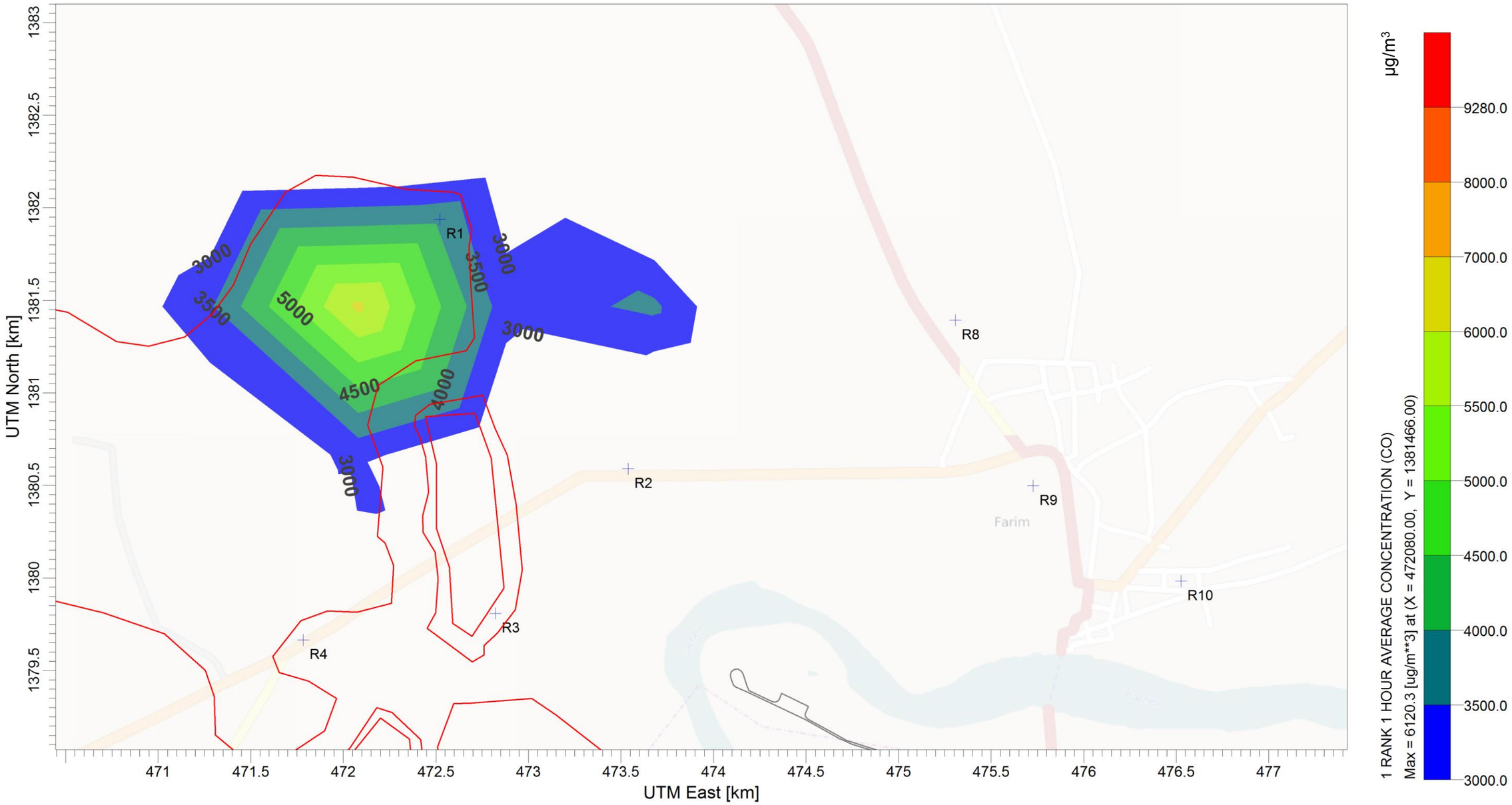


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-4.9	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

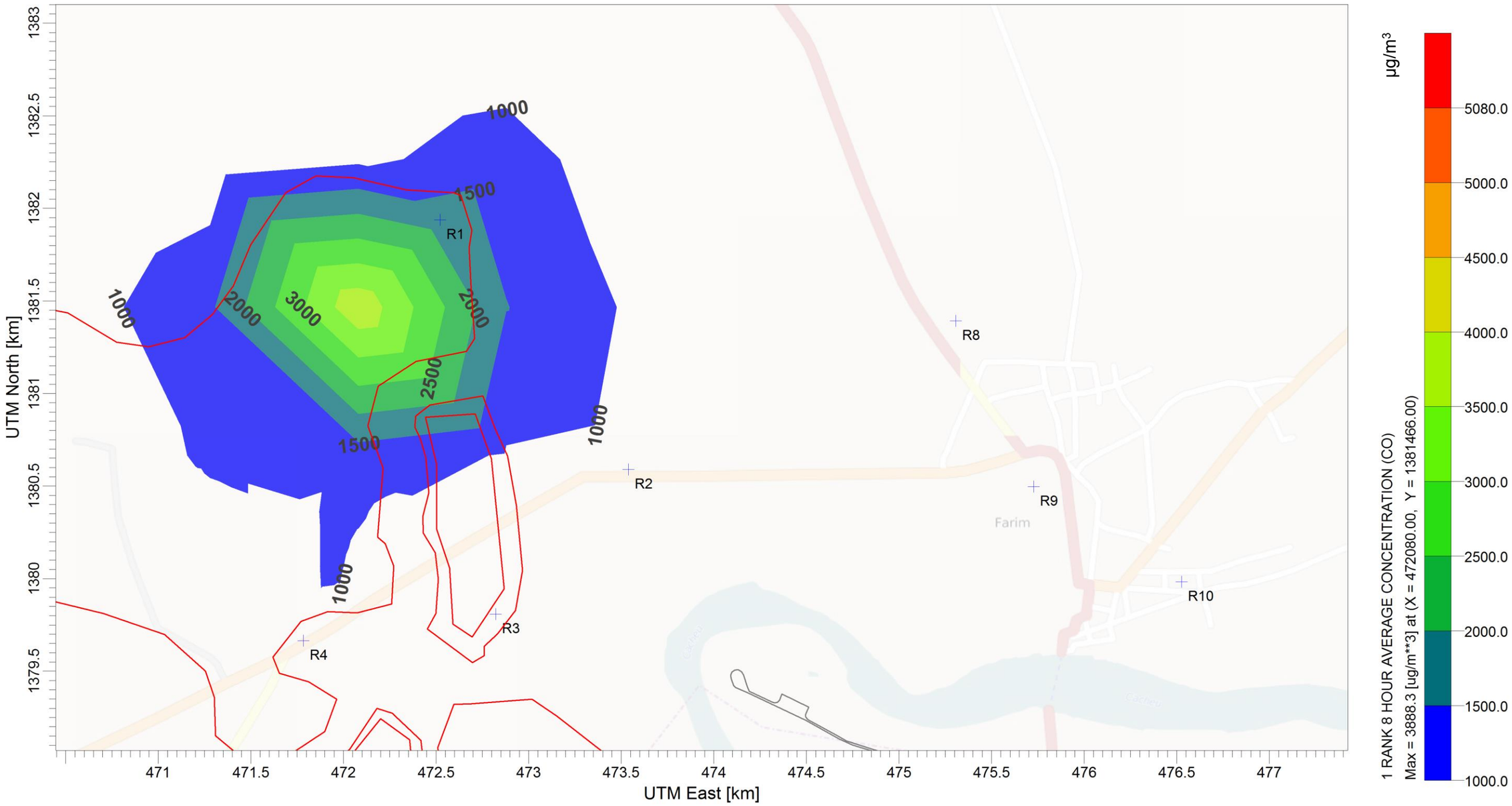


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-4.10**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 8 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 3**

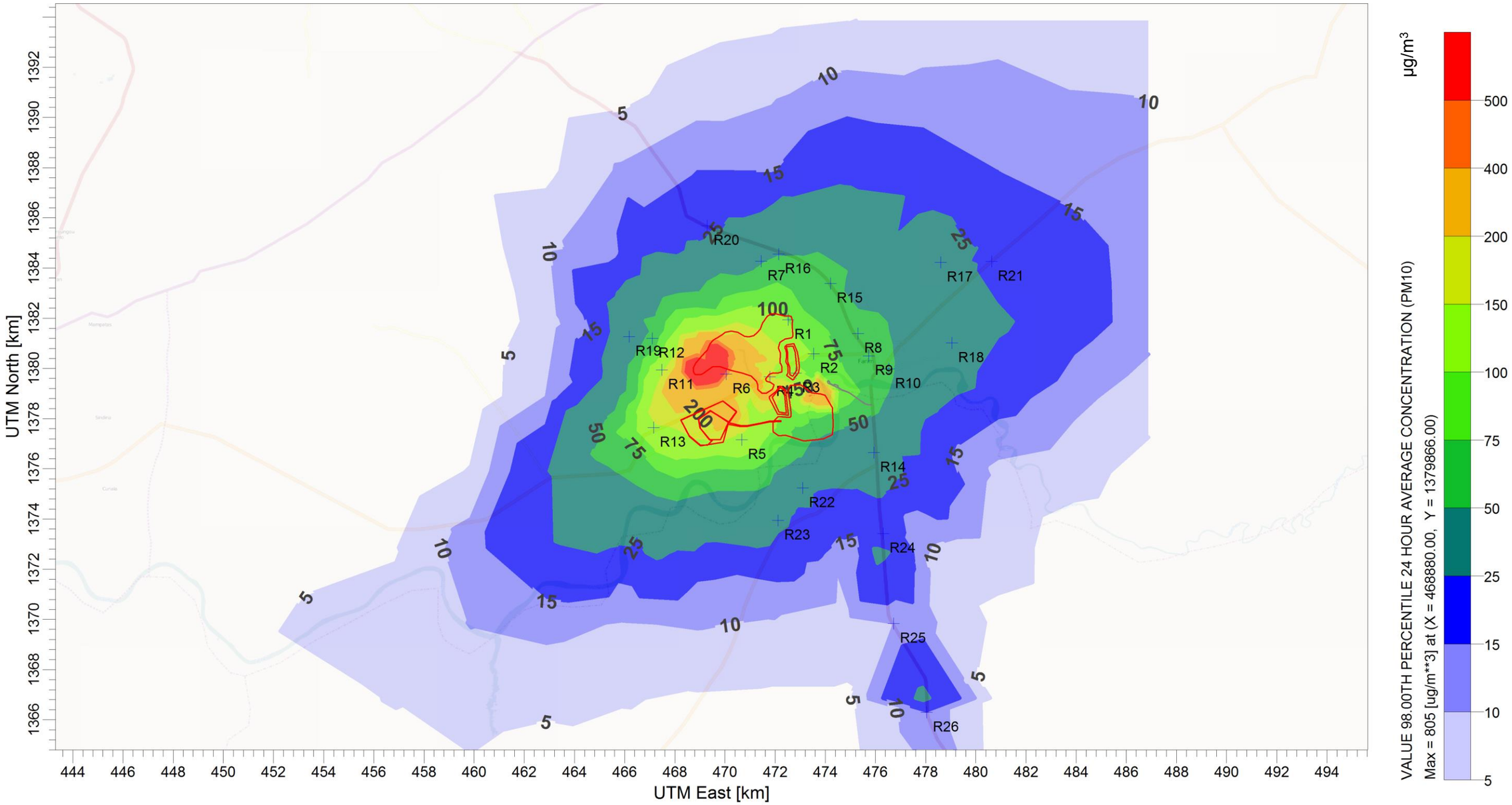
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-4.11**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

Knight Piésold CONSULTING

Appendix B-5

Mine Site – Scenario 4 (Year 25)

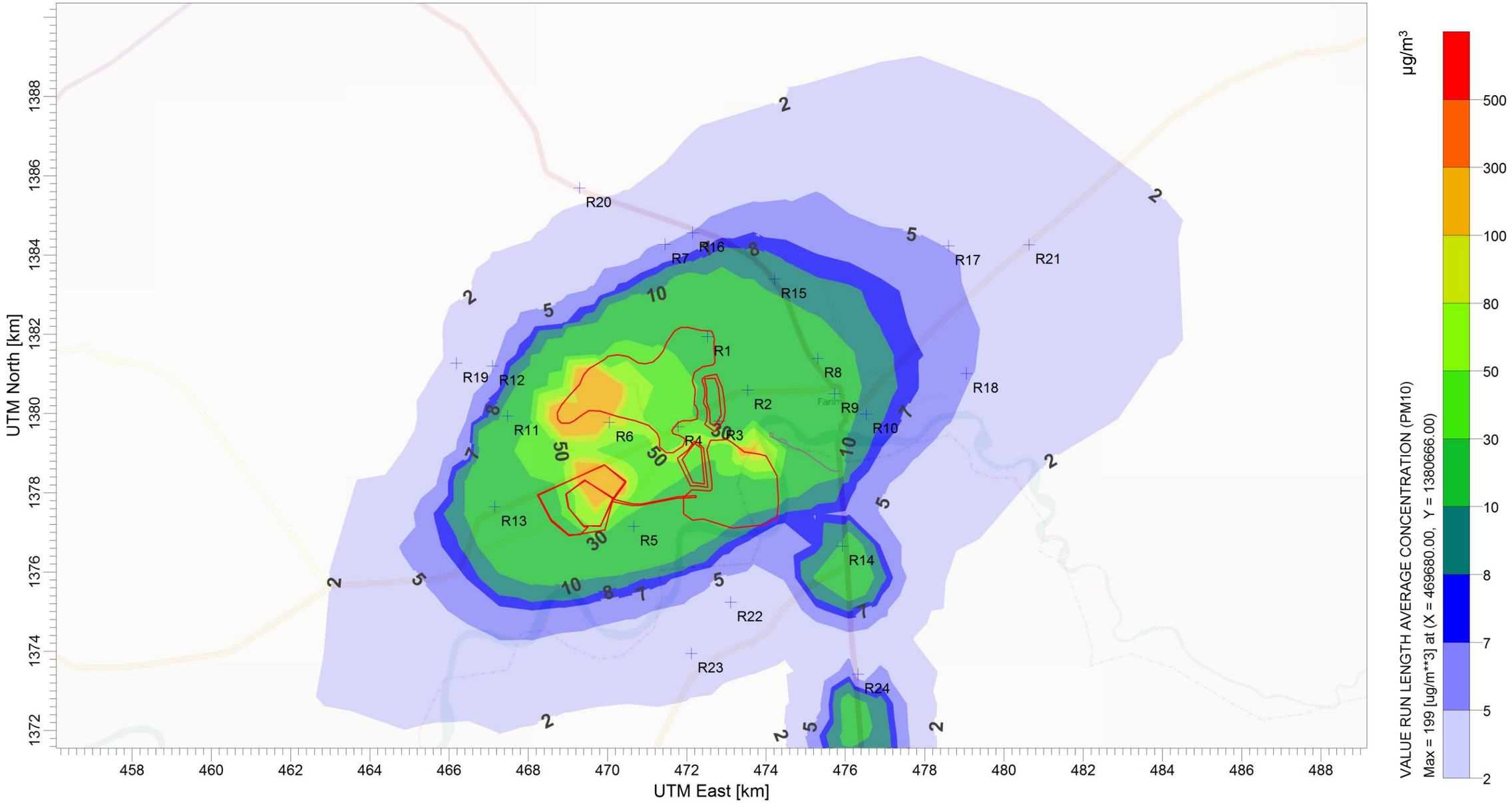


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**PM_{10} DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

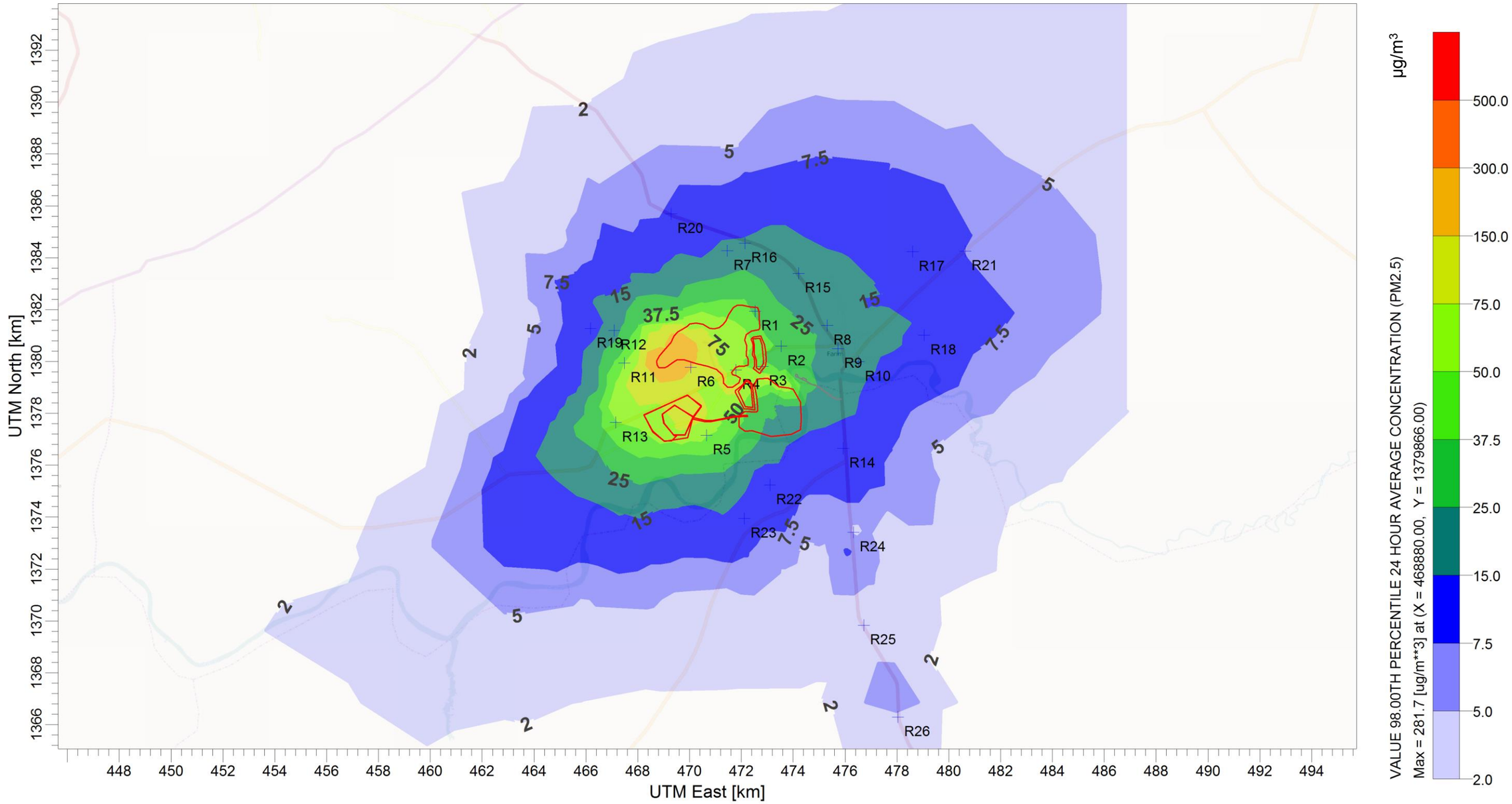
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-5.1	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**PM_{10} DISPERSION FOR ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 4**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-5.2**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

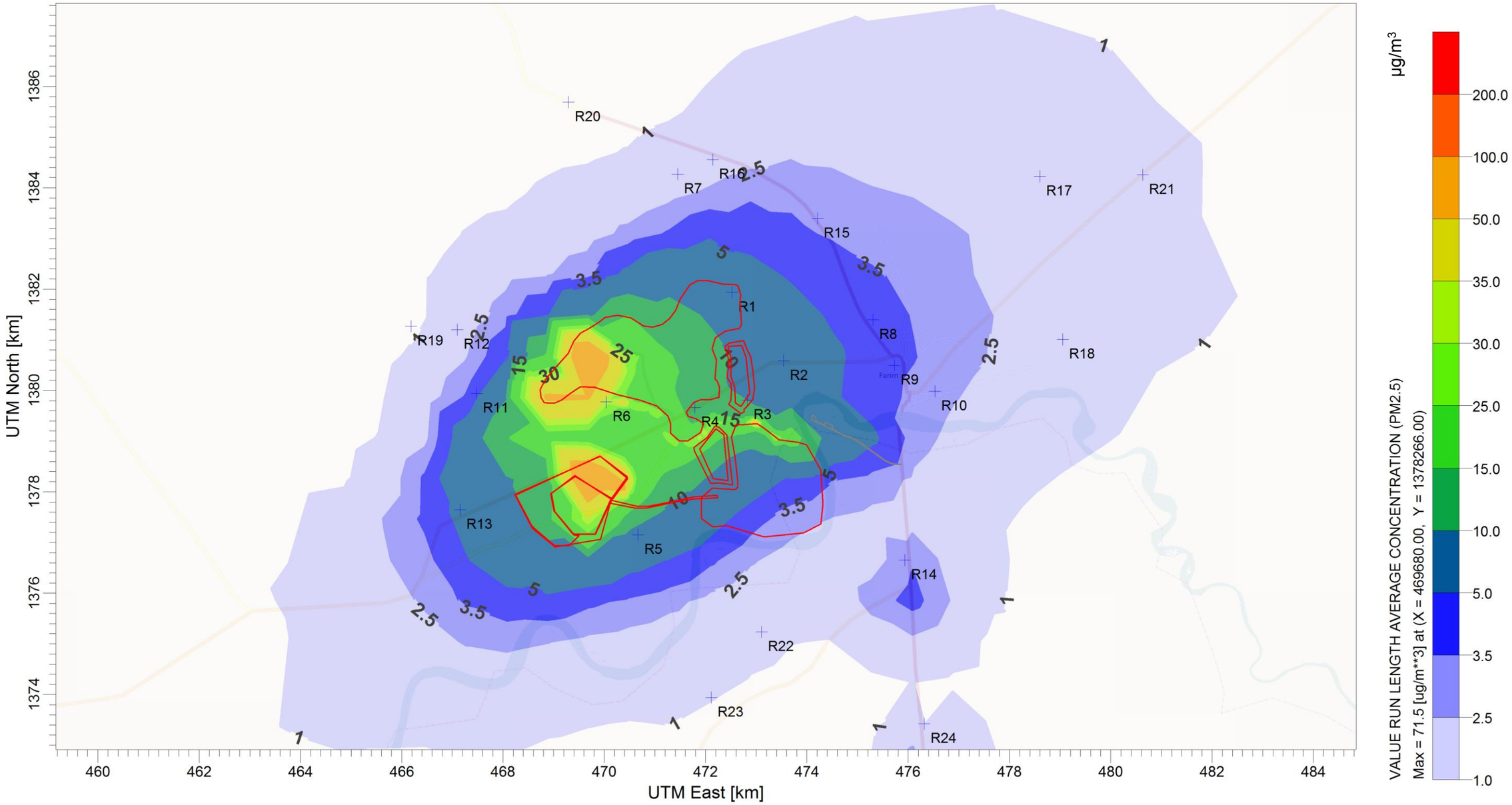


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**$PM_{2.5}$ DISPERSION (98th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

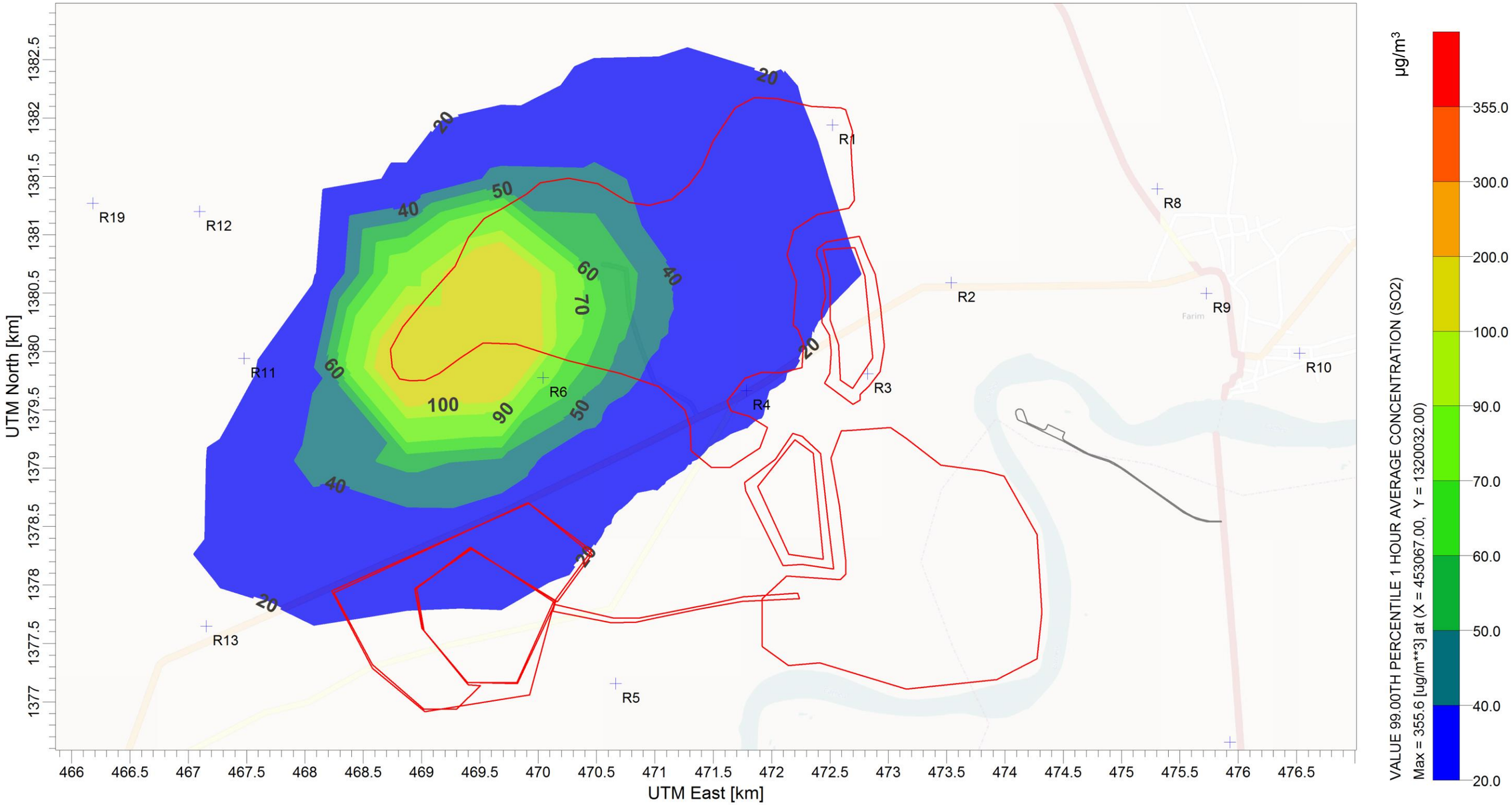
Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-5.3**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD					
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT					
TITLE	**$PM_{2.5}$ DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 4**					
	Knight Piésold CONSULTING					
DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-5.4**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

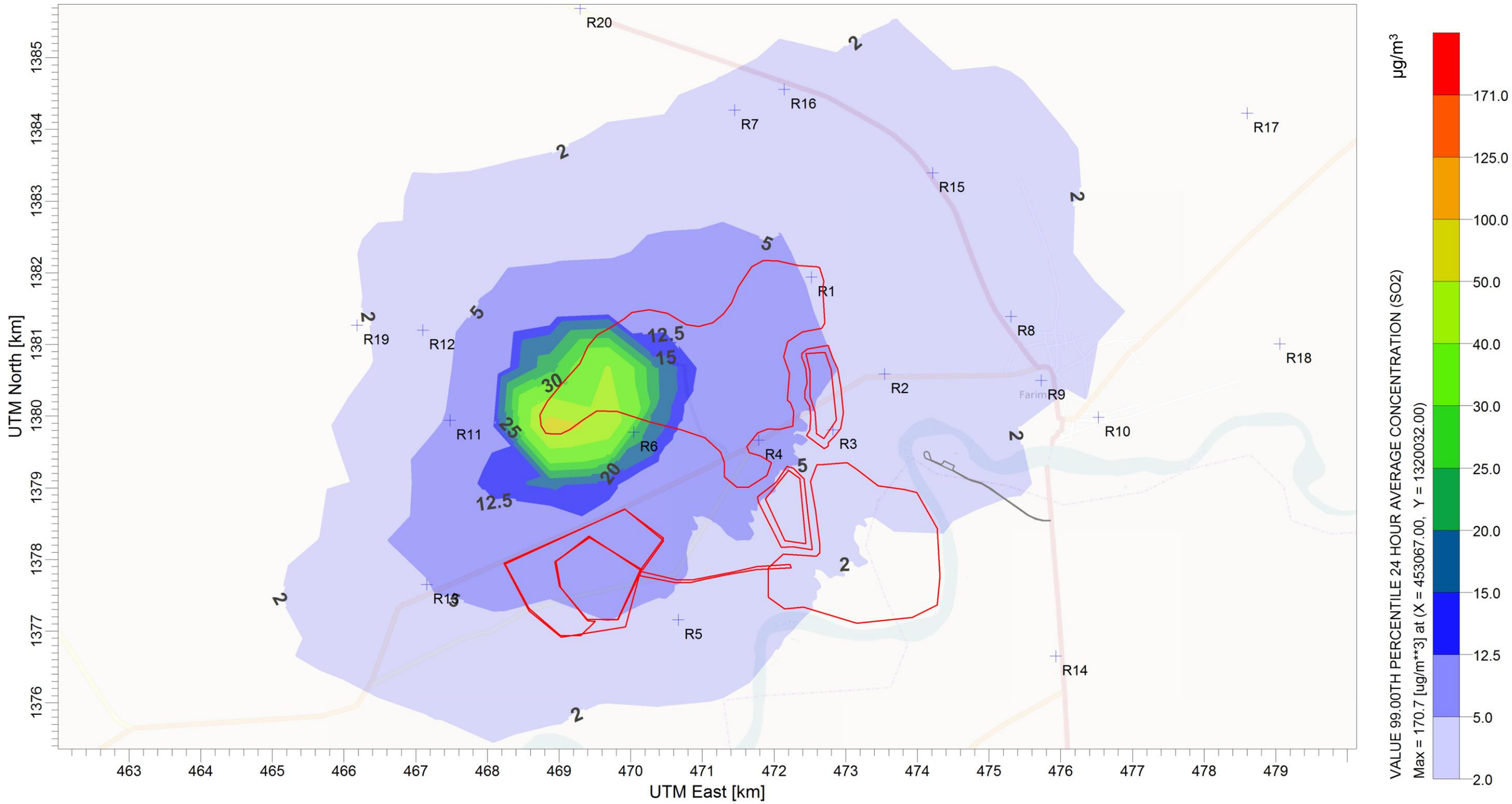


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-5.5	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

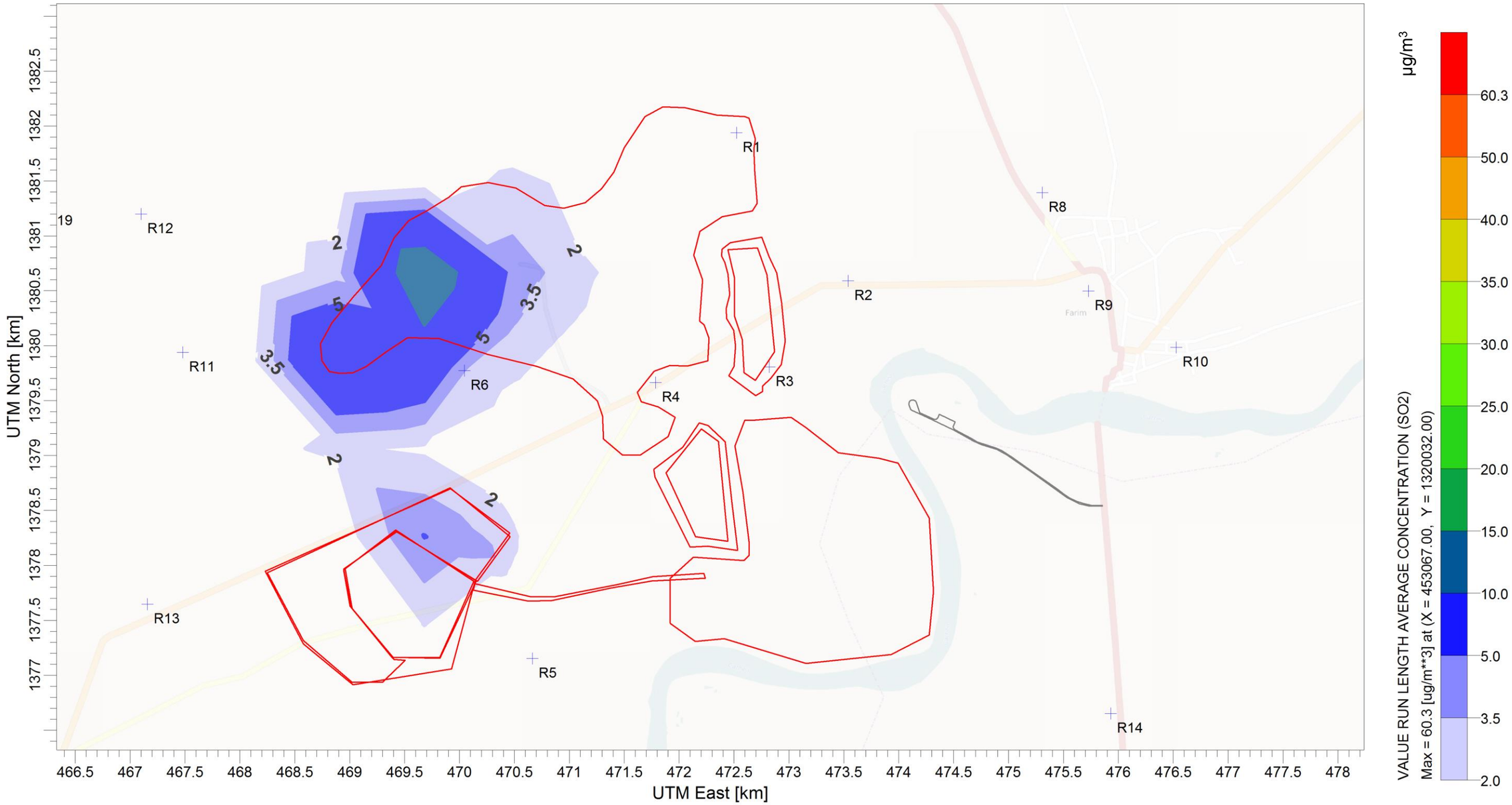


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION (99th PERCENTILE) FOR 24 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-5.6**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

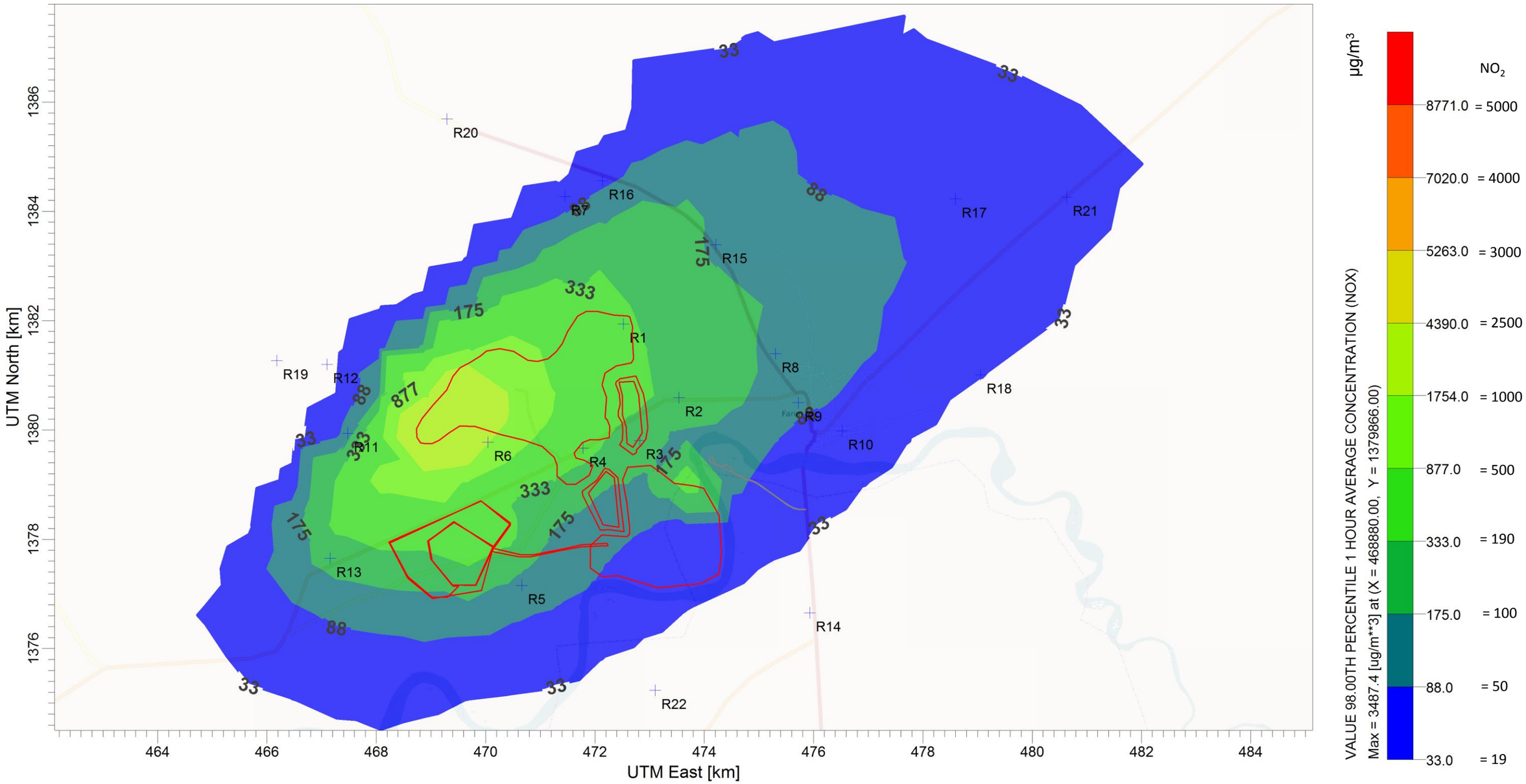


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**SO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-5.7	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



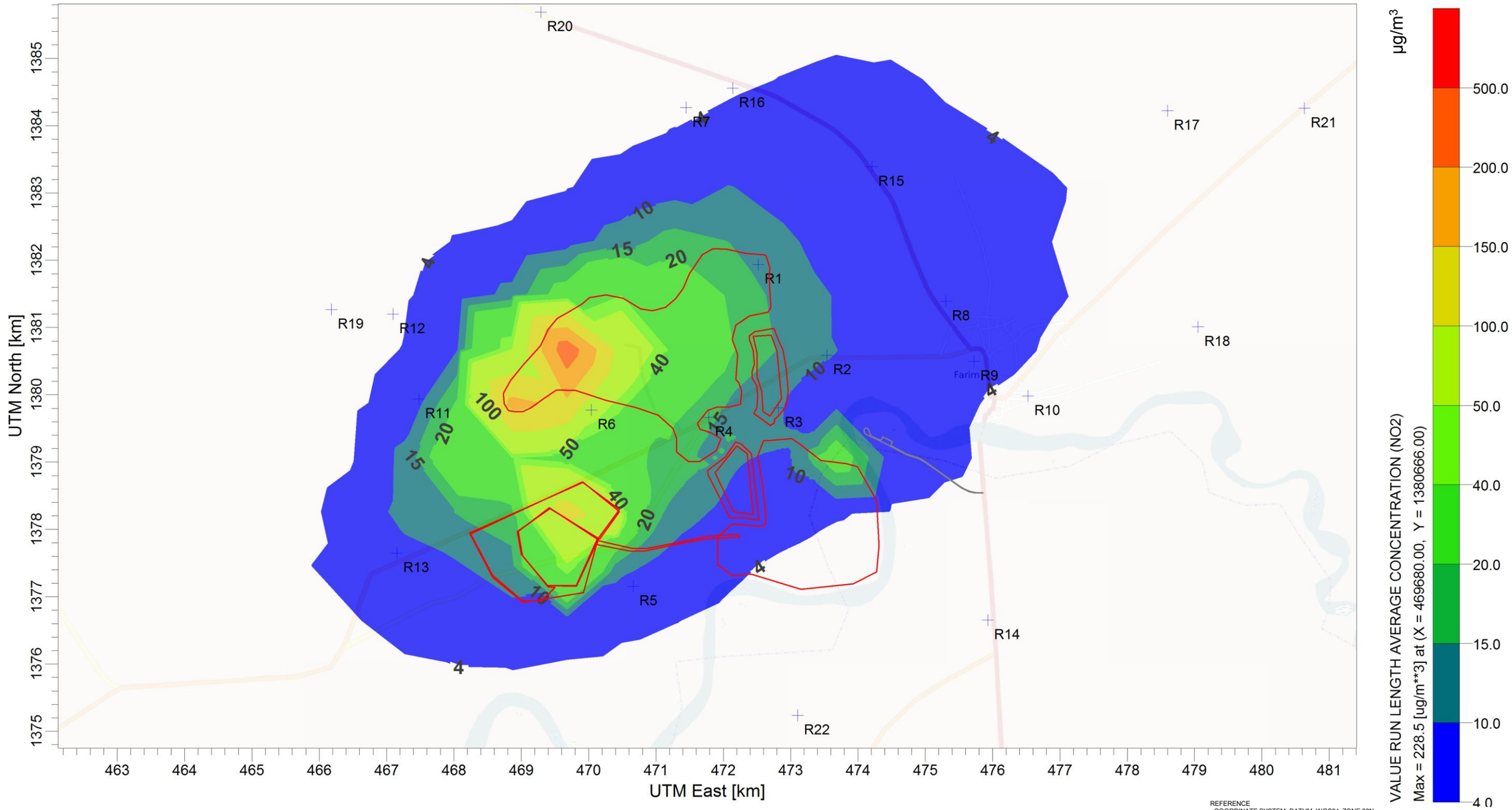
NOTES:
NO_2/NO_x= 0.57

REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_X DISPERSION (99th PERCENTILE) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-5.8	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

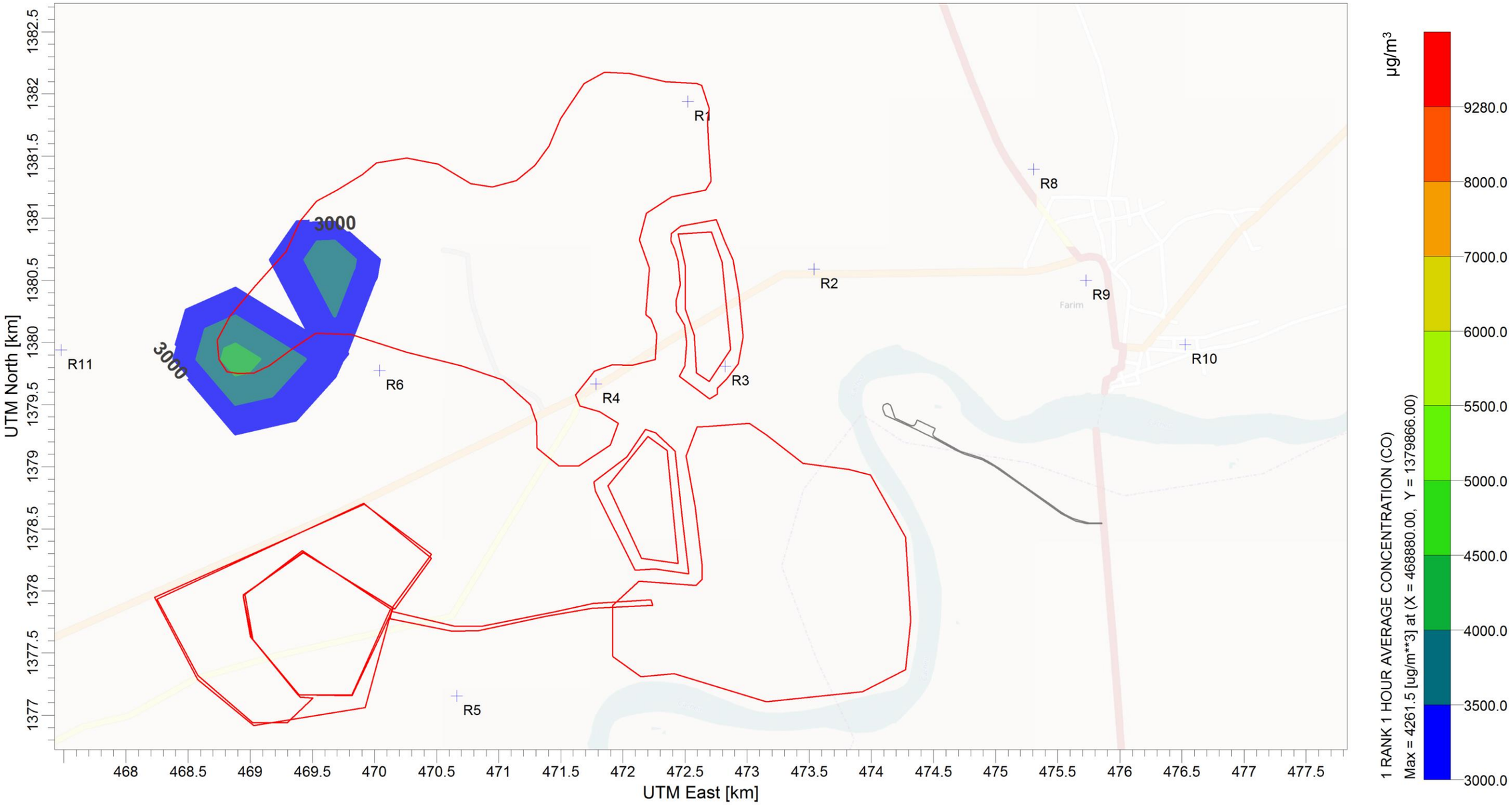


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**NO_2 DISPERSION ANNUAL AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	FIGURE B-5.9	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

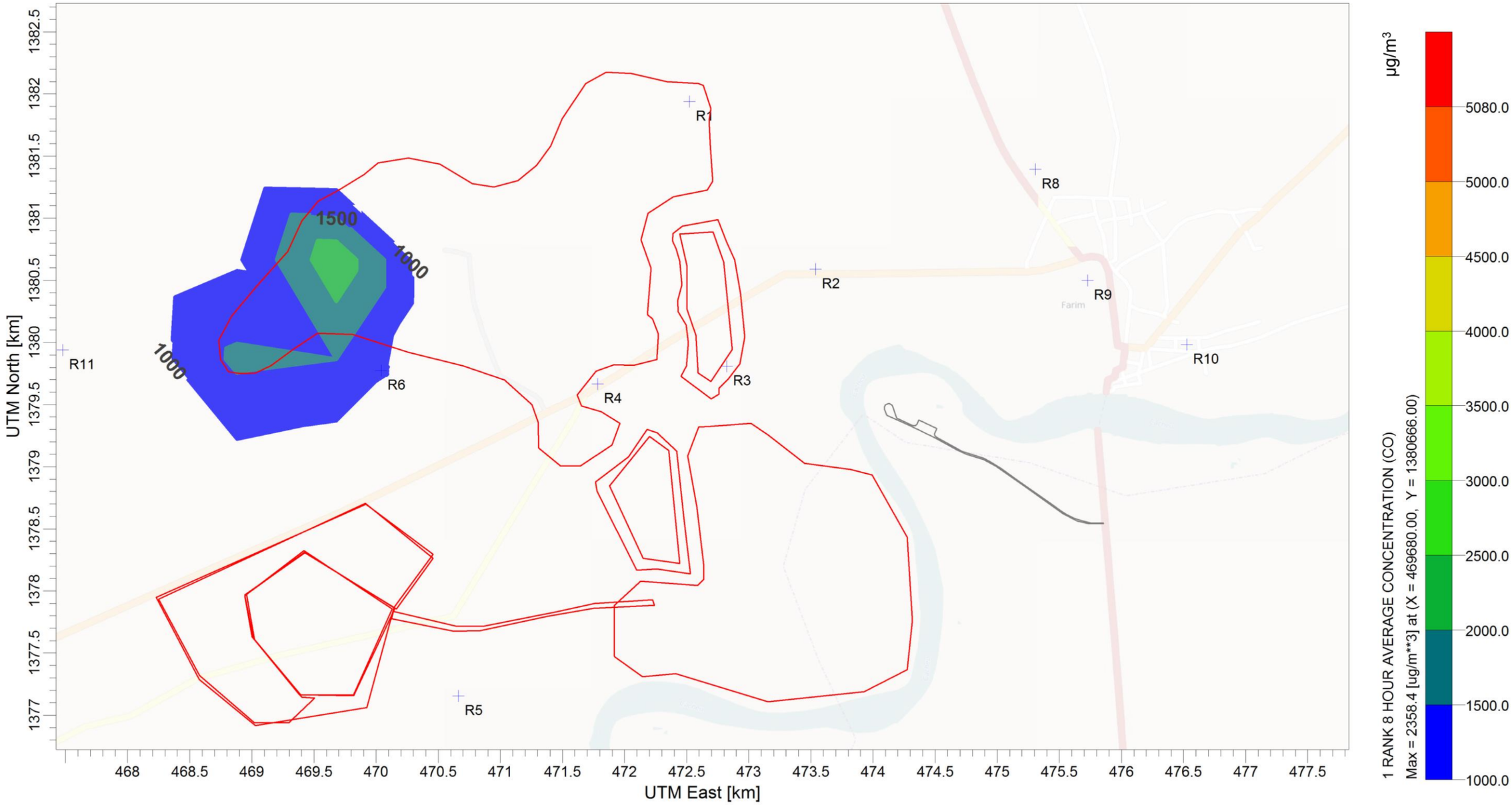


REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 1 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-5.10**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		



REFERENCE
- COORDINATE SYSTEM, DATUM, WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	**CO DISPERSION (RANK 1) FOR 8 HOUR AVERAGE PERIOD IN MINE SITE - SCENARIO 4**

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHEKED BY	EE	DATE	**FIGURE B-5.11**	REV. A
DRAWN BY	AD	APPROVED BY	RC	JUNE 17th 2005		

Knight Piésold CONSULTING

MEMORANDUM

To:	**Lycopodium Minerals Canada Ltd.**	**Date:**	30th March 2015
Attn:	**Dan Markovic**	**Our Ref:**	PE15-00328
		KP File Ref.:	**PE301-520/4-A ab M15004**
cc:	Olga Kovalik – GB Minerals	**From:**	Brett Stevenson

RE: FARIM PHOSPHATE PROJECT - DESIGN CLIMATOLOGY ASSESSMENT

As requested by Lycopodium Minerals Canada Pty Ltd. (Lycopodium), please find herein a summary of the baseline design climatological assessment carried out by Knight Piésold (KP) for the Farim Phosphate Project in Guinea-Bissau. The project is being developed by GB Minerals Ltd and is currently in the Feasibility Study stage.

1. DATA SOURCE / SUMMARY

Sub daily historic data for one climate station was provided to KP by Rigo Cantussan. This station, shown on Figure 1.1 is:

- Farim Climate Station, located at the Farim village adjacent the project at an approximate elevation of 7 m above sea level. The Farim climate station's records consist of 10 minute interval readings that span from December 2011 through to March 2015.

The historic sub daily data from the Farim climate station was used to obtain the following design information, namely:

- Typical variability of monthly temperature.
- Typical variability of relative humidity.
- Typical variability of wind speed and direction.

Climate data from a range of other climate stations in the region, as listed in Table 1.1, were assessed for longer duration climate information (outlined in Section 2). On the basis of the assessment, the Kolda climate station was selected as the most equivalent dataset. Kolda is located 55 km from the project site at an elevation of 10 m, as shown on Figure 1.1. Historic daily and monthly precipitation data was sourced by KP from the KOLDA climate station from publically available World Meteorological Organisation (WMO) datasets. The daily data spanned the period 1973 through to 2015 whilst the monthly data spanned the period 1933 through to 2011.

Table 1.1: List of nearby climate stations

Station Name	WMO Station Number	Station Elevation (m)	Distance from Site (km)	Data Obtained and Reviewed	Record Period
Farim Station	N/A	7	4	Sub-Daily	12/2011 – 03/2015
Sefa-Sedhiou	61698002	34	5	Monthly	01/1951 – 12/1980
Sedhiou	61698003	31	37	Monthly	01/1905 – 12/1996
Kolda	616980	10	55	Monthly	01/1933 – 02/2011
				Daily	01/1973 – 03/2015
				Sub-Daily	01/1973 – 11/2014
Abulzinho	N/A	Unknown	69	Not obtained	
Bafata	617810	43	72	Monthly	01/1954 – 09/1997
Bissau	617660	36	77	Monthly	01/1941 – 12/2000
Bolama	617690	20	102	Monthly	01/1910 – 12/2000

There were some discrepancies noted between the Sub-Daily and Daily Kolda datasets which are discussed further in Section 2. Notwithstanding this, the historic daily precipitation data from the Kolda climate station was used to obtain the 24 hour design storm depths and subsequently the Depth / Duration / Frequency curves for the site.

The historic monthly precipitation data was used to obtain the following design information, namely:

- Typical variability of monthly precipitation.
- Typical variability of annual precipitation.
- Annual precipitation for three climate scenarios:
  - Average precipitation.
  - 1% Annual Exceedance Probability (AEP) dry precipitation.
  - 1% AEP wet precipitation.

2. PRECIPITATION

2.1 GENERAL

There are a number of climate stations with historical precipitation data in the surrounding region. Climate stations within 100 km of the site were assessed for their similarity to the precipitation observed at the climate stations adjacent the site. KP selected climate stations for analysis based on:

- The consistency of the local climate pattern to the climate pattern in the site area.
- The distance of the station to the project site.
- The elevation of the station relative to the elevation of the site.
- The quality and duration of the dataset.

As the data from the Farim climate station was of insufficient length for completing frequency analysis a suitable representative climate station with daily data was required. Monthly data was sourced from the Global Historical Climatology Network (GHCN) monthly datasets in order to compare the precipitation patterns of the climate stations in the vicinity of the site. For the monthly comparison, the Sefa-Sedhiou climate station was considered to be the most representative of the site given its proximity. The six climate stations for which monthly data was sourced were compared using cumulative precipitation plots for the period of 1954 to 1980. If any of the six datasets were missing a month of data, all of the cumulative plots disregarded that month in order to prevent bias due to missing data. The cumulative precipitation plot for the six climate stations is shown on Figure 2.1. Based on the cumulative monthly precipitation plots, the Kolda climate station was selected as the most representative of the precipitation that occurs at the Sefa-Sedhiou climate station and therefore the project site. The other climate stations in the area consistently experienced larger amounts of precipitation than the Sefa-Sedhiou climate station.

The sub-daily and daily datasets for the Kolda climate station were not compared to the Farim station data. The sub-daily Kolda dataset was missing significant amounts of data during 2012 – 2014. The daily Kolda dataset for the same time period showed issues regarding the unit used to record precipitation depth in the dataset (0.1 or 0.01 inches).

Sub-daily and daily historical precipitation datasets for the Kolda climate station were sourced from the Integrated Surface Data (ISD) database and from the National Climate Data Centre (NCDC). The ISD sub-daily dataset was inconsistent with its reading frequency so it was compiled into a daily dataset for use in comparison against the NCDC daily dataset.

Annual daily maxima were compared between the two datasets to ensure dataset consistency. The comparison of the annual daily maxima from the two datasets is shown on Figure 2.2. As shown by Figure 2.2, seven data points are inconsistent, with the remainder fitting very closely to the 1 to 1 line. As it was not possible to tell which dataset was correct, these seven data points were excluded from the daily analysis described in Section 2.1.

2.2 DAILY PRECIPITATION ANALYSIS

KP performed frequency analysis on daily precipitation data (from Kolda) to estimate the statistical likelihood of experiencing extreme storms at the project site. The daily precipitation dataset for Kolda had 19 years of valid data within 42 years of record. A year was not considered valid and was therefore excluded if 30% or more of the data was missing. Additionally if, when compared, the values from the sub-daily and daily datasets differed greatly a year would be excluded as discussed in Section 2. As such the extrapolation involved in the estimation of design storms with AEPs less than 0.4% (Average Recurrence Intervals (ARI) greater than 250 years) has a high degree of uncertainty.

A number of different probability distributions (e.g. Log-Pearson 3, Generalised Extreme Value, Generalised Logistic, Wakeby, Burr, etc.) were fitted to the annual maxima of the daily precipitation data. Three of the best fits were selected for comparison, as shown on Figure 2.3. Based on the comparison, KP selected the Log-Pearson 3 fit for use at the Farim site. The results of the Log-Pearson 3 fit to historic precipitation records are provided in Table 2.1, noting that the values provided have been augmented by 14.3% to account for potential straddling errors in sampling which may occur from the usage of fixed 24 hour duration observational periods for deriving daily design storms (Ref. 1).

The 48 hour precipitation dataset for Kolda had 8 years of valid data within 42 years of record. As such the extrapolation involved in the estimation of design storms with AEPs

less than 2% (ARI greater than 50 years) has a high degree of uncertainty. The 48 hour precipitation dataset had less valid data as if a day of valid data had a day of missing data before it and after it a 48 hour precipitation data point was unable to be computed. This resulted in more data being excluded from the analysis.

The same methodology was used to estimate the 48 hour storm depths. KP selected the Log-Pearson 3 fit to historic precipitation records as shown on Figure 2.4. The results of which are provided in Table 2.1, noting that the values provided have been augmented by 6.7% to account for potential straddling errors in sampling which may occur from the usage of fixed 24 hour duration observational periods for deriving 48 hour design storms (Ref. 1). Multiple day storms were uncommon in the dataset and as such the 48 hour design storms are only slightly larger than the 24 hour design storms.

Table 2.1: Extreme daily (24-hour) design precipitation

Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI) (yr)	24-hour Duration Precipitation Depth (mm)	48-hour Duration Precipitation Depth (mm)
0.4%	250	699	-
1.0%	100	508	-
2.0%	50	396	421
5.0%	20	280	300
10.0%	10	211	228
20.0%	5	154	168
50.0%	2	94	103

The daily design precipitation information in Table 2.1 was utilised to derive Intensity / Frequency / Duration (IFD) curves and Depth / Duration / Frequency (DDF) curves for short duration storms. The rainfall ratio method (Ref. 1) was employed for this purpose. A difference of squares regression was performed in order to estimate the fitting coefficients. This was completed by using data from the Farim climate station as well as 48 hour frequency analysis results from the Kolda climate station. Values were generated for the Farim Project Site, as provided in Table 2.2 and plotted on Figure 2.5.

Table 2.2: Kolda depth / duration / frequency data

Storm Duration	Precipitation Depth (mm) for a Given ARI Storm						
	2	5	10	20	50	100	250
5 min	7	11	15	20	29	37	51
10 min	13	21	28	38	53	69	94
15 min	22	36	50	66	93	120	165
30 min	29	49	66	88	124	160	219
1 h	44	73	100	132	187	240	330
2 h	60	98	134	178	252	323	444
3 h	68	111	152	202	286	367	504
6 h	79	130	177	235	333	428	588
12 h	87	144	196	261	369	474	651
18 h	91	150	205	272	386	495	680
24 h	94	154	211	280	396	508	699

It should be noted that for the Farim climate station dataset, the greatest rainfall recorded was 229 mm in 9 hours, which equates to approximately a 6% AEP or 16 year ARI wet event.

2.3 ANNUAL PRECIPITATION

KP performed summary sampling statistics on the Kolda monthly precipitation dataset, the results of which are shown in Table 2.3. For the annual analysis, only 67 years were analysed. Two (2) years of data were missing completely and 10 years were excluded due to missing data. A year was excluded if 2 or more months of data were missing.

Table 2.3: Annual summary statistics

Statistic	Precipitation (mm)
Mean	1,143
Median	1,116
Minimum	601
Maximum	2,152

2.4 MONTHLY PRECIPITATION

Monthly precipitation data from the Kolda climate station was analysed. Monthly precipitation pattern for the Kolda climate station are summarised below in Table 2.4 and on Figure 2.6.

Table 2.4: Average Monthly Precipitation (mm)

Month	Precipitation (mm)
Jan	0
Feb	0
Mar	0
Apr	0
May	17
Jun	134
Jul	252
Aug	354
Sep	275
Oct	101
Nov	7
Dec	1

2.5 ANNUAL FREQUENCY ANALYSIS

KP performed frequency analysis on annual precipitation values. Exceedance and non-exceedance probabilities were assigned to the annual totals by sorting the values in descending (for the “Wet” series) and ascending (for the “Dry” series) order. Probability distributions were fitted to the data and then plotted for comparison, as shown on figures 2.7 and 2.8. In both cases, the Log Pearson 3 distribution was selected to fit probabilistic estimation of annual rainfall. The results of these calculations are provided in Table 2.5.

Table 2.5: Extreme annual design precipitation

Annual Exceedance Probability (AEP) (yr)	Average Recurrence Interval (ARI) (yr)	Annual Wet Precipitation Depth (mm)	Annual Dry Precipitation Depth (mm)
0.1%	1,000	2,033	520
0.2%	500	1,963	552
0.5%	200	1,865	599
1.0%	**100**	1,785	641
2.0%	50	1,700	689
5.0%	20	1,576	765
10.0%	10	1,470	837
20.0%	5	1,346	930
50.0%	2	1,127	1,127

3. EVAPORATION

Evaporation data is very limited in the area around the project site. Daily potential evapotranspiration (PET) data was sourced from the NCAR Computational Information Systems Laboratory (CISL) databases. Summary statistics were performed on the daily potential evapotranspiration dataset for the Kolda weather station to generate monthly values. The monthly average evaporation for the Kolda weather station is summarised in Table 3.1.

Table 3.1: Monthly evaporation

Month	Evaporation (mm)
Jan	119
Feb	122
Mar	159
Apr	171
May	189
Jun	162
Jul	127
Aug	111
Sep	110
Oct	118
Nov	118
Dec	110
Total	1,615

4. WIND AND RELATIVE HUMIDITY

Basic analyses were undertaken on the wind data and the relative humidity data from the Farim weather station. As shown on figures 4.1, 4.2 and 4.3, the prevailing wind directions for the site during the period of record is primarily from the north-east or the south-west. During the wet season (May to October) the prevailing wind direction is from the south-

west. During the dry season (November to April) the prevailing wind direction is from the north-east, with some wind still blowing from the south-west. The maximum recorded average wind speed over a 10 minute period for each month is shown in Table 4.1.

Table 4.1: Maximum recorded wind speed for each month

Month	Max Recorded Speed (m/s)	Direction of Max (°)
Jan	4.7	55
Feb	5.1	13
Mar	4.4	42
Apr	5.0	251
May	5.7	93
Jun	6.7	63
Jul	7.6	54
Aug	6.0	243
Sep	8.3	349
Oct	5.6	112
Nov	3.5	116
Dec	4.3	107

For the relative humidity for the site, the monthly average was calculated and is shown in Table 4.2.

Table 4.2: Monthly relative humidity

Month	Relative Humidity
Jan	59%
Feb	49%
Mar	53%
Apr	54%
May	62%
Jun	74%
Jul	87%
Aug	92%
Sep	91%
Oct	89%
Nov	84%
Dec	66%

5. AIR TEMPERATURE

The sub daily air temperature readings from the Farim climate station were analysed to calculate the mean monthly temperature. Monthly mean temperatures are shown in Table 5.1 and on Figure 5.1.

Table 5.1: Monthly mean air temperature

Month	Average Min Daily Temperature (℃)	Mean Temperature (℃)	Average Max Daily Temperature (℃)
Jan	12.7	21.9	33.9
Feb	14.1	24.3	36.5
Mar	17.1	27.2	39.0
Apr	19.8	28.7	39.6
May	22.2	29.1	37.8
Jun	23.4	28.5	35.1
Jul	23.1	26.7	32.4
Aug	22.8	25.8	30.9
Sep	22.8	26.2	31.9
Oct	22.8	27.0	33.1
Nov	20.0	25.4	32.9
Dec	14.5	22.0	32.3

At the Farim climate station, the maximum temperature recorded from December 2011 – March 2015 was 42.8℃. The minimum temperature reco rded during the same time period was 8.1℃.

6. PREVIOUS CLIMATIC ASSESSMENTS

Previous climate analyses have been carried out for the site, with the primary report being the surface water management report written by Golder Associates (Ref. 3).

6.1 PRECIPITATION ANALYSIS

For estimating monthly average rainfall, Golder Associates selected the Abulzinho climate station as its source for precipitation data. As shown on Figure 1.1, the town of Abulzinho is located 70 km to the west of the Farim project. The average monthly precipitation calculated for Abulzinho by Golder Associates is similar to that estimated for Kolda by KP.

For design rainfall, Golder Associates used information from a “hydrologically similar catchment” from Gagnoa in the Republic of Côte d'Ivoire. This is approximately 1,200 km to the south-east of the site and it is questionable whether it would be representative of the extreme rainfall in Guinea-Bissau. KP notes that the largest storm on record at the Farim climate station, 229 mm in 9 hours, would be approximately a 0.26% AEP event (381 year ARI) using the IFD/DDF curves developed by Golder Associates.

The IFD/DDF developed using the Gagnoa data is considered to significantly underestimate the design storm depths for the Farim Project. An example of this is the 24 hour 1% AEP event. Using the Kolda data, the storm depth is estimated as 508 mm. The Gagnoa data has this storm depth estimated as 182 mm.

6.2 EVAPORATION ANALYSIS

Golder associates selected the “Kolta” climate station as the source of its evaporation data. It is assumed that the “Kolta” climate station is actually the Kolda climate station. The Golder Associates average monthly evaporation numbers and the average monthly PET numbers are very similar which is to be expected given the same datasets were most likely analysed.

We trust that these results provide sufficient climate information for your current needs. Please contact us if you have any queries.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

ANDREW BROWN
Project Engineer

BRETT STEVENSON
Principal Engineer

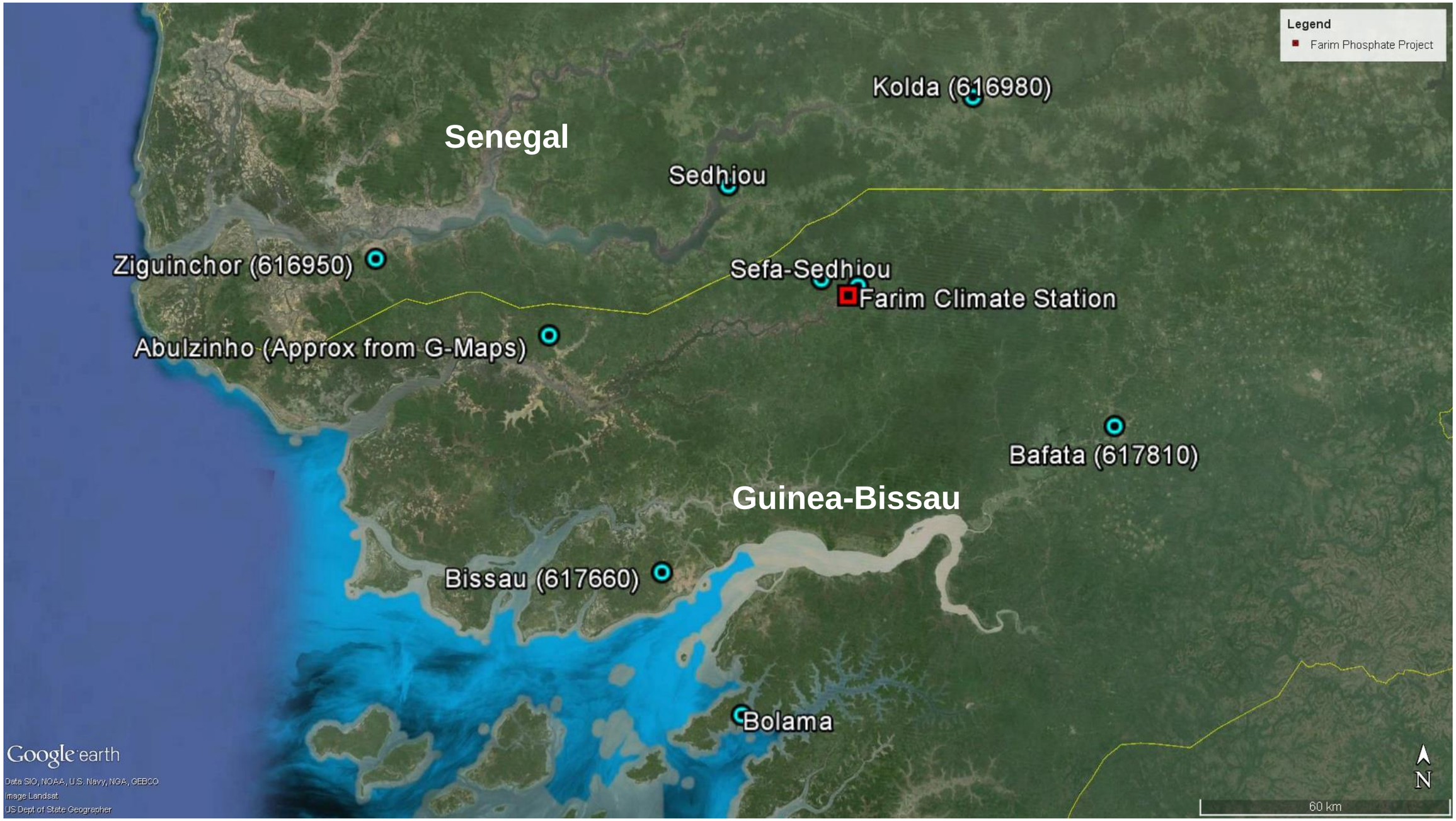
REFERENCES

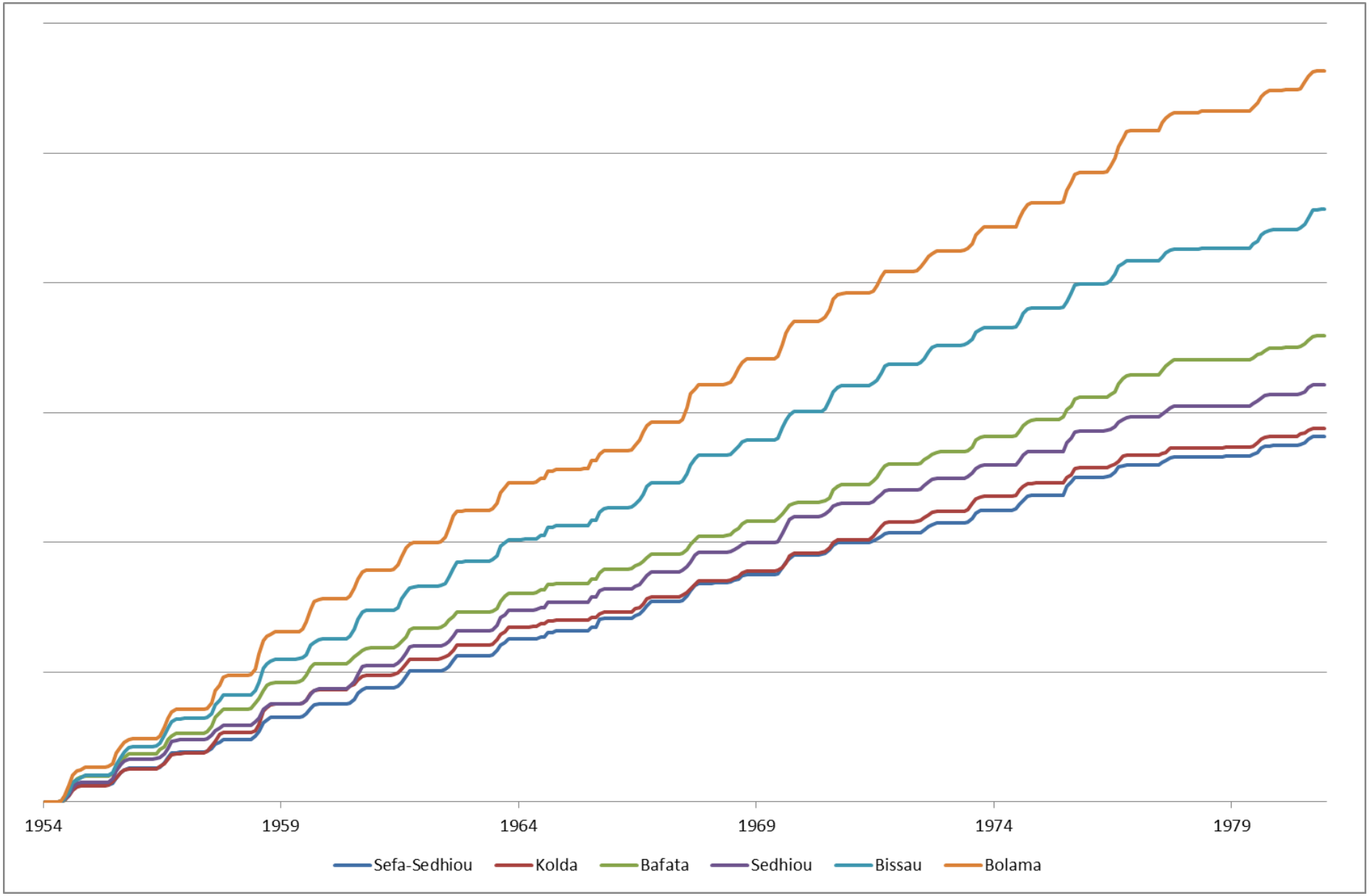
1 Weiss L.L., "*Ratio of true to fixed-interval maximum rainfall*", American Society of Civil Engineers, Journal of the Hydraulics Division, v 90, HY-1, P. 77-82.

2 Watkins L.H., Fiddes D., 1984. "*Highway and Urban Hydrology in the Tropics*", London, Great Britain, Pentech Press Ltd.

3 Golder Associates Report No. 12514950394.502/B.0. *"Surface Water Management 1.3 Mtpa Open Pit Feasibility Study Report"*, October 2012.

FIGURES


Legend
Farim Phosphate Project
Kolda (616980)
Senegal
Sedhiou
Ziguinchor (616950)
Sefa-Sedhiou
Farim Climate Station
Abulzinho (Approx from G-Maps)
Bafata (617810)
Guinea-Bissau
Bissau (617660)
Bolama
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
US Dept of State Geographer
N
60 km



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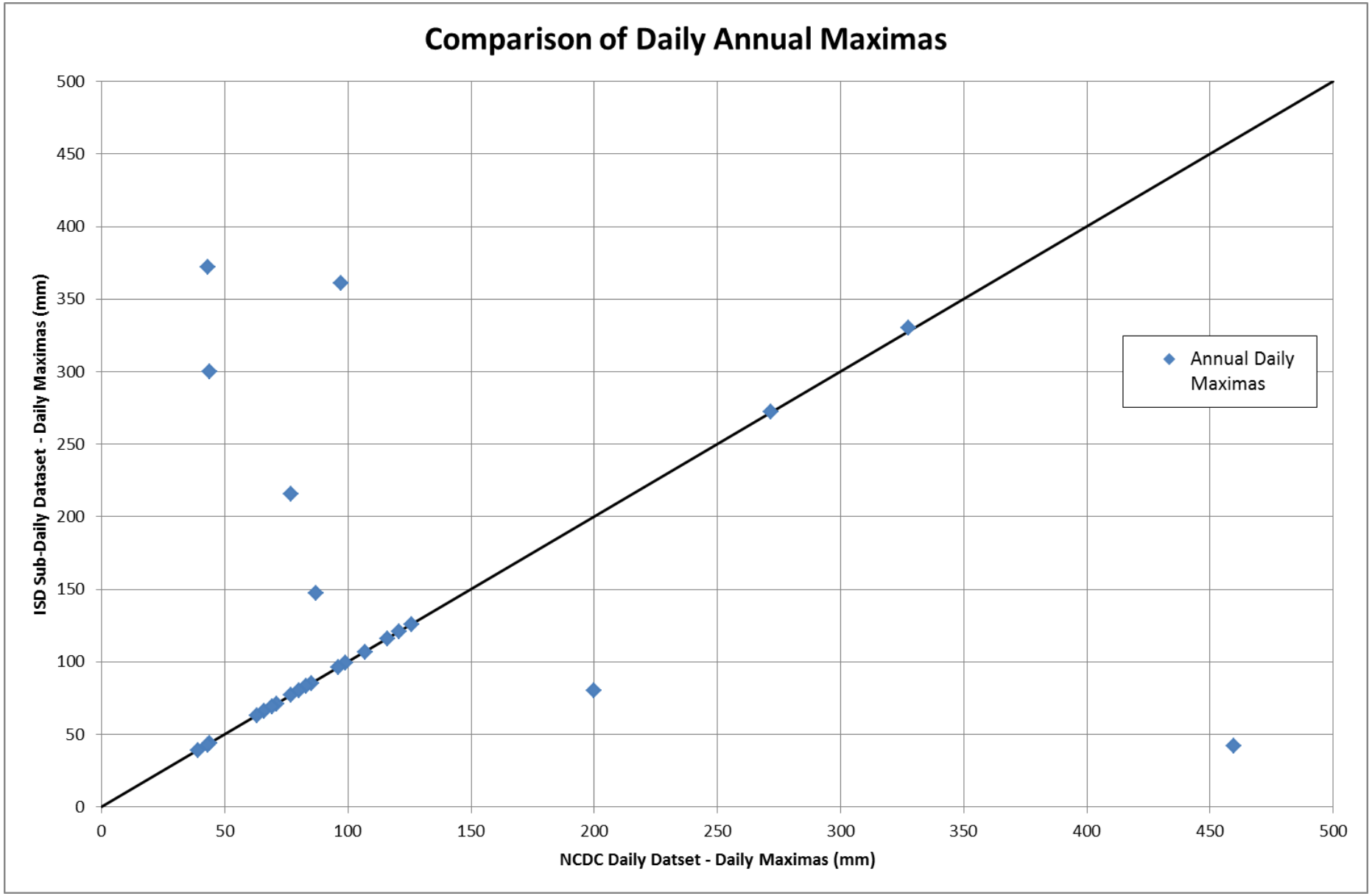
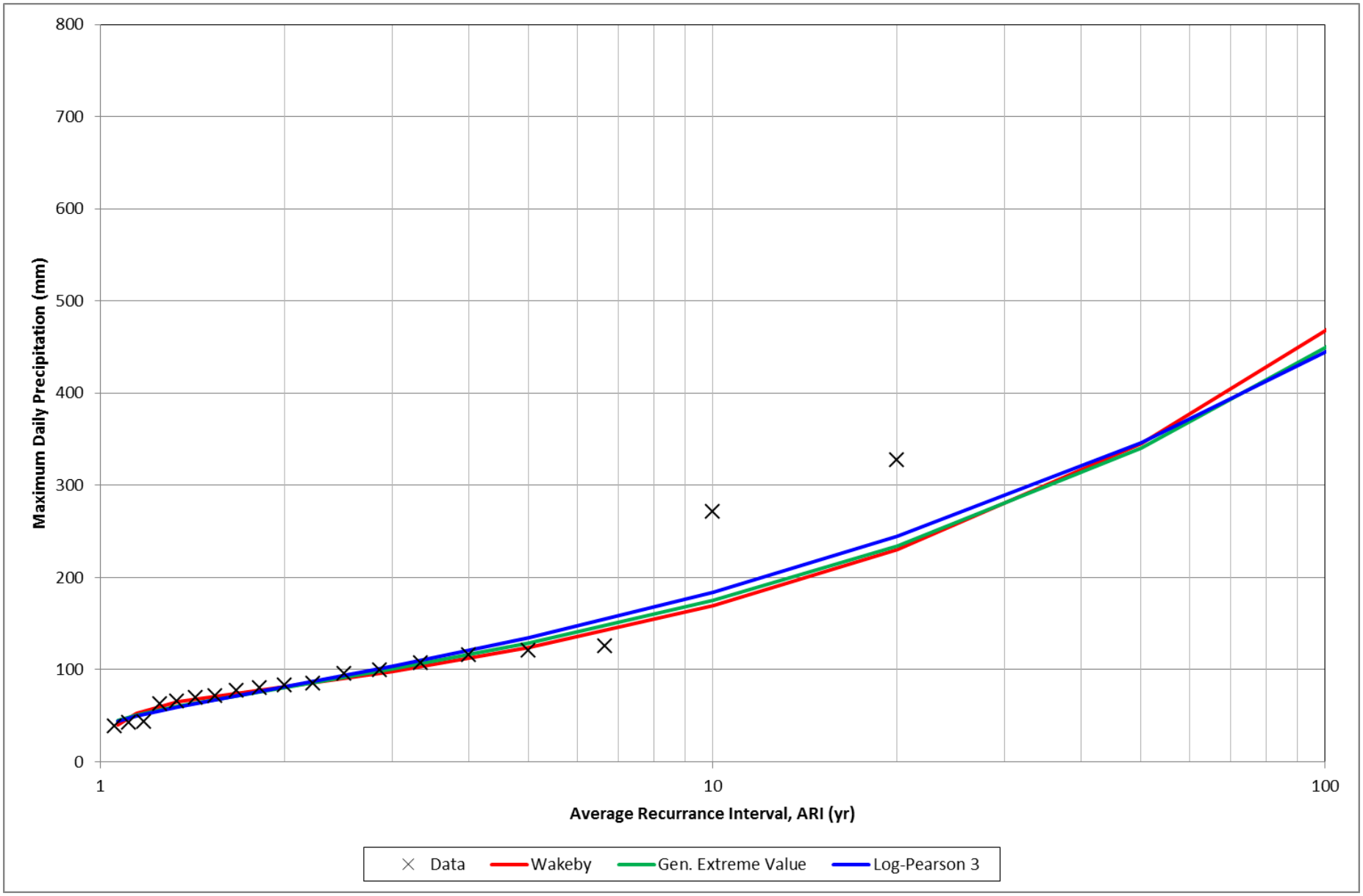
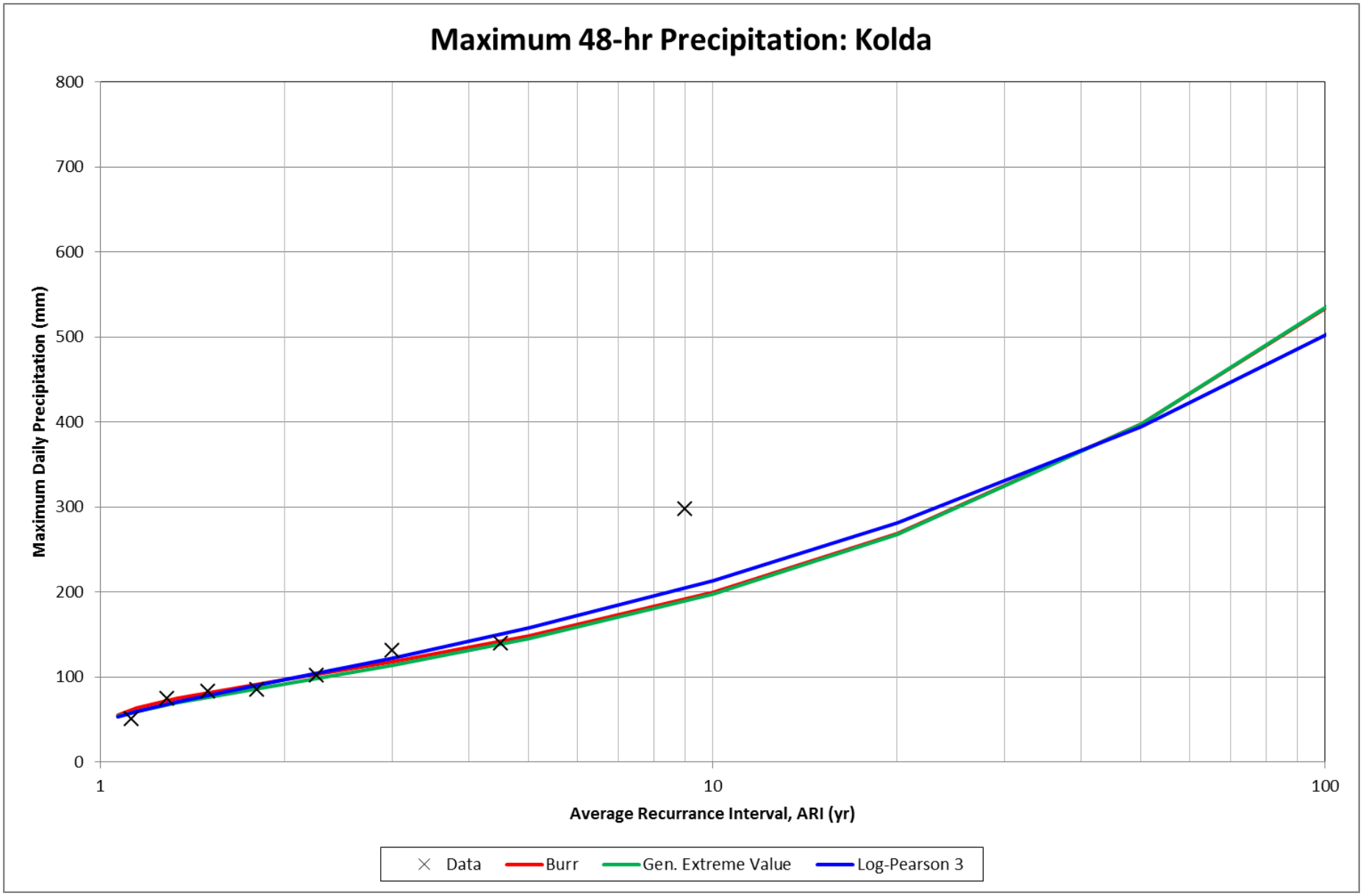
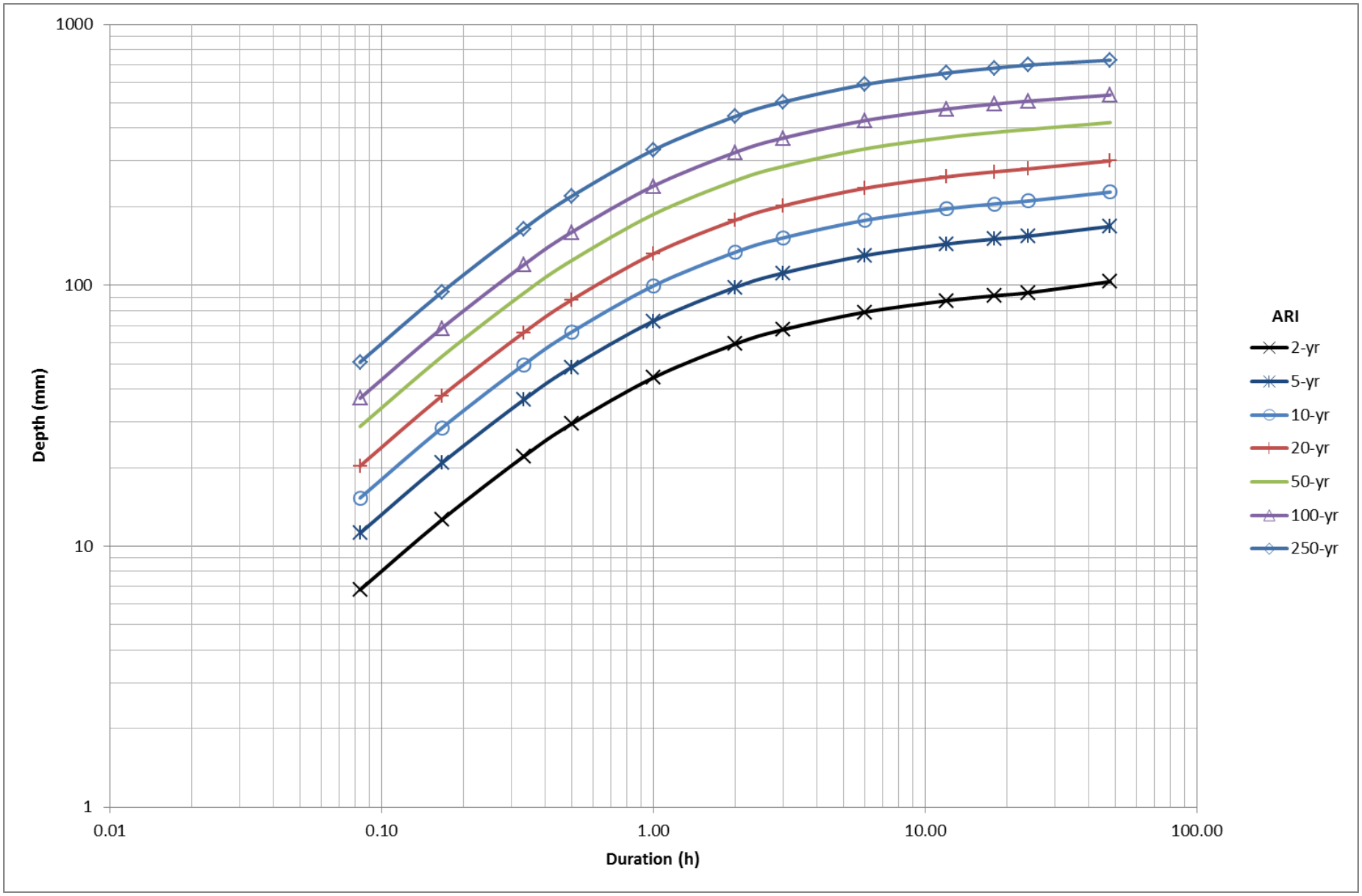
FARIM PHOSPHATE PROJECT – BASELINE DESIGN CLIMATOLOGY
PRECIPITATION – CUMULATIVE MONTHLY PLOT
ALL STATIONS

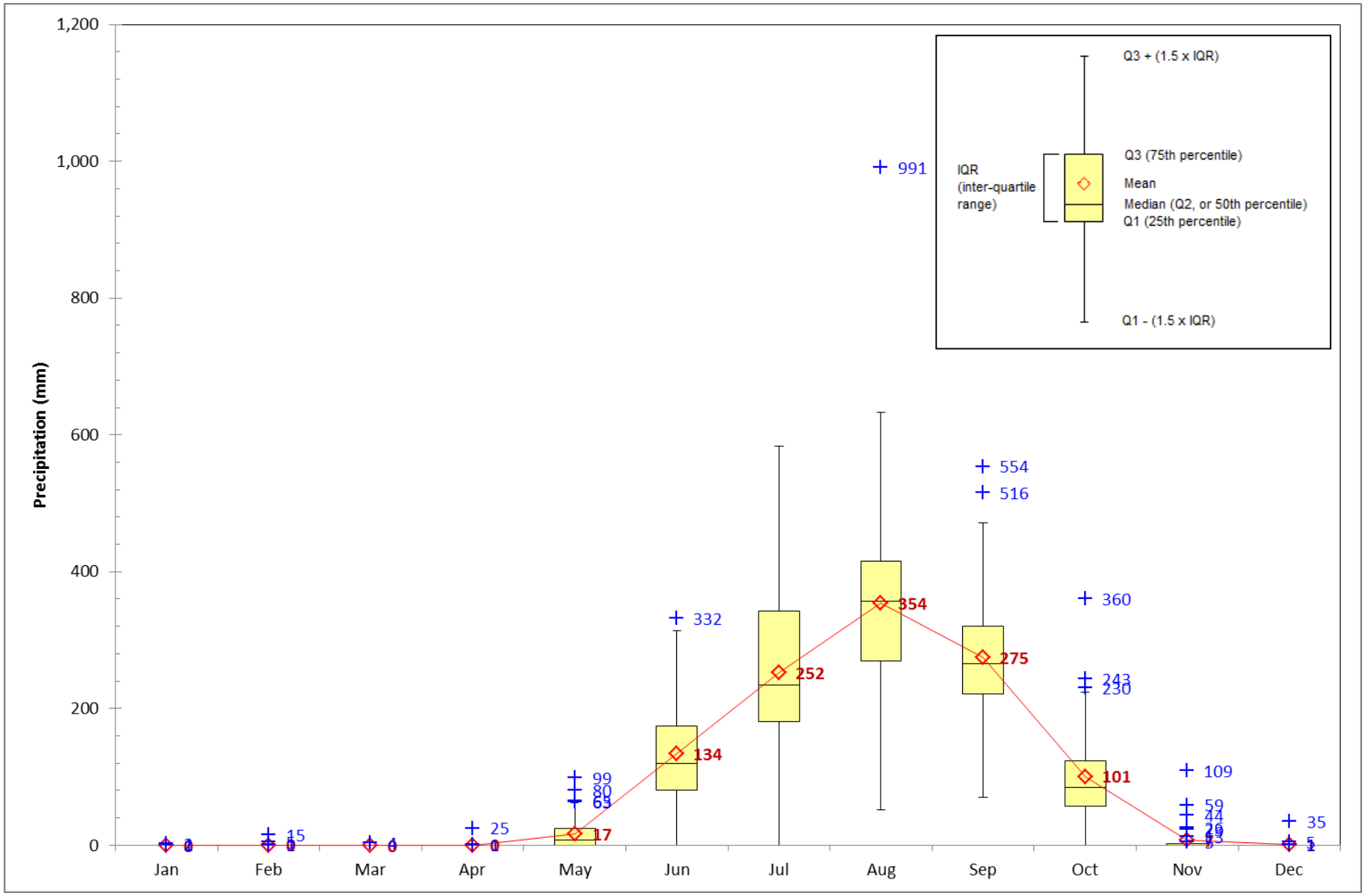
Ref: PE301-00520 M15004
Figure 2.1

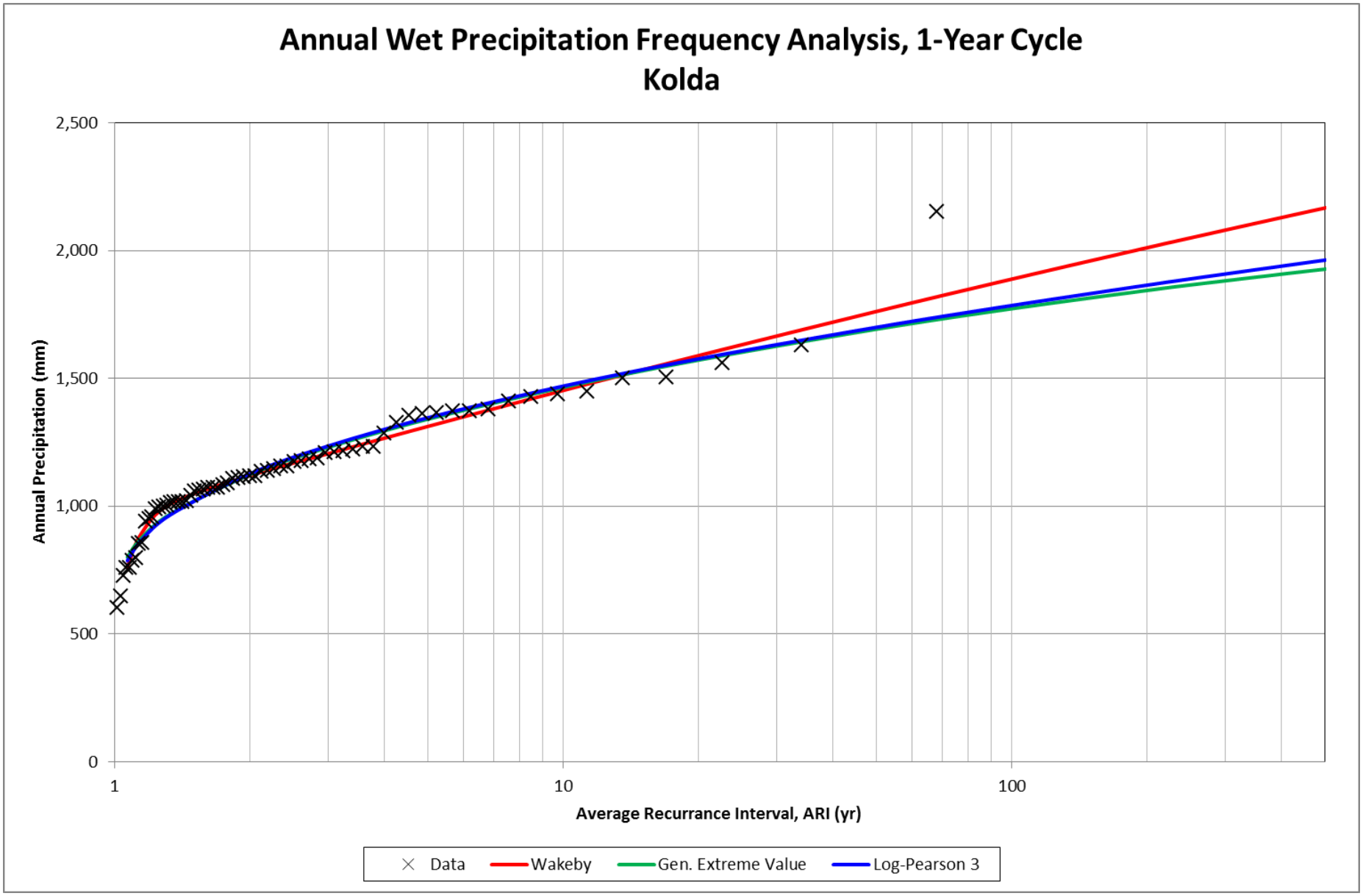

Comparison of Daily Annual Maximas
ISD Sub-Daily Dataset - Daily Maximas (mm)
NCDC Daily Datset - Daily Maximas (mm)
0
50
100
150
200
250
300
350
400
450
500
Annual Daily Maximas

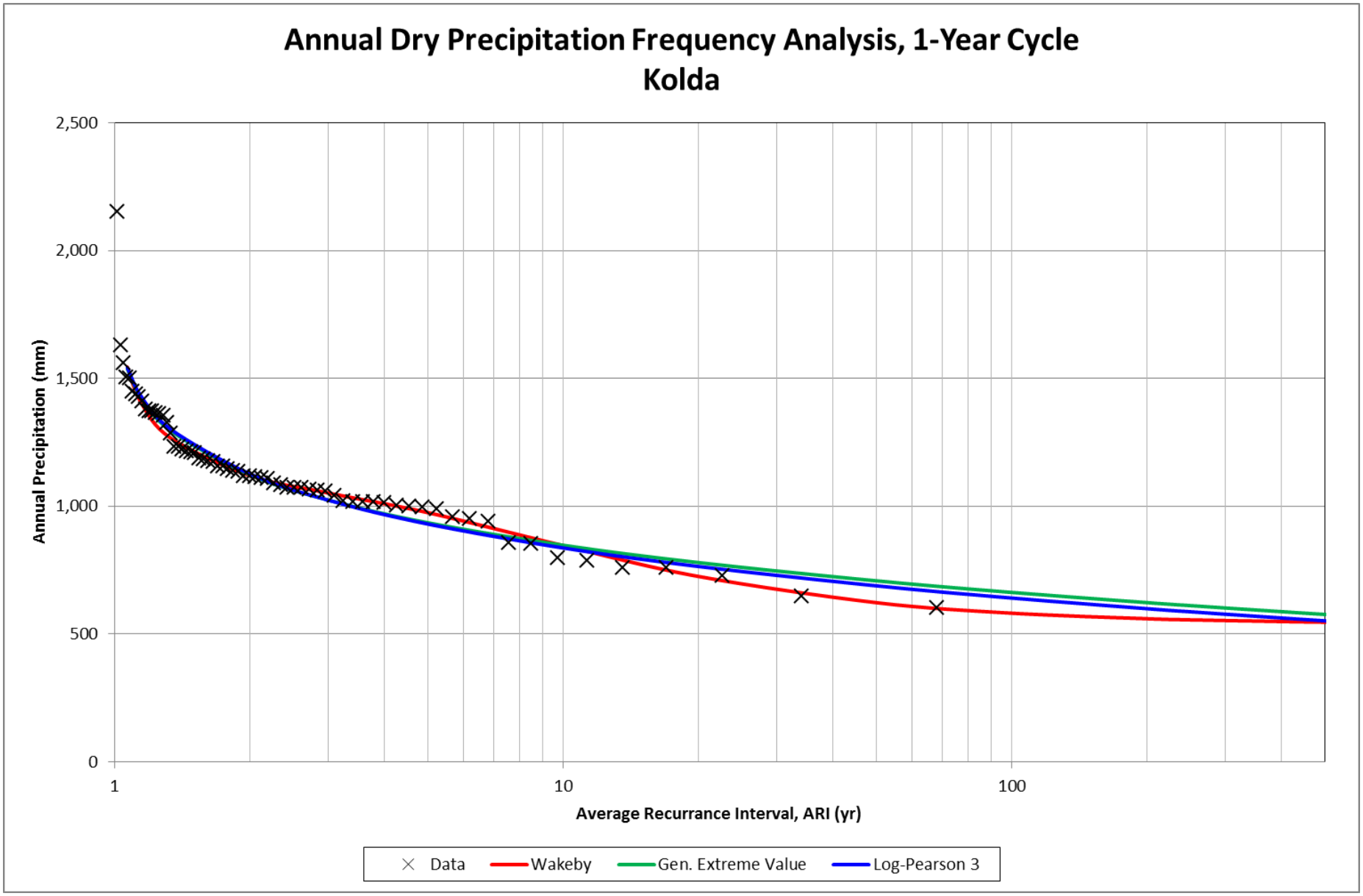

800
700
600
500
400
300
200
100
0
Maximum Daily Precipitation (mm)
1
10
100
Average Recurrance Interval, ARI (yr)
Data
Wakeby
Gen. Extreme Value
Log-Pearson 3


Maximum 48-hr Precipitation: Kolda
Maximum Daily Precipitation (mm)
800
700
600
500
400
300
200
100
0
1
10
100
Average Recurrance Interval, ARI (yr)
Data
Burr
Gen. Extreme Value
Log-Pearson 3


1000
100
10
1
Depth (mm)
0.01
0.10
1.00
10.00
100.00
Duration (h)
ARI
2-yr
5-yr
10-yr
20-yr
50-yr
100-yr
250-yr


Precipitation (mm)
1,200
1,000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Q3 + (1.5 x IQR)
Q3 (75th percentile)
Mean
Median (Q2, or 50th percentile)
Q1 (25th percentile)
Q1 - (1.5 x IQR)
IQR
(inter-quartile
range)
991
554
516
360
332
354
275
252
243
230
134
101
109
99
80
65
59
35
25
17
15


Annual Wet Precipitation Frequency Analysis, 1-Year Cycle
Kolda
Annual Precipitation (mm)
2,500
2,000
1,500
1,000
500
0
1
10
100
Average Recurrance Interval, ARI (yr)
Data
Wakeby
Gen. Extreme Value
Log-Pearson 3


Annual Dry Precipitation Frequency Analysis, 1-Year Cycle
Kolda
Annual Precipitation (mm)
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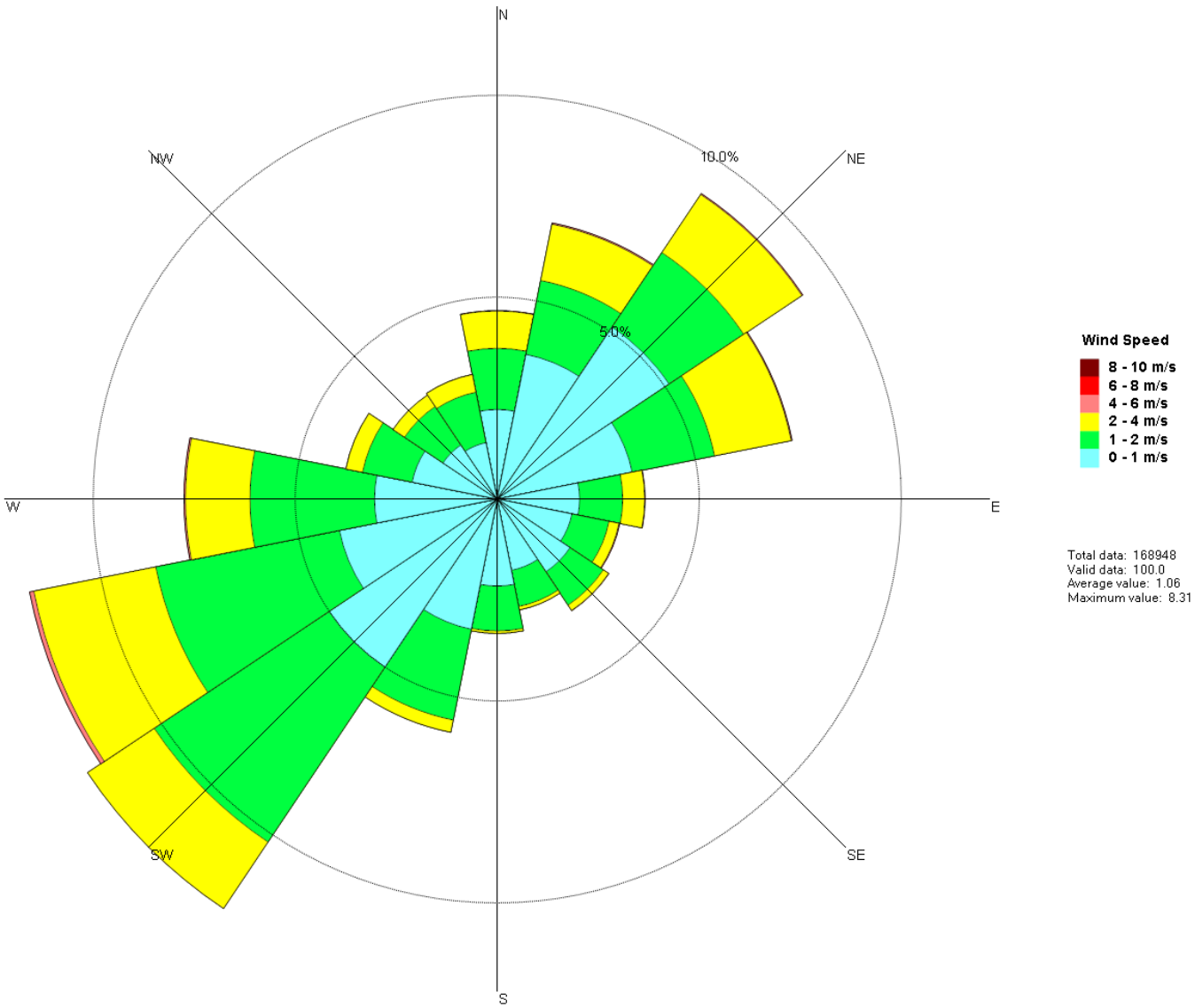
2,000
1,500
1,000
500
0
1
10
100
Average Recurrance Interval, ARI (yr)
Data
Wakeby
Gen. Extreme Value
Log-Pearson 3



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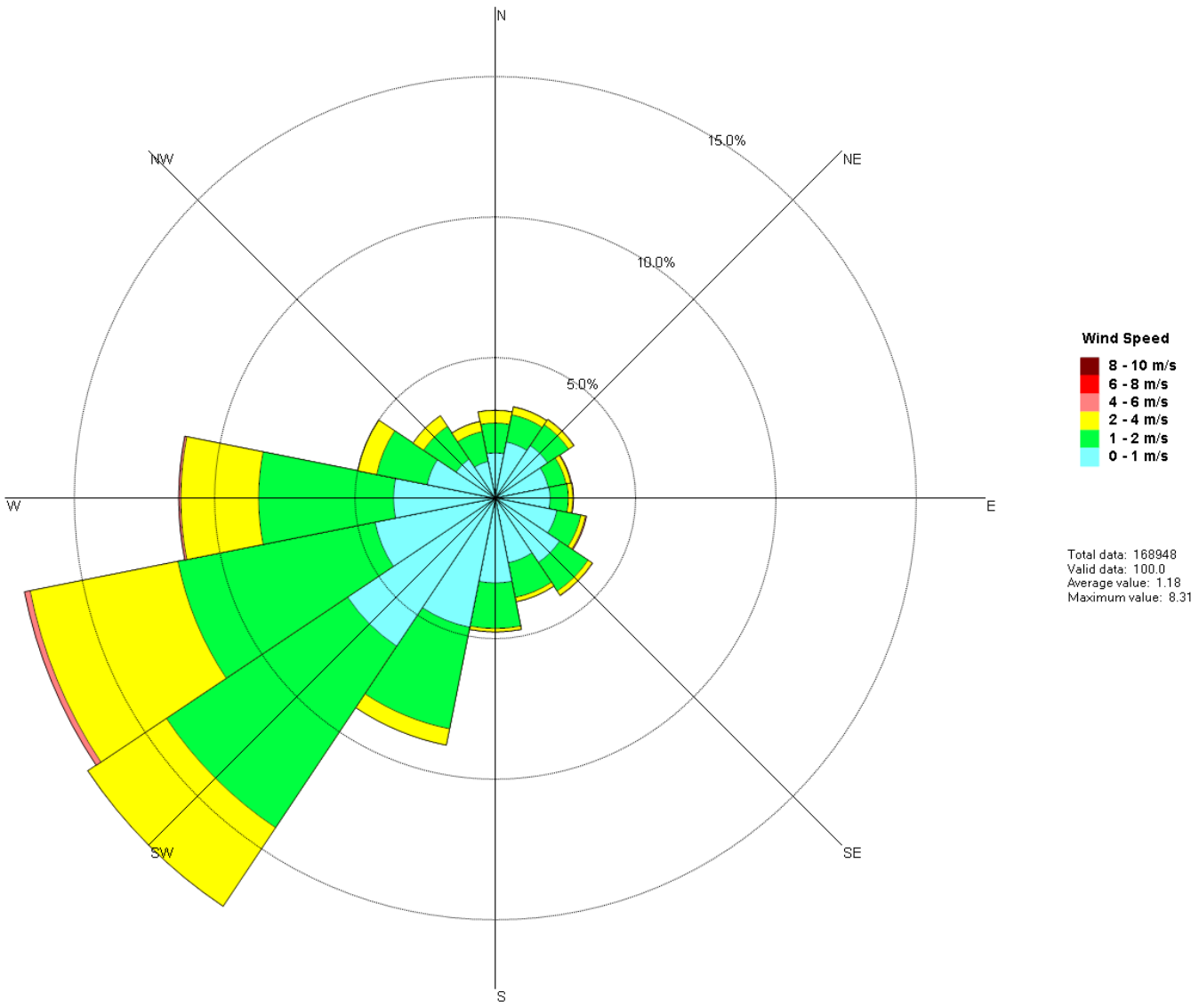
FARIM PHOSPHATE PROJECT – BASELINE DESIGN CLIMATOLOGY
WIND ROSE – ALL DATA
FARIM WEATHER STATION

Ref: PE301-00520 M15004
Figure 4.1



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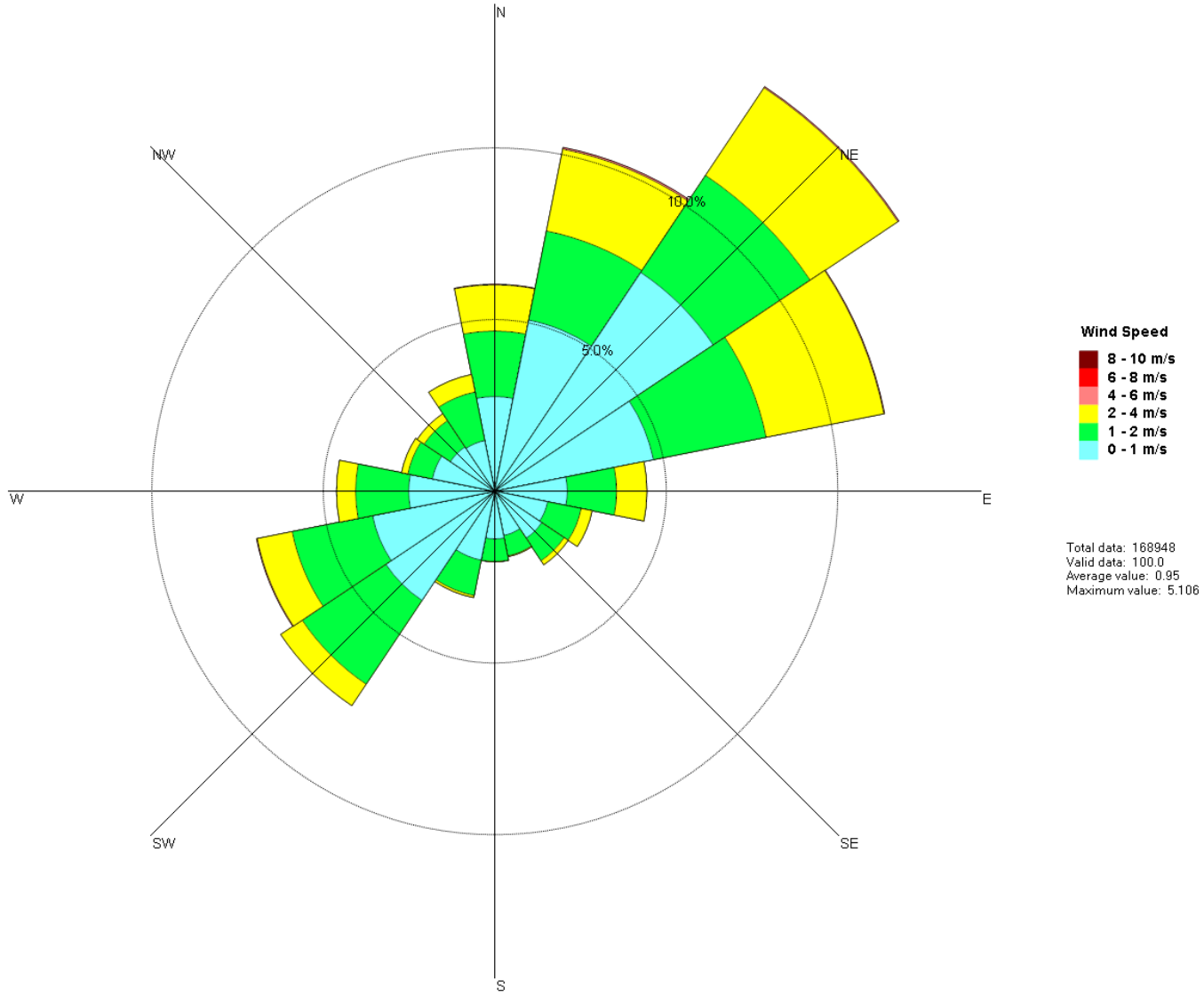
FARIM PHOSPHATE PROJECT – BASELINE DESIGN CLIMATOLOGY
WIND ROSE – WET SEASON
FARIM WEATHER STATION

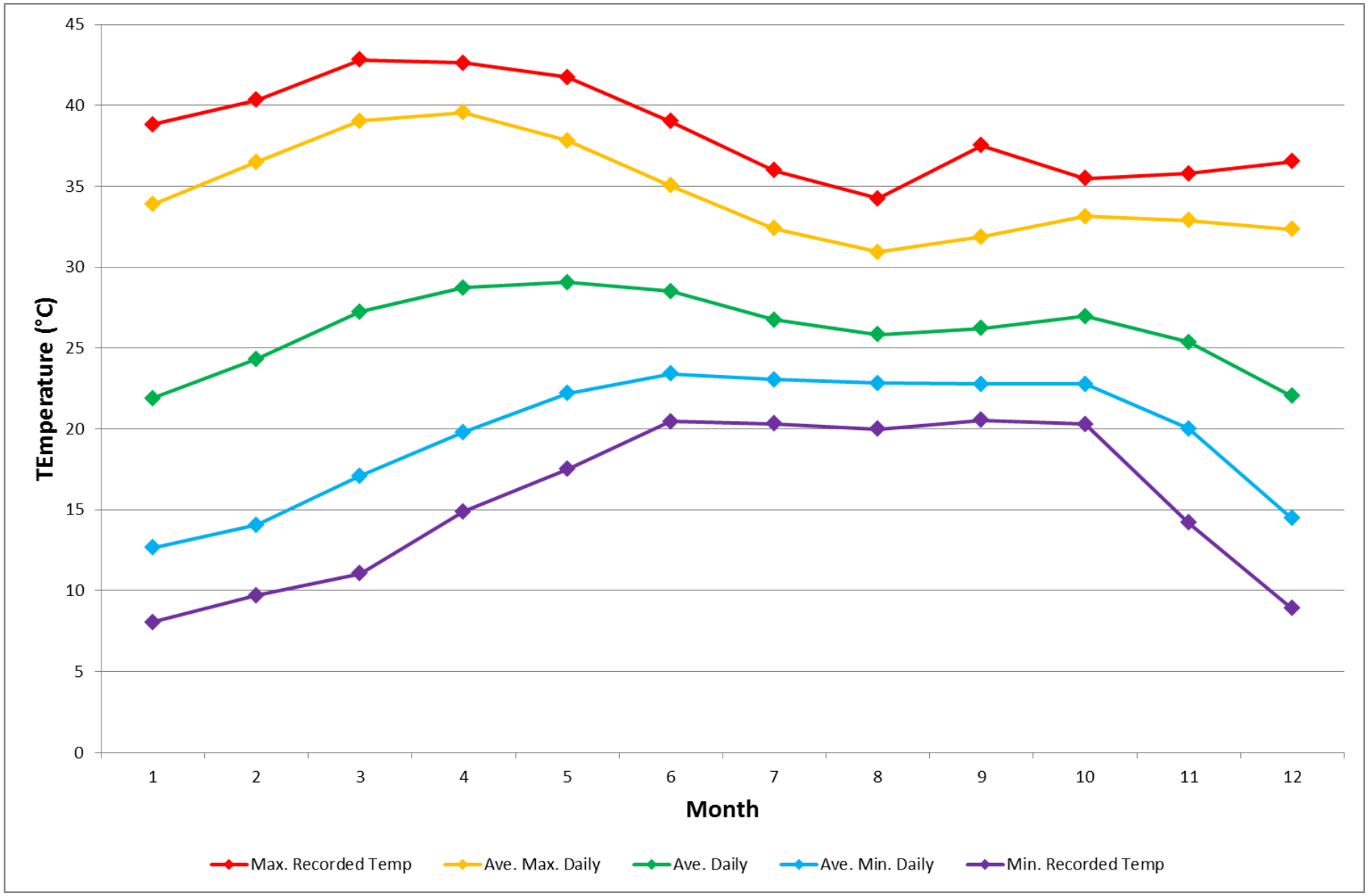
Ref: PE301-00520 M15004
Figure 4.2



Knight Piésold CONSULTING

FARIM PHOSPHATE PROJECT – BASELINE DESIGN CLIMATOLOGY
WIND ROSE – DRY SEASON
FARIM WEATHER STATION

Ref: PE301-00520 M15004
Figure 4.3


45
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15
10
5
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TEmperature (°C)
1
2
3
4
5
6
7
8
9
10
11
12
Month
Max. Recorded Temp
Ave. Max. Daily
Ave. Daily
Ave. Min. Daily
Min. Recorded Temp

MEMORANDUM

To:	Ms. Olga Kovalik	Date:	August 7, 2015
Copy To:		File No.:	NB301-520/2-A.01
From:	Jason Plamondon	Cont. No.:	NB15-00175
Re:	Supplemental Groundwater Quality Baseline Report – Farim Phosphate Project		

1 – INTRODUCTION

A supplemental groundwater quality sampling program was undertaken by Knight Piésold Ltd. (KP) in May 2015. The program was conducted to support the completion of the Environmental and Social Impact Assessment (ESIA) currently under preparation for the Farim Phosphate Project (the Project).

Previous groundwater baseline data were collected by Golder Associates UK Ltd. (Golder). The previous studies were focused on establishing baseline conditions at the Mine Site and near the proposed worker camp located to the northeast of Farim. The existing dataset for the Project consists of results obtained from two sampling events that targeted one dry event and one wet season event between December 2011 and September 2013 (Golder, 2014). This supplemental groundwater quality program was undertaken to add to the existing groundwater quality database with one additional dry season sampling event.

Additional groundwater wells were installed in April 2015 in the vicinity of the proposed process plant, south pit and integrated waste landform (IWL). These wells were established as part of a physical hydrogeology and geotechnical program conducted by KP and were sampled as part of the supplemental baseline program.

Golder (2013) installed groundwater wells at the Port Site area as part of a previous geotechnical investigation; however, groundwater quality data could not be located in the Project files provided by GB Minerals for these wells. As such, supplemental baseline sampling of the Port Site groundwater wells was also undertaken to provide an initial characterization of groundwater quality at the Port Site.

The following describes the supplemental field program undertaken by KP, the groundwater quality laboratory results, and also provides a discussion of the results in relation to relevant groundwater quality criteria and available surface water quality data.

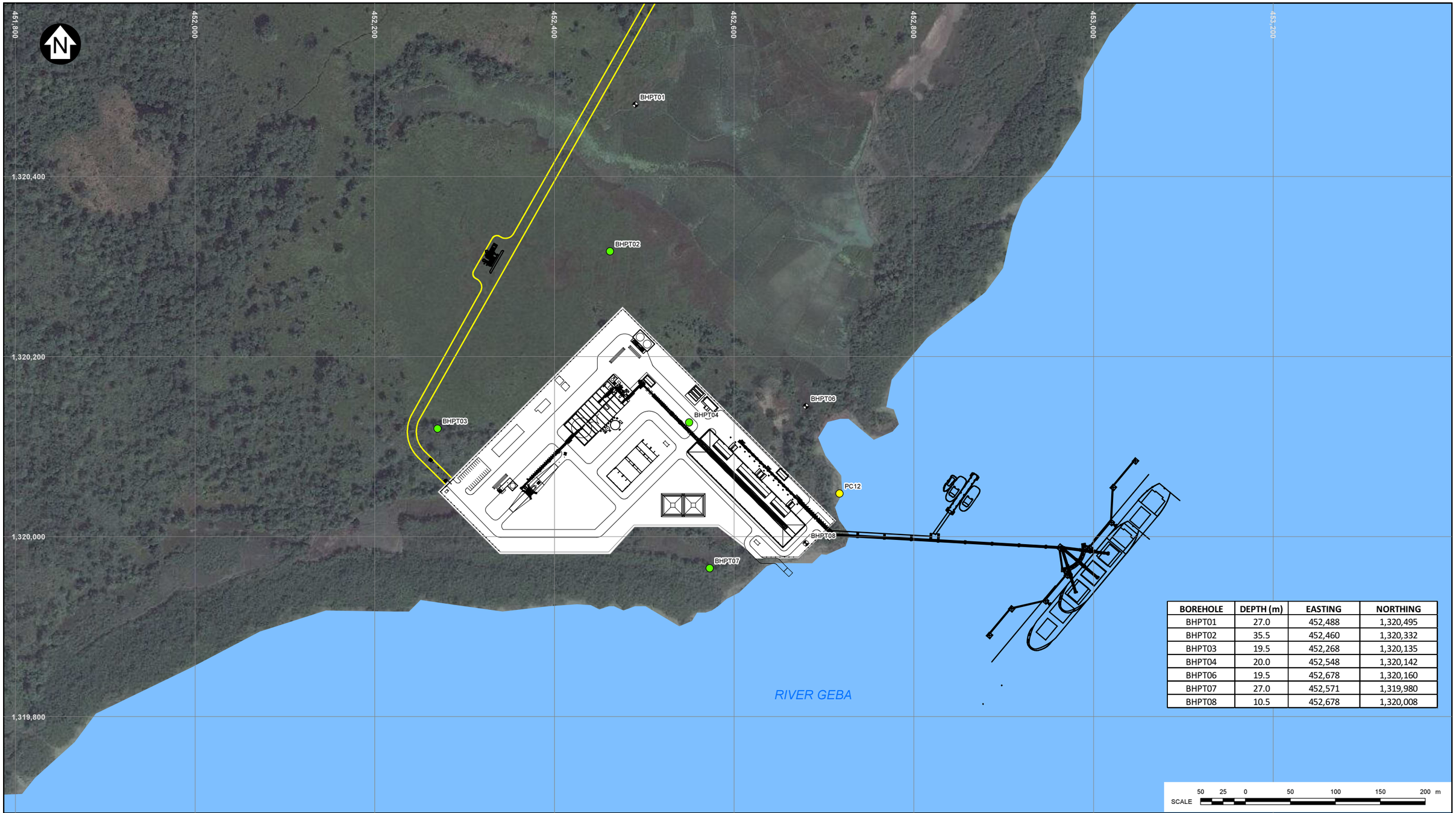
2 – FIELD PROGRAM

Groundwater samples were collected from four (4) groundwater wells within the Port Site area on May 9, 2015 (Figure 1). Eighteen (18) groundwater wells were sampled within the Mine Site and the proposed worker camp area between May 11 and 14, 2015 (Figure 2). Table 1 summarizes the sampling program details, including wells that were inspected and found to have been compromised, were dry, or were blocked and therefore inaccessible to sampling. Representative photographs of the groundwater wells are presented in Appendix A.

Water levels and total well depths were measured using an electronic water level tape and were recorded on field data sheets included in Appendix B. Groundwater wells were purged using a submersible pump equipped with polyvinyl chloride (PVC) tubing. The volume of water contained in each well was calculated beforehand and at least three well volumes were removed, or the well was purged dry and allowed to recover prior to sampling. At several smaller diameter wells, the submersible pump could not be used so they were purged using a plastic bailer. As per previous sampling campaigns a dedicated bailers was used to obtain the samples for consistency. An Extech EC500 water quality probe was used to measure in-situ parameters (i.e., temperature, conductivity, pH, salinity and dissolved oxygen), which were recorded on the field forms. Observations of colour or odour and the condition of the standpipe/well were also noted on the sampling field forms.

Table 1 Groundwater Quality Sampling Summary (May 2015)

Borehole/Well ID	Sampled	Comments	UTM Coordinates (Bissau Zone 28N)	
			Easting	Northing
Port Site Area				
BHPT01	N	Well compromised (Photo 1)	452,488	1,320,495
BHPT02	Y	Sulphur odour and light brown colour noted initially. Quick recharge rate, did not purge dry (Photo 2)	452,460	1,320,332
BHPT03	Y	Purged dry twice, Slow recharge, water was black to start turning brown. Duplicate sample BHPT333 collected	452,268	1,320,135
BHPT04	Y	Sampled	452,548	1,320,142
BHPT06	N	Well compromised	452,678	1,320,160
BHPT07	Y	Sulphur odour noted; sampled	452,571	1,319,980
BHPT08	N	Well compromised	452,678	1,320,008
Mine Site Area				
KP-PS-BH01 (plant site)	Y	Purged well using bailer (Photo 3)	473,592	1,379,219
KP-SGW-BH02 (south pit)	Y	About 5 m away from high tide mark and the screen goes to the soil surface; tidal surface water infiltration possible (Photo 4)	472,398	1,377,505
KP-TMF/OB-BH02 (TSF)	Y	Purged well using bailer	467,669	1,378,940
KP-TMF/OB-BH03 (TSF)	Y	High sediment content in water; purged well using bailer	468,410	1,377,752
DW 01 (north pit)	N	Well blocked; not sampled	470,250	1,380,708
DW 02 (north pit)	Y	Sampled in lieu of DW 01 (Photo 5)	470,250	1,380,708
DW 04 (north pit)	N	Not vehicle accessible; not sampled	470,332	1,380,794
DW 08 (north pit)	Y	Sampled in lieu of DW 04	470,454	1,380,770
DW 07 (north pit)	Y	No field comment	470,460	1,380,653
MW01A(D)	Y	Photo 6	471,453	1,377,404
MW01B(S)	Y	No field comment	471,455	1,377,408
MW02A(D)	Y	Duplicate sample collected	473,431	1,379,147
MW02B(S)	Y	No field comment	473,436	1,379,147
MW03A(D)	Y	No field comment	472,531	1,380,813
MW03B(S)	Y	No field comment	472,528	1,380,818
MW04A (S)	Y	No field comment	470,479	1,378,978
MW04B(D)	Y	No field comment	470,474	1,378,978
MW06(S)	Y	No field comment	472,947	1,378,238
MW07A(D)	Y	No field comment	471,269	1,381,234
MW07B(S)	N	Dry or blocked	471,272	1,381,231
MW08A(D)	N	Well compromised; not sampled (Photo 7)	470,643	1,381,190
MW08B(S)	N	Dry or blocked; not sampled	470,649	1,381,184
PW 01	N	No field comment, not sampled	473,043	1,378,304
PW 02	Y	Photo 8	470,619	1,380,896



BOREHOLE	DEPTH (m)	EASTING	NORTHING
BHPT01	27.0	452,488	1,320,495
BHPT02	35.5	452,460	1,320,332
BHPT03	19.5	452,268	1,320,135
BHPT04	20.0	452,548	1,320,142
BHPT06	19.5	452,678	1,320,160
BHPT07	27.0	452,571	1,319,980
BHPT08	10.5	452,678	1,320,008

LEGEND:

- DESTROYED WELL
- 2015 SAMPLING WELL LOCATION
- WELL BY OTHERS (FROM HYDROCENSUS BY GOLDER)
- PROPOSED INFRASTRUCTURE
- PROPOSED ROAD
- WATER

NOTES:

1. MINE AND PORT SITE INFRASTRUCTURE AS WELL AS BASEMAP DATA PROVIDED BY LYCOPODIUM MINERALS CANADA LTD. (MARCH 18, 2015). MODIFIED BY KNIGHT PIESOLD LTD. TO SHOW PROPOSED INFRASTRUCTURE CHANGES (APRIL 24, 2015).
2. COORDINATE SYSTEM: WGS 1984 UTM ZONE 28N. COORDINATE GRID IS IN METRES.
3. IMAGERY: ESRI DATA AND MAPS [ONLINE] (2015). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUDE. ALL RIGHTS RESERVED.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	13JUL'15	ISSUED WITH MEMO	RAC	SWK	RAC

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

PORT SITE
GROUNDWATER WELL LOCATIONS

Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF NO. NB15-00175

FIGURE 1

REV 0

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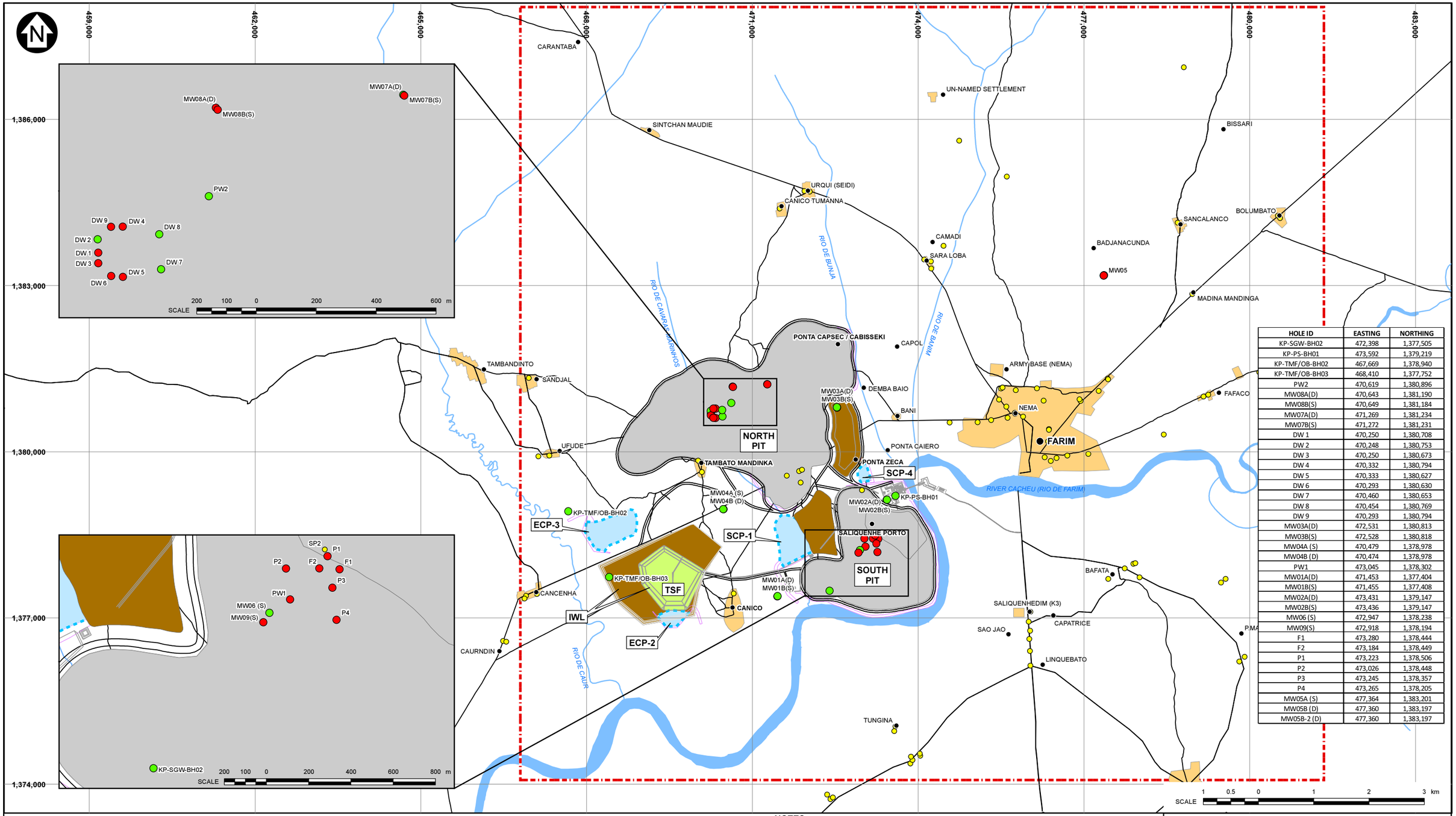

HOLE ID	EASTING	NORTHING
KP-SGW-BH02	472,398	1,377,505
KP-PS-BH01	473,592	1,379,219
KP-TMF/OB-BH02	467,669	1,378,940
KP-TMF/OB-BH03	468,410	1,377,752
PW2	470,619	1,380,896
MW08A(D)	470,643	1,381,190
MW08B(S)	470,649	1,381,184
MW07A(D)	471,269	1,381,234
MW07B(S)	471,272	1,381,231
DW 1	470,250	1,380,708
DW 2	470,248	1,380,753
DW 3	470,250	1,380,673
DW 4	470,332	1,380,794
DW 5	470,333	1,380,627
DW 6	470,293	1,380,630
DW 7	470,460	1,380,653
DW 8	470,454	1,380,769
DW 9	470,293	1,380,794
MW03A(D)	472,531	1,380,813
MW03B(S)	472,528	1,380,818
MW04A (S)	470,479	1,378,978
MW04B (D)	470,474	1,378,978
PW1	473,045	1,378,302
MW01A(D)	471,453	1,377,404
MW01B(S)	471,455	1,377,408
MW02A(D)	473,431	1,379,147
MW02B(S)	473,436	1,379,147
MW06 (S)	472,947	1,378,238
MW09(S)	472,918	1,378,194
F1	473,280	1,378,444
F2	473,184	1,378,449
P1	473,223	1,378,506
P2	473,026	1,378,448
P3	473,245	1,378,357
P4	473,265	1,378,205
MW05A (S)	477,364	1,383,201
MW05B (D)	477,360	1,383,197
MW05B-2 (D)	477,360	1,383,197

LEGEND:

- COMMUNITY
- PROJECT MONITORING WELL
- 2015 SAMPLING WELL LOCATION
- HYDROCENSUS WELL LOCATION
- EXISTING ROAD
- PROPOSED INFRASTRUCTURE
- PROPOSED HAUL ROAD
- WATER MANAGEMENT FACILITY
- RIVER/STREAM/DRAINAGE
- WATER
- POPULATED SETTLEMENT
- NORTH AND SOUTH OPEN PIT
- WASTE DUMP (OVERBURDEN)
- TAILINGS STORAGE FACILITY
- POND EXTENT
- STUDY AREA

NOTES:

1. MINE INFRASTRUCTURE AND BASEMAP DATA PROVIDED BY LYCOPODIUM MINERALS CANADA LTD. (MARCH 18, 2015). LAST UPDATED ON MAY 29, 2015 BASED ON DATA PROVIDED BY KP PERTH. THE OPEN PITS AND WASTE DUMPS WERE CREATED BY GOLDER, THE PROCESS PLANT AND TRUCK LOAD-OUT FACILITY WERE CREATED BY LYCOPODIUM, AND THE TSF AND WATER MANAGEMENT WERE CREATED BY KNIGHT PIESOLD IN PERTH.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: WGS 1984 UTM ZONE 28N.
3. IWL - INTEGRATED WASTE LANDFORM
   TSF - TAILINGS MANAGEMENT FACILITY
   WD - WASTE DUMP
   ECP - ENVIRONMENTAL CONTROL POND
   SCP - SEDIMENT CONTROL POND

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	13JUL'15	ISSUED WITH MEMO	RAC	SWK	RAC

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

MINE SITE
GROUNDWATER WELL LOCATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB301-520/2	NB15-00175

FIGURE 2 REV 0

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The samples were persevered as directed and packed in a cooler/container with ice packs and shipped to ALS Laboratory located in Prague, Czech Republic for analysis. The groundwater samples were analyzed by the laboratory for general chemistry: pH, anions and cations, total and dissolved organic carbon, nitrogen-containing compounds (nitrite, nitrate, ammonia, inorganic, organic, total nitrogen and free ammonia), turbidity, total dissolved solids, total suspended solids, and dissolved metals.

3 – RESULTS AND DISCUSSION

3.1 REFERENCE GUIDELINES

The following guidelines were used for comparison to the groundwater quality results:

- **World Health Organization Drinking Water Guidelines** (WHO, 2011) - Comparison to these guidelines allows for an assessment of the suitability of groundwater at the Project sites for human consumption. Groundwater is the only potentially suitable source of drinking water.
- **International Finance Corporation Mine Effluent Guidelines** (IFC, 2007) - At the Mine Site, groundwater extracted from the open pit dewatering wells and in-pit sumps will be discharged as a mine effluent to the River Cacheu.
- **Canadian Environmental Quality Guidelines for the Protection of Aquatic Life (CEQG-PAL)** (Canadian Council of Ministers of the Environment - CCME, 2015) - As above, mine effluent (groundwater) will be discharged to the River Cacheu; the few available marine CEQG-PAL guidelines were supplemented by the freshwater CEQG-PAL guidelines and have been used for comparison to support an evaluation of potential effects of discharging groundwater-derived mine effluent on the aquatic environment.

The results relative to these guidelines are described below.

3.2 PORT SITE GROUNDWATER QUALITY

The Port Site will utilize groundwater as the main water source for potable, domestic and minor industrial uses (e.g., truck washing). This water will be directed to a septic system or to the stormwater ponds that will discharge into the River Geba.

The Port Site dataset consists of four (4) samples collected from four (4) wells located within or adjacent to the proposed footprint (Appendix C, Table C.1). The samples were obtained during the dry season and were analysed for the full recommended suite of parameters. The wells range in depth between 19.5 m and 35 m below ground level. The notable Port Site groundwater quality results are summarized in Table 2.

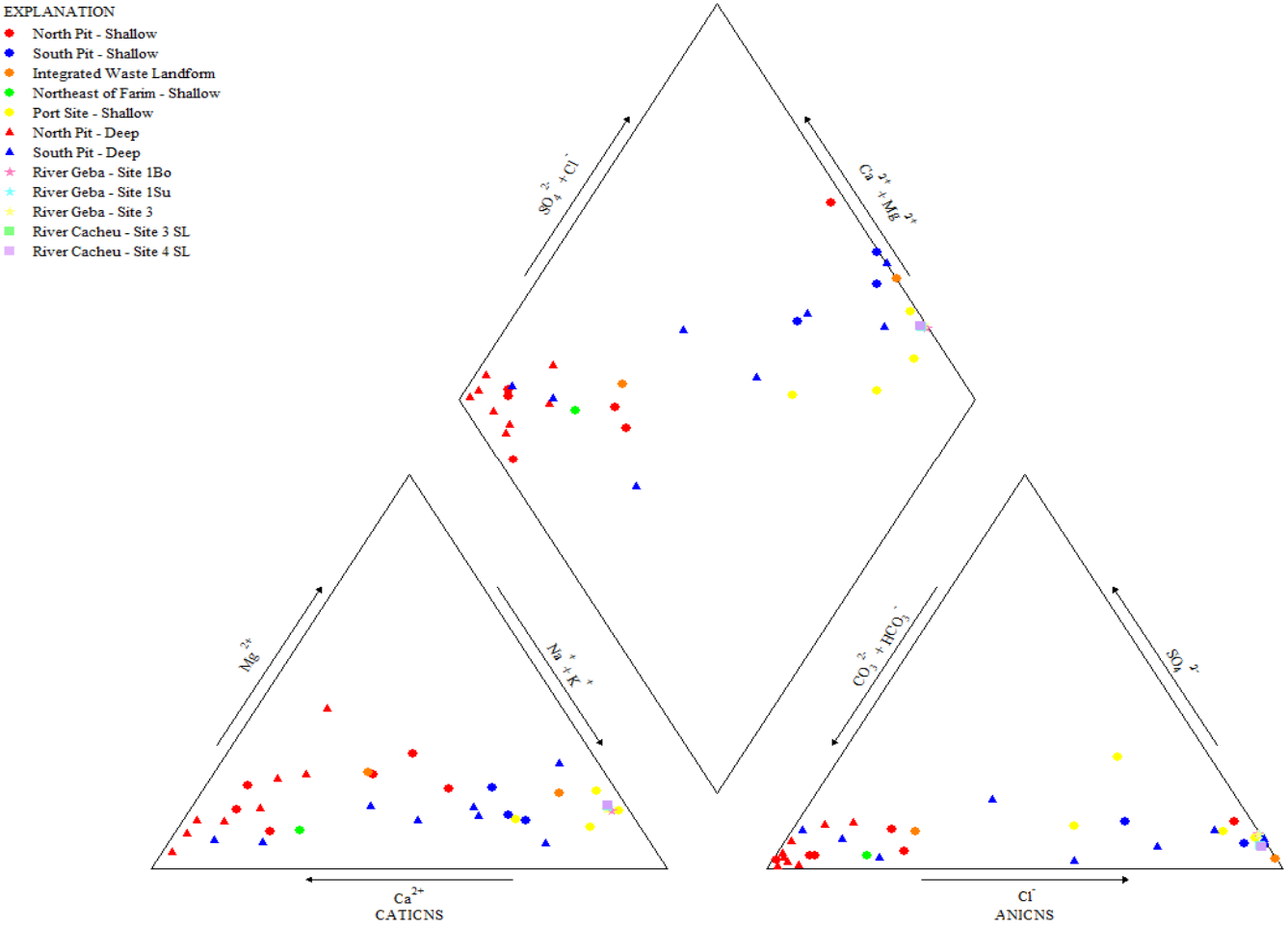
Physical Parameters

Groundwater was observed to be near neutral with field pH measurements ranging from 6.49 to 7.64. The pH of the sample obtained from BHPT07 (6.49) was outside of the lower limit for both the CEQG-PAL values for marine (7.0 to 8.7) and freshwater (6.5 to 9.0). The samples were high in total suspended solids (TSS).

Major Ions

The groundwater anions and cations are presented graphically on a Piper plot (Figure 3). Based on the data presented in the Piper plot, the Port Site groundwater is classified as Na-Cl type water typical of marine ground waters. Samples obtained from wells BHPT02 and BHPT04 are less influenced by salt water intrusion (i.e., the brackish waters of the River Geba) and suggest greater surface recharge of freshwater.

Each well exceeded the CEQG-PAL freshwater criterion for chloride, which is applicable to freshwater environments and not applicable to discharges to the brackish waters of the River Geba (Golder, 2014). There is no health-based drinking water criterion for chloride, but water starts to taste salty at chloride concentrations >250 mg/L to those not accustomed to such chloride levels (WHO, 2011).



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FARIM PHOSPHATE PROJECT

ALL SAMPLES
GROUNDWATER QUALITY PIPER PLOT

Knight Piésold CONSULTING

P/A NO.	REF. NO.
NB301-520/2	NB15-00175

FIGURE 3 REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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Dissolved Metals

In general, baseline dissolved metal concentrations were within guideline limits in Port Site groundwater samples. Several metals had concentration below MDLs including:

- Bismuth
- Cadmium
- Mercury
- Thallium
- Titanium
- Vanadium

Table 2 summarizes the parameters with exceedances of one or more of the selected guidelines.

Table 2 Port Site Groundwater Quality Results Summary

						Sample ID	**BHPT02**	**BHPT03**	**BHPT04**	**BHPT07**
						Sample Date	**12/05/2015**	**09/05/2015**	**09/05/2015**	**09/05/2015**
						Well Depth (m)	**35**	**19.5**	**20**	**27**
Groundwater Quality Guidelines	**IFC Mine Effluent Guidelines**	**WHO DW Standards**	**CEQG PAL (Marine)**	**CEQG PAL (FW)**	**UNITS**	**MDL(1)**	**Stiff moist black grey sandy CLAY with white sand laminations**	**Very dense homogenous grey brown clayey SAND**	**Very dense yellow brown mottled red fine SAND**	**Dense homogenous grey mottled brown clayey fine SAND**
TSS	50				mg/L	1	114	2270	56	118
pH	6 to 9		7.0 to 8.7	6.5 to 9.0			7.06	7.01	7.64	**6.49**
Chloride		250		120	mg/L	1	***402***	***6910***	***436***	***21700***
Boron		2400		1500	µg/L	10	367	1060	***3090***	***2550***
Copper	300	2000		4	µg/L	1	<1.0	**12.90**	1.30	2.60
Iron	2000			300	µg/L	2.0	90.2	<2.0	**3000**	158
Lead	200	10		1 to 7	µg/L	0.05	1.80	<0.050	***644***	<0.050
Manganese		400			µg/L	0.1	*736*	168	248	*1110*
Sulphate		250			mg/L	0.06	110	*1050*	*313*	*2520*
Selenium		40		1	µg/L	0.2	<0.200	**2.50**	<0.200	0.30
Silver				0.1	µg/L	1	**<1.0**	**<1.0**	**<1.0**	**2.50**
Sodium		200			mg/L	0.03	*293*	*4700*	*411*	*10200*
Turbidity		5			NTU	0.1	*10.90*	*1670.00*	*34.70*	*77.70*

NOTES:

1. METHOD DETECTION LIMIT (MDL), DRINKING WATER (DW), FRESH WATER (FW).
2. SHADED RESULTS INDICATE VALUES GREATER THAN THE CEQG-PAL MARINE GIDELINES.
3. UNDERLINED RESULTS INDICATE VALUES GREATER THAN THE IFC MINE EFFLUENT GUIDELINES.
4. ITALICIZED RESULTS INDICATE VALUES GREATER THAN THE WHO DRINKING WATER STANDARDS.
5. BOLDED RESULTS INDICATE VALUES GREATER THAN THE CEQG-PAL FRESHWATER GUIDELINES.
6. MDL FOR SILVER (1.0 µg/L) WAS ABOVE THE CEQG-PAL FOR FRESHWATER GUIDELINE (0.1 µg/L).

3.3 MINE SITE GROUNDWATER QUALITY

Three discrete hydrostratigraphic units have been identified based on our understanding of the site stratigraphy at the Mine Site in the area of the deposit as follows (KP, 2015):

- An overburden layer comprising sands, clays and gravels that extends past the deposit boundaries. This unit can be considered an unconfined aquifer and is assumed to be in hydraulic connection with the River (Rio) Cacheu. This unit contains a discontinuous horizon of blue clay that wedges out towards the River Cacheu.
- The ore body, consisting of three horizons as follows: economic phosphate bed (FPA); the FPB which underlies the FPA and is of less economic interest due to the lower phosphate and high limestone content; and the FPO which is a clayey dolomitic limestone layer that is weakly phosphatic.
- An underlying calcareous layer (limestone) that also extends beyond the deposit boundaries.

The Mine Site stratigraphy in the vicinity of the deposit is summarized in Table 3.

Table 3 Site Stratigraphy

Age	Unit	Description	Thickness (m)
Post Eocene	Sandy/Argillaceous Overburden	Alternating sandy, clayey and sandy clayey layers	27 to 58
	Basal Clay Overburden	Blue/green soft clay and black lignitic clay (anoxic depositional environment)	
Eocene	Sand including FPO (phosphatic interval)	Grey/white fine grained sand including phosphate bearing clayey dolomitic limestone (FPO)	7 (single intercept)
	Upper Dolomitic Limestone	Clayey limestone	>2[1] (single intercept)
	Decarbonised Phosphate Unit (FPA)	Ore zone comprising beige to brown, poorly cemented very fine grained phosphatic sand.	1 to 11
	Calcareous Phosphate Unit (FPB)	Cemented phosphatic limestone	2 to 8
	Limestone	Soft, white and porous limestone	>6 to 17[1]

NOTES:
1. [1] BASE OF UNIT NOT ENCOUNTERED.
2. SOURCE: LYCOPODIUM, 2015.

Groundwater will supply potable and domestic water at the Mine Site and contribute to process water and other associated mining activities (e.g., truck washing). Pit dewatering activities will produce large volumes of water, which will be discharged to the River Cacheu.

Groundwater quality results from the sampling of the Mine Site monitoring wells were compared to IFC Mine Effluent Guidelines, WHO Drinking Water Guidelines and the CEQG-PALs (freshwater and marine) and are presented in Appendix C, Table C.2. Due to the variability of groundwater quality at the Mine Site, the results

have been separated and discussed by facility and depth below ground surface. The variability in groundwater quality at the Mine Site is evident by examining the Piper plot presented as Figure 3.

3.3.1 South Pit

Shallow (overburden) and deep (bedrock) wells were sampled within the limits of the proposed south pit. The water quality results are discussed below.

3.3.1.1 Shallow Wells

The dataset consists of nine (9) samples collected from five (5) shallow wells located within the south pit area (Appendix C, Table C.2). Samples were collected in the dry and wet seasons; however, the majority of the samples (7 out of 9) were obtained during the dry season. Of the nine (9) samples obtained, five (5) were analysed for a full suite of parameters. The other samples were analyzed for only a truncated suite of parameters. The wells range in depth from between 26 m and 30 m below ground surface, except KP-PS-BH01 which is 4.43 m below ground surface.

Physical Parameters

In general, shallow groundwater was observed to be weakly acidic. Field pH measurements range from 4.92 to 6.02, which are below the acceptable ranges of the IFC Mine Effluent Guideline (6 to 9) and both the CEQG-PAL values for marine (7.0 to 8.7) and freshwater (6.5 to 9.0). Total dissolved solids (TDS) concentrations ranged from 13 to 8,530 mg/L. Hardness expressed as calcium carbonate - $CaCO_3$ ranged from 4.75 mg/L to 2,220 mg $CaCO_3$/L, with elevated hardness values (2,220 mg$CaCO_3$/L in KP-SGW-BH02 and 478 mg$CaCO_3$/L in MW02B-S) arising from high concentrations of cations other than calcium and magnesium (aluminum, iron, manganese, and sodium). WHO (non-health based) exceedances were observed for total dissolved solids, sulphate and turbidity.

Major Ions

Piper plots were created to visualize the major ion geochemistry and trends within the data set (Figures 4 and 5). Observations from the Piper plots indicate that shallow groundwater within the south pit ranges from Na-Cl type waters in the more frequently sampled dry season. Two data points are on the Piper plots for the wet season - one (MW01B) exhibits Ca/Mg-HCO_3 waters likely from rainfall infiltration, with the other showing increased chloride influence possibly from river influence to groundwater or surface flooding. Chloride concentrations ranged from 3.3 to 4,140 mg/L in well KP-SGW-BH02, which is located in close proximity to the River Cacheu. Chloride concentrations were above the CEQG-PAL freshwater (120 mg/L) and WHO (non-health based, 250 mg/L) objectives in four (4) of the samples. Concentrations of sodium, the dominant cation, ranged from 2.5 to 1,910 mg/L, while calcium concentrations ranged from 1.26 to 197 mg/L. WHO (non-health based) drinking water recommendations for sodium (four (4) samples) and sulphate (one (1) sample) were exceeded.

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits. Several metals had concentrations below MDLs including:

- Bismuth
- Mercury
- Molybdenum
- Selenium
- Thallium
- Titanium
- Uranium
- Vanadium

The following guideline exceedances were observed in the south pit shallow wells:

- **Arsenic** - Exceeded the WHO drinking water standard, CEQG-PAL freshwater and marine guideline limits in well MW02B(S).
- **Manganese** - Exceeded the WHO health based standard in wells KP-SGW-BH02 and MW02B(S).

- **Cadmium** - Exceeded the IFC effluent guideline and CEQG-PAL freshwater and marine guideline limits in wells MW01B(S) and MW02B(S).
- **Iron** - Exceeded IFC effluent guidelines and CEQG-PAL freshwater guidelines in wells KP-SGW-BH02 and MW02B(S), as well as CEQG-PAL freshwater guideline in well MW02B(S).
- **Copper** - Exceeded CEQG-PAL freshwater guideline in well MW02B(S) in a wet and dry season sample and MW06(S) in wet season samples.
- **Aluminum** - Exceeded the CEQG-PAL freshwater guidelines in wells MW01B(S) and MW02B(S).
- **Lead** - Exceeded the CEQG-PAL freshwater guideline in well MW01B(S).
- **Nickel** - Exceeded the CEQG-PAL freshwater guideline in well MW02B(S).
- **Silver** - Exceeded the CEQG-PAL freshwater guideline in well KP-PS-BH01. Note that the MDL for silver (1 µg/L) exceeded the CEQG-PAL freshwater guideline of 0.1 µg/L.
- **Mercury** - The 2012 MDL for mercury only exceeded the CEQG-PAL freshwater and marine guideline limits.
- **Zinc** - Exceeded the CEQG-PAL freshwater guidelines in wells MW02B(S) and MW06(S).

3.3.1.2 Deep Wells

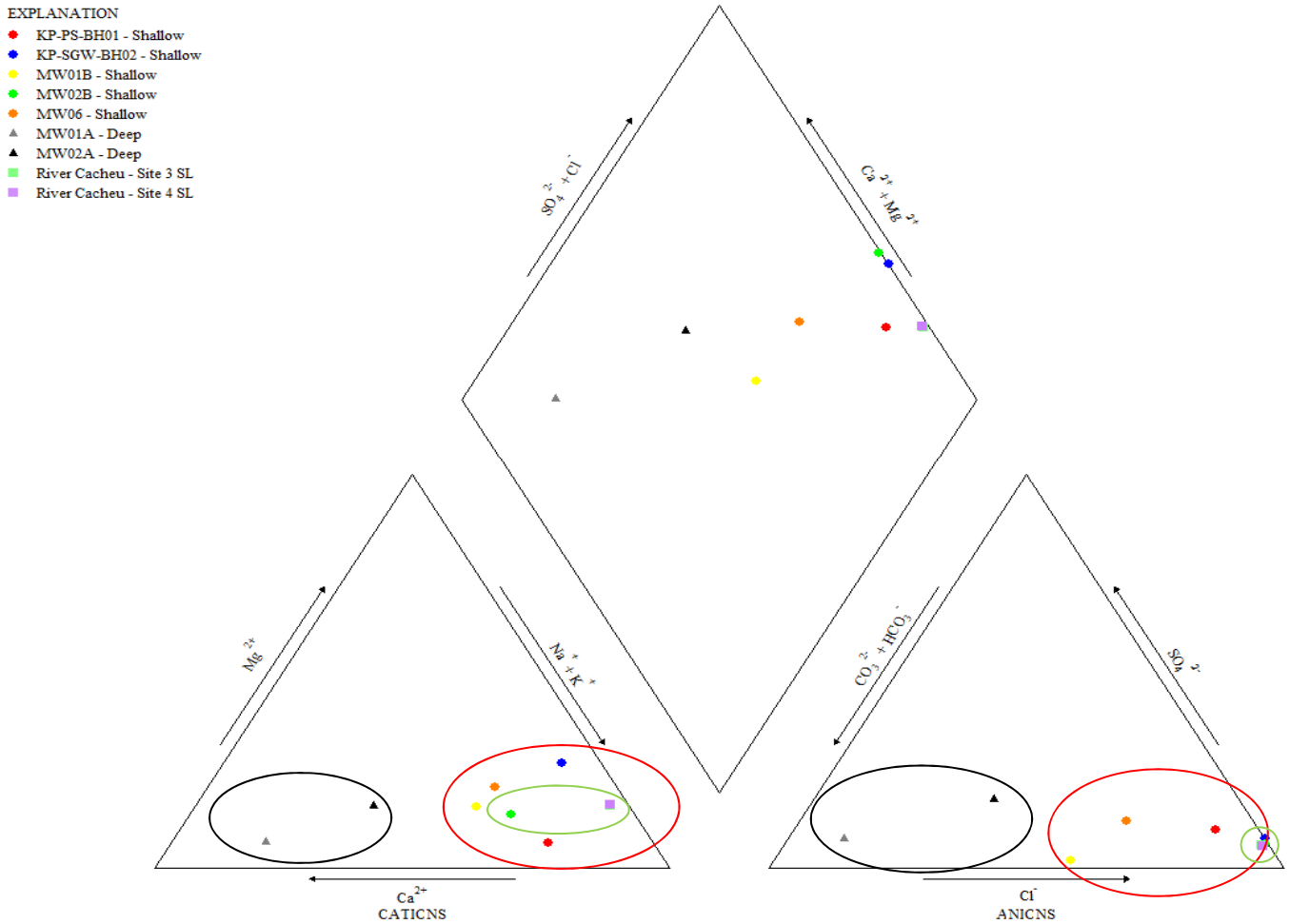
Within the south pit area, the groundwater quality dataset consists of eight (8) samples collected from four (4) deep wells (Appendix C, Table C.2). Samples were collected in the dry and wet seasons; however, the majority of the samples (6 out of 8) were obtained during the dry season. Of the eight (8) samples obtained two (2) were analysed for the full suite of parameters the other samples were analyzed for a truncated suite of parameters. The wells range in depth from between 48 m and 58 m below ground level. All of the wells were screened within the limestone unit.

Physical Parameters

In general, the deep groundwater was observed to be near neutral. Field pH measurements ranged from 6.65 to 7.07. One pH measurement was below the lower CEQG-PAL marine guideline limit (7.0 to 8.7). TDS concentrations ranged from <10 to 1,362 mg/L. Two results for calcium carbonate expressed hardness of 215 and 350 mg $CaCO_3$/L roughly matched the corresponding alkalinity values (220 and 334 mg $CaCO_3$/L) suggesting the hardness is derived from calcium and magnesium carbonates (the limestone). WHO (non-health based) exceedances were observed for TDS and turbidity.

Major Ions

Observations from limited data presented in the Piper plots (Figures 4 and 5) indicate that deep groundwater within the south pit represents Ca/Mg-HCO_3 type waters in the dry season and possibly less so in the wet season. Chloride concentrations ranged from 2.5 to a maximum of 571.9 mg/L in well MW02A, which is the shallowest of the deep wells. Chloride concentrations were above the WHO (non-health based) drinking water quality standard in well MW02A(D) and the CEQG-PAL freshwater guideline limit in wells MW02A and PW1. Concentrations of sodium, the dominant cation, ranged from 2.6 to 276 mg/L, while calcium concentrations ranged from 2.3 to 127.5 mg/L. A single WHO (non-health based) exceedance was observed for sodium in well MW02A.



Shallow Wells

Deep Wells

River Cacheu (Surface Water)

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07AUG'15	ISSUED WITH MEMO	SMA	RAC

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

SOUTH PIT GROUNDWATER PIPER PLOTS
DRY SEASON

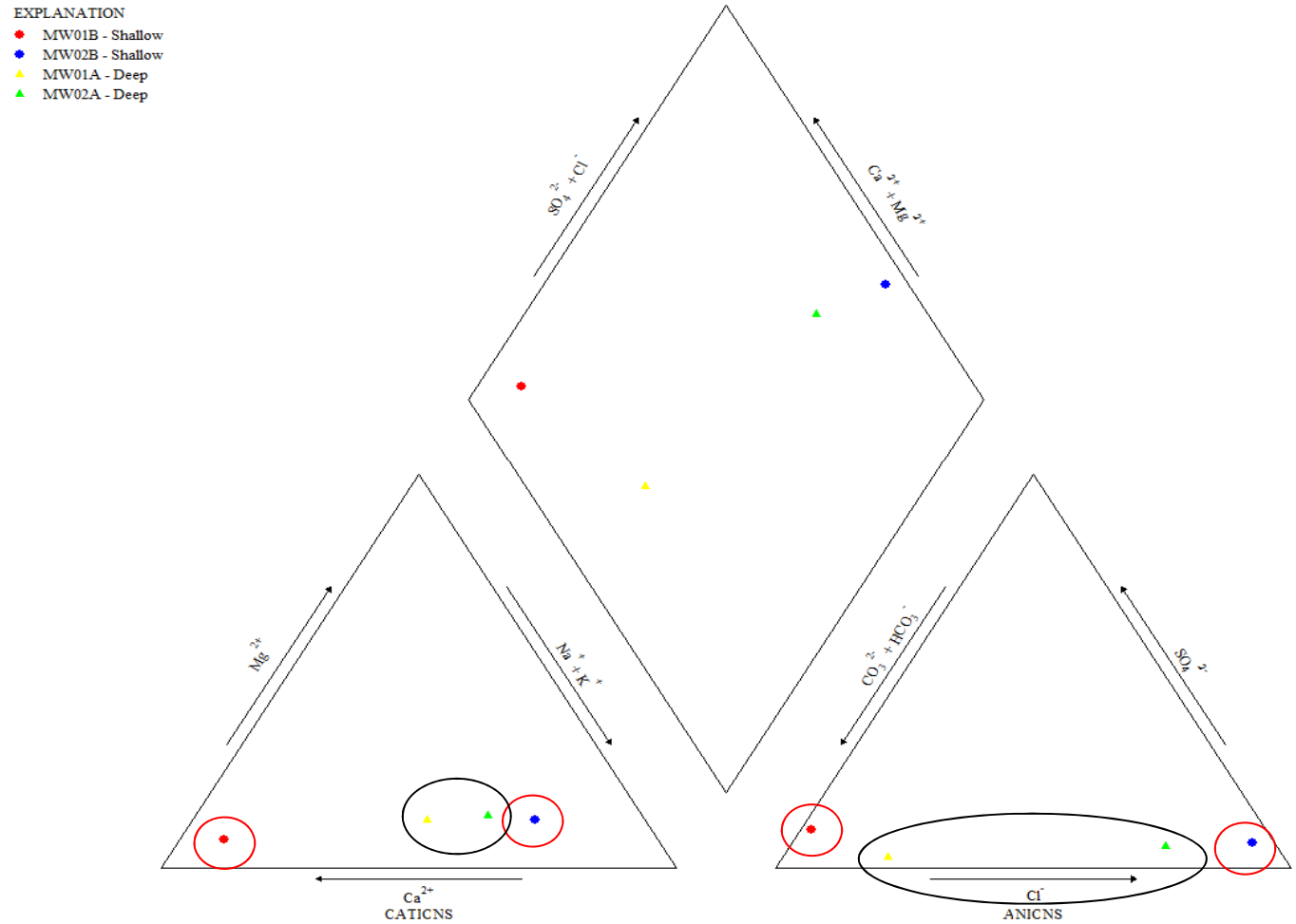
Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF. NO. NB15-00175

FIGURE 4

REV 0



Shallow Wells

Deep Wells

0	07AUG'15	ISSUED WITH MEMO	SMA	RAC
REV	DATE	DESCRIPTION	PREP'D	RVW'D

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

SOUTH PIT GROUNDWATER PIPER PLOTS
WET SEASON

Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF. NO. NB15-00175

FIGURE 5

REV 0

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits. Several metals had concentrations below MDLs including:

- Antimony
- Beryllium
- Bismuth
- Mercury
- Molybdenum
- Selenium
- Silver
- Thallium
- Titanium
- Uranium
- Vanadium
- Zinc

The following guideline exceedances were observed in the south pit deep wells:

- **Manganese** - Exceeded the WHO health based standard in wells MW01A(D) and PW1.
- **Cadmium** - Exceeded IFC effluent guideline and CEQG-PAL freshwater and marine guideline limits in well MW02A(D).
- **Iron** - Exceeded IFC effluent guidelines and CEQG-PAL freshwater guidelines in well MW02A(D).
- **Copper** - Exceeded the CEQG-PAL freshwater guidelines in well MW01A(D), note that the 2011 and early 2012 MDL for copper (50 µg/L) exceeded the hardness dependent CEQG-PAL freshwater guideline of 2 to 4 µg/L.
- **Lead** - Exceeded the CEQG-PAL freshwater guideline in well MW02A(D).
- **Silver** - The MDL for silver (1 µg/L) exceeded the CEQG-PAL freshwater guideline of 0.1 µg/L.
- **Mercury** - The 2012 MDL for mercury exceeded the CEQG-PAL freshwater and marine guideline limits.
- **Zinc** - Exceeded the CEQG-PAL freshwater guidelines in well PW1.

3.3.2 North Pit

Shallow (overburden) and deep (bedrock) wells were sampled within the limits of the proposed north pit. The water quality results are discussed below.

3.3.2.1 Shallow Wells

The dataset consists of eight (8) samples collected from six (6) shallow wells located within the north pit area (Appendix C, Table C.2). Samples were collected in the dry and wet seasons; however, the majority of the samples (7 out of 8) were obtained during the dry season. Of the eight (8) samples obtained five (5) were analysed for a full suite of parameters, while the other samples were analyzed for a truncated suite of parameters. The wells range in depth from between 24 m and 35 m below ground level and were screened within the overburden unit.

Physical Parameters

In general, shallow groundwater was observed to be weakly acidic. Field pH measurements ranged from 5.16 to 6.67, which are consistently below the acceptable ranges of the IFC mine effluent guideline (6 to 9) and both the CEQG-PAL values for marine (7.0 to 8.7) and freshwater (6.5 to 9.0). Total dissolved solids (TDS) concentrations ranged from <10 to 440 mg/L. Hardness expressed as calcium carbonate - $CaCO_3$ ranged from 9.00 to 213 mg $CaCO_3$/L, within similar corresponding alkalinity values, suggesting the hardness is derived from calcium and magnesium carbonates (the limestone). WHO (non-health based) drinking water standards were exceeded for TDS and turbidity.

Major Ions

Piper plots were created to visualize the major ion geochemistry and trends within the data set (Figures 6 and 7). Observations from the Piper plots indicate that shallow groundwater within the north pit are Ca-HCO_3 type waters, with little change in the concentration of major ions between seasons. Chloride concentrations ranged

from 1.43 to 35.5 mg/L. Concentrations of sodium ranged from 1.0 to 21.20 mg/L, while calcium concentrations ranged from 1.96 to 75.4 mg/L.

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits. Several metals had concentrations below MDLs including:

- Beryllium
- Bismuth
- Mercury
- Molybdenum
- Selenium
- Silver
- Thallium
- Tin
- Titanium
- Uranium
- Vanadium

The following guideline exceedances were observed in the north pit shallow wells:

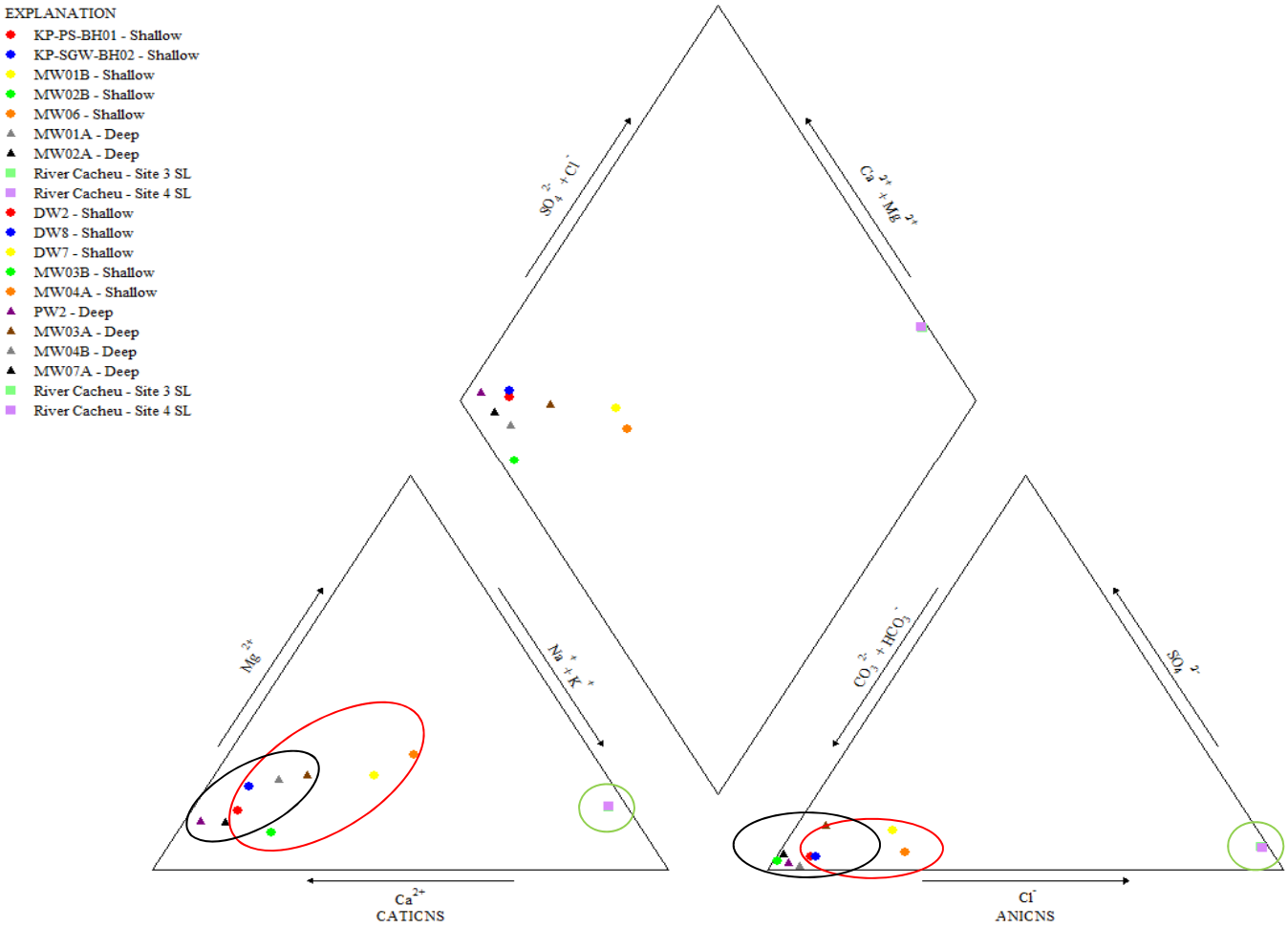
- **Manganese** - Exceeded the WHO drinking water standard in well MW07B(S).
- **Cadmium** - Exceeded IFC effluent guideline and CEQG-PAL freshwater and marine guideline limits in well MW04A(S).
- **Iron** - Exceeded the CEQG-PAL freshwater guidelines in well MW05A(S).
- **Lead** - Exceeded the CEQG-PAL freshwater guidelines in well MW04A(S).
- **Mercury** - The 2012 MDL for mercury exceeded the CEQG-PAL freshwater and marine guideline limits.
- **Silver** - The MDL for silver (1 µg/L) exceeded the CEQG-PAL freshwater guideline (0.1 µg/L).

3.3.2.2 Deep Wells

The dataset consists of eleven (11) samples collected from four (4) deep wells located within the north pit area (Appendix C, Table C.2). Samples were collected in the dry and wet seasons; however, the majority of the samples (8 out of 11) were obtained during the dry season. Of the eleven (11) samples obtained four (4) were analysed for a full suite of parameters, while the other samples were analyzed for a truncated suite of parameters. The wells range in depth from between 55 m and 73 m below ground level. The wells were installed within the limestone unit, except well PW2, which has the upper screen within the deposit unit and the lower screen within the limestone unit.

Physical Parameters

In general, the deep groundwater was observed to be neutral to weakly acidic. Field pH measurements ranged from 5.26 to 7.12. Two pH measurements were below the lower CEQG-PAL marine and freshwater guideline limits of 7.0 and 6.5, respectively. TDS concentrations ranged from 22 to 510 mg/L. Hardness expressed as calcium carbonate - $CaCO_3$ ranged from 23.8 to 298 mg $CaCO_3$/L, within similar corresponding alkalinity values, suggesting the hardness is derived from calcium and magnesium carbonates (the limestone). The WHO (non-health based) drinking water standard was exceeded for turbidity. Concentrations of TSS exceeded the IFC mine effluent guidelines in two of the samples.



Shallow Wells

Deep Wells

River Cacheu (Surface Water)

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07AUG'15	ISSUED WITH MEMO	SMA	RAC

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

NORTH PIT GROUNDWATER PIPER PLOT
DRY SEASON

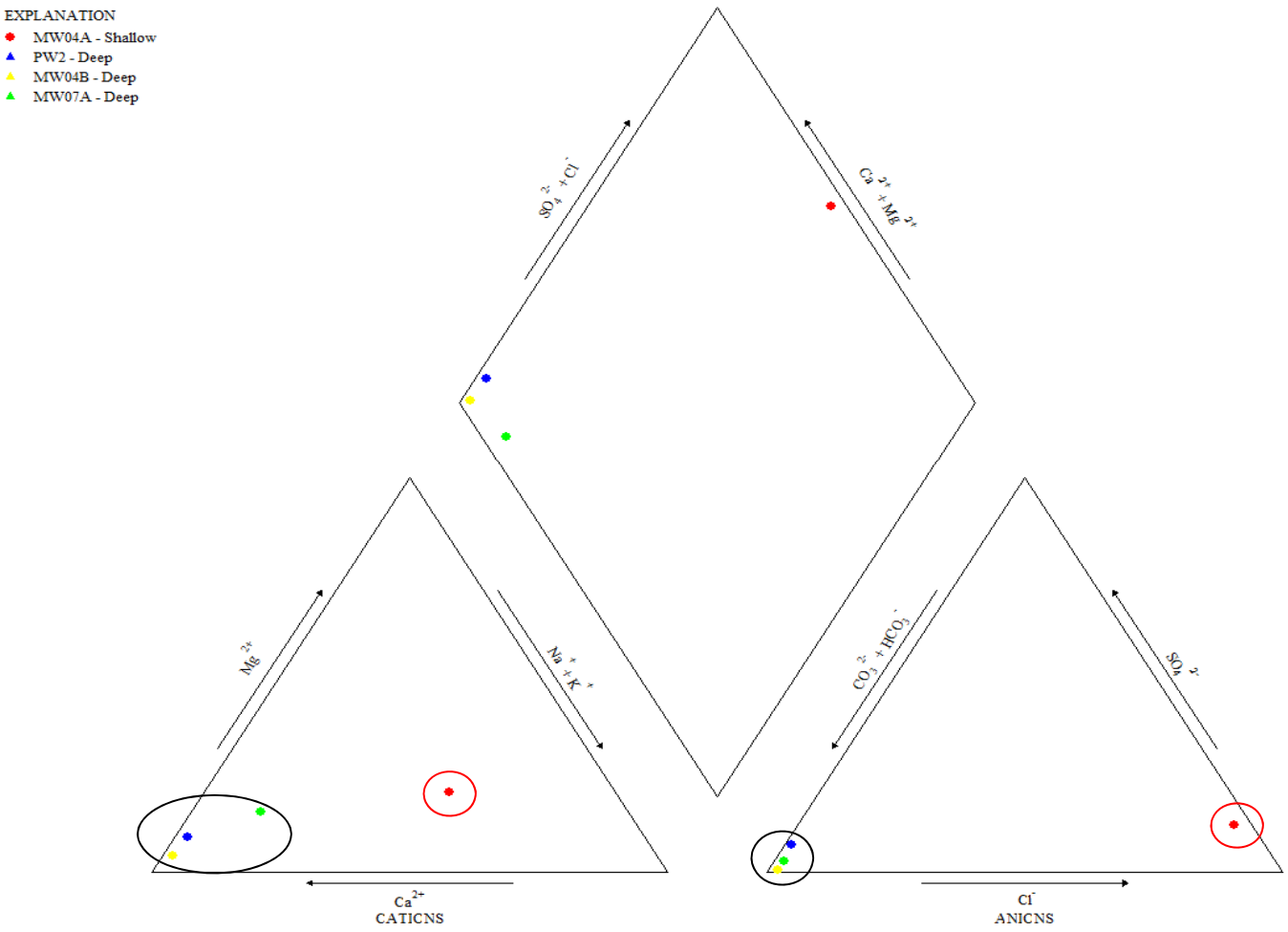
Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF. NO. NB15-00175

FIGURE 6

REV 0



Shallow Well

Deep Wells

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

NORTH PIT GROUNDWATER PIPER PLOT
WET SEASON

Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF. NO. NB15-00175

FIGURE 7

REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07AUG'15	ISSUED WITH MEMO	SMA	RAC

Major Ions

Observations from the Piper plots (Figures 6 and 7) indicate that deep groundwater within the north pit are Ca-HCO_3 type waters. This suggests that the deep and shallow groundwater are similar within the north pit and are not influenced by the River Cacheu. Chloride concentrations ranged from 1.02 to 53.25 mg/L. Concentrations of sodium ranged from 1.11 to 26.70 mg/L, while calcium concentrations ranged from 6.98 to 98.6 mg/L.

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits. Several metals had concentrations below MDLs including:

- Beryllium
- Bismuth
- Copper
- Mercury
- Molybdenum
- Selenium
- Silver
- Thallium
- Tin
- Titanium
- Vanadium

The following guideline exceedances were observed in the north pit deep wells:

- **Manganese** - Exceeded the WHO drinking water standard in well MW04B(D) and MW07A(D).
- **Cadmium** - Exceeded the IFC effluent guideline in PW2 and the IFC effluent guideline and CEQG-PAL freshwater guideline in wells MW04B(D), MW07A(D) and PW2 in the wet season samples.
- **Iron** - Exceeded the IFC effluent guideline and CEQG-PAL freshwater guideline in wells MW07A(D) and PW2.
- **Copper** - The 2011 MDL for copper (50 µg/L) exceeded the hardness dependent CEQG-PAL freshwater guideline of 2 to 4 µg/L.
- **Aluminum** - Exceeded the CEQG-PAL freshwater guideline in well MW04B(D).
- **Lead** - Exceeded the CEQG-PAL freshwater guidelines in well MW07A(D).
- **Silver** - The MDL for silver (1 µg/L) exceeded the CEQG-PAL freshwater guideline of 0.1 µg/L.
- **Mercury** - The 2012 MDL for mercury exceeded the CEQG-PAL freshwater and marine guideline limits.
- **Zinc** - Exceeded the CEQG-PAL freshwater guideline in well PW2.

3.3.3 IWL Area

Two shallow (overburden) wells were sampled within the limits of the proposed IWL (Appendix C, Table C.2). Samples were collected in the dry season and were analysed for the full suite of parameters. The wells were installed to a depth of 30 m below ground level and screened within the overburden unit.

Physical Parameters

In general, groundwater was observed to be weakly acidic. Field pH measurements were 5.01 and 5.98, which are below the acceptable ranges of the IFC mine effluent guideline (6 to 9) and both the CEQG-PAL values for marine (7.0 to 8.7) and freshwater (6.5 to 9.0). Total dissolved solids (TDS) concentrations ranged from 268 to 3190 mg/L. Hardness (as calcium carbonate - $CaCO_3$) ranged from 88.6 to 751 mg $CaCO_3$/L, with hardness values in most instances well above the corresponding alkalinity values indicating cations other than calcium and magnesium contributing to hardness. Total suspended solids exceeded the IFC effluent guideline limit of 50 mg/L in both samples. WHO (non-health based) drinking water standards were exceeded for TDS and turbidity.

Major Ions

A Piper plot was created to visualize the major ion geochemistry and trends within the data set (Figure 3). Observations from the Piper plot indicate that shallow groundwater ranges from Na-Cl type waters to Ca-HCO_3

waters. This suggests that the groundwater at KP-TMF/OB-BH03 is influenced by the brackish waters of the Rio de Caur, which is tidally influenced. Chloride concentrations were 19.7 in KP-TMF/OB-BH02 and 1,710 mg/L in well KP-TMF/OB-BH03, which exceeded the CEQG-PAL freshwater limit of 120 mg/L and the WHO (non-health based) standard of 250 mg/L. Sodium was also above the WHO (non-health based) standard in KP-TMF/OB-BH03.

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits; no exceedances were observed in KP-TMF/OB-BH02. Several metals had concentrations below MDLs including:

- Antimony
- Bismuth
- Mercury
- Molybdenum
- Silver
- Thallium
- Tin
- Titanium
- Vanadium

Aluminum, barium, lead, manganese and nickel exceeded their respective WHO drinking water standards in well KP-TMF/OB-BH03. In addition, the following metals exceeded the CEQG-PAL freshwater guidelines in KP-TMF/OB-BH03:

- Aluminium
- Copper
- Iron
- Lead
- Nickel
- The MDL for silver (1 µg/L) exceeded the CEQG-PAL freshwater guideline (0.1 µg/L)
- Zinc

3.3.4 Worker Camp (Northeast of Farim)

Shallow (overburden) and deep (bedrock) wells were sampled near the proposed worker camp. The groundwater quality results are discussed below.

3.3.4.1 Shallow Wells

Samples were obtained from well MW05A(S) located near the proposed worker camp (northeast of Farim) (Appendix C, Table C.2). Samples were collected in the wet and dry seasons and were analysed for a truncated suite of parameters. The well was installed to a depth of 37 m below ground level and screened within the overburden unit.

Physical Parameters

Field pH measurements are not available. TDS concentrations ranged from <10 to 24 mg/L.

Major Ions

A Piper plot was created to visualize the major ion geochemistry and trends within the data set (Figure 3). A single observation point on the Piper plot indicates that groundwater within the shallow hydrostatic unit is Ca-HCO_3 type. Chloride concentrations were measured at 3.4 and 35.50 mg/L. Concentrations of calcium were measured at 5.6 and 20 mg/L and sodium at 2.1 and 3.6 mg/L.

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits. Cadmium and iron were the only exceedances observed in the data set. Cadmium exceeded the CEQG-PAL freshwater and marine guideline limits in the wet season sample. Iron was in exceedance of the CEQG-PAL freshwater limit in both samples.

The MDL for copper (50 µg/L) exceeded the hardness dependent CEQG-PAL freshwater guideline of 2 to 4 µg/L.

3.3.4.2 Deep Wells

The dataset consists of three (3) samples collected from one (1) well MW05B(D) (Appendix C, Table C.2). Samples were collected in the dry and wet seasons (2 dry, 1 wet). The samples were analyzed for a truncated suite of parameters. The well has a depth of 66 m and was screened within the overburden unit.

Physical Parameters

Field pH measurements are not available. TDS concentrations ranged from 86 to 100 mg/L.

Major Ions

A single observation point on the Piper plot (Figure 3) indicates that shallow groundwater is Ca-HCO_3 type water. Chloride concentrations were measured between 7.00 and 177.50 mg/L, which is in exceedance of the CEQG-PAL limit of 120 mg/L. Concentrations of calcium ranged from 13.9 to 24 mg/L and sodium between 2.7 and 3.9 mg/L.

Dissolved Metals

In general baseline dissolved metal concentrations were within guideline limits. Cadmium, iron, lead and manganese were the only metal exceedances observed in the data set.

- Cadmium - Exceeded the CEQG-PAL freshwater and marine guideline limits in wet season sample.
- Iron - Was in exceedance of the CEQG-PAL freshwater and IFC mine effluent guideline limits in two of the samples.
- Lead - Exceeded the CEQG-PAL freshwater limit in one sample.
- Copper - The MDL for copper (50 µg/L) exceeded the hardness dependent CEQG-PAL freshwater guideline of 2 to 4 µg/L. Manganese exceeded the WHO drinking water standard of 400 µg/L.

4 – QA/QC

4.1 QUALITY CONTROL SAMPLES

One duplicate groundwater sample was taken at each of the Mine and Port sites. Analytical results obtained for the two samples were flagged if the relative percent difference (RPD) was greater than 20% and the measured concentrations were greater than five times the MDL. The RPD is the absolute difference in concentrations of the two duplicate samples divided by the average of the two values. Flagged results were further reviewed to determine whether the high RPD was a result of naturally variable conditions, sampling error or other confounding factors. If the latter cases were suspected, the result in question may be rejected. If the high RPD is most likely a result of natural variability, then the data are flagged for discussion, but are not rejected. A complete list of the QA/QC groundwater quality results are presented in Appendix C, Table C.3.

There were a number of differences greater than 25% and at concentrations greater than 5 times the MDL noted between the initial and duplicate samples. These differences are likely partially attributed the extended time between sampling and laboratory analysis where sample refrigeration may not have been continuous (e.g., nutrients and general parameters). Differences noted for some metals (e.g., As, Cu, Mn, Ni, and Sb), which were between 30% and 62% RPD, may be attributed to natural variation and the timing between samples (i.e., differences in purged volumes). The copper concentrations were the only values above quality criteria and were more than double the CEQG-PAL freshwater guideline. No results were rejected from the data set.

4.2 DATA MANAGEMENT AND QUALITY

Delays in sample shipment from Guinea-Bissau, as well as, delays in customs clearance resulted in the groundwater samples arriving at ALS on June 15, 2015. As such, ALS recommended holding times for water, based on International Standards Organisation (ISO) Standard 5667-3 (ISO, 2012), were exceeded for pH,

phenols, phosphorus, sodium, solids, turbidity, and most metals. The majority of metals have a one month recommended storage time, except for lead, mercury, nickel and zinc, which have six month recommended holding times. Additionally, all of the samples were stored at room temperature while in-transit, which is above the recommended temperature of 4°C. The data with hold time and temperature exceedances were flagged and assessed for validity. Due to the lack of data to compare the results against, none of the results were rejected from the data set; however, the results will remain flagged and will continue to be reviewed as additional data is gathered.

5 – SUMMARY

Four groundwater monitoring wells at the Port Site area were sampled in May 2015. No previous sampling was conducted at the Port Site. Elevated baseline metal concentrations were identified in three wells (BHPT03, 04 and 07). BHPT02 is the best candidate for a potable water source for the port site facility; however, it will still require treatment and may receive minor influence from the brackish waters of the River Geba. Borehole logs contained in Golder (2013) do not provide well installation details (i.e., screened interval) but BHPT02 is the deepest of the four wells sampled (35 m depth compared with a range of 19.5 to 27 m depth). No bacteriological analyses were completed. If this well or another well installed in this area and depth, is to be used as the potable water source for the Port Site, follow-up sampling is recommended to confirm groundwater quality over time.

Groundwater sampling at the Mine Site occurred in 2011, 2012, 2013 and 2015. The wells were distributed within the various facility footprints (i.e., North Pit, South Pit and IWL) to characterize baseline conditions and differences among the areas. The South Pit wells MW02A (deep) and MW02B (shallow), as well as the IWL well KPTMFBH03 had the most water quality criteria exceedances. Dewatering or water taking from these areas will likely produce water with elevated metal concentrations (e.g., Cu, Fe, Pb, Ni, and Zn). Chloride concentrations from several wells (KP-PS-BH01, KP-SGW-BH02, MW02A&B, and PW1) in the south pit area were above the WHO aesthetic (taste) standard (250 mg/L). As such, these areas should be avoided for potable water withdrawal.

In general, most wells produced water with low pH values. Deep well MW01A located east of the South Pit boundary shows the best water quality in regard to drinking water standards and would likely be a suitable potable water source based on the sample results. Alternatively, the shallow DW-series wells located in the North Pit also had good water quality and would likely produce suitable quality potable water.

Groundwater quality within the deep and shallow overburden unit at the proposed worker camp (northeast of Farim) showed acceptable drinking water quality within the shallow and deep samples collected. Generally, concentrations of TDS and dissolved metals were observed to increase with depth. That being said, most of parameters analyzed met the applicable WHO drinking water standards, the exception being manganese.

6 – REFERENCES

Canadian Council of Ministers of the Environment (CCME), 2015. *Canadian Environmental Quality Guidelines (CEQGs) for the Protection of Marin and Freshwater Aquatic Life (PAL)*.

Golder Associates (UK) Ltd. (Golder), 2014. *Mine Component Environmental and Social Impact Assessment*. Volumes 1 to 5. Prepared for GB Minerals Ltd. March.

Golder Associates (UK) Ltd. (Golder), 2013. *2012 Ground Characterization - Factual Report.* Farim Phosphate Project. Guinea Bissau. Prepared for GB Minerals Ltd. October.

International Finance Corporation (IFC), 2007. *Environmental, Health and Safety Guidelines for Mining*.

International Standards Organisation, 2012. *International Standard ISO 5667-3, Water Quality - Sampling - Part 3: Preservation and Handling of Water Samples.* ISO Reference No. ISD 5667-3: 2012 (E), Copyright ISO 2012.

Knight Piésold Ltd. (KP), 2015. Groundwater Modelling: Pit Inflow and Dewatering Impact Estimation. Prepared for Lycopodium Minerals Canada Ltd. July.

Lycopodium Minerals Canada Ltd. (Lycopdium), 2015. *Farim Phosphate Project –Definitive Feasibility Study*. In Progress.

World Health Organization (WHO), 2011. *Guidelines for Drinking-Water Quality*. 4th Edition.

Prepared: _____
Jason Plamondon, B.Sc. – Project Scientist

Reviewed: _____
Richard Cook. P.Geo.(Ltd.) – Senior Scientist

Approval that this document adheres to Knight Piésold Quality Systems: JMA

Attachments:

Appendix A	Site Photographs
Appendix B	Field Data Sheets
Appendix C	Groundwater Analytical Data, Guideline Comparisons and QA/QC

/jsp

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CONSULTING

APPENDIX A

SITE PHOTOGRAPHS

(Pages A-1 to A-2)

PHOTO 1 – Destroyed groundwater well at Port Site

PHOTO 2 – Existing well at the Port Site

PHOTO 3 – Well KP-PS-BH01 at the Mine Site

PHOTO 4 – Well KP-SGW-BH02 at the Mine Site

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NB15-00175
August 7, 2015

PHOTO 5 – Well DW 02 at the Mine Site

PHOTO 6 – Well MW 01A at the Mine Site

PHOTO 7 – Well MW08A(D) at the Mine Site

PHOTO 8 – Well PW 02 at the Mine Site

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APPENDIX B

FIELD DATA SHEETS

(Pages B-1 to B-23)

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Port (e.g. Mine / Port) DATE: 09/05/2015 (e.g. 05-MAY-2015)

WELL ID: BHPT03 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature ____ °C Wind Southing light (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☐ Sturdy / Undamaged ☒ Repairs required; No Lock

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: cow / (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: ____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: ____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.41 TOH ____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 2.87 (TOP) TOE ____ m

Depth to Bottom (m below top of PVC): 19.5 Sample method: Bail (i.e.hydrolift, manual)

1 Well Volume (L): 34.4 l Purge Date: 09/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 103.20 Start: 12:08 (24 hr)

Purged Volume (L): ~~[illegible]~~ 59.5 l End: ____ (24 hr)

Comments: Purge till Dry. x2 → well did not seem as deep as recorded

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: BHPT03 (i.e. MW08A-D) UTM mE 0452269 (i.e. 558407)

Sample Date / Time: ____ (e.g.05-MAY-2015/14:35) UTM mN 7791355 (i.e. 7914885)

No. of bottles 2 l 2S 2x acid Zone / Datum ____ (i.e. 17T / NAD83)

Quote No. ____ Accuracy ____ (± m)

ODOUR: ☒ None ☐ Describe: ____ (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: ~~Light~~ black to dark (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☒ Opaque than Brown

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.: ____

IN-SITU DATA: Temperature 36.1 °C WQ INSTRUMENT: (Make/Model/CALIBRATION)

Conductivity 18.71 µS/cm ____ (i.e. Hanna/HI 98129)

pH 7.01 ____ (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

Duplicate Collected: ☐ No ☒ Yes, ID: BHPT333 (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: ____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: ____ Filename: ____

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

2.46 = 17.03 Sat Lunch = 59 ph = 7.16 EC = 18.5

Bore hole Not that D.

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: ~~BHP 07~~ Port (e.g. Mine / Port) DATE: 09/05/2015 (e.g. 05-MAY-2015)

WELL ID: BHPT07 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Warm °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☐ Sturdy / Undamaged ☒ Repairs required; Not in good condition

Lock/Tie ☐ Present ☐ Absent Highly Corroded

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: Just coiled (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☒ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: Had to break lock for access

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 36cm TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 2m 85cm (TOP) TOE m

Depth to Bottom (m below top of PVC): ~~3m 72~~ 27m Sample method: Bailer (i.e.hydrolift, manual)

1 Well Volume (L): 49.6 Purge Date: 09/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 148.8 Start: (24 hr)

Purged Volume (L): ~~148.8~~ 100L End: 10:43 (24 hr)

Comments: had to Purge by hand no vehicle access

SAMPLE DESCRIPTION/OBSERVATIONS

Purged 1 well Volume.

Sample ID: BHPT07 (i.e. MW08A-D) UTM mE 0452568 (i.e. 558407)

Sample Date / Time: 10:23 (e.g.05-MAY-2015/14:35) UTM mN 1319980 (i.e. 7914885)

No. of bottles 1L 1S 1P Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☐ None ☒ Describe: Sulphur (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.:

IN-SITU DATA: Temperature 32.8 °C WQ INSTRUMENT: (Make/Model/CALIBRATION) Extrinsically Calibrated

Conductivity OL µS/cm Extrd. (i.e. Hanna/HI 98129)

pH 6.49 ~~[illegible]~~ (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

DO: 11.2 %

QA/QC INFORMATION

Sal OL — Over Limit Limit = 19.99 mS/cm

Duplicate Collected: ☒ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☒ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☒ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

2.49

24.51 X 2.024

10 buckets.

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: ~~BHPTO~~ Port (e.g. Mine / Port) DATE: 09/05/2015 (e.g. 05-MAY-2015)

WELL ID: BHPT 02. (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot 39.4 °C Wind Southly Brisk (direction, speed) Weather clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☐ Sturdy / Undamaged ☒ Repairs required; broken off

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: stick blocking off (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 2.215 (TOP) TOE m

Depth to Bottom (m below top of PVC): 35 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 66.36 Purge Date: (i.e.12MAR2013)

3 Well Volumes (L): 199.1 Start: (24 hr)

Purged Volume (L): ~210 l. End: (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: BHPT 02 (i.e. MW08A-D) UTM mE 0452462 (i.e. 558407)

Sample Date / Time: 09/05/2015 / 12:10 (e.g.05-MAY-2015/14:35) UTM mN 1320332 (i.e. 7914665)

No. of bottles 1 l 1 small 1 acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy ~~±~~ ±15m (± m)

ODOUR: ☐ None ☒ Describe: Sulphur, to start, soapy, then none (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: Light brown (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☒ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 32.7 °C Conductivity 2.09 ~~µS/cm~~ mS pH 7.06

WQ INSTRUMENT: (Make/Model/CALIBRATION) Exstick500 (i.e. Hanna/HI 98129) (Date/Time)

PHOTOS: ☒ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

Sal 1.04 ppt TDS 1.46 ppt DO 18.1

Duplicate Collected: ☒ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☒ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☒ No ☐ Yes, Serial Number: Filename:

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

32.79

24 buckets → 30

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Port (e.g. Mine / Port) DATE: 09/05/2015 (e.g. 05-MAY-2015)

WELL ID: BHP04 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature 38.5 °C Wind Northery Gentel (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☒ Repairs required; No lock

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: Cap-V (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.360 m TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 3.430 m (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 20 Sample method: bailer (i.e.hydrolift, manual)

1 Well Volume (L): 34.2 Purge Date: 09/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 102.61 Start: _____ (24 hr)

Purged Volume (L): 150l End: 11:27 (24 hr)

Comments: Pumped out very fast

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: BHP04 (i.e. MW08A-D) UTM mE 0452524 (i.e. 558407)

Sample Date / Time: 09/05/2015 (e.g.05-MAY-2015/14:35) UTM mN 7320146 (i.e. 7914885)

No. of bottles 1 l 1S 1 acid Zone / Datum _____ (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☒ None ☐ Describe: _____ (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: Brown (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☒ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 34.6 °C Conductivity 2.14 ~~µS/cm~~ mS pH 7.64

WQ INSTRUMENT: (Make/Model/CALIBRATION) Eutick 500 (i.e. Hanna/HI 98129) _____ (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

Sal 1.05 ppt DO 57.2%

Duplicate Collected: ☒ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☒ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☒ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

16.9

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: _____ (e.g. Mine / Port) DATE: 14/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW03AD (e.g. MW08A-D) STAFF: _____ (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required; _____

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: _____ (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.07 TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 11.02 (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 61 Sample method: _____ (i.e.hydrolift, manuel)

1 Well Volume (L): 750 Purge Date: 14/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 2250 Start: 10:20 (24 hr)

Purged Volume (L): 2:20 @ 3:50/50l. End: 13.45 (24 hr)

Comments: Had to wait for Recharge

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW03AD (i.e. MW08A-D) UTM mE _____ (i.e. 558407)

Sample Date / Time: 14/05/2015 13:51 (e.g.05-MAY-2015/14:35) UTM mN _____ (i.e. 7914885)

No. of bottles 1x1l 1x150 1x150acid Zone / Datum _____ (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☒ None ☐ Describe: _____ (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: _____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☒ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 22.6 °C Conductivity 604 µS/cm pH 7.12

WQ INSTRUMENT: (Make/Model/CALIBRATION) Extech (i.e. Hanna/HI 98129) 7.50 14/05 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

Sal 287ppm TDS 422 DO 23.7

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

50
45 = 7650 = 2hrs 20

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Faith (e.g. Mine / Port) DATE: 11/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW02B(S) (e.g. MW08A-D) STAFF: ST. (e.g. DKK)

SITE CONDITIONS

Air Temperature ____ °C Wind ____ (direction, speed) Weather ____ (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required; ____

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: ____ (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: ____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: ____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.16 TOH ____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 3.98 (TOP) TOE ____ m

Depth to Bottom (m below top of PVC): 26m Sample method: ____ (i.e.hydrolift, manual)

1 Well Volume (L): 345 Purge Date: 11/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1035 Start: 16:00 (24 hr)

Purged Volume (L): >1.5 hrs @ 50l/3:50 End: 17:30 (24 hr)

Comments: ____

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW02BS (i.e. MW08A-D) UTM mE ____ (i.e. 558407)

Sample Date / Time: 11/05/2015 17:40 (e.g.05-MAY-2015/14:35) UTM mN ____ (i.e. 7914885)

No. of bottles 1l 1x150 1x150 acid Zone / Datum ____ (i.e. 17T / NAD83)

Quote No. ____ Accuracy ____ (± m)

ODOUR: ☒ None ☐ Describe: ____ (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: ____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.: ____

IN-SITU DATA: Temperature 32.7 °C Conductivity 2.52 µS/cm pH 5.12

WQ INSTRUMENT: (Make/Model/CALIBRATION) Exstick (i.e. Hanna/HI 98129) 11/05/2015 9:50 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO 22.3 TDS 1.84 ppt

Duplicate Collected: ☐ No ☐ Yes, ID: ____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: ____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: ____ Filename: ____

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

50l = 4m 40 = 280 Sec 96 1.5 hrs

207 x 50l = 5796 Sec = 1.60 m

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farin. South Pit (e.g. Mine / Port) DATE: 11/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW06(S) (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature 33 °C Wind Yes (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.17 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 21.58 (TOP) TOE m

Depth to Bottom (m below top of PVC): 29 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 336 l Purge Date: 11/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1008 Start: 12:00 (24 hr)

Purged Volume (L): 950 l End: @ Sample time (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW06S (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 11/05/2015 13:28 (e.g.05-MAY-2015/14:35) UTM mN 472952 (i.e. 7014885)

No. of bottles 1x1l 1x150ml 1x150ml acid Zone / Datum 1378234 (i.e. 17T / NAD83)

Quote No. Accuracy ±1 11m (± m)

ODOUR: ☐ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.:

IN-SITU DATA: Temperature 33.5 °C WQ INSTRUMENT: (Make/Model/CALIBRATION)

Conductivity 205 µS/cm Exstick (i.e. Hanna/HI 98129)

pH 5.61 11/05/2015 (Date/Time)

PHOTOS: ☒ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO: 4.16 SAL TDS

Duplicate Collected: ☐ No ☐ Yes, ID: ~~Exstick~~ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

	0	6	13	30	41	48	54	60	66	72
PH	5.46	5.65	5.12	5.11	5.58	5.44	5.17	5.13	5.13	5.14
Con	496	63.2	46.6	69.3	68.8	60.4	47.3	42.8	43.3	43.7

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 12/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW02A(D) (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Cool °C Wind None (direction, speed) Weather clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.105 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 3m 55cm (TOP) TOE m

Depth to Bottom (m below top of PVC): 53m Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 742 Purge Date: 12/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 2227 Start: 8:05 (24 hr)

Purged Volume (L): 2h-1 @ 50l/2:50 End: 10:10 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: ~~MW~~ MW02AD (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 10:15 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914885)

No. of bottles 12x1 150x2 150acid x2 Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 32.7 °C Conductivity 1084 µS/cm pH 7.07

WQ INSTRUMENT: (Make/Model/CALIBRATION) ExStick (i.e. Hanna/HI 98129) 8:15 12/05 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO 28.7% SAL 541 ppm TDS 765 ppm

Duplicate Collected: ☐ No ☒ Yes, ID: MW222AD (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

49.5 x 15

50l = 2 min 50 - 170 sec

46.5 x 50 = 7571 sec = 126 m = 2 hrs

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 11/05/2015 (e.g. 05-MAY-2015)

WELL ID: KP-SW-BH02 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Warm °C Wind Light (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: Cap (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): ~~1.05~~ 0.23 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 1.05 (TOP) TOE m 61

Depth to Bottom (m below top of PVC): 30 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 450 Purge Date: 11/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1350 l Start: 9:48 (24 hr)

Purged Volume (L): 1450 l End: 11:18 (24 hr)

Comments: So close to high tide mark - sucking sea water

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: KPSWBH02 (i.e. MW08A-D) UTM mE 0472396 (i.e. 558407)

Sample Date / Time: 11:10 (e.g.05-MAY-2015/14:35) UTM mN 1377505 (i.e. 7914885)

No. of bottles 1x1l 1x150ml 1x150ml acid Zone / Datum P28 (i.e. 17T / NAD83)

Quote No. Accuracy ~~4~~ 4+ 8m (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 30.4 °C Conductivity 12.61 µS/cm pH 5.60

WQ INSTRUMENT: (Make/Model/CALIBRATION) Eutech (i.e. Hanna/HI 98129) 11/05/2015 9:50 (Date/Time)

PHOTOS: ☒ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO 19.1 TDS 8.84 SAL 7.31 ppt

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

1000 x 7² x π = 15

	48	51	56	60	61
con	11.73	12.64	12.83	11.44	12.42
pH	5.79	5.78	5.87	5.87	5.80

Bore located Right <10m from surface water

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 12/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW08A(D) (e.g. MW08A-D) STAFF: _____ (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☒ Repairs required; Blocked with log

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: _____ (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): _____ TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): _____ (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): _____ Sample method: _____ (i.e.hydrolift, manual)

1 Well Volume (L): _____ Purge Date: _____ (i.e.12MAR2013)

3 Well Volumes (L): _____ Start: _____ (24 hr)

Purged Volume (L): _____ End: _____ (24 hr)

Comments: Blocked with log.

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: _____ (i.e. MW08A-D) UTM mE _____ (i.e. 558407)

Sample Date / Time: _____ (e.g.05-MAY-2015/14:35) UTM mN _____ (i.e. 7914885)

No. of bottles _____ Zone / Datum _____ (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☐ None ☐ Describe: _____ (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: _____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.: _____

IN-SITU DATA: Temperature _____ °C WQ INSTRUMENT: (Make/Model/CALIBRATION)

Conductivity _____ µS/cm _____ (i.e. Hanna/HI 98129)

pH _____ _____ (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

No Sample.

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: _____ (e.g. Mine / Port) DATE: 13/05/2015 (e.g. 05-MAY-2015)

WELL ID: KP-TMF/03-BH03 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Warm °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required; _____

Lock/Tie ☐ Present ☒ Absent

Labelled ☐ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: Plastic (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.5 TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 6.17 (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 30 Sample method: _____ (i.e.hydrolift, manual)

1 Well Volume (L): 47.3l Purge Date: 13/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 142 Start: 09:20 (24 hr)

Purged Volume (L): 145 End: _____ (24 hr)

Comments: Bail by hand/stopped ~~as~~ to let well recharge

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: KP TMF BH03 (i.e. MW08A-D) UTM mE _____ (i.e. 558407)

Sample Date / Time: 13/05/2015 13:10 (e.g.05-MAY-2015/14:35) UTM mN _____ (i.e. 7914885)

No. of bottles 1x1l 1x150 1x150Acid Zone / Datum _____ (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☒ None ☐ Describe: _____ (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☒ Describe: Brown and turbid (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☒ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 32.2 °C WQ INSTRUMENT: (Make/Model/CALIBRATION)

Conductivity 5.23 ~~µS~~ mS/cm Eristich (i.e. Hanna/HI 98129)

pH 5.01 8:00 13/05/2015 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL 2.77ppt TDS 3.63 ppt DO 33.1

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

30 - 6.17 - 0.45 = 23.38
= 47

Pulling w Bound

	1	2	3	4	5
1	X	X	X	X	X
2	X	X	X	X	X
3	X	X	X	X	X

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farlin (e.g. Mine / Port) DATE: 13/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW4AS (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature 16.6 °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.27 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 16.30 (TOP) TOE m

Depth to Bottom (m below top of PVC): 55 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 580.5 Purge Date: 13/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1741.5 Start: 10:30 (24 hr)

Purged Volume (L): 1hr 40 min @ 3:50/50l End: 12:00 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW04AS (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 13/05/2015 12:04 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914865)

No. of bottles 1x1l 1x150 1x150 acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 32.1 °C WQ INSTRUMENT: (Make/Model/CALIBRATION) PHOTOS: ☐ Well Casing

Conductivity 60.4 µS/cm Exstick (i.e. Hanna/HI 98129) ☐ Purge/Sample water

pH 5.16 800 13/05 (Date/Time) ☐ None taken

QA/QC INFORMATION

Sal 27.6 ppm TDS 44.4 ppm

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

38.

1741

34.8 = 5916 = 98.6 min = 1.5hr

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 11/05/15 (10:43) (e.g. 05-MAY-2015)

WELL ID: KP-PS-BH01 (e.g. MW08A-D) STAFF: _____ (e.g. DKK)

SITE CONDITIONS

Air Temperature Moderate °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required; _____

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: Plastic (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: No logger - Stolen by locals.

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 49cm TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 4.920m (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 4.43 Sample method: _____ (i.e.hydrolift, manual)

1 Well Volume (L): 51.61 Purge Date: Start 11/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 154.83 Start: 8:50 (24 hr)

Purged Volume (L): _____ End: 18:01 (24 hr)

Comments: Bail by hand 150L @ 38°C. 16:45

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: KPPSBH01 (i.e. MW08A-D) UTM mE _____ (i.e. 558407)

Sample Date / Time: 11/05/2015 18:02 (e.g.05-MAY-2015/14:35) UTM mN _____ (i.e. 7914885)

No. of bottles 1L 1x150 1x150 acid Zone / Datum _____ (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☒ None ☐ Describe: _____ (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: _____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 32.2°C Conductivity 2.22 mS/cm pH 6.02

WQ INSTRUMENT: (Make/Model/CALIBRATION) Exstick (i.e. Hanna/HI 98129) 11/05/2015 9:50 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO 17.3 CAL 1.07ppt Bris TDS 1.51 ppt

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

30 - 4.5 = 25.5

1	10	10	10
2	10	10	10
3	10	10	10
4	10	10	10
5	10	10	10

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 13/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW04BD (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☐ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 18 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 17.14 (TOP) TOE m

Depth to Bottom (m below top of PVC): 26 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 135 Purge Date: (i.e.12MAR2013)

3 Well Volumes (L): 450 Start: 12:12 (24 hr)

Purged Volume (L): 30 min @ 3:50/50l End: 12:45 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW04BD (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 12:50 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914865)

No. of bottles 1x1l 1x150 1x150 Acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 33.1 °C WQ INSTRUMENT: (Make/Model/CALIBRATION)

Conductivity 57.3 µS/cm Exstick (i.e. Hanna/HI 98129)

pH 5.26 13/05/2015 8:00 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

Sal 25.7ppt TDS 38.7 ppm DO 38.0

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

9 x 170 = 25 min

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Faraday (e.g. Mine / Port) DATE: 13/05/2015 (e.g. 05-MAY-2015)

WELL ID: KP-TMF-BH102 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Warm °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☐ Present ☒ Absent

Labelled ☐ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☒ Present, Cap Type: ~~Flat~~ Plastic (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.71 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 5.39 (TOP) TOE m

Depth to Bottom (m below top of PVC): 30 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 51 Purge Date: 13/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 153 Start: 8:05 (24 hr)

Purged Volume (L): 159 End: 9:09 (24 hr)

Comments: Bail by hand

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: KPTMFBH102 (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 13/05/2015 9:10 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914885)

No. of bottles 1X1l 1X150ml 1X150 acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☒ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 28.4 °C WQ INSTRUMENT: (Make/Model/CALIBRATION)

Conductivity 278 µS/cm Exstick (i.e. Hanna/HI 98129)

pH 5.98 8:00 13/05/2015 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL 133 ppm TDS 196 ppm DO 21.4

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

25.32 = 51

	1	2	3	4	5	
1	X	X	X	X	X	
2	X	X	X	X	X	
3	X	X	X	X	X	X

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 12/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW07A(D) (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot °C Wind None (direction, speed) Weather clear. (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☐ No label ☐ PVC labelled ☒ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.140 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 17.91 (TOP) TOE m

Depth to Bottom (m below top of PVC): 73 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 828 Purge Date: 12/05/15 (i.e.12MAR2013)

3 Well Volumes (L): 2.482 Start: 10:24 12/05/2015 (24 hr)

Purged Volume (L): End: 16:50 (24 hr)

Comments: Had to return later for Recharge

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW07AD (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 16:58 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914885)

No. of bottles 1x1L 1x150 1x150acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 34.0 °C Conductivity 373 µS/cm pH 6.41

WQ INSTRUMENT: (Make/Model/CALIBRATION) Exstick (i.e. Hanna/HI 98129) 8:15 12/05/2015 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL 171 ppm TDS 256 ppm DO: 26.5

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

55 - 828 = 49.6x50 10:46

170sec x50 = 2hrs 20

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Faviin (e.g. Mine / Port) DATE: 12/05/2015 (e.g. 05-MAY-2015)

WELL ID: DW07 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot °C Wind Light (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.18 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 10.22 (TOP) TOE m

Depth to Bottom (m below top of PVC): 30-35? Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 375 Purge Date: 12/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1125 Start: 17:15 (24 hr)

Purged Volume (L): 1hr 10min @50l/170sec End: 18:20 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: DW07 (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 18:20 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914885)

No. of bottles 1x1l 1x100ml 1x150ml acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☐ None ☒ Describe: Sulphur (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 32.4 °C Conductivity 105.6 µS/cm pH 6.23

WQ INSTRUMENT: (Make/Model/CALIBRATION) Eastech (i.e. Hanna/HI 98129) 12/05/2015 8:15 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO 20.6 SAL 48.8 TDS 75.1 ppm

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

25x15 = 375

63 min = 1h.

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Cariboo Farm (e.g. Mine / Port) DATE: 13/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW01BS (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot! °C Wind Starting up (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.14 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 8.98 (TOP) TOE m

Depth to Bottom (m below top of PVC): 26 Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 270 Purge Date: 13/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 810 Start: 15:15 (24 hr)

Purged Volume (L): 50min @ 3:50/50l End: 16:00 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW01BS (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 13/05/2015 16:03 (e.g.05-MAY-2015/14:35) UTM mN (i.e. 7914885)

No. of bottles 1x1L 1x150 1x150 acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 34.8 °C Conductivity 51.7 µS/cm pH 4.92

WQ INSTRUMENT: (Make/Model/CALIBRATION) Extech (i.e. Hanna/HI 98129) 9:00 13/05 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL 22.2 ppm TDS 34.4 ppm DO 21.3

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

17 810/50 = 16.2 = 2754
= 45 min

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 12/05/2015 (e.g. 05-MAY-2015)

WELL ID: DW 8 (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot! °C Wind Slight (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required; Needs cover

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: _____ (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): ±66cm TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 11.0 (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 35m ? unknown Sample method: _____ (i.e.hydrolift, manual)

1 Well Volume (L): 360 Purge Date: 12/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1080 Start: 13:00 (24 hr)

Purged Volume (L): 70min @ 3min 50/60L End: 14:00 (24 hr)

Comments: _____

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: DW8 (i.e. MW08A-D) UTM mE 0470454 (i.e. 558407)

Sample Date / Time: 14:05 (e.g.05-MAY-2015/14:35) UTM mN 1380770 (i.e. 7914885)

No. of bottles 1x12 1x150 1x150acid Zone / Datum 47 21 (i.e. 17T / NAD83)

Quote No. _____ Accuracy 3m (± m)

ODOUR: ☐ None ☒ Describe: Sulphur (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: _____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 35.2 °C Conductivity 332 µS/cm pH 6.56

WQ INSTRUMENT: (Make/Model/CALIBRATION) ExStick (i.e. Hanna/HI 98129) 12/05/2015 8:15 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO: 26.0% Sal 222 ppm TDS 331 ppm

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

11-35 = 24 x 15 =

21 x 170sec = 62min = 1hr

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Farim (e.g. Mine / Port) DATE: 14/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW03BS (e.g. MW08A-D) STAFF: _____ (e.g. DKK)

SITE CONDITIONS

Air Temperature HOL °C Wind Norm (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required; _____

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: _____ (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.18 TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 12.09 (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 27 Sample method: ~~14/05/2015~~ (i.e.hydrolift, manual)

1 Well Volume (L): 225 Purge Date: 14/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 675 Start: 9:37 (24 hr)

Purged Volume (L): 4.5 min @ 50/50l End: 10:20 (24 hr)

Comments: _____

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW03BS (i.e. MW08A-D) UTM mE _____ (i.e. 558407)

Sample Date / Time: 14/05 10:30 (e.g.05-MAY-2015/14:35) UTM mN _____ (i.e. 7914685)

No. of bottles 1x1l 1x150 1x150 acid Zone / Datum _____ (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☐ None ☐ Describe: _____ (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: _____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 31.3 °C Conductivity 450 µS/cm pH 6.67

WQ INSTRUMENT: (Make/Model/CALIBRATION) ExStick (i.e. Hanna/HI 98129) 7:50 14/05 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL 208ppm TDS 314 DO: 28.1

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: *(i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)*

15 x 15 = 225

13.5 x 170 = 2295 = 38.25 min.

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Box Cut Farim (e.g. Mine / Port) DATE: 14/05/2015 (e.g. 05-MAY-2015)

WELL ID: DW2 (e.g. MW08A-D) STAFF: _____ (e.g. DKK)

SITE CONDITIONS

Air Temperature cool °C Wind None (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☒ Repairs required; Cover

Lock/Tie ☐ Present ☒ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☒ Absent ☐ Present, Cap Type: _____ (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: _____ (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance: _____

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.38 TOH _____ m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 5.4 (TOP) TOE _____ m

Depth to Bottom (m below top of PVC): 30? Sample method: 14/05/2015 (i.e.hydrolift, manual)

1 Well Volume (L): 367 Purge Date: " (i.e.12MAR2013)

3 Well Volumes (L): 1.102 l Start: 7:45 (24 hr)

Purged Volume (L): 1h30 @ ~ 3:50/50l End: 9:20 (24 hr)

Comments: _____

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: DW02 (i.e. MW08A-D) UTM mE 0470254 (i.e. 558407)

Sample Date / Time: 14/05/2015 9:23 (e.g 05-MAY-2015/14:35) UTM mN 1380766 (i.e. 7914885)

No. of bottles 1x1 1x150 1x150 acid Zone / Datum 28P (i.e. 17T / NAD83)

Quote No. _____ Accuracy _____ (± m)

ODOUR: ☐ None ☒ Describe: Sulphur (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: _____ (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.: _____

IN-SITU DATA: Temperature 29.7 °C

Conductivity 272 µS/cm

pH 5.99

WQ INSTRUMENT: (Make/Model/CALIBRATION) Exstick (i.e. Hanna/HI 98129) 7.50 14/05 (Date/Time)

PHOTOS: ☒ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL: 115 ppm TDS 177 ppm DO: 21.3

Duplicate Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: _____ (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: _____ Filename: _____

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

24.5 x 15

22.05 x 170 = 3748.5

= 62.5

= 1h.24

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Cariboo Farm (e.g. Mine / Port) DATE: 13/05/2015 (e.g. 05-MAY-2015)

WELL ID: MW01AD (e.g. MW08A-D) STAFF: ST (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot °C Wind ~5 light (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☐ Well casing labelled

Well Cap: ☐ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 8.78 (TOP) TOE m

Depth to Bottom (m below top of PVC): 53 Sample method: (i.e. hydrolift, manual)

1 Well Volume (L): 660 Purge Date: 13/05/2015 (i.e. 12MAR2013)

3 Well Volumes (L): 1980 Start: 13:20 (24 hr)

Purged Volume (L): 1hr 48@ 3:50/50l End: 15:05 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: MW01AD (i.e. MW08A-D) UTM mE (i.e. 558407)

Sample Date / Time: 13/05/2015 15:07 (e.g. 05-MAY-2015/14:35) UTM mN (i.e. 7914885)

No. of bottles 1x1l 1x150 1x150 acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☒ None ☐ Describe: (i.e. light grey, brown, black, white)

TRANSPARENCY: ☒ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 32.6 °C Conductivity 504 µS/cm pH 6.65

WQ INSTRUMENT: (Make/Model/CALIBRATION) Eastech (i.e. Hanna/HI 98129) 8:00 13/05 (Date/Time)

PHOTOS: ☐ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

DO 24.4 SAL 241 ppm TDS 360

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

44 x 15 = 660 ~~1980~~ 40 x 170 = 6800

x3 = 1980 /60 = 113 min

150 - 40 /60 = 1.8 hrs

= 1hr 48 min

GROUNDWATER QUALITY PURGING AND SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO. NB301-520/02

SITE: Ewim (e.g. Mine / Port) DATE: 14/05/2015 (e.g. 05-MAY-2015)

WELL ID: PW 2 (e.g. MW08A-D) STAFF: ST. (e.g. DKK)

SITE CONDITIONS

Air Temperature Hot! °C Wind Slight (SW) (direction, speed) Weather Clear (clear, o'cast, rain, etc.)

Casing/Headworks: Condition: ☒ Sturdy / Undamaged ☐ Repairs required;

Lock/Tie ☒ Present ☐ Absent

Labelled ☒ No label ☐ PVC labelled ☒ Well casing labelled W2

Well Cap: ☒ Absent ☐ Present, Cap Type: (J-plug, friction fit, etc.)

Sample Tubing: ☐ Present ☐ Absent ☐ Removed ☐ New Tubing Installed

Tubing Type: (i.e. 1/2" waterra, peristaltic, etc.)

Other Observations/Maintenance:

SAMPLING INFORMATION

Volume = ∏r2 x (Depth To Bottom (m below top of PVC) - Depth To Water Level (m below top of PVC))*1000

Top of PVC stick-up (m above ground): 0.15 TOH m (i.e., 2" PVC well V = 2.024 * (DTB - DTWL)

Depth to Initial Water (m below top of PVC): 17.12 (TOP) TOE m

Depth to Bottom (m below top of PVC): 50? Sample method: (i.e.hydrolift, manual)

1 Well Volume (L): 493 Purge Date: 14/05/2015 (i.e.12MAR2013)

3 Well Volumes (L): 1479 Start: 14:06 (24 hr)

Purged Volume (L): 85 min @ 3:50/30 End: 15:30 (24 hr)

Comments:

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: PW02 (i.e. MW08A-D) UTM mE 0470619 (i.e. 558407)

Sample Date / Time: 14/05/2015 15:33 (e.g.05-MAY-2015/14:35) UTM mN 1380899 (i.e. 7914885)

No. of bottles 1l 1x150 1x150 acid Zone / Datum (i.e. 17T / NAD83)

Quote No. Accuracy 3m (± m)

ODOUR: ☒ None ☐ Describe: (i.e. sulphur, mineral, organic)

COLOUR: ☐ None ☐ Describe: White (i.e. light grey, brown, black, white)

TRANSPARENCY: ☐ Clear ☒ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☒ Yes, analytes incl.:

IN-SITU DATA: Temperature 23.2 °C Conductivity 336 µS/cm pH 6.71

WQ INSTRUMENT: (Make/Model/CALIBRATION) Exstick (i.e. Hanna/HI 98129) 7:50 & 14/05 (Date/Time)

PHOTOS: ☒ Well Casing ☐ Purge/Sample water ☐ None taken

QA/QC INFORMATION

SAL: 151 ppm TDS 229 ppm DO: 25.3

Duplicate Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-DUP)

Field Blank Collected: ☐ No ☐ Yes, ID: (i.e. MW12-01-FB)

DATA LOGGER INFORMATION

Logger Downloaded: ☐ No ☐ Yes, Serial Number: Filename:

NOTES: (i.e. additional WQ instrument calibration notes, purging notes, changes since last site visit, other maintenance details)

32
~~24~~ 36 = 83 min

Knight Piésold CONSULTING

APPENDIX C

GROUNDWATER ANALYTICAL DATA, GUIDELINE COMPARISONS, AND QA/QC

Table C.1 Rev 0	Port Site Groundwater Quality Summary
Table C.2 Rev 0	Mine Site - Groundwater Quality Summary
Table C.3 Rev 0	Groundwater Quality QA/QC Summary

(Pages C-1 to C-4)

Knight Piésold CONSULTING

TABLE C.1

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTAL GROUNDWATER QUALITY BASELINE REPORT
PORT SITE - GROUNDWATER QUALITY SUMMARY

Print Aug/07/15 17:01:59

						Sample ID	**BHPT02**	**BHPT03**	**BHPT04**	**BHPT07**
						Sample Date	**12/05/2015**	**09/05/2015**	**09/05/2015**	**09/05/2015**
						Total Well Depth (metres)	**35**	**19.5**	**20.0**	**27**
						Season Sampled (Dry or Wet)	**DRY**	**DRY**	**DRY**	**DRY**
						Screened Interval Description	**Stiff moist black grey sandy CLAY with laminations of white sand**	**Very dense homogenous grey brown clayey SAND**	**Very dense yellow brown mottled red fine SAND**	**Dense homogenous grey mottled brown clayey fine SAND**
						Sampling Notes	**Good rate of recharge**	**Poor rate of recharge**	**-**	**No vehicle access. Purged one well volume by hand.**
QUALITY GUIDELINES	**IFC Mine Effluent Guidelines [1]**	**WHO DW Guidelines[2]**	**CEQG PAL (Marine)[3]**	**CEQG PAL (FW)[4]**	**UNITS**	**MDL[5]**				
In situ Measurements										
Temperature					°C	-	32.7	36.1	34.6	32.8
Conductivity					µS/cm	-	2.09	18.71	2.14	Over Limit
pH	**6 to 9**		*7.0 to 8.7*	6.5 to 9.0	pH units	1	7.06	7.01	7.64	*6.49*
Salinity					ppm	-	1.04E-06	-	1.05E-06	Over Limit
Total dissolved solids (TDS)		1000 [12]			ppm	-	1.46E-06	-	-	-
Dissolved Oxygen					%	-	18.1	-	37.2	11.2
Laboratory Results										
Alkalinity as $CaCO_3$					mg $CaCO_3$/L	2	445	950	250	569
Ammonia				0.021 to 231	mg/L	0.01	0.03	0.28	<0.010	0.09
Ammonia and ammonium ions					mg/L	0.05	1.15	13.30	<0.050	7.24
Ammonia as N					mg/L	0.04	0.89	10.30	<0.040	5.62
Bromide					mg/L	0.5	4.05	31.60	4.39	112.00
Chloride		250 [12]		120	mg/L	1	402	6910	436	21700
Dissolved solids dried at 105 °C					mg/L	10	1370.00	15300.00	1420.00	40900.00
Nitrate as N		50	*45*	3	mg/L	0.06	<0.060	7.68	0.22	<0.300
Nitrates					mg/L	0.27	<0.27	34.00	0.96	<1.33
Nitrite + Nitrate as N					mg/L	0.06	<0.060	9.04	0.22	<0.300
Nitrite as N		3		0.06	mg/L	0.002	<0.0020	1.36	0.01	<0.0200
Nitrites					mg/L	0.005	<0.0050	4.48	0.02	<0.0658
Sulphate as SO_4 2-		250 [12]			mg/L	0.06	110	1050	313	2520
Suspended solids dried at 105 °C	**50**				mg/L	1	**114**	**2270**	**56**	**118**
Total Kjeldahl Nitrogen as N					mg/L	0.50	2.29	16.00	4.08	7.26
Total Nitrogen as N					mg/L	1	2.30	25.00	4.30	7.30
Total Phosphorus as P					mg/L	0.01	1.14	0.72	0.02	0.83
Electrical Conductivity @ 25°C					µS/cm	0.1	2130	34800	2370	84800
Turbidity		5 [12]			ZFn (NTU)	0.1	10.90	1670.00	34.70	77.70
Calcium Hardness					mmol/L	0.0002	2.52	2.64	1.11	11.80
Dissolved Organic Carbon					mg/L	0.5	16.20	10.40	19.10	3.72
Hardness					mmol/L	0.0002	3.9	21.3	2.3	70.1
Hardness as $CaCO_3$					mg $CaCO_3$/L	0.02	387.00	2130.00	233.00	7010.00
Magnesium Hardness					mmol/L	0.0002	1	19	1	58
Phenol Index					mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Total Organic Carbon					mg/L	0.5	16.60	11.20	19.20	5.31
Dissolved Metals										
Aluminium		900		5 to 100	µg/L	2	21.30	<2.00	23.40	<2.00
Antimony		20			µg/L	0.05	0.14	0.33	0.47	<0.050
Arsenic	**100**	10	*12.5*	5	µg/L	0.2	0.24	0.81	1.52	1.44
Barium		700			µg/L	0.2	73.50	80.10	64.00	166.00
Beryllium					µg/L	0.2	<0.20	0.22	<0.20	0.25
Bismuth					µg/L	1	<1.0	<1.0	<1.0	<1.0
Boron		2400		1500	µg/L	10	367	1060	3090	2550
Cadmium	**50**	3	*0.12*	0.09	µg/L	0.02	<0.020	<0.020	<0.020	<0.020
Calcium					mg/L	0.005	101	106	45	474
Chromium		50			µg/L	0.2	<0.200	<0.200	<0.200	0.41
Cobalt					µg/L	0.05	0.95	1.68	2.19	0.06
Copper	**300**	2000		2 to 4	µg/L	1	<1.0	12.90	1.30	2.60
Iron	**2000**			300	µg/L	2	90.20	<2.0	**3000**	158
Lead	**200**	10		1 to 7	µg/L	0.05	1.80	<0.050	**644**	<0.050
Lithium					µg/L	1	19.40	1.00	<1.0	13.70
Magnesium					mg/L	0.003	32.9	454.0	29.6	1420.0
Manganese		400			µg/L	0.1	736	168	248	1110
Mercury	**2**	6	*0.016*	0.026	µg/L	0.01	<0.010	<0.010	<0.010	<0.010
Molybdenum		70		73	µg/L	1	<1.0	5.20	2.50	<1.0
Nickel	**500**	70		25 to 150	µg/L	0.2	2.86	1.24	3.83	0.86
Potassium					mg/L	0.015	47.50	173.00	31.80	430.00
Selenium		40		1	µg/L	0.2	<0.200	2.50	<0.200	0.30
Silicon					mg/L	0.01	6.08	3.00	4.80	4.89
Silver				0.1	µg/L	1	<1.0	<1.0	<1.0	2.50
Sodium		200 [12]			mg/L	0.03	293	4700	411	10200
Strontium					mg/L	0.001	0.21	2.14	0.24	6.07
Thallium				0.8	µg/L	0.5	<0.50	<0.50	<0.50	<0.50
Tin					µg/L	1	<1.0	<1.0	1.70	<1.0
Titanium					mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010
Uranium		30		15	µg/L	0.5	0.73	7.68	0.52	<0.50
Vanadium					µg/L	1	<1.0	<1.0	<1.0	<1.0
Zinc	**500**	3000 [12]		30	µg/L	2	2.40	2.30	14.90	7.90

I:\3\01\00520\02\A\Correspondence\NB15-00175 - Supl. GW Baseline Report\Appendices\[Appendix C Tables_RWT_RAC.xlsx]Table C.1-PORT

NOTES:

1. INTERNATIONAL FINANCE CORPORATION (IFC) ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINES FOR MINING, EFFLUENT GUIDELINES, 2007.
2. WORLD HEALTH ORGANIZATION (WHO) GUIDELINES FOR DRINKING-WATER QUALITY, FOURTH EDITION, 2011.
3. CANADIAN MINISTERS OF THE ENVIRONMENT (CCME), CANADIAN ENVIRONMENTAL QUALITY GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE (CEQG PAL), MARINE (CCME, 2015).
4. CANADIAN MINISTERS OF THE ENVIRONMENT (CCME), CANADIAN ENVIRONMENTAL QUALITY GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE (CEQG PAL), FRESHWATER (CCME, 2015).
5. METHOD DETECTION LIMIT (MDL).
6. BOLDED RESULTS INDICATE VALUES GREATER THAN THE MINE EFFLUENT GUIDELINES (IFC, 2007).
7. SHADED RESULTS INDICATE VALUES GREATER THAN THE DRINKING-WATER STANDARDS (WHO, 2011).
8. ITALICIZED RESULTS INDICATE VALUES GREATER THAN THE CEQG-PAL MARINE GUIDELINES (CCME, 2015).
9. UNDERLINED RESULTS INDICATE VALUES GREATER THAN THE CEQG-PAL FRESHWATER GUIDELINES (CCME, 2015).
10. GUIDELINES ARE DEVELOPED BASED ON TOTAL CONCENTRATION VALUES, COMPARISONS TO DISSOLVED FRACTIONS ARE PROVIDED WHERE TOTAL VALUES WERE NOT AVAILABLE.
11. METHOD DETECTION LIMIT FOR SILVER (1.0 µG/L) WAS ABOVE THE CEQG-PAL FOR FRESHWATER GUIDELINE (0.1 µG/L).
12. NO HEALTH BASED GUIDELINE IS AVAILABLE.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07AUG'15	ISSUED WITH MEMO NB15-00175	DKK	RAC

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TABLE C.2

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTAL GROUNDWATER QUALITY BASELINE REPORT
MINE SITE - GROUNDWATER QUALITY SUMMARY

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								Sample ID	**KP-PS-BH01**	**KP-SGW-BH02**	**MW01B(S)**			**MW02B(S)**			**MW06(S)**	**KP-TMF/OB-BH02**	**KP-TMF/OB-BH03**	**DW 2**	**DW 8**	**DW 7**	**MW03B(S)**	**MW04A(S)**			**MW07B(S)**	**MW05A(S)**	
								Sample Date (dd-mm-yyyy)	**11/05/2015**	**11/05/2015**	**13/05/2015**	**07/09/2013**	**06/02/2012**	**12/05/2015**	**09/09/2013**	**07/02/2012**	**11/05/2015**	**11/05/2015**	**13/05/2015**	**14/05/2015**	**12/05/2015**	**12/05/2015**	**14/05/2015**	**14/05/2015**	**07/09/2013**	**07/02/2012**	**05/02/2012**	**10/09/2013**	**04/02/2012**
								Total Well Depth (metres)	**4.43**	**30**	**26**	**26**	**26**	**27**	**27**	**27**	**29.5**	**30**	**30**	**30**	**35**	**30**	**27**	**26**	**26**	**26**	**24**	**37**	**37**
								Season Sampled (Dry or Wet)	**DRY**	**DRY**	**DRY**	**WET**	**DRY**	**DRY**	**WET**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**DRY**	**WET**	**DRY**	**DRY**	**WET**	**DRY**
								Project Component or Area	**South Pit**									**Integrated Waste Landform**		**North Pit**								**Northeast of Farim**	
								Screened Interval Description	**N/A**	**N/A**	**Red brown grey CLAY and fine SAND**			**Pale yellow poorly sorted fine to coarse SAND**			**Brown grey fine-med SAND**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**Orange yellow coarse SAND**	**Light yellow-grey CLAY, orange-red well sorted fine SAND**			**Light yellow brown med SAND**	**Pale yellow well sorted fine to medium SAND**	
QUALITY GUIDELINES	**IFC Mine Effluent Guidelines [1]**	**WHO DW Guidelines[2]**	**CEQG PAL (Marine)[3]**	**CEQG PAL (FW)[4]**	**UNITS**	**MDL[5] 2011/2012**	**MDL 2013**	**MDL 2015**	**SHALLOW WELLS**									**SHALLOW WELLS**											
In situ Measurements									**In situ Measurements**									**In situ Measurements**											
Temperature					°C	-	-	-	32.2	30.4	34.8			32.7			33.5	28.8	32.2	29.2	35.2	32.4	31.3	32.1					
Conductivity					µS/cm	-	-	-	2.2E+03	12.61	51.7			2.52			205	278	5.23	272	82	105.6	450	60.4					
pH	**6 to 9**		*7.0 to 8.7*	6.5 to 9.0	pH units	1	1	1	6.02	**5.60**	**4.92**			**5.12**			**5.61**	**5.98**	**5.01**	**5.99**	6.56	*6.23*	*6.67*	**5.16**					
Salinity					ppm	-	-	-	1.07E+06	7.31E+06	2.22E+01							133	2.77E+06	115	222	48.8	208	28					
Total dissolved solids (TDS)		1000 [12]			ppm	-	-	-	1.51E+06	8.86E+06	34.4			1.84E+06				196	3.63E+06	117	331	75	314	44					
Dissolved Oxygen					%	-	-	-	17.3	19.1	21.3			22.3			45.6	21.4	33.1	21.3	26.0	20.6	28.1						
Laboratory Results																													
Alkalinity as $CaCO_3$					mg $CaCO_3$/L	0.4	0.1	2.0	107	<2.0	5.8	240	<0.4	5.20	56	1.26	11	94	<2.0	74	121	24	249	13	0.16	<0.4	9.90	26	2.40
Ammonia				0.021 to 231	mg/L	0.5	NA	0.01	<0.010	<0.010	<0.010	0.52	<0.5	<0.010	1.01	<0.5	<0.010	<0.010	<0.010	0	<0.010	<0.010	<0.010	<0.010	0.48	<0.5	<0.5	0.36	<0.5
Ammonia and ammonium ions					mg/L	-	-	0.05	0	5.09	<0.050			0.26			<0.050	0.20	0.54	7	<0.050	<0.050	<0.050	0.33					
Ammonia as N					mg/L	-	-	0.04	0.26	3.95	<0.040			0.20			<0.040	0.158	0.417	5.54	<0.040	<0.040	<0.040	0.25					
Bromide					mg/L	-	-	0.5	5.18	22	<0.50			10.10			<0.50	<0.50	19.4	<0.50	<0.50	<0.50	<0.50	<0.50					
Chloride		250 [12]		120	mg/L	NA	NA	1.00	616	4140	4.99	3.3	35.50	998.00	661.9	88.75	16.6	19.7	1710	3.10	5.98	3.77	1.43	2.61	2.5	35.50	53.25	3.4	35.50
Dissolved solids dried at 105 °C					mg/L	10	10	10	1490	8530	34	234	13	2010.00	1397	256	100	268	3190	178	179	112	440.00	60.00	<10	22	92	<10	24
Nitrate as N		50	*45*	3	mg/L	-	-	0.06	<0.060	<0.060	0.182			0.44			1.06	<0.060	<0.060	0.53	0.08	1.50	0.18	0.12					
Nitrates					mg/L	-	-	0.27	<0.27	<0.27	0.8			1.95			4.67	<0.27	<0.27	2	0	7	0.81	0.55					
Nitrite + Nitrate as N					mg/L	-	-	0.06	<0.060	<0.060	0.182			0.44			1.06	<0.060	<0.060	0.77	0.08	1.50	0.18	0.12					
Nitrite as N		3		0.06	mg/L	-	-	0.002		<0.0020	<0.0020			<0.0020			<0.0020	<0.0020	<0.0020		<0.0020	<0.0020	<0.0020	<0.0020					
Nitrites					mg/L	-	-	0.005		<0.0050	<0.0050			<0.0050			<0.0050	<0.0050	<0.0050	1	<0.0050		<0.0050	<0.0050					
Sulphate as SO_4 2-		250			mg/L	2 and 50	2	0.06	99.40	446.00	0.231	21.03	<2	90.30	63.94	68	4.27	10.50	62.00	2.20	3.51	2.65	4.31	0.64	0.48	2	<50	0.88	<50
Suspended solids dried at 105 °C	**50**				mg/L	-	10	1	**51.9**	**166**	7.6	<10		15	26		41.5	**52**	**994**	8.4	33.7	21.3	12.0	7.9	<10			<10	
Total Kjeldahl Nitrogen as N					mg/L	-	-	0.50	0.64	4.7	<0.50			0.74			1.08	0.8	1.2	5.57	0.62	0.68	<0.50	0.62					
Total Nitrogen as N					mg/L	-	-	1	<1.0	4.700	<1.0			1.20			2.1	<1.0	1.200	6.30	<1.0	2.20	<1.0	<1.0					
Total Phosphorus as P					mg/L	-	-	0.01	0.0160	<0.010	<0.010			<0.010			0.036	<0.010	0.12	0.8	0.2	0.5	0.03	<0.010					
Electrical Conductivity @ 25°C					µS/cm	NA	NA	0.1	2260	20200	35	492	23.7	2880	2335	480	108	262	5720	174	248	87	464	42	1638	42	173	1760	45.9
Turbidity		5			ZFn (NTU)	-	-	0.1	14.30	35.6	1.6			6.90			15	18.6	1500	9.82	30.10	4.11	12.60	3.35					
Calcium Hardness					mmol/L	-	-	0.0002	2.09	4.92	0.0315			3.06			0.088	0.576	2.78	0.471	0.914	0.161	1.88	0.05					
Dissolved Organic Carbon					mg/L	-	-	0.5	1.06	3.97	0.75			1.23			3.15	1.26	5.15	2.45	1.31	3.05	0.92	2.93					
Hardness					mmol/L	-	-	0.0002	3	22.2	0.0475			4.8			0.165	0.886	7.51	1	1	0	2.1	0.1					
Hardness as $CaCO_3$					mg $CaCO_3$/L	-	-	0.02	275.00	2220	4.75			478.00			16.5	88.6	751	56.40	119.00	24.60	213.00	9.00					
Magnesium Hardness					mmol/L	-	-	0.0002	0.665	17.3	0.016			2			0.0773	0	5	0	0	0	0	0					
Phenol Index					mg/L	-	-	0.005	<0.005	<0.005	<0.005			<0.005			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					
Total Organic Carbon					mg/L	-	-	0.5	1.38	4.15	1.06			1.62			3.24	1.65	5.52	2.79	1.72	3.39	1.03	3.28					
Dissolved Metals																													
Aluminium		900		5 to 100	µg/L	-	-	2	4	4.03	19.1			46.80			<2.00	<2.00	2550	<2.00	<2.00	<2.00	<2.00	30.40					
Antimony		20			µg/L	-	-	0.05	<0.050	<0.050	0.51			<0.050			0.725	<0.050	<0.050	<0.050	<0.050	0.13	<0.050	0.08					
Arsenic	**100**	10	*12.5*	5	µg/L	0.9	0.5	0.2	<0.200	0.524	<0.200	1.5	<0.5	<0.200	18.7	0.6	0.386	4.23	1.23	0.89	0.88	0.79	0.31	<0.200	<0.9	<0.5	0.6	1.1	1.3
Barium		700			µg/L	-	-	0.2	84.40	86.1	19.40			266.00			15.7	102	797	4.00	5.77	6.92	56.40	11.90					
Beryllium					µg/L	-	-	0.2	<0.20	<0.20	<0.20			0.51			<0.20	<0.20	3.89	<0.20	<0.20	<0.20	<0.20	<0.20					
Bismuth					µg/L	-	-	1	<1.0	<1.0	<1.0			<1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0					
Boron		2400		1500	µg/L	-	-	10	69.00	403	<10			55.00			18	19	131	16.00	11.00	22.00	12.00	12.00					
Cadmium	**50**	3	*0.12*	0.09	µg/L	0.05	NA	0.02	<0.020	<0.020	<0.020	0.14	<0.05	<0.020	1.23	<0.05	<0.020	<0.020	0.062	<0.020	<0.020	<0.020	<0.020	<0.020	0.15	<0.05	<0.05	0.46	<0.05
Calcium					mg/L	NA	NA	0.005	83.60	197	1.26	79.6	16	122.00	87.2	24	3.53	23.1	112	18.90	36.60	6.46	75.40	1.96	2.1	32	32	5.6	20
Chromium		50			µg/L	0.5	0.2	0.2	<0.200	<0.200	<0.200	<0.2	1	<0.200	<0.2	<0.5	<0.200	<0.200	1.18	<0.200	<0.200	<0.200	<0.200	<0.200	0.9	1	1	<0.2	<0.5
Cobalt					µg/L	-	-	0.05	<0.050	6.98	1			24			0.137	2.73	132	1.0	<0.050	<0.050	<0.050	2					
Copper	**300**	2000		2 to 4	µg/L	1	3	1	<1.0	1.6	<1.0	<3	1.3	7.00	4	<1	2.1	<1.0	5	<1.0	<1.0	<1.0	<1.0	2.00	<3	1.3	<1	<3	<50
Iron	**2000**			300	µg/L	5	4.7	2	<2.0	**87800**	<2.0	879.2	<5	<2.0	**5024**	<5	<2.0	<2.0	1690	30	<2.0	<2.0	<2.0	<2.0	15.6	<5	10	1192	1140
Lead	**200**	10		1 to 7	µg/L	0.2	0.4	0.05	0.322	<0.050	0.348	1.5	0.30	<0.050	<0.4	<0.2	0.636	0.343	27.6	<0.050	0.08	<0.050	<0.050	1.80	<0.4	<0.2	<0.2	<0.4	<0.2
Lithium					µg/L	-	-	1	<1.0	4.2	<1.0			<1.0			<1.0	<1.0	31.9	6.80	<1.0	1.60	<1.0	1.50					
Magnesium					mg/L	-	-	0.003	16.20	421	0.4	4.2		42.00	30.4		1.88	7.54	115	2.26	6.65	2.07	5.93	1.00	0.8			0.5	
Manganese		400			µg/L	-	-	0.1	67.60	963	16	81.4	<10	826.00	562	208	10.9	334	2880	238.00	<0.100	1.26	119.00	67.70	54.8	<10	550	96.4	40
Mercury	**2**	6	*0.016*	0.026	µg/L	0.05	-	0.01	<0.010	<0.010	<0.010		<0.05	<0.010		<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		<0.05	<0.05		<0.05
Molybdenum		70		73	µg/L	-	-	1	<1.0	<1.0	<1.0			<1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0					
Nickel	**500**	70		25 to 150	µg/L	0.5	0.2	0.2	0.24	5	1.82	<0.2	3.6	30.10	9.2	2.7	10.7	2	131	0.85	<0.200	1.44	1.60	8.40	3.3	3.1	3.4	0.7	1.1
Potassium					mg/L	0.5 and 5	NA	0.015	9.49	77	0.317	1.7	<0.5	12.30	7.4	4.5	2.11	3	21	2.82	1.71	1.89	1.62	0.91	0.9	0.8	2.0	0.4	0.5
Selenium		40		1	µg/L	-	-	0.2	<0.200	<0.200	<0.200			<0.200			<0.200	<0.200	0.487	<0.200	<0.200	<0.200	<0.200	<0.200					
Silicon					mg/L	-	-	0.01	5.86	8.44	5.55			10.80			14.8	11.50	17.20	17.20	11.30	18.00	7.06	9.64					
Silver				0.1	µg/L	-	-	1	16.30	<1.0.	<1.0			<1.0.			<1.0.	<1.0	<1.0.	<1.0.	<1.0	<1.0	<1.0	<1.0.					
Sodium		200 [12]			mg/L	NA	NA	0.03	342	1910	2.5	8.3	3.5	359.00	307.6	69.7	8.41	15.6	776	1	4	4	21.20	1.82	3	5.8	13.8	2.1	3.6
Strontium					mg/L	-	-	0.001	0.24	2.36	0.0106			0.31			0.0142	0.0963	0.953	0.04	0.06	0.01	0.22	0.01					
Thallium				0.8	µg/L	-	-	0.5	<0.50	<0.50	<0.50			<0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50					
Tin					µg/L	-	-	1	<1.0	<1.0	1.2			<1.0			1.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0					
Titanium					mg/L	-	-	0.001	<0.0010	<0.0010	<0.0010			<0.0010			<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010					
Uranium		30		15	µg/L	-	-	0.5	<0.50	<0.50	<0.50			<0.50			<0.50	<0.50	1.66	<0.50	<0.50	<0.50	0.65	<0.50					
Vanadium					µg/L	-	-	1	<1.0	<1.0	<1.0			<1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0					
Zinc	**500**	3000 [12]		30	µg/L	NA	1.5	2	2.10	11.6	11.5	3.5	4	50.50	21	4	49.2	2.8	286	<2.0	<2.0	6.70	4.50	22.50	13.5	8	14	10.1	11

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TABLE C.2

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTAL GROUNDWATER QUALITY BASELINE REPORT
MINE SITE - GROUNDWATER QUALITY SUMMARY

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Sample ID									MW01A(D)			MW02A(D)			PW1	PW1	PW2				MW03A(D)	MW04B(D)			MW07A(D)			MW05B(D)		
Sample Date (dd-mm-yyyy)									11/05/2015	07/09/2013	06/02/2012	13/05/2015	09/09/2013	07/02/2012	25/01/2012	01/02/2012	14/05/2015	08/09/2013	12/12/2011	12/12/2011	11/05/2015	13/05/2015	07/09/2013	07/02/2012	13/05/2015	08/09/2013	05/02/2012	26/01/2012	10/09/2013	04/02/2012
Total Well Depth (metres)									53	53	53	48	48	48	58	58	71	71	71	71	61	55	55	55	73	73	73	66	66	66
Season Sampled (Dry or Wet)									DRY	WET	DRY	DRY	WET	DRY	DRY	DRY	DRY	WET	DRY	DRY	DRY	DRY	WET	DRY	DRY	WET	DRY	DRY	WET	DRY
Project Component or Area									South Pit								North Pit				North Pit							Northeast of Farim		
Screened Interval Description									White sandy slightly clayeye LIMESTONE			Fine to medium sandy LIMESTONE			Light grey clayey LIMESTONE	Light grey clayey LIMESTONE	Upper Screen: Light browm silty fine sandy CLAY 53-62 m (possibly phosphatic), Lower Screen: light grey clayey LIMESTONE 62-71 m				Light grey fine grained fragmented LIMESTONE	Soft damp light grey, medium clayey LIMESTONE			Possible LIMESTONE (as per logs)			Grey well sorted fine SAND		Grey well sorted fine SAND
QUALITY GUIDELINES	IFC Mine Effluent Guidelines (1)	WHO DW Guidelines(2)	CEQG PAL (Marine)(3)	CEQG PAL (FW)(4)	UNITS	MDL(5) 2011/2012	MDL 2013	MDL 2015	DEEP WELLS												DEEP WELLS									
In situ Measurements									In situ Measurements												In situ Measurements									
Temperature					°C	-	-	-	32.6			32.7					33.2				33.6	33.1			34					
Conductivity					µS/cm	-	-	-	504			1084					336				604	57.3			373					
pH	**6 to 9**		*7.0 to 8.7*	6.5 to 9.0	pH units	1	1	1	*6.65*			7.07					*6.71*				7.12	**5.26**			*6.41*					
Salinity					ppm	-	-	-	241			541					151				287	25.7			171					
Total dissolved solids (TDS)		1000 [12]			ppm	-	-	-	360			765					229				422	38.7			256					
Dissolved Oxygen					%	-	-	-	24.4			28.7					25.3				23.7	38.0			26.5					
Laboratory Results																														
Alkalinity as $CaCO_3$					mg $CaCO_3$/L	0.4	0.1	2.0	220	16	2.00	334	290	2.96	33.70	30.40	187	250	2.08	2.08	326	28	306	3.04	177	130	2.94	13.60	86	7.20
Ammonia				0.021 to 231	mg/L	0.5	NA	0.01	<0.010	0.22	<0.5	<0.010	0.58	<0.5	<0.5	<0.5	<0.010	0.21	<0.5	<0.5	<0.010	<0.010	0.22	<0.5	<0.010	0.21	<0.5	NR	0.43	<0.5
Ammonia and ammonium ions					mg/L	-	-	0.05	<0.050			<0.050					<0.050				<0.050	<0.050			<0.050					
Ammonia as N					mg/L	-	-	0.04	<0.040			<0.040					<0.040				<0.040	<0.040			<0.040					
Bromide					mg/L	-	-	0.5	0.71			3.2					<0.50				0.74	<0.50			<0.50					
Chloride		250 [12]		120	mg/L	NA	NA	1.00	17.4	2.5	53.25	142	571.9	106.50	213.00	39.05	3.73	2.3	6.00	6.00	12.80	1.02	3.8	35.50	1.23	1.6	53.25	177.50	7	35.50
Dissolved solids dried at 105 °C					mg/L	10	10	10	485	<10	268	700	1362	491	453	433	381	238	230	233	510.00	67.00	304	289	222.00	132	22	100	86	88
Nitrate as N		50	*45*	3	mg/L	-	-	0.06	4.73			0.638					0.51				0.26	<0.060			<0.060					
Nitrates					mg/L	-	-	0.27	21			2.82					2				1.17	<0.27			<0.27					
Nitrite + Nitrate as N					mg/L	-	-	0.06	4.73			0.638					0.51				0.26	<0.060			<0.060					
Nitrite as N		3		0.06	mg/L	-	-	0.002	<0.0020			<0.0020					<0.0020				<0.0020	<0.0020			<0.0020					
Nitrites					mg/L	-	-	0.005	<0.0050			<0.0050					<0.0050				<0.0050	<0.0050			<0.0050					
Sulphate as SO_4 2-		250			mg/L	2 and 50	2	0.06	15.7	0.44	27	95.7	58.54	73	65	73	2.60	14.66	20	20	34.60	0.17	1.13	<2	5.77	2.92	<50	<50	10.17	<50
Suspended solids dried at 105 °C	**50**				mg/L	-	10	1	10	<10		21	20				**175**	14			**50.2**	12.2	25		19.8	42			<10	
Total Kjeldahl Nitrogen as N					mg/L	-	-	0.50	0.82			<0.50					0.88				0.56	<0.50			<0.50					
Total Nitrogen as N					mg/L	-	-	1	5.6			<1.0					1.40				<1.0	<1.0			<1.0					
Total Phosphorus as P					mg/L	-	-	0.01	0.334			0.011					1.7				0.37	0.17			0.07					
Electrical Conductivity @ 25°C					µS/cm	NA	NA	0.1	476	42	503	1040	2280	922	803	816	361	471	432	438	633	58	4774	544	342	266	41	190	8732	166
Turbidity		5			ZFn (NTU)	-	-	0.1	4.77			31.7					155.00				14.30	2.71			19.30					
Calcium Hardness					mmol/L	-	-	0.0002	1.98			2.65					1.7				2.11	0.17			1.51					
Dissolved Organic Carbon					mg/L	-	-	0.5	2.52			0.71					1.87				0.97	1.10			1.46					
Hardness					mmol/L	-	-	0.0002	2.15			3.5					2				3.0	0.2			1.7					
Hardness as $CaCO_3$					mg $CaCO_3$/L	-	-	0.02	215			350					194.00				298.00	23.60			174.00					
Magnesium Hardness					mmol/L	-	-	0.0002	0			1					0				1	0			0					
Phenol Index					mg/L	-	-	0.005	<0.005			<0.005					<0.005				<0.005	<0.005			<0.005					
Total Organic Carbon					mg/L	-	-	0.5	3.06			1.17					2.10				1.45	1.32			1.79					
Dissolved Metals																														
Aluminium		900		5 to 100	µg/L	-	-	2	<2.00			<2.00					<2.00				<2.00	33.80			<2.00					
Antimony		20			µg/L	-	-	0.05	<0.050			<0.050					<0.050				0.06	0.31			<0.050					
Arsenic	**100**	10	*12.5*	5	µg/L	0.9	0.5	0.2	2.460	<0.9	0.7	0.588	1.8	0.6	0.7	0.6	1.17	<0.9	<0.5	<0.5	1.72	<0.200	<0.9	<0.5	<0.200	1.7	1.2	NR	1.4	<0.5
Barium		700			µg/L	-	-	0.2	39.00			83.80					3.52				29.50	14.10			27.80					
Beryllium					µg/L	-	-	0.2	<0.20			<0.20					<0.20				<0.20	<0.20			<0.20					
Bismuth					µg/L	-	-	1	<1.0			<1.0					<1.0				<1.0	<1.0			<1.0					
Boron		2400		1500	µg/L	-	-	10	20.00			69.00					12.00				99.00	<10			21.00					
Cadmium	**50**	3	*0.12*	0.09	µg/L	0.05	NA	0.02	<0.020	0.08	<0.05	<0.020	*0.39*	<0.05	<0.05	<0.05	<0.020	*0.15*	<0.05	<0.05	<0.020	<0.020	*0.12*	0.06	<0.020	*0.5*	<0.05	NR	*1.26*	<0.05
Calcium					mg/L	NA	NA	0.005	79.20	2.3	32	106.00	127.5	48	72	40	68.10	83.6	56	60	84.50	6.98	98.6	54	60.60	36	16	24	13.9	24
Chromium		50			µg/L	0.5	0.2	0.2	<0.200	7.9	<0.5	<0.200	<0.2	<0.5	<0.5	<0.5	<0.200	5.2	<0.5	<0.5	<0.200	<0.200	0.2	<0.5	<0.200	<0.2	3	NR	<0.2	<0.5
Cobalt					µg/L	-	-	0.05	<0.050			0					<0.050				<0.050	3			<0.050					
Copper	**300**	2000		2 to 4	µg/L	1	3	1	<1.0	<3	10	<1.0	<3	<1	<50	<50	<1.0	<3	<50	<50	<1.0	<1.0	<3	<1	<1.0	<3	<1	<50	<3	<50
Iron	**2000**			300	µg/L	5	4.7	2	11.00	<4.7	80	<2.0	**2111**	50	40	30	<2.0	239.5	**4090**	**3600**	<2.0	<2.0	<4.7	<5	<2.0	**3407**	**320**	**3340**	**4118**	30
Lead	**200**	10		1 to 7	µg/L	0.2	0.4	0.05	0.081	<0.4	0.20	<0.050	2.2	<0.2	<0.2	<0.2	<0.050	0.8	<0.2	<0.2	0.53	<0.050	0.6	<0.2	<0.050	1.2	1.30	NR	1.5	<0.2
Lithium					µg/L	-	-	1	<1.0			25.80					1.30				5.30	2.50			3.50					
Magnesium					mg/L	-	-	0.003	4.2	0.4		20.6	34.5				5.95	5.1			21.10	1.50	2.7		5.46	4.7			7.5	
Manganese		400			µg/L	-	-	0.1	8.91	13.8	610	37.4	120	<10	1430	810	<0.100	101.8	280	360	<0.100	109.00	105.4	1480	<0.100	628.3	240	890	457.9	<10
Mercury	**2**	6	*0.016*	0.026	µg/L	0.05	-	0.01	<0.010		*<0.05*	<0.010		*<0.05*	*<0.05*	*<0.05*	<0.010		*<0.05*	*<0.05*	<0.010	<0.010		<0.05	<0.010		<0.05	NR		<0.05
Molybdenum		70		73	µg/L	-	-	1	<1.0			<1.0					<1.0				<1.0	<1.0			<1.0					
Nickel	**500**	70		25 to 150	µg/L	0.5	0.2	0.2	1.89	4.1	0.8	1.61	5.8	3.2	0.6	0.7	1.43	3.2	<0.5	<0.5	1.46	4.68	1.6	2.8	<0.200	1.6	2.9	NR	0.7	<0.5
Potassium					mg/L	0.5 and 5	NA	0.015	2.89	0.4	2.0	7.29	4.8	5.9	<5	<5	1.63	1.9	<5	<5	5.83	0.90	0.9	1.4	2.14	1.8	0.5	<5	3.7	3.9
Selenium		40		1	µg/L	-	-	0.2	<0.200			<0.200					<0.200				<0.200	<0.200			<0.200					
Silicon					mg/L	-	-	0.01	6.55			12.3					10.80				15.00	9.55			7.39					
Silver				0.1	µg/L	-	-	1	<1.0			<1.0					<1.0				<1.0	<1.0			<1.0					
Sodium		200 [12]			mg/L	NA	NA	0.03	20.6	2.6	9.0	81.6	276	92.7	48.4	48.7	1.63	1.5	1.5	1.7	26.70	1.11	1.8	6.0	5.75	6.7	7.7	NR	2.7	3.9
Strontium					mg/L	-	-	0.001	0.11			0.41					0.14				0.51	0.02			0.15					
Thallium				0.8	µg/L	-	-	0.5	<0.50			<0.50					<0.50				<0.50	<0.50			<0.50					
Tin					µg/L	-	-	1	2.9			<1.0					<1.0				<1.0	<1.0			<1.0					
Titanium					mg/L	-	-	0.001	<0.0010			<0.0010					<0.0010				<0.0010	<0.0010			<0.0010					
Uranium		30		15	µg/L	-	-	0.5	<0.50			<0.50					<0.50				1.00	<0.50			<0.50					
Vanadium					µg/L	-	-	1	<1.0			<1.0					<1.0				<1.0	<1.0			<1.0					
Zinc	**500**	3000 [12]		30	µg/L	NA	1.5	2	2.3	6	6	<2.0	1.8	2	220	174	<2.0	<1.5	148	120	2.10	10.20	8.7	5	<2.0	23	6	**714**	7.8	4

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NOTES:

1. INTERNATIONAL FINANCE CORPORATION (IFC) ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINES FOR MINING, EFFLUENT GUIDELINES, 2007.
2. WORLD HEALTH ORGANIZATION (WHO) GUIDELINES FOR DRINKING-WATER QUALITY, FOURTH EDITION, 2011.
3. CANADIAN MINISTERS OF THE ENVIRONMENT (CCME), CANADIAN ENVIRONMENTAL QUALITY GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE (CEQG PAL), MARINE (CCME, 2015).
4. CANADIAN MINISTERS OF THE ENVIRONMENT (CCME), CANADIAN ENVIRONMENTAL QUALITY GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE (CEQG PAL), FRESHWATER (CCME, 2015).
5. METHOD DETECTION LIMIT (MDL).
6. BOLDED RESULTS INDICATE VALUES GREATER THAN THE MINE EFFLUENT GUIDELINES (IFC, 2007).
7. SHADED RESULTS INDICATE VALUES GREATER THAN THE DRINKING-WATER STANDARDS (WHO, 2011).
8. ITALICIZED RESULTS INDICATE VALUES GREATER THAN THE CEQG-PAL MARINE GUIDELINES (CCME, 2015).
9. UNDERLINED RESULTS INDICATE VALUES GREATER THAN THE CEQG-PAL FRESHWATER GUIDELINES (CCME, 2015).
10. GUIDELINES ARE DEVELOPED BASED ON TOTAL CONCENTRATION VALUES, COMPARISONS TO DISSOLVED FRACTIONS ARE PROVIDED WHERE TOTAL VALUES WERE NOT AVAILABLE.
11. METHOD DETECTION LIMIT FOR SILVER (1.0 µG/L) WAS ABOVE THE CEQG-PAL FOR FRESHWATER GUIDELINE (0.1 µG/L).
12. NO HEALTH BASED GUIDELINE IS AVAILABLE.

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TABLE C.3

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTAL GROUNDWATER QUALITY BASELINE REPORT
GROUNDWATER QUALITY QA/QC SUMMARY

Print Aug/07/15 17:04:21

		Sample ID	BHPT03	BHPT03_Dup	RPD (13)	MW02A(D)	MW2A(D)_Dup	RPD (13)
		Sample Date	09/05/2015	09/05/2015		13/05/2015	12/05/2051	
	UNITS	MDL(5)		Duplicate			Duplicate	
Alkalinity as $CaCO_3$	mg $CaCO_3$/L	2	950	939	1	334	334	0
Ammonia	mg/L	0.01	0.28	0.13	73	<0.010	<0.010	0
Ammonia and ammonium ions	mg/L	0.05	13.30	5.85	78	<0.050	<0.050	0
Ammonia as N	mg/L	0.04	10.30	4.54	78	<0.040	<0.040	0
Bromide	mg/L	0.5	31.60	29.90	6	3.2	1.01	104
Chloride	mg/L	1	6910	7100	3	142	99.70	35
Dissolved solids dried at 105 °C	mg/L	10	15300	13000	16	700	748	7
Nitrate as N	mg/L	0.06	7.68	1.34	141	0.638	0.49	27
Nitrates	mg/L	0.27	34.00	5.94	141	2.82	2.16	27
Nitrite + Nitrate as N	mg/L	0.06	9.04	14.60	47	0.638	0.49	27
Nitrite as N	mg/L	0.002	1.36	13.20	163	<0.0020	<0.0020	0
Nitrites	mg/L	0.005	4.48	43.60	163	<0.0050	<0.0050	0
Sulphate as SO_4 2-	mg/L	0.06	1050	1060	1	95.7	76.10	23
Suspended solids dried at 105 °C	mg/L	1	2270	2600	14	21	23.8	13
Total Kjeldahl Nitrogen as N	mg/L	0.50	16.00	10.20	44	0.5	0.59	17
Total Nitrogen as N	mg/L	1	25.00	24.80	1	<1.00	1.10	10
Total Phosphorus as P	mg/L	0.01	0.72	0.87	19	<0.01	0.01	9
Electrical Conductivity @ 25°C	µS/cm	0.1	34800	35800	3	1040	1010	3
pH Value	pH units	1	7.60	7.64	1	7.59	7.87	4
Turbidity	ZFn (NTU)	0.1	1670.00	524.00	104	31.7	23.60	29
Calcium Hardness	mmol/L	0.0002	2.64	3.24	20	2.65	2.93	10
Dissolved Organic Carbon	mg/L	0.5	10.40	11.60	11	0.71	0.71	0
Hardness	mmol/L	0.0002	21.3	23.3	9	3.5	3.8	8
Hardness as $CaCO_3$	mg $CaCO_3$/L	0.02	2130.00	2330.00	9	350	378.00	8
Magnesium Hardness	mmol/L	0.0002	19	20	8	1	1	0
Phenol Index	mg/L	0.005	<0.005	<0.005	0	<0.005	<0.005	0
Total Organic Carbon	mg/L	0.5	11.20	12.10	8	1.17	1.41	19
Dissolved Metals								
Aluminium	µg/L	2	<2.00	<2.00	0	<2.00	<2.00	0
Antimony	µg/L	0.05	0.33	0.62	62	<0.050	0.07	35
Arsenic	µg/L	0.2	0.81	0.94	15	0.588	0.42	33
Barium	µg/L	0.2	80.10	85.50	7	83.80	82.10	2
Beryllium	µg/L	0.2	0.22	0.21	5	<0.20	<0.20	0
Bismuth	µg/L	1	<1.0	<1.0	0	<1.0	<1.0	0
Boron	µg/L	10	1060	1230	15	69.00	83.00	18
Cadmium	µg/L	0.02	<0.020	<0.020	0	<0.020	<0.020	0
Calcium	mg/L	0.005	106	130	20	106.00	118.00	11
Chromium	µg/L	0.2	<0.200	<0.200	0	<0.200	<0.200	0
Cobalt	µg/L	0.05	1.68	1.53	9	0.08	<0.050	46
Copper	µg/L	1	12.90	9.40	31	<1.0	<1.0	0
Iron	µg/L	2	<2.0	3.70	60	<2.0	<2.0	0
Lead	µg/L	0.05	<0.050	0.35	150	<0.050	<0.050	0
Lithium	µg/L	1	1.00	<1.0	0	25.80	25.70	0
Magnesium	mg/L	0.003	454.0	488.0	7	20.6	20.60	0
Manganese	µg/L	0.1	168	168	0	37.4	23.80	44
Mercury	µg/L	0.01	<0.010	<0.010	0	<0.010	<0.010	0
Molybdenum	µg/L	1	5.20	5.50	6	<1.0	<1.0	0
Nickel	µg/L	0.2	1.24	1.67	30	1.61	1.32	20
Potassium	mg/L	0.015	173.00	183.00	6	7.29	7.10	3
Selenium	µg/L	0.2	2.50	2.11	17	<0.200	<0.200	0
Silicon	mg/L	0.01	3.00	3.44	14	12.3	12.90	5
Silver	µg/L	1	<1.0	<1.0	0	<1.0	<1.0	0
Sodium	mg/L	0.03	4700	4810	2	81.6	71.10	14
Strontium	mg/L	0.001	2.14	2.25	5	0.41	0.40	3
Thallium	µg/L	0.5	<0.50	<0.50	0	<0.50	<0.50	0
Tin	µg/L	1	<1.0	<1.0	0	<1.0	<1.0	0
Titanium	mg/L	0.001	<0.0010	<0.0010	0	<0.0010	<0.0010	0
Uranium	µg/L	0.5	7.68	7.66	0	<0.50	<0.50	0
Vanadium	µg/L	1	<1.0	<1.0	0	<1.0	<1.0	0
Zinc	µg/L	2	2.30	9.10	119	<2.0	<2.0	0

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NOTES:
1. DARK SHADED RESULTS INDICATE A RELATIVE PERCENT DIFFERENCE GREATER THAN 20% BETWEEN SAMPLES, AND THE MEASURED CONCENTRATIONS ARE GREATER THAN FIVE TIMES THE MDL.

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GB MINERALS LTD
FARIM PHOSPHATE PROJECT

GROUNDWATER MODELLING: PIT INFLOW AND DEWATERING IMPACT ESTIMATION

PREPARED FOR:

Lycopodium Minerals Canada Ltd.
5060 Spectrum Way, Suite 302,
Mississauga,
ON L4W 5N5
CANADA

PREPARED BY:

Knight Piésold Pty Limited
Level 1, 184 Adelaide Terrace
East Perth, WA 6004, AUSTRALIA
p. +61 9223 6300 • f. +61 9223 6399

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Rev 0
July, 2015

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CONSULTING
www.knightpiesold.com

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FARIM PHOSPHATE PROJECT

GROUNDWATER MODELLING: PIT INFLOW AND DEWATERING IMPACT ESTIMATION

FINAL REPORT

KP Job No. PE301-00520/04

KP Report No. PE301-00520/03

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Water Level Predictions

EXECUTIVE SUMMARY

Knight Piésold (KP) constructed a numerical groundwater flow model of the proposed open pits at the Farim Phosphate Project on behalf of GB Minerals. The model was used to predict groundwater inflows at various stages of the Farim open pit development and the associated drawdown extents. Significant improvements to the hydrogeological conceptual model and the estimated dewatering infrastructure were achieved. The major findings of the study are summarised below.

REFINEMENT OF CONCEPTUAL MODEL

Following recent field investigations and detailed data analysis the conceptual model has significantly changed from that presented previously. This includes the following revised conceptualisation of the hydrostratigraphy of the site:

- The overburden layer comprising sands, clays and gravels, extends from the land surface to the absolute elevation of -30 m RL. This unit can be considered an unconfined aquifer and is shown to be of limited hydraulic connection with the River (Rio) Cacheu due to the presence of extensive superficial clay in the lowland plain.
- The blue clay horizon is not continuous over the region; it occurs in localised areas only and ranges in thickness.
- A calcareous layer (the Limestone) lies beneath the orebody. Water levels in this unit sit at a higher elevation than those of the overburden suggesting that groundwater in this unit is under pressure with a vertically upwards hydraulic gradient. Field observations do not support this being a dolomitic limestone, instead indicate that the unit be better characterised as a calcareous clayey friable sandstone, justifying the low hydraulic conductivities associated with this layer.

GROUNDWATER INFLOWS

The groundwater model constructed by Knight Piésold demonstrates active dewatering of the mining areas to levels below the pit floor. KP has improved the estimated pit inflows and determined potential impacts to nearby community/private wells.

Modelled pit inflows for the simulation period are shown graphically in Figure 7.1 and are summarised as follows:

- Southern Pit: Average daily pit inflows, are of the order of 13,000 m^3/d (542 m^3/hr) ranging from 9,800 m^3/d to 16,700 m^3/d,
- Northern Pit: Average calculated inflows are 6,500 m^3/d (271 m^3/hr) ranging from a peak of 8,900 m^3/d to 5,100 m^3/d at the end of mining in Year 25.

GROUNDWATER IMPACTS

The drawdown resulting from pit dewatering has the potential to impact a significant number of nearby community water users. A summary of the potentially impacted wells is provided in Table 7.1. A series of figures illustrating the predicted drawdown in nearby wells is presented in Appendix B.

DEWATERING INFRASTRUCTURE

The groundwater model provides a revised dewatering configuration that is a significant improvement on previous estimations. Dewatering bore depth and pumping rates were determined from analysis of the pumping test results and the infrastructure configuration was designed through refinement of the modelled scenario. The revised mining area was 40% larger than previously modelled. Both sumps and in pit bores were included in the infrastructure estimation. This coupled with the increased bore spacing (from 75 m to 150 m) in the majority of the dewatering bores and a viable increase in average bore pumping rate (3.6 to 10.5 m^3/h) is a large improvement on the previous estimation conducted in 2014. A comparison between the 2014 and 2015 infrastructure designs is presented in Table E1. The modelled infrastructure is displayed on Figure 7.2.

In addition, an estimate of the dewatering infrastructure requirements over time has been developed, using a staged approach, distributing capital expenditure over the 26 year mine life. The infrastructure requirements over the life of mine are presented in Section 7.

Table E1: Comparison of Dewatering Infrastructure Estimates

Infrastructure Configuration	Golder 2014 (Ref 2)	Knight Piésold 2015
Relative dewatering area	100%	140%
Dewatering Stages	15	14
Estimated bore rate	3.6-7.2 m^3/h	10.5 m^3/h
Average bore base level	-70m RL (about 70m deep)	-70m RL (about 70m deep)
In Pit Bores	Undefined	Included
Bore spacing	75 m	150 m inland and 75 m by river
Sumps	Undefined	26
Adequate dewatering for dry working conditions	No	Yes

The previous dewatering plan required a large number of bores to be constructed up front. By staging the dewatering program KP envisages that the upfront dewatering infrastructure can be reduced to 40 dewatering bores. Thereafter, additional bores will be added, as summarised in Table 7.3. This will provide the opportunity to update the groundwater model as a predictive tool

to more accurately define the future dewatering requirements. It is noted that the total number of bores required over the life of the mine has increased by 8% due to the increase in the mining area of 40%.

RECOMMENDATIONS

To further improve the understanding of the dewatering needs and the potential associated hydrogeological impacts a number of actions are recommended:

- Provide an improved geological model to allow a refinement of the hydrogeological model domain. In this regard, the development of a block geological model, to be used as a basis for the hydrogeological and other mining design and development purposes is essential.
- Conduct additional pumping tests in the southern pit, during Phase 1 development to further develop the groundwater flow regime, the hydraulic connection with nearby creeks and surface water bodies, water impacts associated with mining the pit and the variation of aquifer hydraulic properties over the area of interest.
- A Groundwater Management Plan will be required to address the drawdown impacts on local water supplies. This should include:
  - The establishment of a groundwater monitoring network and a mitigation plan to ensure that water availability is maintained.
  - Undertaking an updated hydrocensus and survey of nearby bores to determine use, depth, water level elevation.
  - A hydrogeochemical survey to understand baseline groundwater quality, the role of hydrogeochemical processes in the system and the degree of interaction between the brackish surface water bodies and groundwater both at current condition and during dewatering.
- These will provide additional information for further model calibration and greater certainty around dewatering impacts both with respect to groundwater levels and quality.
- Incorporate new pumping tests and hydrocensus data into the groundwater model to provide additional calibration and refinement.
- The long term response of the aquifer to pumping, especially at the southern pit, should be tested by additional pumping tests during the initial installation of dewatering bores.

- Investigate alteration of the mine plan to improve dewatering efficiencies.
- Develop a preliminary borefield operating strategy to determine likely monitoring, equipment recycling and maintenance requirements.
- A surface water management plan is recommended to understand and mitigate the risk of surface water flooding of the southern pit and marshland inflows over the mangrove marshy area.

1. INTRODUCTION

1.1 GENERAL

GB Minerals has engaged Knight Piésold Pty Ltd (KP) to assist with the development of a feasibility study (FS) for the Farim Phosphate Project (the "Project") in Guinea-Bissau, West Africa.

The Project is located in the central north part of Guinea-Bissau, approximately 25 km south of the Senegal border, 5 km west of the town of Farim and 120 km north-east of Bissau, the capital of Guinea-Bissau. The Project comprises a high grade sedimentary phosphate deposit of one continuous phosphate bed, which extends over a known surface area of approximately 40 km^2, with two pits and an expected 25 year life of mine.

1.2 MODEL OBJECTIVES

For successful mining at the Farim Phosphate Project both pits will require dewatering. In order to understand the dewatering requirements a groundwater model was constructed to determine the following:

- Estimation of pit inflow rates from groundwater.
- Prediction of the effects of mining upon the groundwater system.

Resolution of the two objectives allowed for the development of a preliminary dewatering plan including an estimation of infrastructure requirements.

2. CONCEPTUALISATION

2.1 CONCEPTUAL MODEL

The hydrogeological conceptual model for the project area was determined from previous groundwater investigations and recent data provided by GB Minerals.

Recent site visits and field investigations assisted in significantly updating the conceptual model both with regards to the aquifer structure and the potential effect of the surface water regime on the proposed mining operations. The key features of the conceptual model are essential in the design and development of the groundwater flow model. The significant updates of the conceptual model are summarised below:

2.1.1 Surface Water Regime

The area is characterised by undulating topography comprising lowland riparian zones of nearly zero elevation surrounded to the north-west by hilly areas with elevations of up to about 50 m (Figure 2.1, source: local topographic map).

The major surface water body in the area is the River Cacheu, a permanent water body, about 300 m wide. This river, in the vicinity of the mining zone, is fed by various permanent creeks.

Water level in the River Cacheu is affected by short and longer term tides with a daily range of about 2 metres. The river tides affect the water levels along the creeks.

The lowland plain area is affected by tidal water level fluctuations, mainly over the mangrove coverage, as well as by seasonal inundations during the rainy season. In fact, the plain which covers almost half of the southern pit is said by the locals, to be completely inundated by water during the rainy season.

Based on the above, it is evident that the surface hydrologic regime in the vicinity of the proposed mining pits is of essential importance in the design of mine dewatering.

2.1.2 Aquifer Structure and Hydrostratigraphy

The key features of the existing conceptual hydrogeological model (Golder, 2012, 2014) identified four distinct hydrostratigraphic units as follows:

- An overburden layer comprising sands, clays and gravels, extends from the land surface to an elevation of -20 m RL. This unit can be considered an unconfined aquifer and is initially assumed to be in hydraulic connection with the River (Rio) Cacheu.
- A continuous horizon of "blue clay" extending at an elevation of -20 to -30 m RL and wedging out towards the River Cacheu.

- The ore body from -30 to -36 mRL.
- The above sequence is underlain by a bedrock of dolomite limestone starting from an elevation -36 m RL.

Based on a review of the available borehole logs, it was identified that the postulated layer of blue clay occurs locally and is not consistent over the mining area. Also a review of the borehole core at the site indicates that the bedrock could be characterised more as a friable - calcareous- clayey sandstone rather than strictly as "dolomite limestone".

The available borehole logs were combined together to re-interpret, as practicable as possible, the stratigraphy and hydro-stratigraphy of the area of interest. Stratigraphic correlations of the borehole logs were made by making use of the Rockworks™ software to produce a preliminary block model. Figure 2.2 shows a fence diagram extracted from this stratigraphic block model. Figure 2.3 shows the same fence diagram produced by classifying together the various kinds of clays and sands in more abstract hydrostratigraphic units pertinent to the modelling needs.

The modified findings discerned from the construction of the above preliminary block model are as follows:

- The overburden layer comprising sands, clays and gravels, extends from the land surface to the absolute elevation of -30 m RL. This unit can be considered an unconfined aquifer and is initially assumed in hydraulic connection with the River (Rio) Cacheu.
- However field observations and borelogs suggest that in the lowland plain area, near the river, an extensive superficial clay layer occurs which may act as a low permeability barrier that may lead to significantly lower groundwater inflows from the River Cacheu into the pits during dewatering.
- The blue clay horizon is not continuous over the region, it occurs in localised areas only and ranges in thickness. For the purposes of the model this has been associated with the overburden formation, which overlies the FPA horizon.
- A calcareous layer (the Limestone) lies beneath the orebody. Water levels in this unit sit at a higher elevation than those of the overburden suggesting that groundwater in this unit is under pressure with a vertically upwards hydraulic gradient.

  Field observations of the core samples do not support this being a dolomitic limestone. Core observed on site indicates that the unit could be better

characterised as a calcareous clayey friable sandstone. The calcareous clay portion of this layer justifies the low hydraulic conductivities of this layer produced by both the pump test and the model calibration.

As discussed earlier, the River Cacheu at the southern side of the project area experiences tidal fluctuations of 2 m. The occurrence of the superficial clay in the lowland areas, suggest that the river might have limited impact on the nearby groundwater levels. This evidence is supported by the different groundwater quality signature between surface river water and groundwater. Isolated measurements conducted in the vicinity of the River Cacheu during the recent site visit (April 2015) show that surface water has a high electrical conductivity ranging from 3500 to 7500 µS/cm and alkaline pH of 7.2 to 7.6 whereas groundwater had significantly lower electrical conductivity of 2150 µS/cm and acid pH of 6.7.

2.2 MODEL ASSUMPTIONS AND LIMITATIONS

A number of assumptions and limitations were considered when assessing the model outputs. These are described as follows:

- Tidal fluctuations in the River Cacheu are considered to have a limited impact on groundwater levels in the mining areas.
- Hydrogeological units are considered to be horizontally uniform, homogeneous and isotropic with consistent aquifer properties.
- Model calibration was completed based on the aquifer response observed during the 10-day constant discharge pumping test conducted at borehole PW2 and with the 5-day constant discharge pumping test conducted at borehole DGW01.
- The pit walls were modelled with vertical sides as opposed to progressive benching.
- The simulated saturated flow conditions do not account for any perched or unsaturated zones due to dewatering beneath the blue clay layer.
- The assumed maximum yield per bore is higher than previously assumed based on the PW2 and DGW01 pumping test yields.
- A large number of hydrocensus wells have not been surveyed in. Including these will provide greater accuracy of water levels at the project area.
- Surface water inflows into the pits due to the seasonal inundation of the southern pit - lowland area during the rainy period (May to November) and

potential marshland inflows over the mangrove marshy area have not been modelled.

3. MODEL DESIGN

3.1 SELECTION OF NUMERICAL CODE

The USGS MODFLOW numerical code (Ref 1) was selected as the model code. Visual MODFLOW (developed by Schlumberger Water Services, Canada), was selected for simulating the groundwater flow regime, estimating the pit inflows and the associated drawdown extents.

3.2 DISCRETISATION OF THE MODEL DOMAIN

The model origin is at 463,800 mE, 1,374,100 mN (UTM28N, WGS84 grid). The model domain extends 15,200 m east-west and 16,200 m north-south and was discretised, spatially in 290 rows and 303 columns ranging in size from 25 m at the pit zones expanding gradually to 200 m at the model boundaries (Figure 3.1).

The hydrostratigraphy of the study region was divided vertically into five distinct horizontal layers, representing the upper overburden layer of clays and gravels that incorporates also the river clay, the lower overburden layer, the FPA ore body, and two layers of the underlying limestone (Figure 2.3). Since the blue clay occurs mostly as localised lenses (Fig. 2.2) it wasn't represented separately in the model as a distinct layer and was incorporated in the overburden (sands and clays) layer.

The first horizon of the overburden layer extends from the land surface to the absolute elevation -15 mRL while the second horizon extends to elevation -30 mRL. The overburden layer was split into two different horizons in order to represent occurrence of the superficial clay layers in the vicinity of the River Cacheu.

The FPA ore horizon was represented as a single layer from -30 mRL to -36 mRL and the underlying calcareous limestone horizon was discretised in two model layers, one from -36 mRL to -70 mRL and the second from -70 mRL to the base of the model at -150 mRL.

3.3 EXTERNAL BOUNDARY CONDITIONS

The model boundaries are shown in Figure 3.1. The River Cacheu, along the model boundary (A - B in Figure 3.1) is approximately 300 m wide and constitutes the south-eastern boundary of the model. The water level in the river fluctuates daily, due to tides, between 0 and 2 m RL. Its' relatively wide width over the length of the model domain justifies the allocation of this boundary as a 1st type (Dirichlet) boundary condition of average constant head of 0 m RL.

Based on the following features and assumptions, all the other boundaries of the model are represented as 2nd type - zero flow boundary conditions (Neuman type):

- The north-eastern (BC) and south-western (DA) boundaries are aligned with the regional topographic ridges and are assumed to coincide hydraulically with local groundwater divides of diverging flow.
- The north-western boundary (CD) of the model extends along a linear drainage feature (creek) which is assumed to coincide with a flow line or a locally converging groundwater divide.

3.4 INTERNAL BOUNDARY CONDITIONS

Internal boundary conditions are also included in the model design. The comparison of existing groundwater level data with Lidar topography data indicate that the various streams and tributaries of the River Cacheu, namely Rio de Caur, Rio de Cavaros, Rio de Bunja and Rio de Banim are gaining streams receiving permanent or seasonal groundwater discharge. The streams are represented as general head boundaries in the model (GHB package) by assigning 3rd type Cauchy boundary conditions. The representation of these creeks in the model is of essential importance since:

- At pre-mining conditions they act as gaining streams receiving groundwater discharge.
- During the mine dewatering phase they are expected to act as losing streams supplying water into the system due to water level gradients developing by drawing down the water levels in the pit areas.

Internal drains were also used to represent pit stages in the existing mining plan. The configurations of these drains (usually referred to as sinks in the model) were employed to simulate the dewatering of the pits.

3.5 AQUIFER PARAMETERS

The aquifer is conceptualised as a three geological - layer system comprising the overburden layer of mostly sands and gravels, the FPA orebody, and the underlying sequence of limestone. Investigation of the hydraulic properties of these layers and aquifer units was conducted by a number of pumping tests by various contractors. Those tests have mainly targeted the two aquifer units i.e. the underlying limestone and the overburden while no data exists for the hydraulic properties of the FPA ore horizon. A summary of the hydraulic property values for the three aquifer units, from various sources, is presented in Table 3.1.

Table 3.1: Summary of hydraulic properties of the aquifer units

Test Well	Obs. Well	Aquifer	Source	T[m^2/s]	Aquifer Thickness [m]	K[m/s]	K[m/d]	S
PW1	PW1	Overburden	Golder, 2012	3.10E-05	10	3.10E-06	0.268	
PW1	PW1	Limestone	Golder, 2012	2.30E-04	18	1.30E-05	1.123	
PW1	PW1	Overburden	Golder, 2012	4.00E-05	10	4.00E-06	0.346	
PW1	PW1	Limestone	Golder, 2012	1.70E-04	18	9.50E-06	0.821	
PW1	Various	Limestone	Golder, 2012	3.20E-04	18	1.80E-05	1.555	1.30E-04
PW1	MW09	Overburden	Golder, 2012	1.80E-03	10	1.80E-04	15.552	6.20E-03
PW1	F1	Limestone	Golder, 2012	3.40E-04	18	1.90E-05	1.642	2.90E-03
PW1	F2	Limestone	Golder, 2012	2.00E-04	18	1.10E-05	0.950	1.90E-04
PW1	P1	Limestone	Golder, 2012	2.90E-04	18	1.60E-05	1.382	3.10E-04
PW1	P2	Limestone	Golder, 2012	1.90E-04	18	1.00E-05	0.864	3.30E-04
PW1	P3	Limestone	Golder, 2012	2.00E-04	18	1.10E-05	0.950	2.20E-04
PW1	P4	Limestone	Golder, 2012	2.70E-04	18	1.50E-05	1.296	3.60E-04
PW2	PW2	Overburden	Golder, 2012	6.60E-05	9	7.40E-06	0.639	
PW2	PW2	Limestone	Golder, 2012	4.00E-04	19	2.10E-05	1.814	
PW2	PW2	Overburden	Golder, 2012	6.10E-05	9	6.80E-06	0.588	
PW2	PW2	Limestone	Golder, 2012	4.10E-04	19	2.20E-05	1.901	
PW2	Various	Limestone	Golder, 2012	7.40E-04	19	3.90E-05	3.370	1.10E-03
PW2	MW07A	Limestone	Golder, 2012	3.30E-03	19	1.80E-04	15.552	9.00E-04
PW2	MW08A	Limestone	Golder, 2012	5.00E-04	19	2.60E-05	2.246	1.20E-04
PW2	DW1	Limestone	Golder, 2012	1.10E-03	19	5.90E-05	5.098	2.30E-04
PW2	DW4	Limestone	Golder, 2012	1.20E-03	19	6.20E-05	5.357	3.80E-04
PW2	DW7	Limestone	Golder, 2012	7.50E-04	19	3.90E-05	3.370	6.50E-04
PW2	DW8	Limestone	Golder, 2012	1.10E-03	19	5.70E-05	4.925	3.80E-04
PW2	DW9	Limestone	Golder, 2012	1.10E-03	19	5.60E-05	4.838	8.60E-04
PW1		Limestone	Golder, 2012	1.00E-05	18	5.56E-07	0.048	
PW1		Overburden	Golder, 2012	8.00E-05	18	4.44E-06	0.384	
PW1		Limestone	Golder, 2012	3.00E-04	18	1.67E-05	1.440	
PW2		Limestone	Golder, 2012	6.00E-05	19	3.16E-06	0.273	
PW2		Overburden	Golder, 2012	3.00E-04	19	1.58E-05	1.364	
PW2		Limestone	Golder, 2012	1.00E-03	19	5.26E-05	4.547	
H1	H1	Overburden	BRGM, 1986	6.50E-04	18*	3.61E-05	3.120	4.00E-04
H1	P1	Overburden	BRGM, 1986	1.10E-03	18*	6.11E-05	5.280	1.00E-03
H1	H1	Overburden	BRGM, 1986	1.10E-03	18*	6.11E-05	5.280	1.00E-03
H1	P1	Overburden	BRGM, 1986	1.60E-03	18*	8.89E-05	7.680	3.00E-03
H2	P2	Overburden	BRGM, 1986	2.50E-03	18*	1.39E-04	12.000	1.30E-02
H4	H4	Overburden	BRGM, 1986	2.00E-04	18*	1.11E-05	0.960	1.00E-03
H3	H3	All	GEEM_2009	4.00E-05	18*	2.22E-06	0.192	1.00E-05
F2	F1	Limestone	GEEM_2009	2.20E-04	18*	1.22E-05	1.056	
F2	P1	Limestone	GEEM_2009	1.60E-04	18*	8.89E-06	0.768	
F2	P2	Limestone	GEEM_2009	2.20E-04	18*	1.22E-05	1.056	
S.S. Model		Overburden	Golder, 2014			1.00E-05	0.864	
S.S. Model		Blue Clay	Golder, 2014			1.00E-07	0.009	
S.S. Model		FPA/FPB	Golder, 2014			8.00E-06	0.691	
S.S. Model		Limestone	Golder, 2014			8.00E-06	0.691	

* Inferred thickness.

Table 3.1 also contains hydraulic properties of the various layers according to a Steady-State calibrated model, developed by Golder (Ref 2) in order to assess the long term regional drawdown effects attributed to pit dewatering. A statistical analysis of the range of hydraulic conductivities presented in the above table for the two major layers, namely the overburden and the underlying limestone, is shown in Figure 3.2.

The above analysis suggests that the average hydraulic conductivities of the overburden and the calcareous limestone, are relatively high, 2.98 and 2.62 m/d respectively. In reality they follow a skewed distribution with lower median statistics. The higher values of 12.0 m/d and 15.5 m/d observed are outliers which probably reflect the occurrence of local sandy or gravel lenses.

The validity of model parameters and hydraulic properties adopted in the above model were re-assessed in the calibration phase (presented in Section 5).

As mentioned previously there is evidence of the existence of a superficial layer located in the lowlands alongside the River Cacheu. The anticipated extent of this clay layer in the model domain is shown in Figure 3.3.

3.6 GROUNDWATER LEVELS

A number of groundwater level data are available in the project area from measurements conducted largely between 2011 and 2015. The measurements were mostly taken at locations near the proposed open pits during various campaigns including the pumping tests of boreholes PW2 and PW1 (conducted in December 2011 and January 2012 respectively) and of DGW01 (conducted in April 2015).

Additional water level data exists at numerous private wells (referred to as ‘Hydrosensus Wells’ (W01 TO W87)), but these wells are missing surveyed elevations. The lack of reliable elevations at these points precludes water level measurements from these wells being used together with the above data for the compilation of an approximate piezometric map of the region. Attempts to deduce point elevations from LIDAR data resulted in doubtful results. Table 3.2 provides a summary of the groundwater level data available to the modelling process.

Table 3.2: Summary of available groundwater level data

Borehole	Aquifer	Easting [m]	Northing [m]	Elevation [m R.L]	Number of meas.	From Date	To Date	Water Level (m RL)		
								max	min	average
DW1	Limestone	470251	1380708	9.68	35	22/06/2011	8/02/2012	4.07	3.17	3.56
DW4	Limestone	470332	1380794	11.59	36	22/06/2011	8/02/2012	3.94	3.15	3.51
DW5	Limestone	470333	1380627	8.42	34	22/06/2011	8/02/2012	3.92	3.21	3.50
DW6	Limestone	470293	1380630	8.62	35	22/06/2011	8/02/2012	3.88	3.14	3.46
DW7	Limestone	470459	1380652	13.35	35	22/06/2011	8/02/2012	3.90	3.05	3.42
DW8	Limestone	470454	1380769	14.85	36	22/06/2011	8/02/2012	3.87	1.47	3.31
DW9	Limestone	470292	1380795	11.08	35	4/07/2011	8/02/2012	3.91	2.96	3.45
F1	Limestone	473279	1378447	2.33	31	26/08/2009	6/02/2012	0.30	-1.22	-0.66
F2	Limestone	473186	1378449	3.24	36	26/08/2009	6/02/2012	0.42	-1.29	-0.71
MW01A(D)	Limestone	471454	1377403	7.95	36	20/11/2011	8/02/2012	0.02	-0.61	-0.44
MW01B(S)	Overburden	471456	1377409	8.06	36	20/11/2011	8/02/2012	-0.01	-0.81	-0.62
MW02A(D)	Limestone	473431	1379147	2.65	27	23/11/2011	7/02/2012	0.30	-0.56	-0.30
MW02B(S)	Overburden	473437	1379148	2.73	28	23/11/2011	8/02/2012	0.28	-0.87	-0.56
MW03A(D)	Limestone	472531	1380813	10.95	27	9/11/2011	8/02/2012	0.20	-0.77	0.10
MW03B(S)	Overburden	472528	1380818	10.98	27	9/11/2011	8/02/2012	0.19	-0.27	-0.06
MW04A(S)	Overburden	470479	1378978	16.97	54	14/07/2011	7/02/2012	1.88	0.46	1.43
MW04B(D)	Limestone	470474	1378978	17.04	54	14/07/2011	7/02/2012	1.72	0.68	1.39
MW05A(D)	Limestone	477364	1383201	33.62	14	6/08/2011	8/02/2012	5.80	5.33	5.68
MW05B(S)	Overburden	477360	1383197	33.50	13	6/08/2011	7/02/2012	5.67	5.08	5.52
MW06(S)	Overburden	472947	1378239	5.24	34	11/11/2011	7/02/2012	0.32	-0.82	-0.52
MW07A(D)	Limestone	471269	1381234	21.94	20	11/11/2011	6/02/2012	3.76	3.59	3.67
MW07B(S)	Overburden	471272	1381231	21.98	20	11/11/2011	6/02/2012	3.45	3.40	3.42
MW08A(D)	Limestone	470643	1381191	25.71	23	11/11/2011	8/02/2012	4.01	2.81	3.51
MW08B(S)	Overburden	470648	1381184	25.85	22	11/11/2011	8/02/2012	4.46	4.09	4.28
MW09B(S)	Overburden	472919	1378194	5.33	31	3/12/2011	7/02/2012	-0.05	-0.81	-0.59
P1	Limestone	473226	1378505	3.12	37	26/08/2009	6/02/2012	0.47	-1.05	-0.56
P2	Limestone	473028	1378450	5.32	42	26/08/2009	6/02/2012	0.46	-1.27	-0.74
P3	Limestone	473246	1378356	2.55	39	26/08/2009	6/02/2012	0.38	-1.27	-0.72
P4	Limestone	473264	1378206	1.74	40	26/08/2009	6/02/2012	0.27	-1.09	-0.65
PW1	Limestone	473045	1378302	4.47	19	11/11/2011	5/02/2012	0.40	-1.70	-0.42
PW2	Limestone	470620	1380896	21.15	20	29/10/2011	8/02/2012	3.87	3.20	3.72

3.7 SOURCES AND SINKS

The presence of numerous populated settlements in the area including the nearby town of Farim indicates active groundwater abstraction, potentially for domestic and limited agricultural purposes. No data were available for the occurrence of any large scale abstraction in the area. Groundwater abstraction occurs exclusively from hand dug wells for domestic water needs whilst large scale irrigation from groundwater is absent.

A rainfall infiltration rate of 5 mm per year was assumed initially by Golder (Ref 2) in their steady – state regional model. However, in groundwater modelling, a combination of different recharge rates and hydraulic conductivities could yield equally well calibrated models with completely different dewatering inflows. This is a result of the non-uniqueness of the various parameters introduced in a steady – state calibration especially due to the correlation of recharge with the aquifer hydraulic conductivity. This problem can be overcome by calibrating the model at transient state conditions by simulating the aquifer response against well-known stresses such as the water level hydrographs recorded at a number of observation wells during the long term pumping test at borehole PW2. In this scenario an acceptable model calibration was achieved by using a recharge value of 10 mm per year, as presented in Table 4.1.

4. MODEL CALIBRATION

The data available for model calibration comprises average water levels, as presented in Table 3.2, and transient aquifer stress data produced during the 10-day pumping tests (Ref. 3) at bores PW1 and PW2, and the 5-day pumping test at bore DGW01.

4.1 STEADY STATE CALIBRATION

Steady state calibration involves variation of model parameters either by trial and error method or by more advanced inverse methodologies in order to regenerate with regards to the stated model calculated values (i.e. groundwater levels or quality) which resemble as much as possible the observed field measurements. For this project the available data that describe the long term average groundwater conditions at the site are the water level measurements presented in Table 3.2. The replication of these long term average or steady-state water level data with the model, except for the hydrostratigraphic structure of the system, depends only on the optimum values of hydraulic conductivities of the aquifer and the corresponding rate of aquifer replenishment or natural groundwater recharge.

Unfortunately, the calibration of the model at steady state conditions suffers from the problem of non-uniqueness of calibration parameters. This is largely due to the strong correlation of various model parameters, mainly of natural recharge with the hydraulic conductivity of the aquifer. That means that coordinated variations of both natural recharge rate and the hydraulic conductivity of the aquifer can produce an apparently equally well calibrated model.

Based on the above uncertainties, the model was initially calibrated by selecting the fixed value of average annual groundwater recharge of 10 mm/year. The calibration of the model will be refined further in the next stage of transient state calibration.

The correlation between the model calculated water levels versus field observed levels are shown in Figure 4.1 while the spatial distribution of the calculated groundwater levels over the model domain are shown in Figure 4.2. As shown from calibration statistics in the bottom right side of Figure 4.1, the correlation coefficient of the calibrated vs the observed values is 95.3% the RMS Error is 0.1 m and the Normalised RMS Error is 8.9% which means that this model can replicate the field values (water levels) with acceptable accuracy within an average error of +/-10 cm. However, as mentioned above this type of calibration suffers from the problem of non-uniqueness (which will be overcome at the next stage of transient model calibration).

4.2 TRANSIENT STATE CALIBRATION

The problem of non-uniqueness, discussed in the previous section, can be overcome by transient state calibration where additional information such as aquifer stress data is introduced and the responses of the aquifer to specific stresses are measured. Transient stress data are available for the three pumping tests conducted at bores PW2, PW1 and DGW01. PW2 was pumped for 11 days at a constant rate of 8.54 m^3/h with a noticeable drawdown at a number of observation wells at various distances. Likewise, PW1 was pumped for 10 days at an average constant rate of 1.59 m^3/h but without any noticeable drawdown at the observation wells, possibly due to the low discharge rate. DGW01 was pumped for 5 days at an average constant rate of 4.09 m^3/hr, with noticeable though limited drawdown in the pumped well and no drawdown at two observation wells at distances of 307 m and 506 m.

The model was calibrated against the transient data produced from PW2 and DGW01 pumping tests. The model was set up to run for a period of 20 days, starting with a steady – state calibration to generate the initial conditions of the model, and applying a constant discharge rate at PW2 (from 1/12/2011 16:45 hrs to 11/12/2011 16:45 hrs). The calibration of the model was achieved by varying the parameters of recharge and the hydraulic conductivities and storage properties of the two major units, i.e. the overburden phosphate and the limestone. The variation of parameters was initially conducted by trial and error and then by using the PEST parameter estimation programme (Ref 4).

A good agreement was achieved between the model and the observed water levels recorded during the pumping test. The calibrated model parameters are listed in Table 4.1.

Table 4.1: Model parameters selected via transient - state calibration

Model Layer	Aquifer Property	Value	Units
1,2. Overburden	K_h	2.21	[m/d]
	K_v	0.221	[m/d]
	S_s	2.15E-6	
	S_y	0.007	
	Recharge Rate	10	[mm/year]
3. Phosphate	K_h	0.4	[m/d]
	K_v	0.04	[m/d]
	S_s	2.15E-6	
	S_y	0.007	
4,5. Limestone	K_h	0.4	[m/d]
	K_v	0.017	[m/d]
	S_s	2.15E-6	
	S_y	0.007	
1. River Clay	K_h	0.2	[m/d]
	K_v	0.02	[m/d]
	S_s	2.15E-6	
	S_y	0.007	
	Recharge Rate	10	[mm/year]

A scatter plot of calculated vs observed water levels and the pertinent calibration statistics are displayed in Figure 4.3. Plots of model generated hydrographs against field recorded water levels during both the pumping and recovery stages of the test are shown in Appendix A. The RMS of 0.161 m with a Normalised RMS of 11.21 % and a correlation coefficient of 0.68 indicate an acceptable model calibration that could be used for the predictive simulations.

4.3 DATA GAPS

The long term response of the aquifer to pumping, especially at the southern pit, should be tested by additional pumping tests, focusing on the interconnection of the underlying limestone with the overburden.

Additional testing should initially focus on the southern pit which is planned to be developed first. For example there is a cluster of existing bores at the southern pit which form an ideal location to do a pumping test using existing bores as observation bores.

5. SENSITIVITY ANALYSIS

As noted the model was calibrated at steady state conditions by varying the model parameters, initially by trial and error and then by automatic inverse optimisation methodologies making use of the widely accepted PEST code. Hence the majority of model parameters were selected at their optimum values and there is no need for further sensitivity analyses at this stage.

However due to the problem of non-uniqueness, apparently equally well calibrated models can be produced, at steady state, by various combinations of hydraulic conductivity and recharge. At transient state the same problem occurs, in some cases, by coordinated changes of the Transmissivity and Storage coefficient, which as a ratio are usually referred to as the diffusivity of the aquifer.

Figure 5.1 shows a sensitivity analysis of the natural recharge and the most sensitive to recharge layer, the overburden. The model was calibrated at different recharge rates and a linear relationship was found between hydraulic conductivity and recharge.

By monitoring the Scaled Normalised Root Mean Squared error (NRMS) for all these calibrated models (Figure 5.1) it was identified that this error increases significantly at low recharge rates and decreases exponentially at higher recharge rates. By testing various scenarios it was identified that the optimum combination of recharge and hydraulic conductivity is at the inflection point of the NRMS curve which corresponds to a recharge value of 10 mm/year and hydraulic conductivity of 2.21 m/day, which is consistent with the field data (Figure 3.3).

6. PREDICTIVE MODELLING

6.1 MINE PLAN

During the course of the feasibility study the mine plan was updates and includes two pits to be mined in distinct stages over a time period of 26 years (Figure 6.1). The excavation will be completed to the base of the phosphate ore body at an approximate elevation of -36 m RL in 26 mining stages. It must be noted that the updated mining plan has increased the mined area by approximately 40%.

6.2 ESTIMATION OF PIT INFLOWS

6.2.1 Model Configuration and Estimation of Pit Inflows

The estimation of dewatering inflows was modelled using the Drain Package of MODFLOW. Based on the mine plan, 26 mining stages were introduced into the model as transient instant drains (i.e. sumps) at the base of the ore body.

A pre-draining period of 6 months was initially assumed for the first mining stage and the model was run for a total simulation period of 26.5 years, i.e. 26 years of mining plus 6 months of initial pre-drainage. The mining stages were assumed to be completely backfilled so they behave as porous media with constant hydraulic properties post-excavation.

The drain water level was set at -40 m RL which is 4 m below the base of the ore body to allow for dry working conditions to be maintained at the pit base at elevation -36 mRL.

Calculated dewatering inflows with this scenario are shown in Figure 6.2.

Average daily pit inflows in the southern pit, are of the order of 11,000 m^3/d ranging from 8,500 m^3/d to 14,000 m^3/d, while the northern pit calculated inflows are significantly lower at average inflows of 6,500 m^3/d and ranging from a peak of 8,900 m^3/d to about 5,100 m^3/d at the end of mining.

6.2.2 Prediction Uncertainty Analysis

The calculated groundwater inflows into the mining pits were made based on the model calibrated parameters presented in Table 4.1. However, as noted previously, there is still some uncertainty with regards to the range of values of key hydraulic properties in the system and their spatial heterogeneities. These types of uncertainties also introduce uncertainty into the model outputs, mainly onto the calculated pit inflows.

Thus, due to the ambiguity of the various parameters involved, both National and International modelling standards require the implementation of prediction uncertainty analysis on model results. The methodologies employed in this kind of analysis range

from model execution with different parameter values, within a range of confidence, to highly sophisticated methodologies such as parameter randomization, stochastic modelling, null space Monte Carlo simulations etc.

The methodology employed here involved the execution of the model multiple times by using different model parameters with the range of values produced by field tests and evaluating the corresponding model results, which in this case are the calculated pit inflows.

Figures 6.3 - 6.6 show the variation of calculated pit inflows produced at different values of hydraulic conductivity for the overburden, the FPA, the underlying limestone and the river clay. A synthetic image showing all the sensitivities together is presented in Figure 6.7.

The above results of the uncertainty analysis show that calculated pit inflows are sensitive to the range of values of hydraulic conductivities (K) of all tested layers to varying degrees. Modelling results are most sensitive to the K values of the limestone layer followed to a much lesser degree by the K values of the overburden. The model is less sensitive to the K values of the FPA layer and only at the southern pit, at the initial stages of mining, to the K values of the river clay.

The above uncertainties can be reduced by gaining higher confidence in the range of estimated values of the hydraulic properties pertaining to the hydrostratigraphic layer with the highest uncertainties.

7. PIT INFLOWS, DEWATERING INFRASTRUCTURE AND IMPACTS

The model was run for a total simulated period of 26 years, as a realistic scenario, by activating and de-activating the model drain zones and wells according to the updated mine plan with the southern pit being dewatered over the first 8 years and the northern pit for the subsequent 18 years. Both pits are dewatered during year 8.

7.1 PIT INFLOWS

Figure 7.1 shows the modelled pit inflows throughout the simulation period. Average daily pit inflows in the southern pit are of the order of 13,000 m^3/d ranging from 9,800 m^3/d to 16,700 m^3/d, while northern pit calculated inflows are significantly lower at average inflows of 6,500 m^3/d, ranging from a peak of 8,900 m^3/d to about 5,100 m^3/d at the end of mining in Year 26 (Figure 7.1). This is a preliminary estimate and is likely to change as the conceptual model is improved as a result of further field investigations.

7.2 GROUNDWATER DRAWDOWN

Figures in Appendix B show maps of calculated drawdown levels throughout the entire simulation period. Drawdowns due to mining of the northern pit are higher than those of the Southern pit due to the latter's proximity to and influence from the River Cacheu.

7.3 POTENTIAL DEWATERING IMPACTS ON NEARBY WATER USERS

The drawdown resulting from pit dewatering has the potential to impact nearby water users. Wells identified in the hydrocensus completed by Golders in 2012 (Ref 3) have been assessed against the drawdown contours simulated by the model. A series of figures illustrating the predicted drawdown in nearby wells is presented in Appendix B. A summary of the potentially impacted wells is provided in Table 7.1.

Table 7.1: Summary of potentially impacted wells

Bore	Easting	Northing	Elevation (mRL)	Type	Depth to Water (m)	Water Elevation (mRL)	Drawdown (m) (Drains scenario)	Drawdown (m) (Wells & drains scenario)
W05	475323.45	1380588.1	16	Private	13.15	2.85	0.9	1.2
W06	475077.13	1380549.6	15	Community	Unknown	-	0.8	1.0
W07	474571.85	1380544.5	15	Private	15.1	-0.1	0.6	0.8
W08	471847.24	1379664.2	17	Community	14.76	2.24	3.1	5.2
W09	470664.18	1377455.6	14	Community	13.4	0.6	2.0	2.9
W15	470086.87	1379649.4	22	Community	18.9	3.1	8.3	12.9
W16	470018.26	1379855.9	27	Community	18	9	8.9	13.9
W17	467325.33	1379945.4	18	Community	Unknown	-	4.7	7.1
W18	467126.1	1379932.8	17	Community	15.7	1.3	3.7	5.5
W19	466952.05	1381346.6	18	Community	10.05	7.95	5.2	7.4
W20	471942.73	1384723.3	31	Community	22.8	8.2	5.8	7.6
W21	471495.16	1384408.6	38	Community	24	14	6.0	7.9
W22	472038.69	1384714	29	Community	Unknown	-	5.7	7.5
W23	470683.24	1389033.6	32	Community	10.45	21.55	6.2	8.0
W24	474112.69	1383484.6	24	Private	8.5	15.5	3.9	5.1
W25	474232.18	1383451.3	19	Community	14.5	4.5	3.7	4.9
W27	475597.12	1380829.3	16	Private	14.6	1.4	1.1	1.4
W29	474239.3	1383322.3	17	Community	14	3	3.6	4.8
W30	474460.59	1383733.1	24	Community	15.1	8.9	3.9	5.1
W31	474744.75	1385631.2	25	Community	10	15	4.8	6.2
W32	475501.42	1381157.4	21	Community	Unknown	-	1.3	1.8
W33	475528.6	1381174	22	Community	16.9	5.1	1.3	1.8
W34	475767.6	1381125.9	21	Community	16.5	4.5	1.3	1.7
W35	475606.08	1384983.5	19	Community	7.9	11.1	4.3	5.5
W36	476151.56	1381160.6	25	Community	Unknown	-	1.4	1.8
W37	476270.9	1380937.4	18	Community	11.1	6.9	1.2	1.5
W38	476367.31	1380426.2	9	Community	7.5	1.5	0.8	1.1
W39	476350.83	1380201.3	14	Community	7.5	6.5	0.7	0.9
W41	476368.26	1380410.3	26	Community	17	9	0.8	1.1
W45	477432.04	1381336.5	36	Community	21.05	14.95	1.3	1.7
W46	477439.28	1381321.7	31	Community	Unknown	-	1.3	1.6
W47	477267.07	1381111.7	30	Community	17.05	12.95	1.2	1.5
W48	476940.95	1380931.4	28	Community	12.3	15.7	1.1	1.5
W49	476922.87	1380960.9	24	Community	Unknown	-	1.1	1.5
W50	476455.04	1380229.6	19	Private	12.15	6.85	0.7	0.9
W51	476402.21	1379849.9	19	Community	Unknown	-	0.5	0.6
W52	476507.29	1379901.5	10	Private	8.1	1.9	0.5	0.7
W53	476701.11	1379947.4	16	Private	8.32	7.68	0.6	0.7
W54	477081.45	1379976.6	18	Private	10	8	0.6	0.7

7.4 REVISED DEWATERING INFRASTRUCTURE CONFIGURATION

This model provides a revised dewatering configuration. Dewatering bore depth and pumping rates were determined from pumping test results. The configuration was designed through refinement of the modelled scenario. The revised mining area was 40% larger than previously modelled and this is reflected in the increase in the number of planned dewatering bores. Both sumps and in pit bores were included in the infrastructure estimation. This coupled with the increased bore spacing in the majority of the dewatering bores is a large improvement on the previous estimation conducted in 2014. A comparison between the two infrastructure designs is presented in Table 7.2. The modelled infrastructure is displayed on Figure 7.2.

The previous dewatering plan required a large number of bores to be constructed up front. By staging the dewatering program KP envisages that the upfront dewatering infrastructure can be reduced to 40 dewatering bores. Thereafter, additional bores will be added, as summarised in Table 7.3. This will provide the opportunity to update the groundwater model as a predictive tool to more accurately define the future dewatering requirements. It is noted that the total number of bores required over the life of the mine has increased by 8% due to the increase in the mining area of 40%.

Table 7.2: Comparison of Dewatering Infrastructure Estimates

Infrastructure Configuration	Golder 2014 (Ref 2)	Knight Piésold 2015
Relative dewatering area	100%	140%
Dewatering Stages	15	14
Estimated bore rate	3.6-7.2 m^3/h	10.5 m^3/h
Average bore base level	-70m RL (about 70m deep)	-70m RL (about 70m deep)
In Pit Bores	Undefined	Included
Bore spacing	75 m	150 m inland and 75 m by river
Sumps	Undefined	26
Adequate dewatering for dry working conditions	No	Yes

Table 7.3: Estimated dewatering infrastructure

Quantities	Per Bore	Year																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
# of bores		40	60	44	53	0	45	0	45	0	36	0	34	0	42	0	39	0	28	0	29	0	23	0	28	0	0
Drilled m	75	3000	4500	3300	3975	0	3375	0	3375	0	2700	0	2550	0	3150	0	0	0	2100	0	2175	0	1725	0	2100	0	0
8" Casing Blank	15	600	900	660	795	0	675	0	675	0	540	0	510	0	630	0	0	0	420	0	435	0	345	0	420	0	0
8" Casing Slot	60	2400	3600	2640	3180	0	2700	0	2700	0	2160	0	2040	0	2520	0	0	0	1680	0	1740	0	1380	0	1680	0	0
Gravel (tonnes)	7	280	420	308	371	0	315	0	315	0	252	0	238	0	294	0	0	0	196	0	203	0	161	0	196	0	0
Pump	1	40	60	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Head works	1	40	60	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reserve bore pump		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sump Pump		2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reserve Sump Pump		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sump length (km)		2.3	40	4000	900	900	800	800	1250	1250	1400	1400	900	900	500	500	1800	1800	1650	1650	1000	1000	1000	1000	250	250	250
Volume of sump earth moved (1000 m^3)		11.5	200	200	45	45	40	40	62.5	62.5	70	70	45	45	25	25	90	90	82.5	82.5	50	50	50	50	12.5	12.	12.5

7.5 PRE-DRAINAGE

Dewatering should commence twelve months before mining in the first pit stage. As the mining advances to subsequent stages, the water levels will already be lowered to an extent and the pre-dewatering time may reduce down to six months.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The model constructed by Knight Piésold demonstrates active dewatering of the mining areas to levels below the pit floor. Pit inflows and potential impacts to nearby community/private wells were estimated. Additionally a revised dewatering infrastructure configuration was developed.

8.1.1 Groundwater Inflows

Modelled pit inflows throughout the simulation period are shown graphically in Figure 6.2 and are summarised as follows.

- Southern Pit: Average daily pit inflows are of the order of 13,000 m^3/d ranging from 9,800 m^3/d to 16,700 m^3/d,
- Northern Pit: Average calculated inflows are 6,500 $m^{3/}$d ranging from a peak of 8,900 m^3/d to 5,100 m^3/d at the end of mining in Year 26.

Following recent field investigations and detailed data analysis the conceptual model has changed significantly from that presented by Golder (Ref 1). This includes the following revised conceptualisation of the hydrostratigraphy of the site:

- The overburden layer comprising sands, clays and gravels, extends from the land surface to the absolute elevation of -30 m RL. This unit can be considered an unconfined aquifer and is shown to be in limited hydraulic connection with the River (Rio) Cacheu due to the presence of extensive superficial clay in the lowland plain.
- The blue clay horizon is not continuous over the region, it occurs in localised areas only and ranges in thickness.
- A calcareous layer (the Limestone) lies beneath the orebody. Water levels in this unit sit at a higher elevation than those of the overburden suggesting that groundwater in this unit is under pressure with a vertically upwards hydraulic gradient. Field observations do not support this being a dolomitic limestone and instead indicate that the unit be better characterised as a calcareous clayey friable sandstone, justifying the low hydraulic conductivities of this layer.

8.1.2 Groundwater Impacts

The drawdown resulting from pit dewatering has the potential to impact a significant number of nearby water users. A summary of the potentially impacted wells is provided in Table 7.1. A series of figures illustrating the predicted drawdown in nearby wells is presented in Appendix B.

8.1.3 Dewatering Infrastructure

By assuming a higher yield per bore of around 10 - 12 m^3/hr the total number of bores required for each phase has reduced (150m spacing inland and 75 m spacing close to the river). The bore depths will be -70 mRL level (about 70 m deep). A total of 26 sumps will also be required. An estimate of the dewatering infrastructure requirements over time has been made utilising a staged approach, distributing capital expenditure over the 26 year mine life.

8.2 RECOMMENDATIONS

To further develop the groundwater modelling and the potential associated hydrogeological impacts a number of actions are recommended:

- Provide an improved orebody geological model to allow a refinement of the hydrogeological model domain. In this regard, the development of a block geological model, to be used as a basis for the hydrogeological and other mining design and development purposes is essential.
- Completion of additional pumping tests in the southern pit to improve understanding of the groundwater flow regime, the hydraulic connection with nearby creeks and surface water bodies, water impacts associated with mining the pit and the variation of aquifer hydraulic properties over the area of interest.
- A Groundwater Management Plan is required to address the drawdown impacts on local water supplies. This would typically include:
  - The establishment of a groundwater monitoring network and a mitigation plan to ensure that water availability is maintained.
  - This would also include updating the hydrocensus and surveying nearby bores to determine use, depth, water level elevation.
  - The occurrence of at least two different water types, i.e. fresh groundwater and surface brackish river and creek water, support the need for a hydrogeochemical survey to understand baseline groundwater quality, the role of hydrogeochemical processes in the system and the degree of interaction between the brackish surface water bodies and groundwater both at current conditions and during dewatering.
- This will provide additional information for further model calibration and greater certainty around severity of likely dewatering impacts both with respect to groundwater levels and quality.

- Incorporate new pumping tests and hydrocensus data into the above model to provide additional calibration and refinement.
- The long term response of the aquifer to pumping, especially at the southern pit, should be tested by additional pumping tests.
- Investigate alteration of the mine plan to maximise dewatering efficiencies.
- Develop a borefield operating strategy to determine likely monitoring, equipment recycling and maintenance requirements.
- A surface water management plan is recommended to understand and mitigate the risk of surface water flooding of the southern pit and marshland inflows over the mangrove marshy area.

9. REFERENCES

1. Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G. (2000) *MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process*. U.S. Geological Survey Open-File Report 00-92, 121 p.

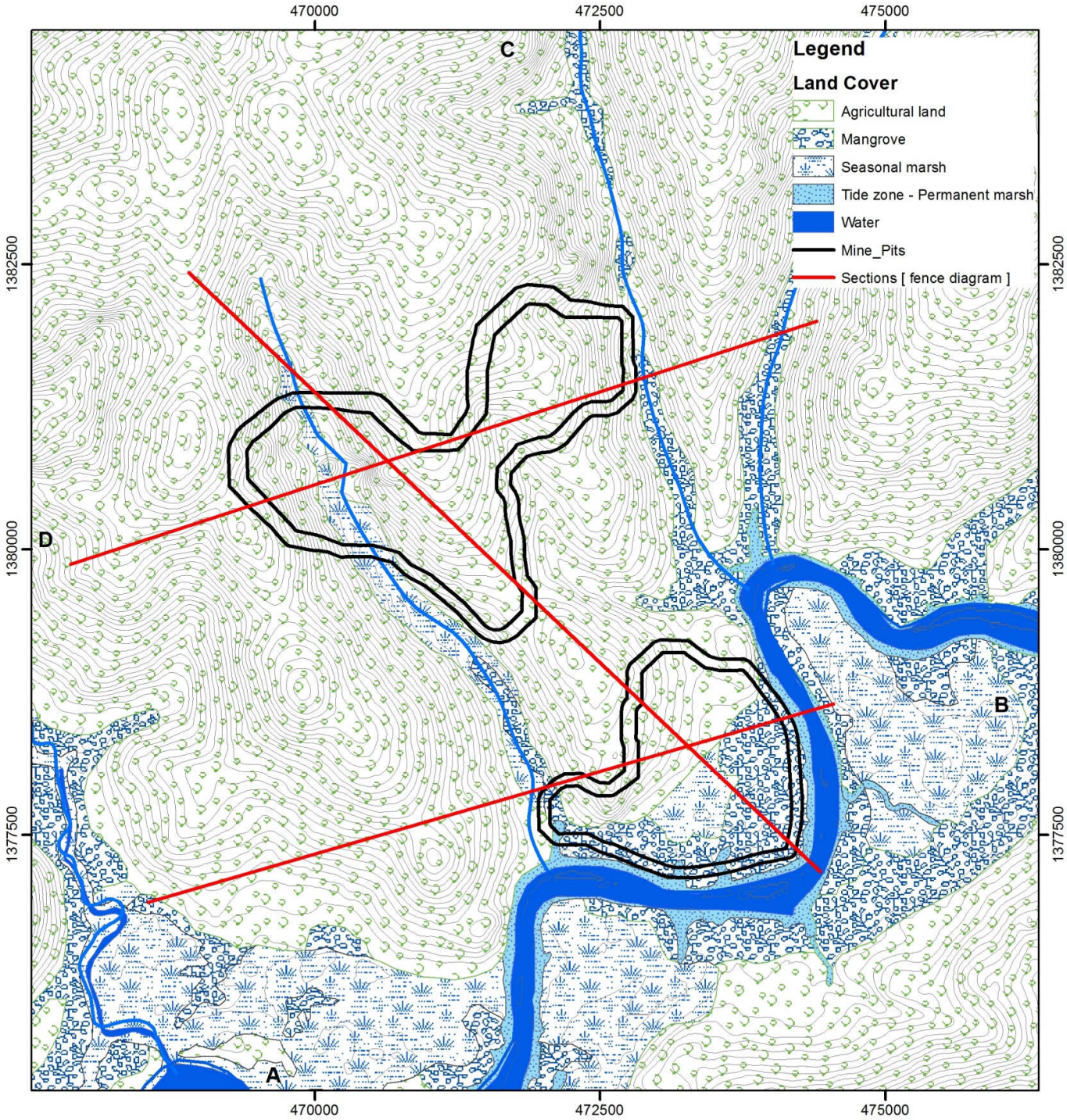
2. Golder, *Farim Phosphate Project, Guinea Bissau, Open Pit Groundwater Modelling,* 2014.

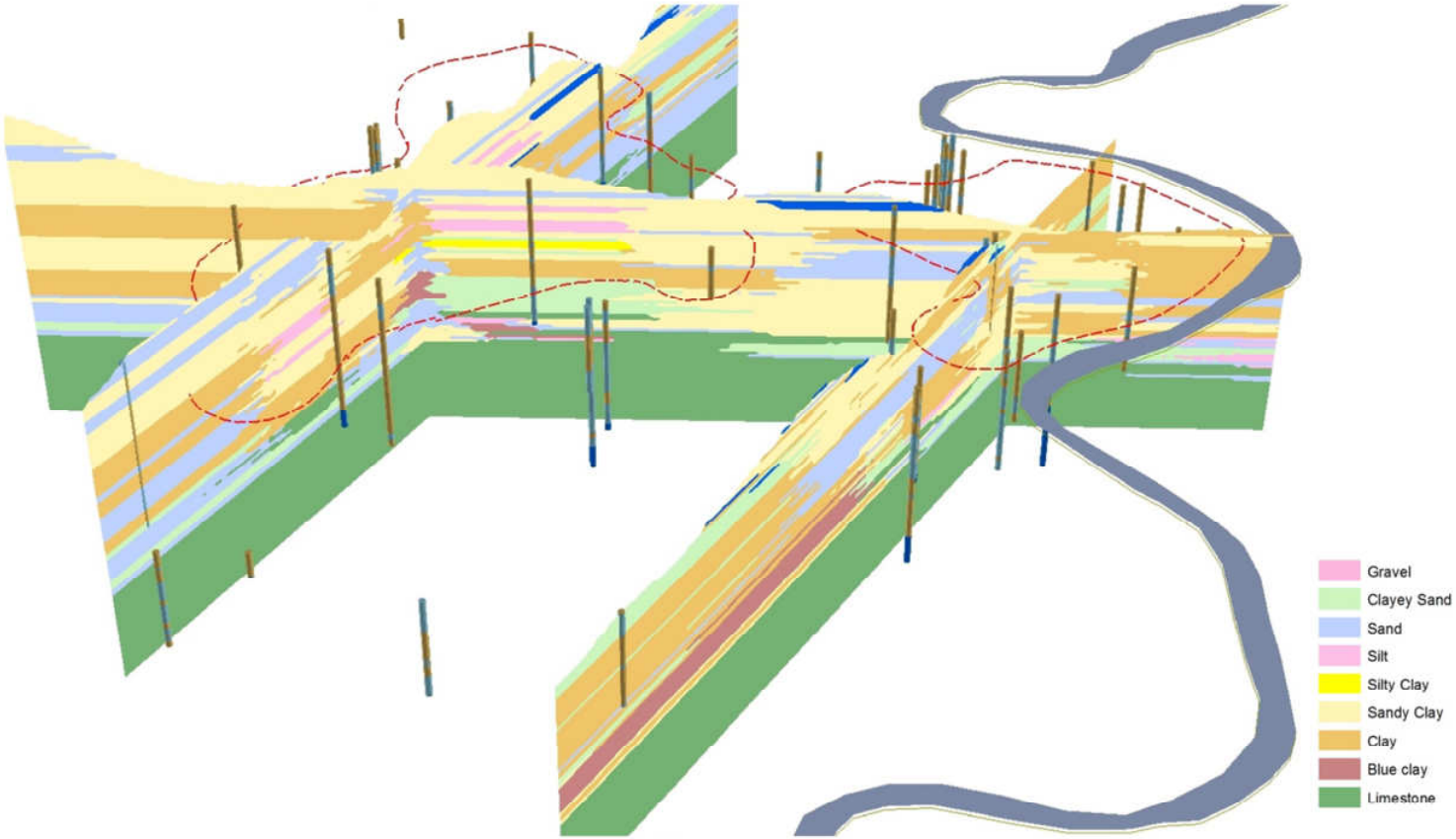
3. Golder, *Farim Phosphate Project, Guinea Bissau, Groundwater and Dewatering 1.32 mtpa open Pit Feasibility Study Report, 2012.*

4. Doherty JE and Hunt RJ, *Approaches to Highly Parameterized Inversion: A Guide to Using PEST for Groundwater-Model Calibration,* USGS, 2010.

5. Golder, *Farim Phosphate Project, Guinea Bissau, Technical Specification for Open Pit Dewatering System,* 2013.

FIGURES


470000
472500
475000
1382500
1380000
1377500
Legend
Land Cover
Agricultural land
Mangrove
Seasonal marsh
Tide zone - Permanent marsh
Water
Mine_Pits
Sections [fence diagram]
A
B
C
D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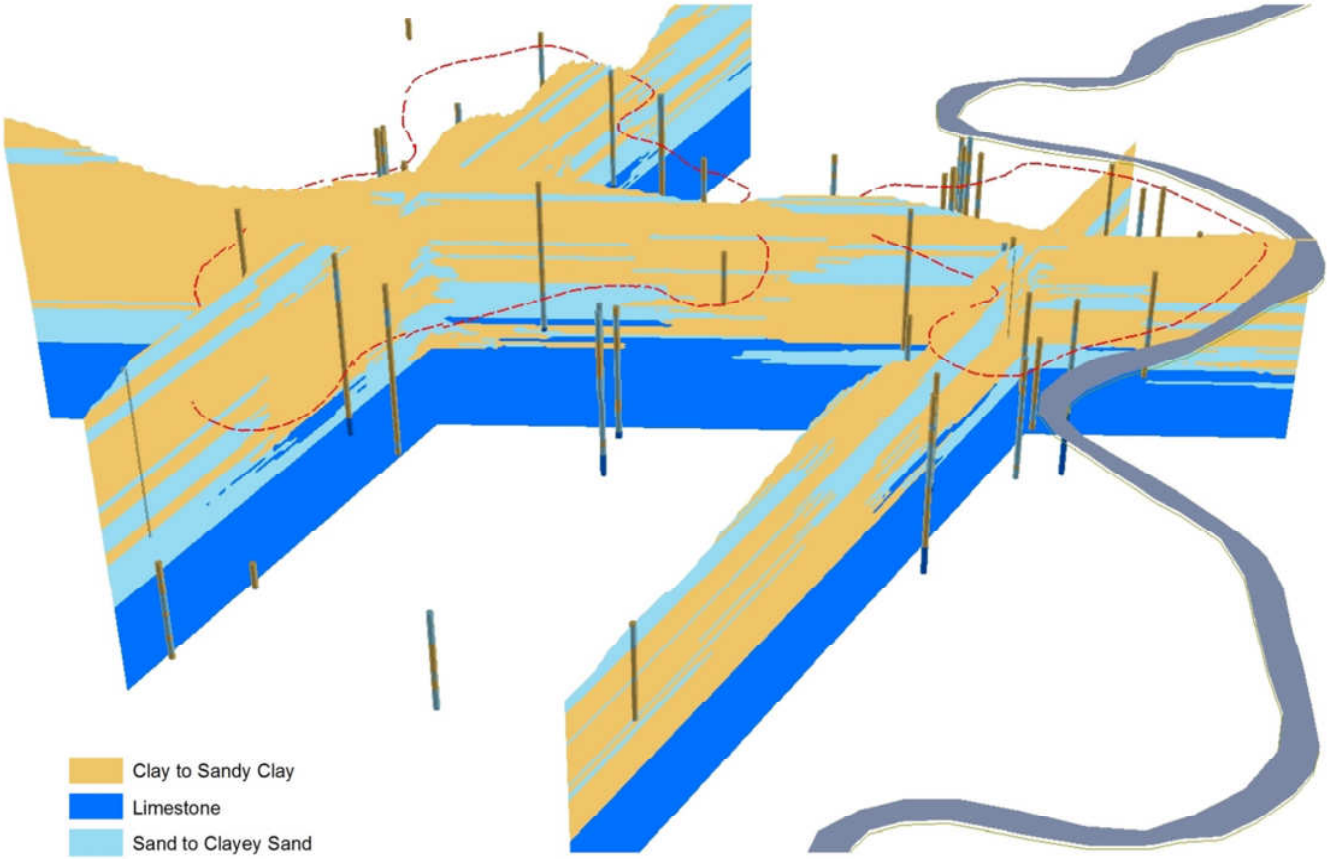
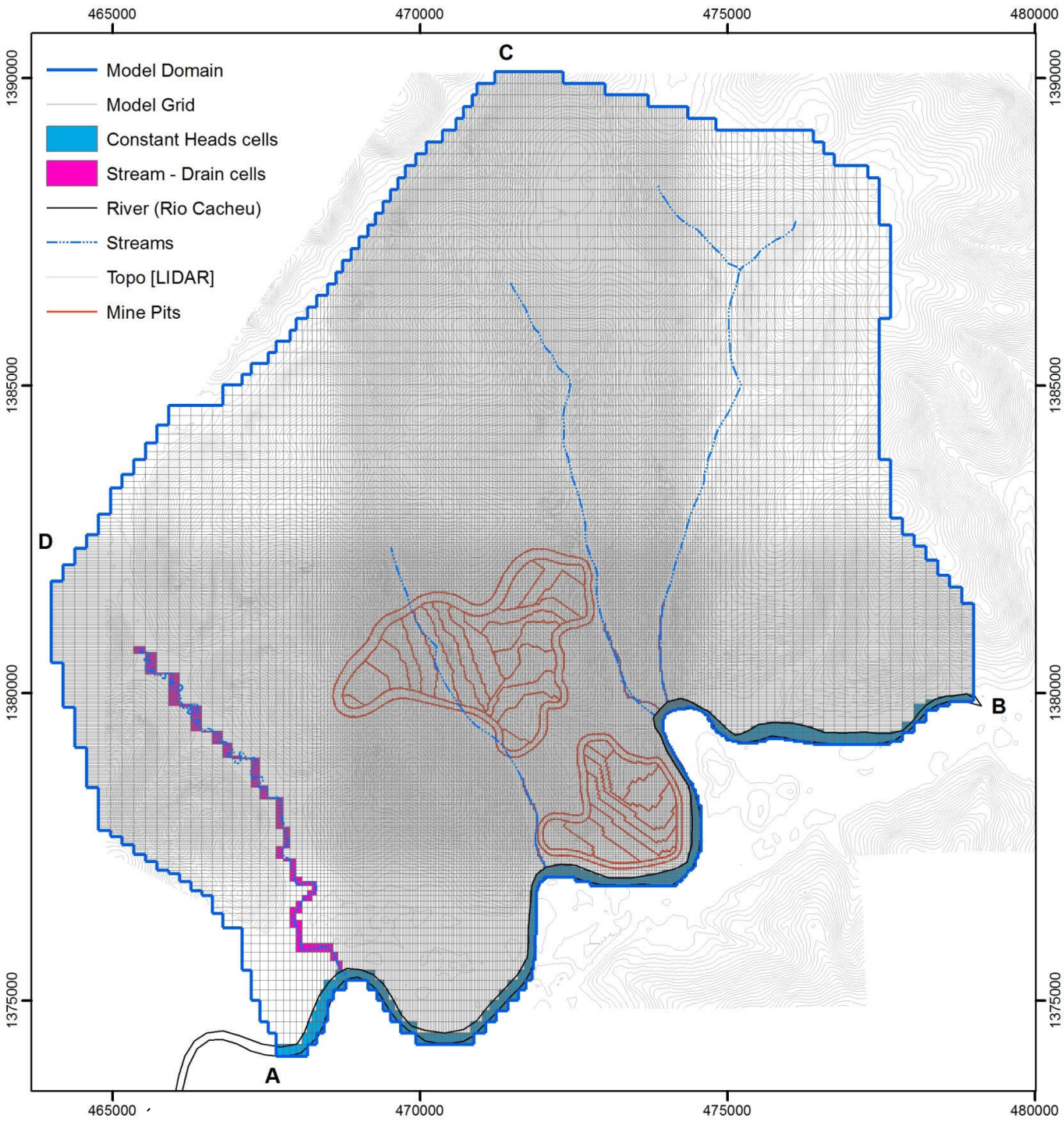
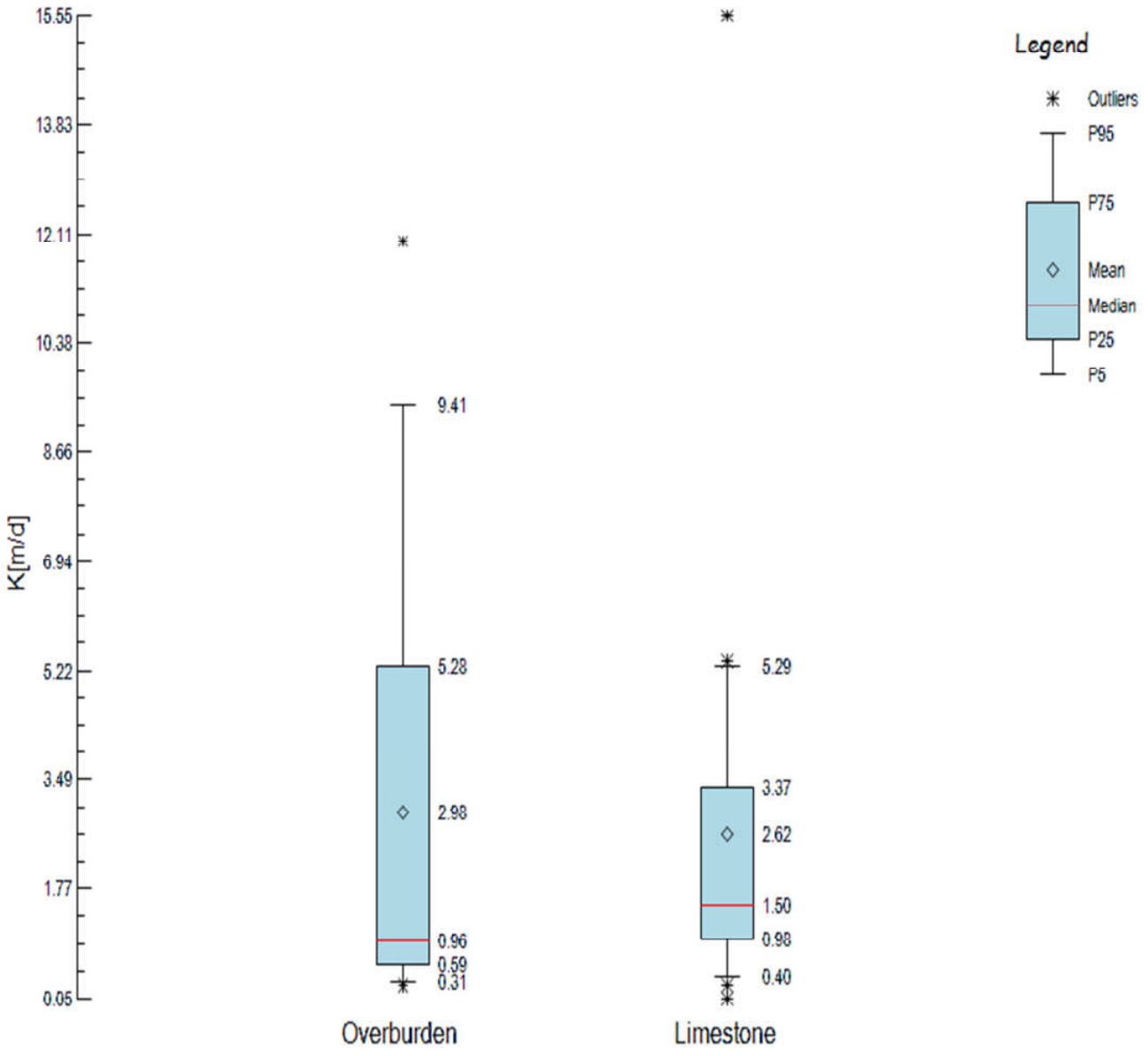
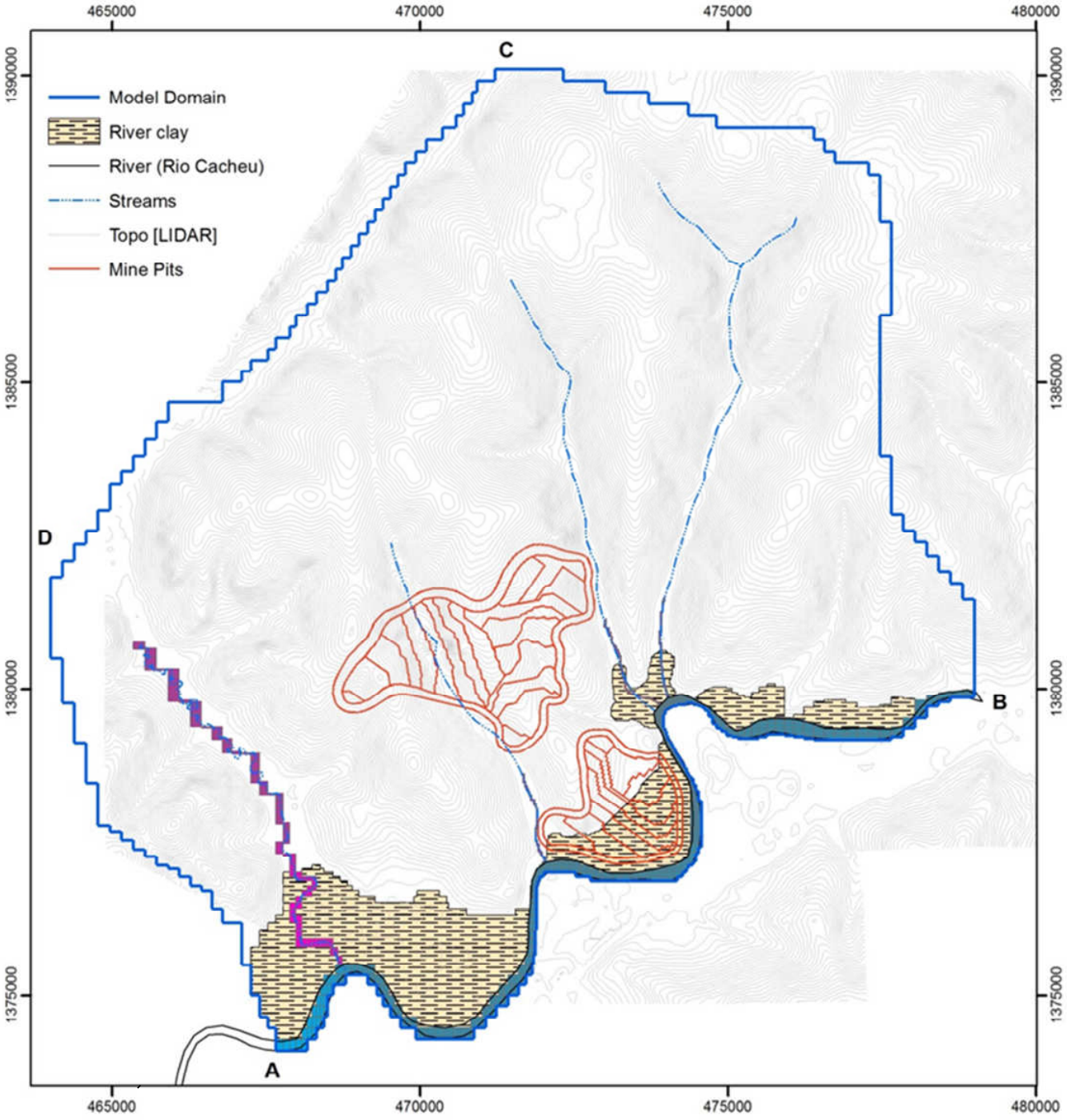
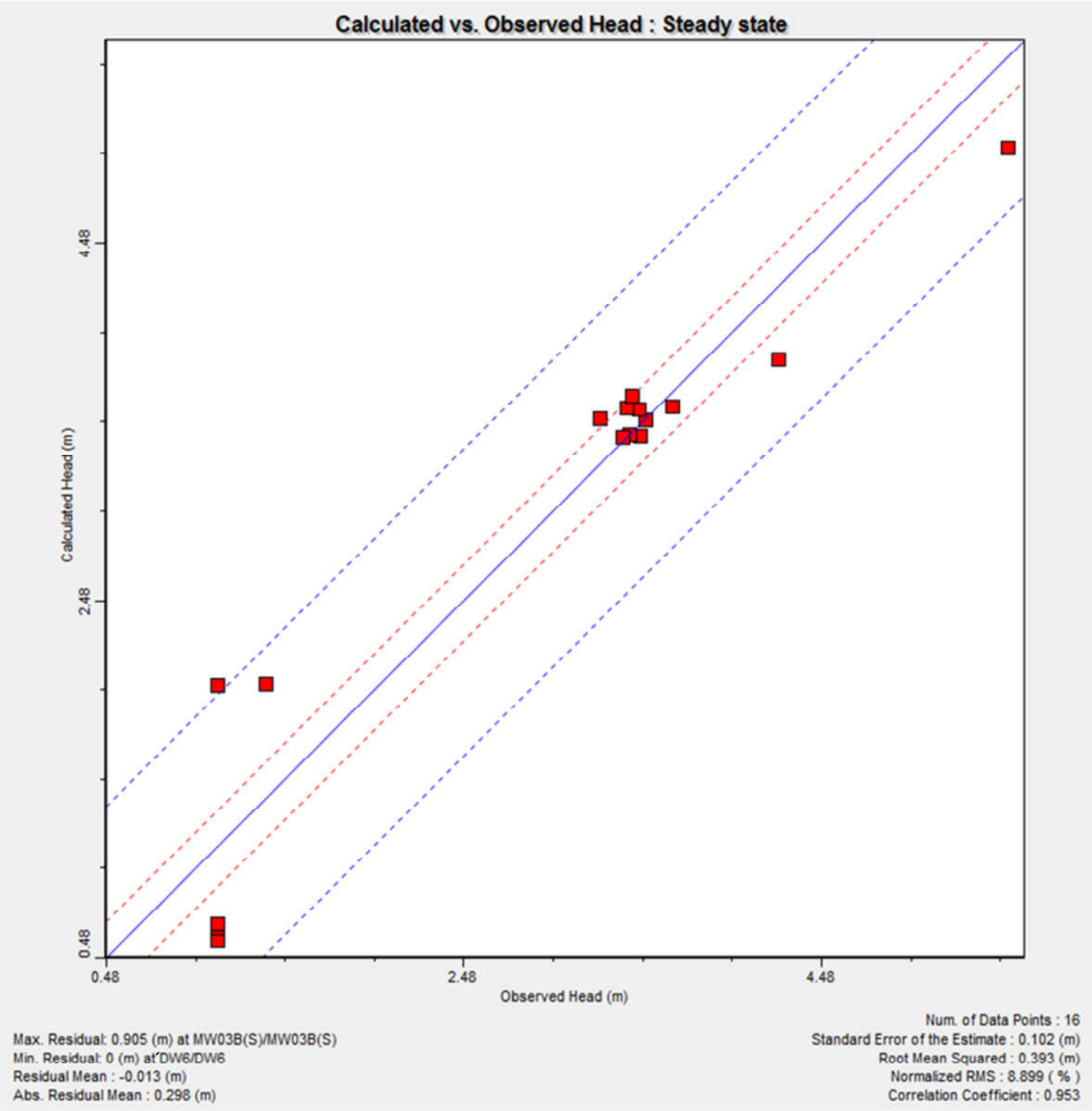
Sand
Silt
Silty Clay
Sandy Clay
Clay
Blue clay
Limestone

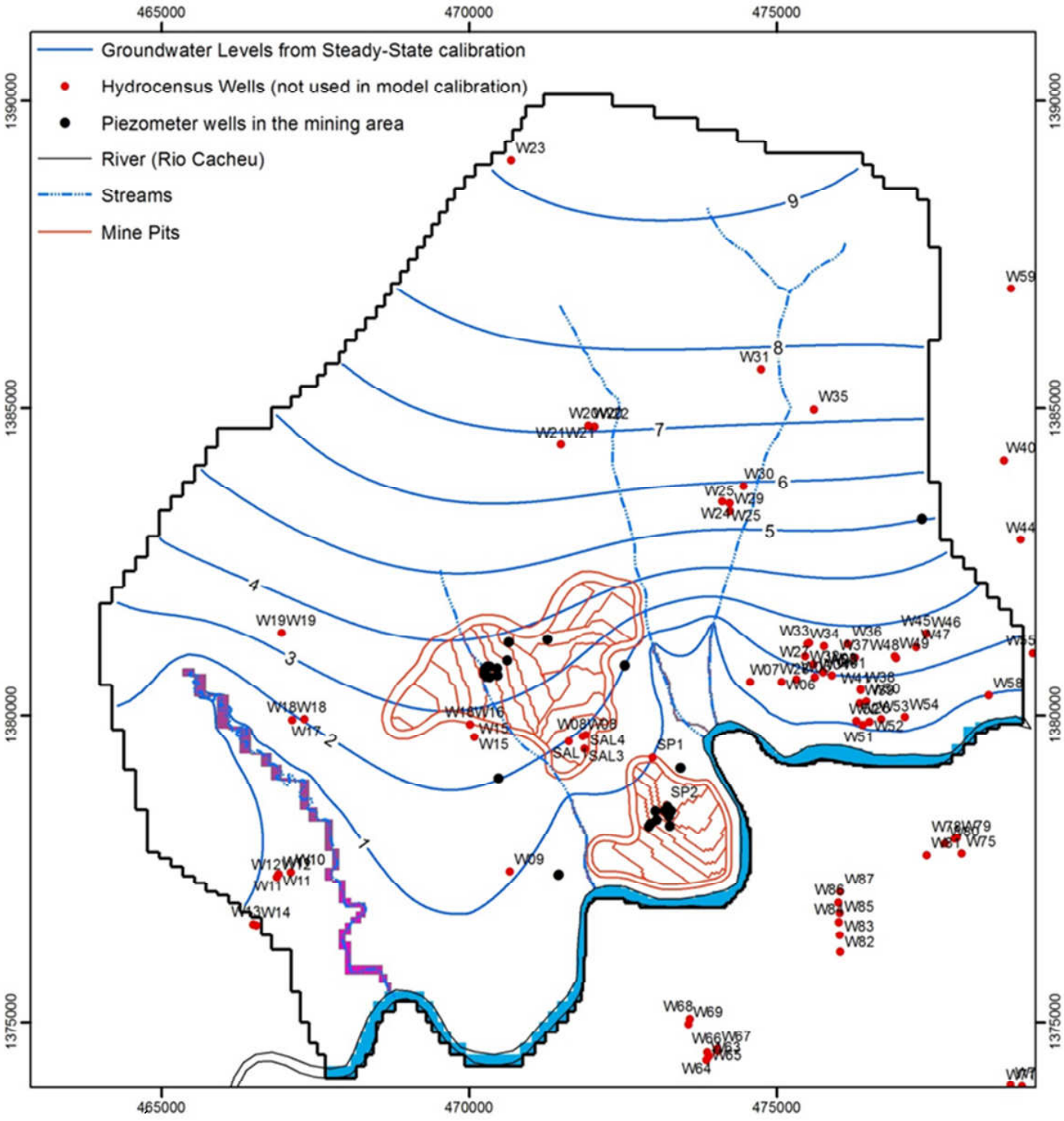

Clay to Sandy Clay
Limestone
Sand to Clayey Sand

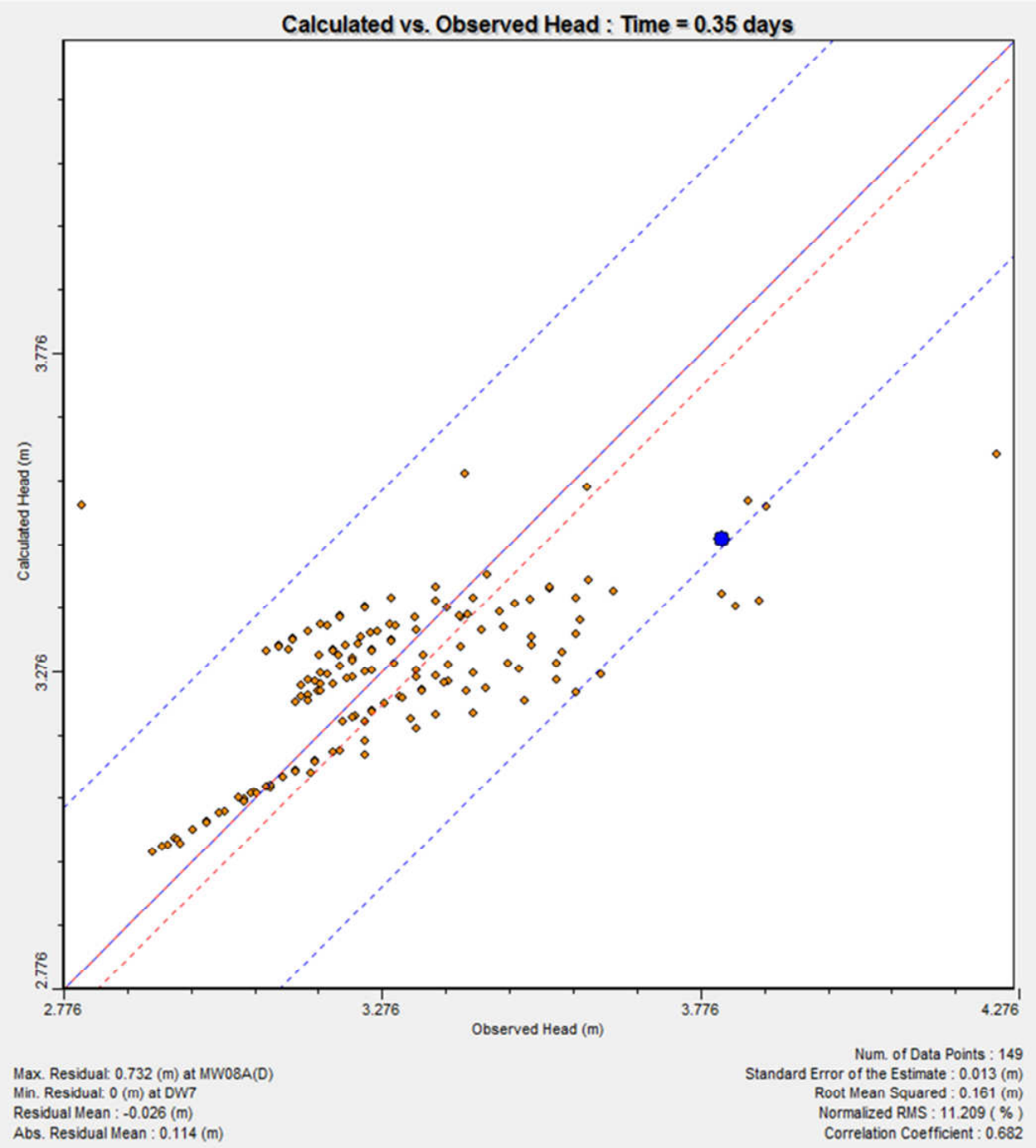

465000
470000
475000
480000
1390000
1385000
1380000
1375000
Model Domain
Model Grid
Constant Heads cells
Stream - Drain cells
River (Rio Cacheu)
Streams
Topo [LIDAR]
Mine Pits
A
B
C
D

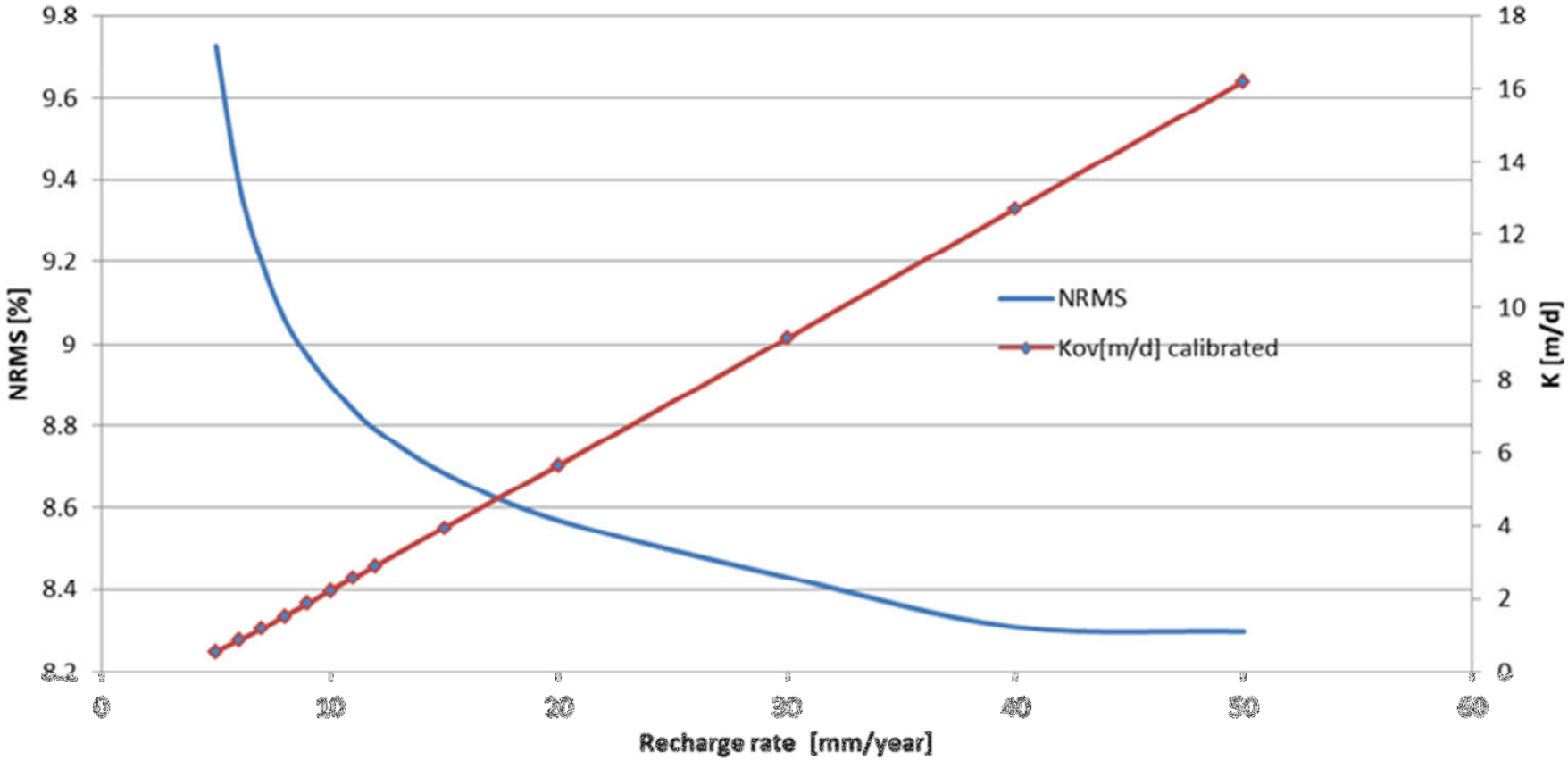

15.55
13.83
12.11
10.38
8.66
6.94
5.22
3.49
1.77
0.05
K[m/d]
9.41
5.28
2.98
0.96
0.59
0.31
5.29
3.37
2.62
1.50
0.98
0.40
Overburden
Limestone
Legend
Outliers
P95
P75
Mean
Median
P25
P5

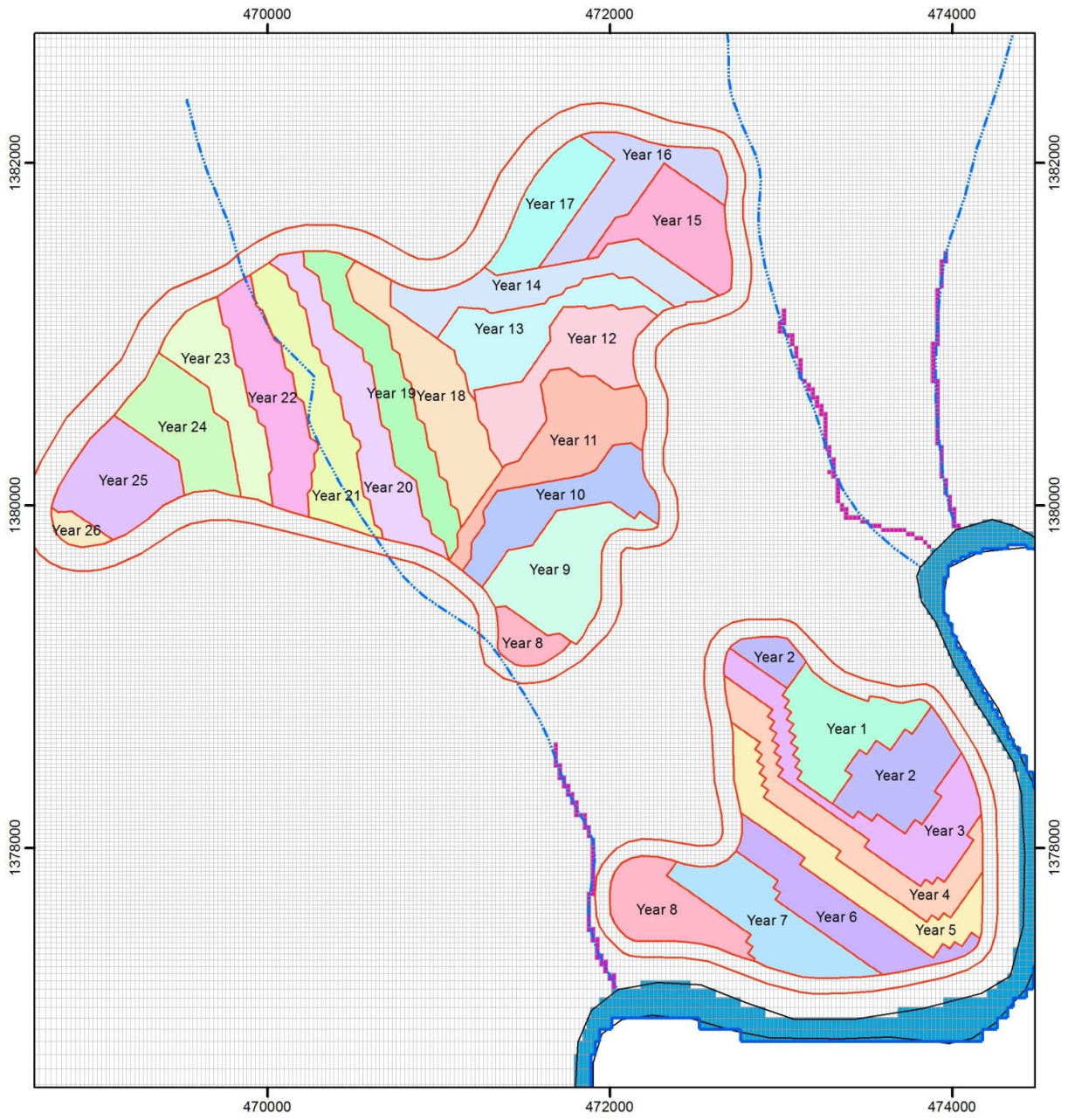

465000
470000
475000
480000
1390000
1385000
1380000
1375000
Model Domain
River clay
River (Rio Cacheu)
Streams
Topo [LIDAR]
Mine Pits
A
B
C
D

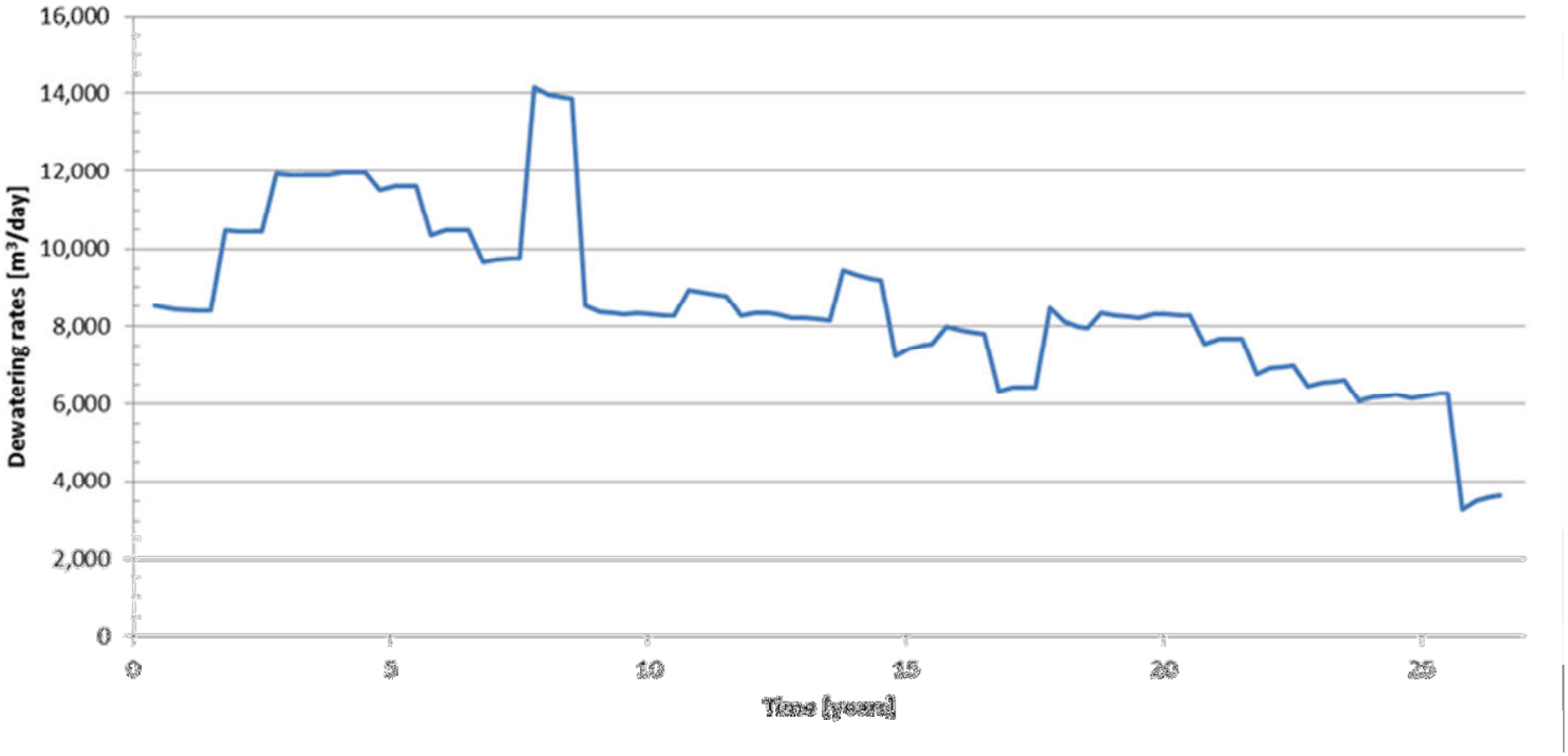

Calculated vs. Observed Head : Steady state
Calculated Head (m)
Observed Head (m)
0.48
2.48
4.48
0.48
2.48
4.48
Max. Residual: 0.905 (m) at MW03B(S)/MW03B(S)
Min. Residual: 0 (m) at DW6/DW6
Residual Mean : -0.013 (m)
Abs. Residual Mean : 0.298 (m)
Num. of Data Points : 16
Standard Error of the Estimate : 0.102 (m)
Root Mean Squared : 0.393 (m)
Normalized RMS : 8.899 (%)
Correlation Coefficient : 0.953

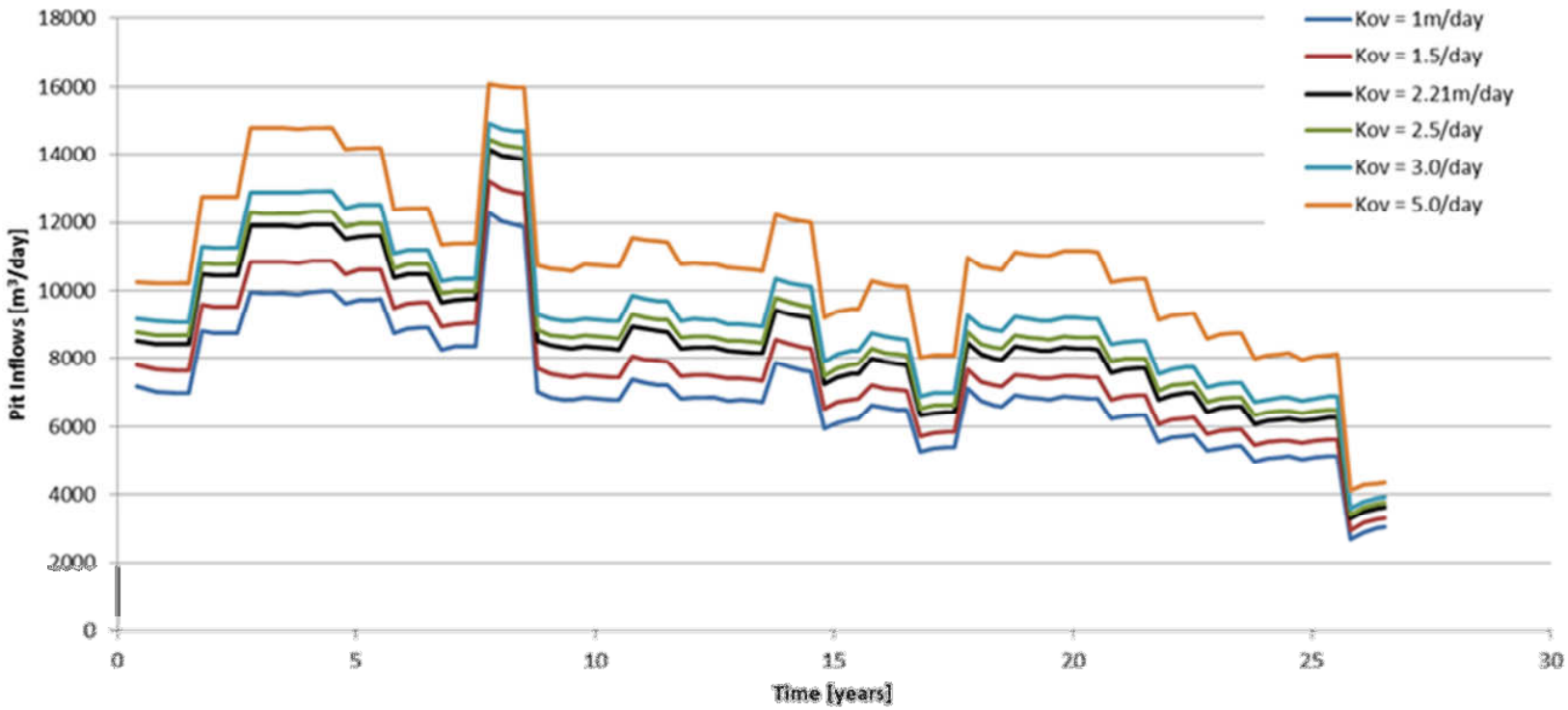

465000
470000
475000
1390000
1385000
1380000
1375000
Groundwater Levels from Steady-State calibration
Hydrocensus Wells (not used in model calibration)
Piezometer wells in the mining area
River (Rio Cacheu)
Streams
Mine Pits
9
8
7
6
5
4
3
2
1
SP1
SP2

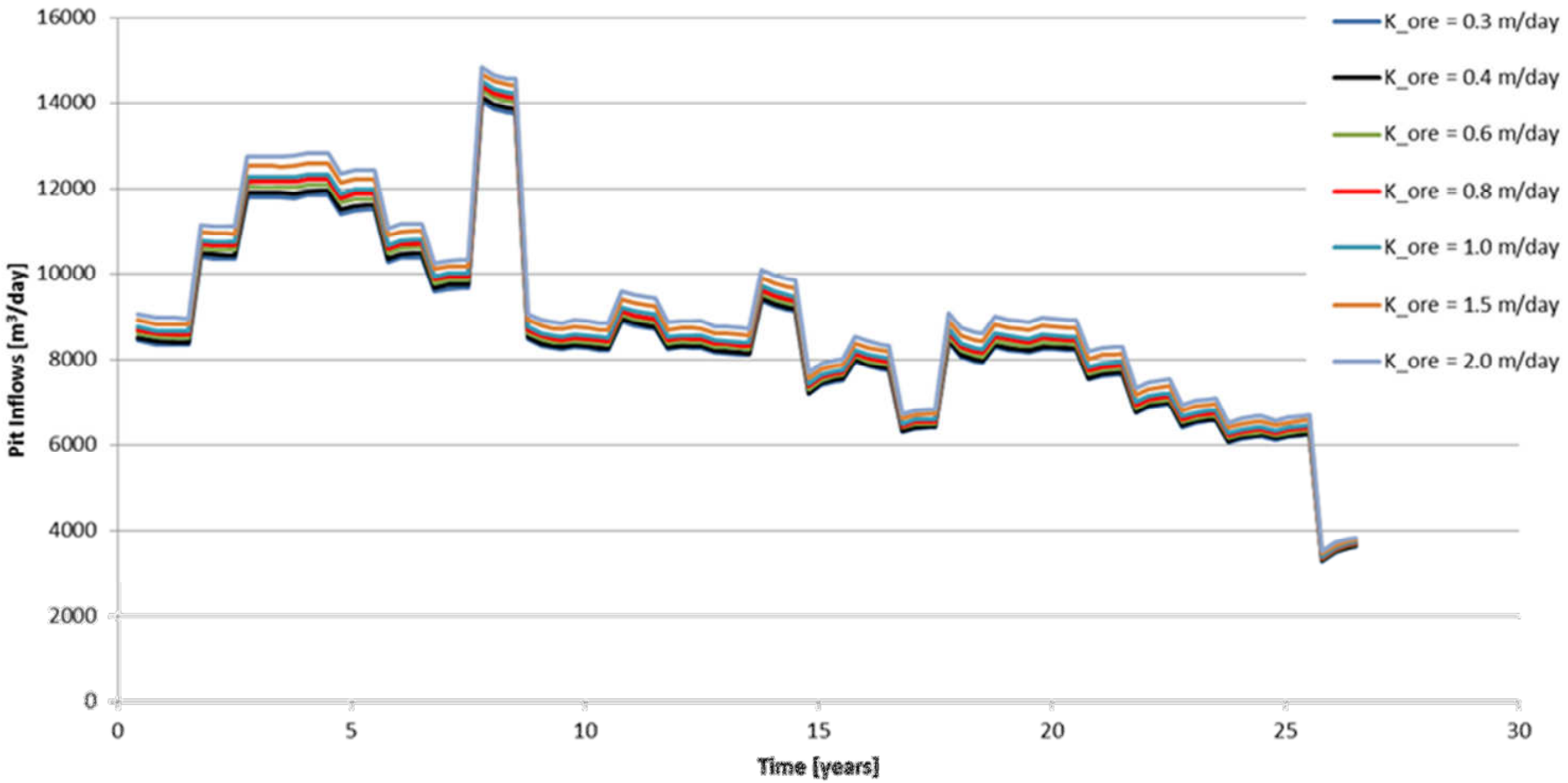

Calculated vs. Observed Head : Time = 0.35 days
Calculated Head (m)
2.776
3.276
3.776
Observed Head (m)
2.776
3.276
3.776
4.276
Max. Residual: 0.732 (m) at MW08A(D)
Min. Residual: 0 (m) at DW7
Residual Mean : -0.026 (m)
Abs. Residual Mean : 0.114 (m)
Num. of Data Points : 149
Standard Error of the Estimate : 0.013 (m)
Root Mean Squared : 0.161 (m)
Normalized RMS : 11.209 (%)
Correlation Coefficient : 0.682

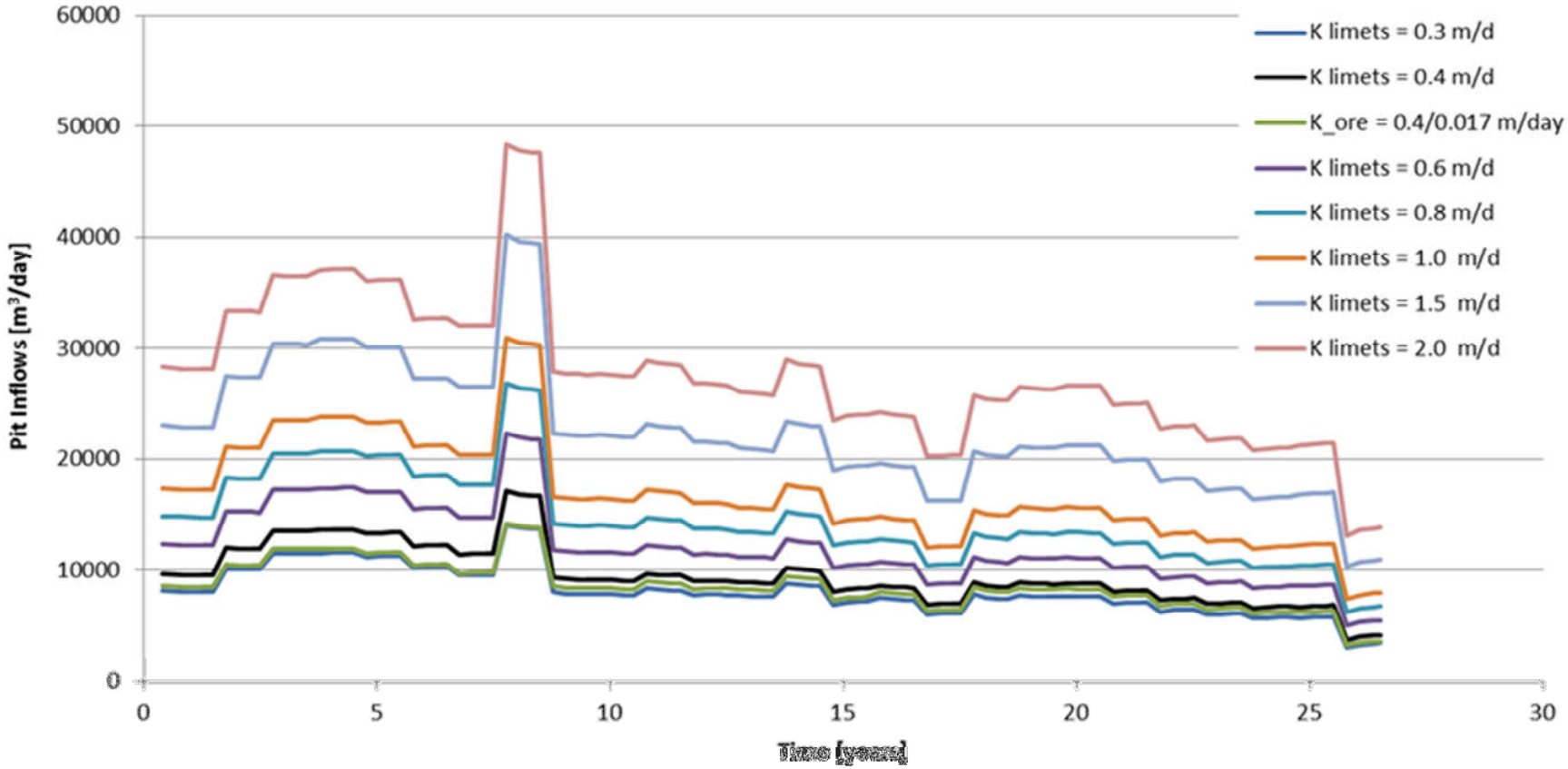

9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
NRMS [%]
18
16
14
12
10
8
6
4
2
0
K [m/d]
NRMS
Kov[m/d] calibrated
0
10
20
30
40
50
60
Recharge rate [mm/year]

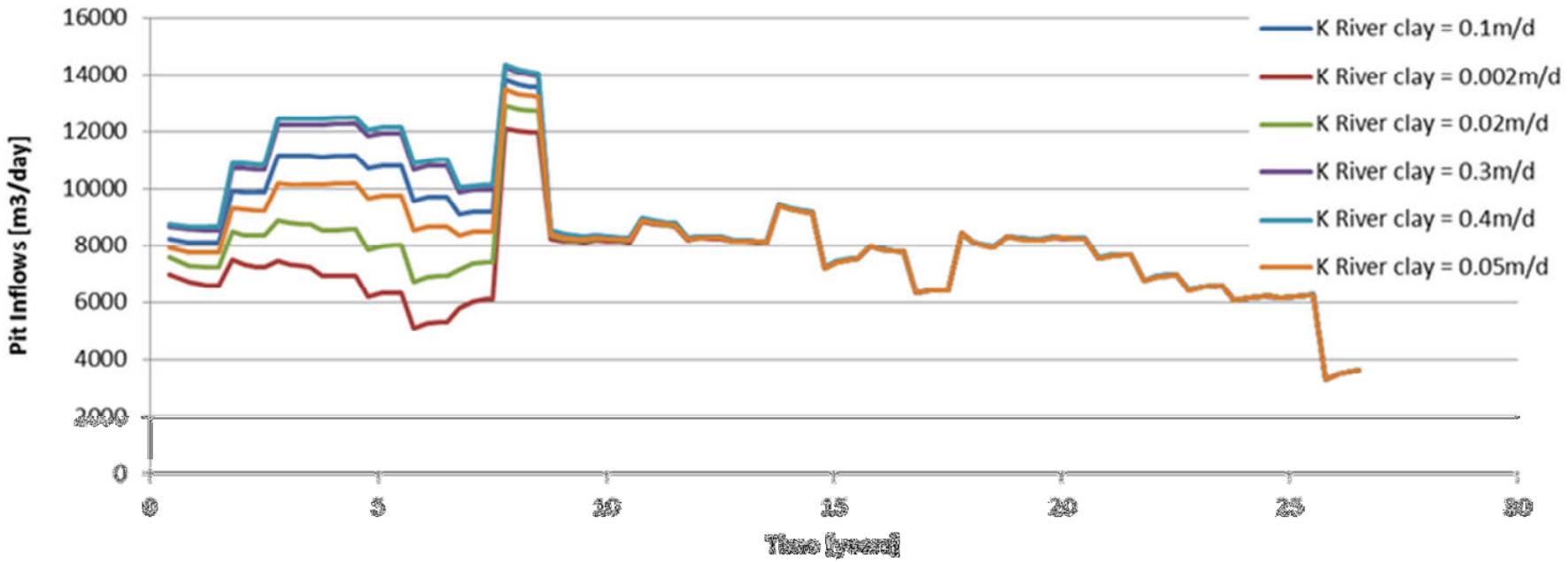

470000
472000
474000
1382000
1380000
1378000
Year 16
Year 17
Year 15
Year 14
Year 13
Year 12
Year 23
Year 22
Year 19
Year 18
Year 24
Year 11
Year 25
Year 21
Year 20
Year 10
Year 26
Year 9
Year 8
Year 2
Year 1
Year 2
Year 3
Year 4
Year 8
Year 7
Year 6
Year 5

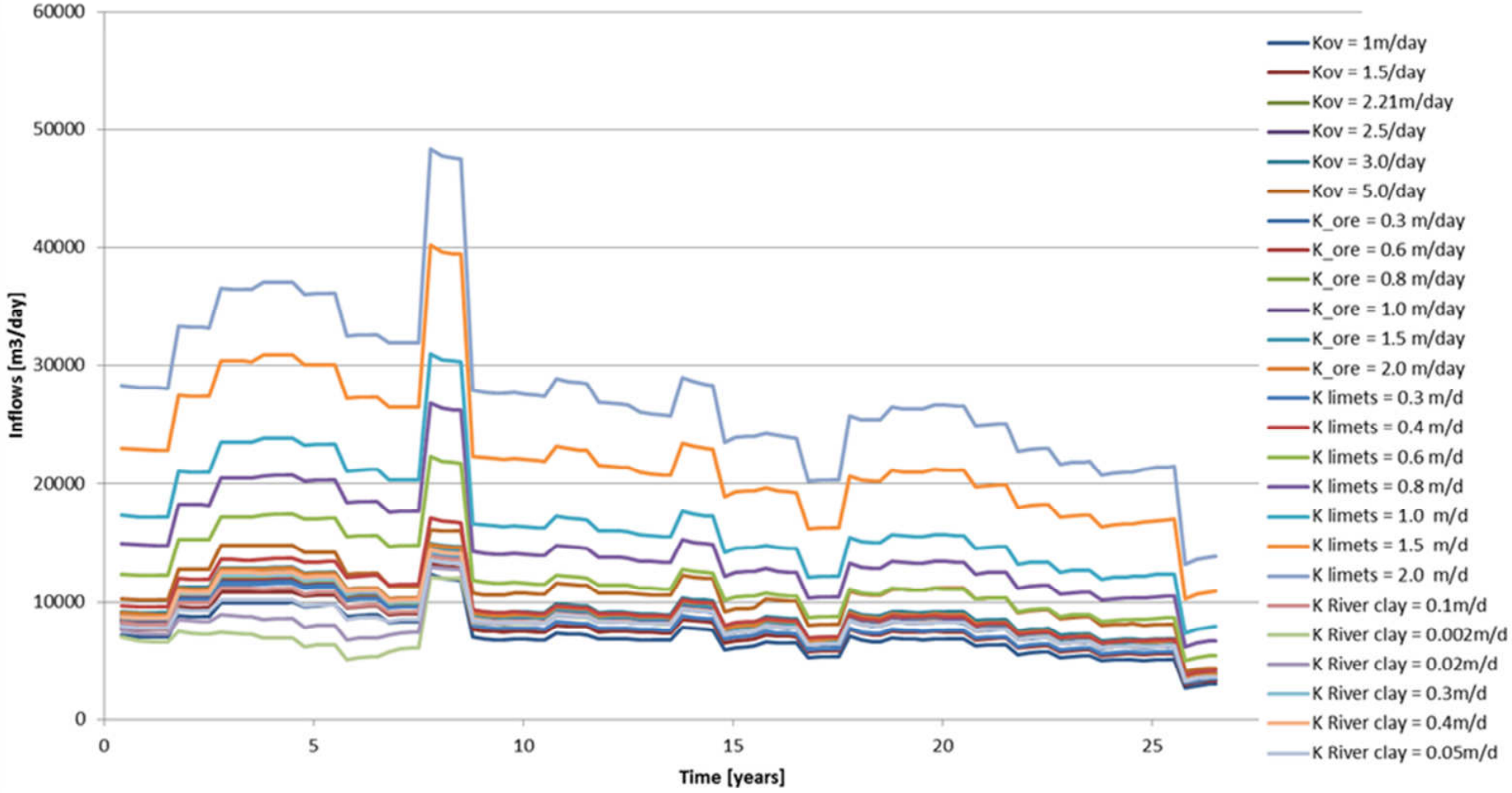

16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Dewatering rates [m³/day]
0
5
10
15
20
25
Time [years]

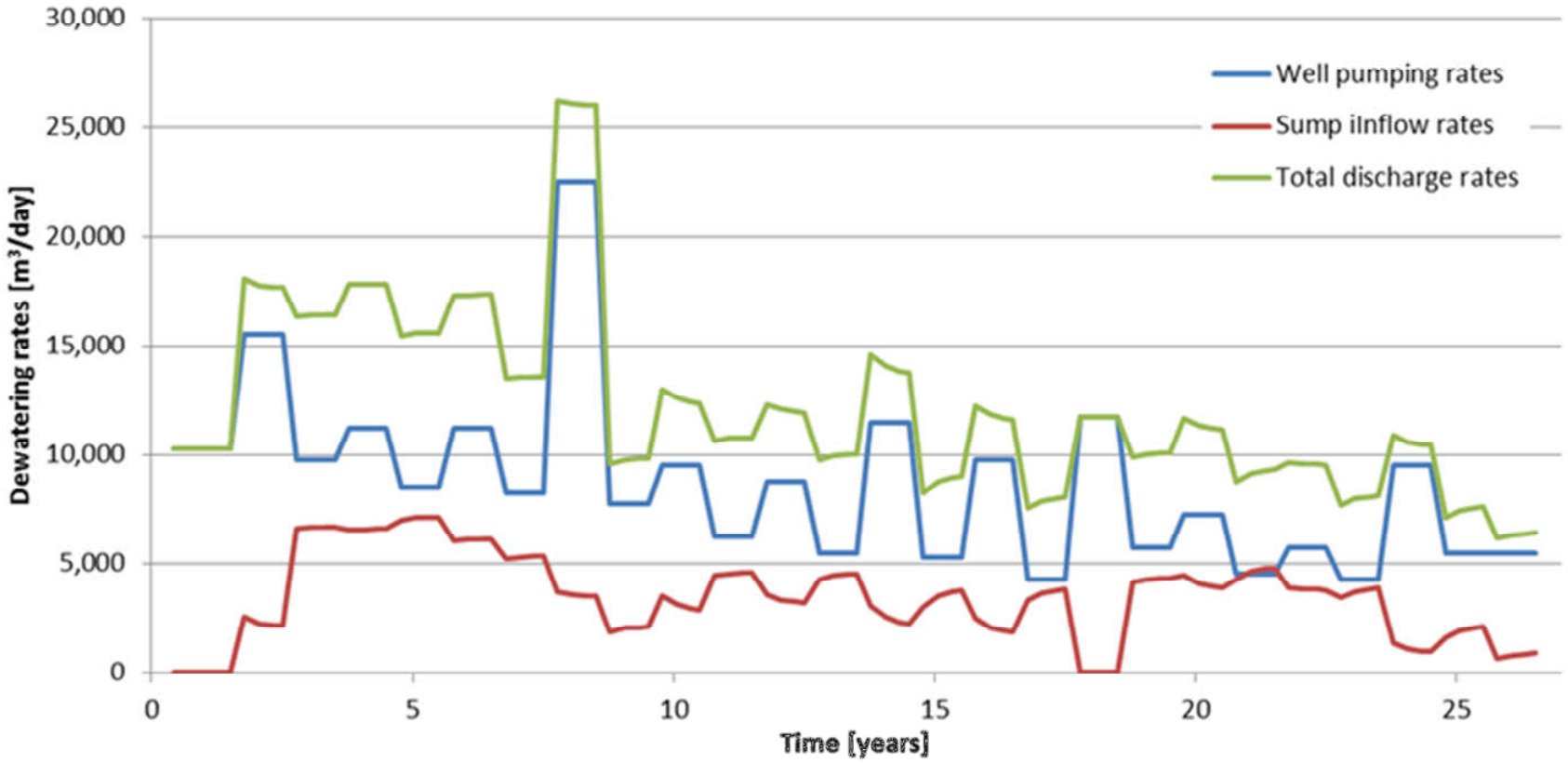

18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Pit Inflows [m³/day]
0
5
10
15
20
25
30
Time [years]
Kov = 1m/day
Kov = 1.5/day
Kov = 2.21m/day
Kov = 2.5/day
Kov = 3.0/day
Kov = 5.0/day

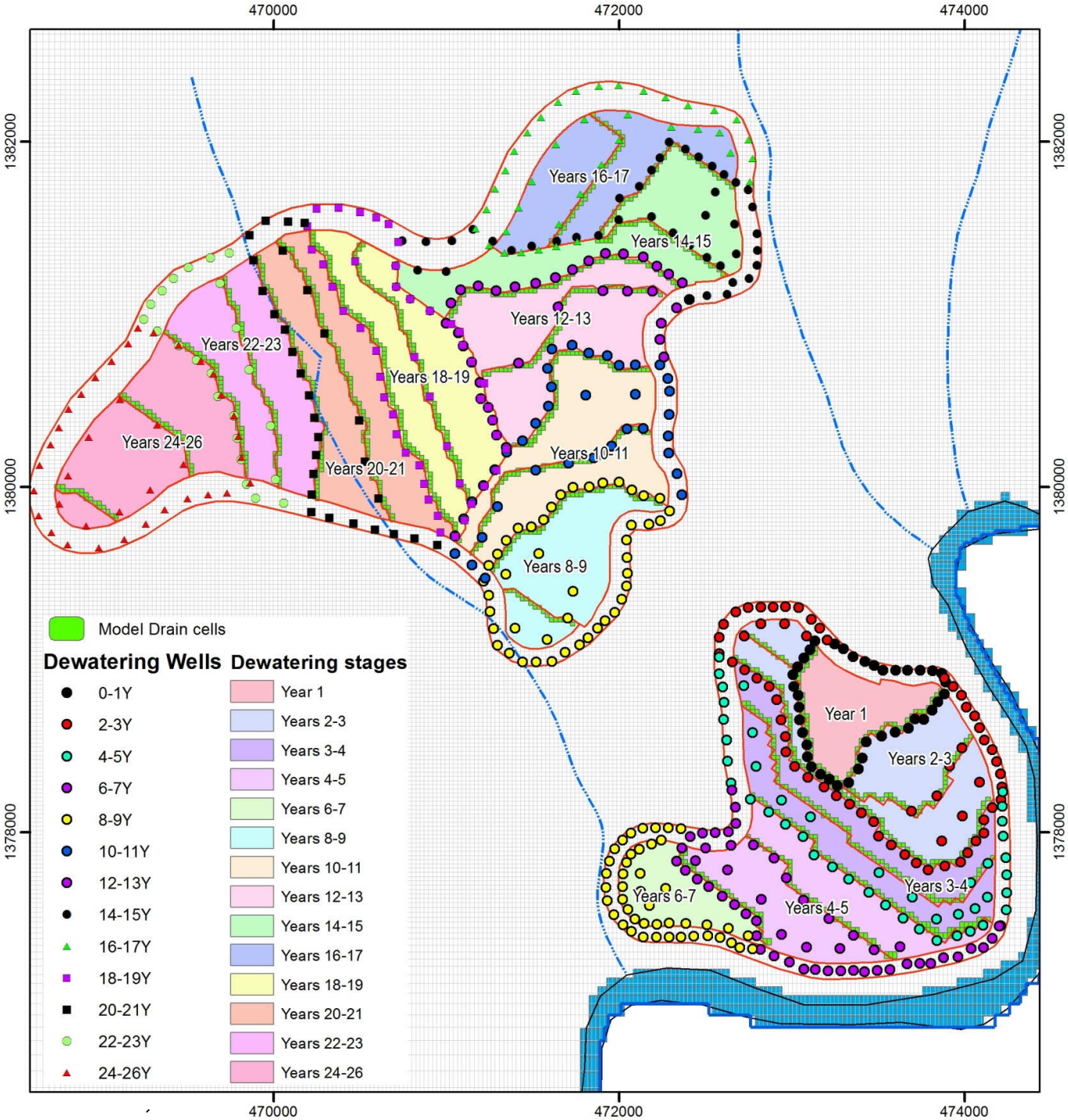

16000
14000
12000
10000
8000
6000
4000
2000
0
Pit Inflows [m³/day]
0
5
10
15
20
25
30
Time [years]
K_ore = 0.3 m/day
K_ore = 0.4 m/day
K_ore = 0.6 m/day
K_ore = 0.8 m/day
K_ore = 1.0 m/day
K_ore = 1.5 m/day
K_ore = 2.0 m/day


60000
50000
40000
30000
20000
10000
0
Pit Inflows [m³/day]
0
5
10
15
20
25
30
Time [years]
K limets = 0.3 m/d
K limets = 0.4 m/d
K_ore = 0.4/0.017 m/day
K limets = 0.6 m/d
K limets = 0.8 m/d
K limets = 1.0 m/d
K limets = 1.5 m/d
K limets = 2.0 m/d


16000
14000
12000
10000
8000
6000
4000
2000
0
Pit Inflows [m3/day]
0
5
10
15
20
25
30
Time [years]
K River clay = 0.1m/d
K River clay = 0.002m/d
K River clay = 0.02m/d
K River clay = 0.3m/d
K River clay = 0.4m/d
K River clay = 0.05m/d

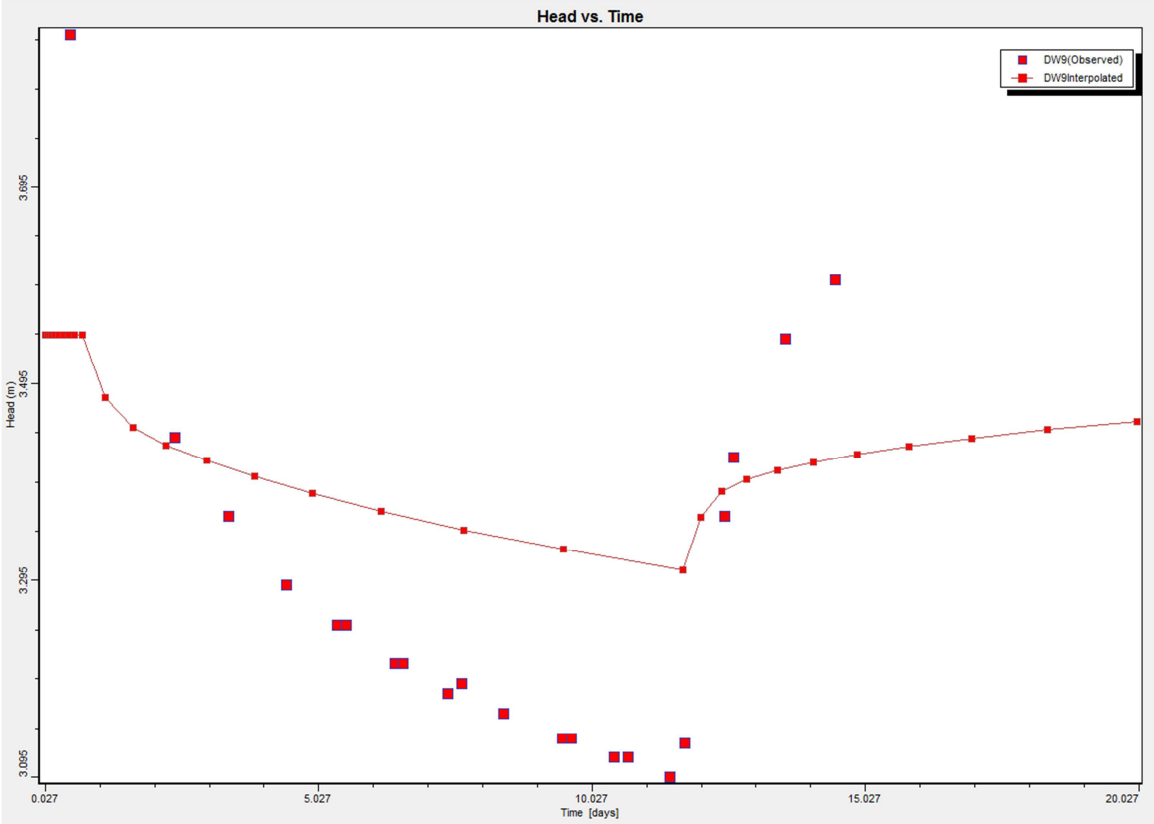

60000
50000
40000
30000
20000
10000
0
Inflows [m3/day]
0
5
10
15
20
25
Time [years]
Kov = 1m/day
Kov = 1.5/day
Kov = 2.21m/day
Kov = 2.5/day
Kov = 3.0/day
Kov = 5.0/day
K_ore = 0.3 m/day
K_ore = 0.6 m/day
K_ore = 0.8 m/day
K_ore = 1.0 m/day
K_ore = 1.5 m/day
K_ore = 2.0 m/day
K limets = 0.3 m/d
K limets = 0.4 m/d
K limets = 0.6 m/d
K limets = 0.8 m/d
K limets = 1.0 m/d
K limets = 1.5 m/d
K limets = 2.0 m/d
K River clay = 0.1m/d
K River clay = 0.002m/d
K River clay = 0.02m/d
K River clay = 0.3m/d
K River clay = 0.4m/d
K River clay = 0.05m/d

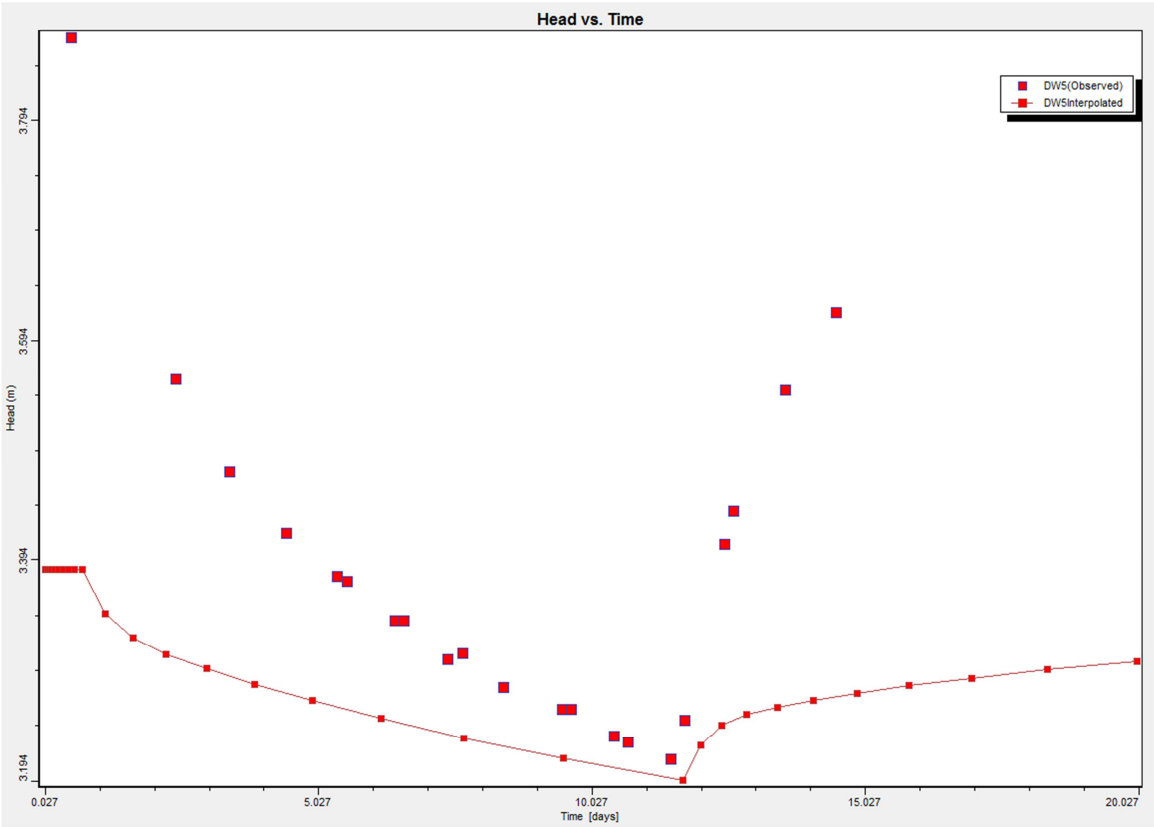

30,000
25,000
20,000
15,000
10,000
5,000
0
Dewatering rates [m³/day]
0
5
10
15
20
25
Time [years]
Well pumping rates
Sump iInflow rates
Total discharge rates

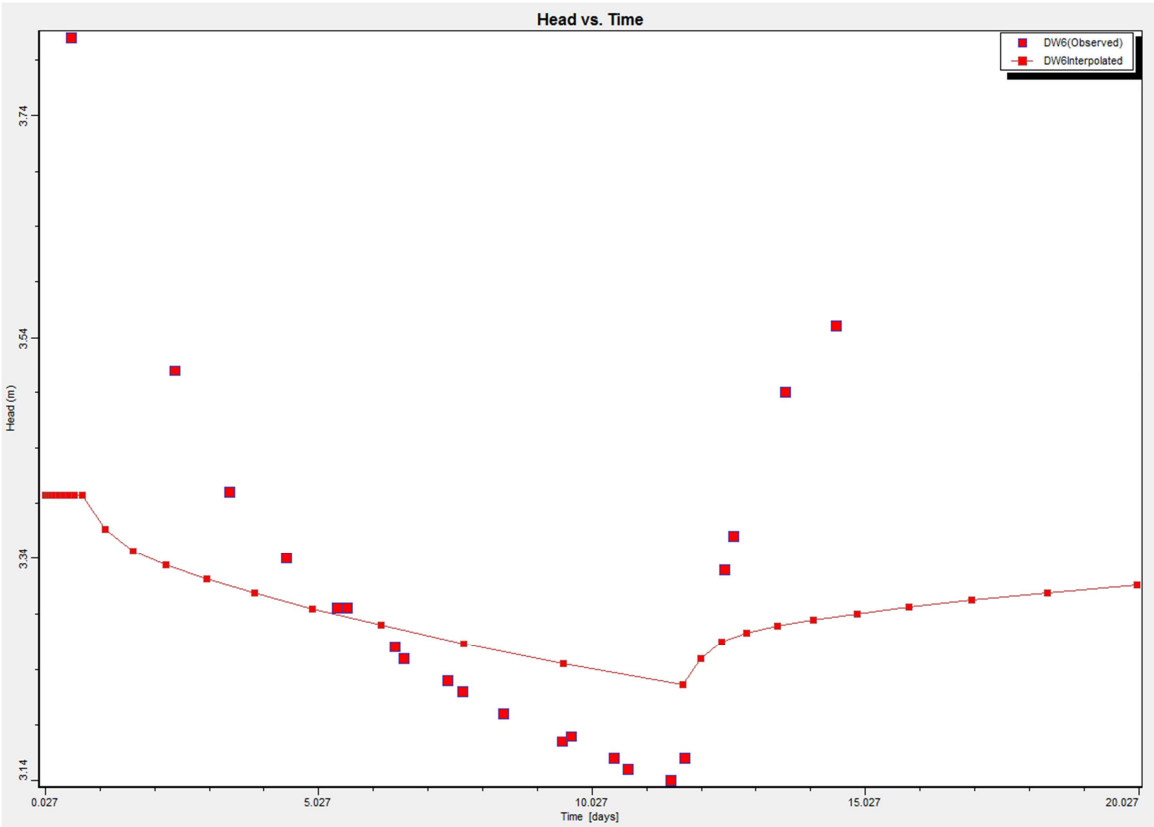

470000
472000
474000
1382000
1380000
1378000
Years 16-17
Years 14-15
Years 12-13
Years 22-23
Years 18-19
Years 24-26
Years 20-21
Years 10-11
Years 8-9
Year 1
Years 2-3
Years 3-4
Years 6-7
Years 4-5
Model Drain cells
Dewatering Wells
0-1Y
2-3Y
4-5Y
6-7Y
8-9Y
10-11Y
12-13Y
14-15Y
16-17Y
18-19Y
20-21Y
22-23Y
24-26Y
Dewatering stages
Year 1
Years 2-3
Years 3-4
Years 4-5
Years 6-7
Years 8-9
Years 10-11
Years 12-13
Years 14-15
Years 16-17
Years 18-19
Years 20-21
Years 22-23
Years 24-26

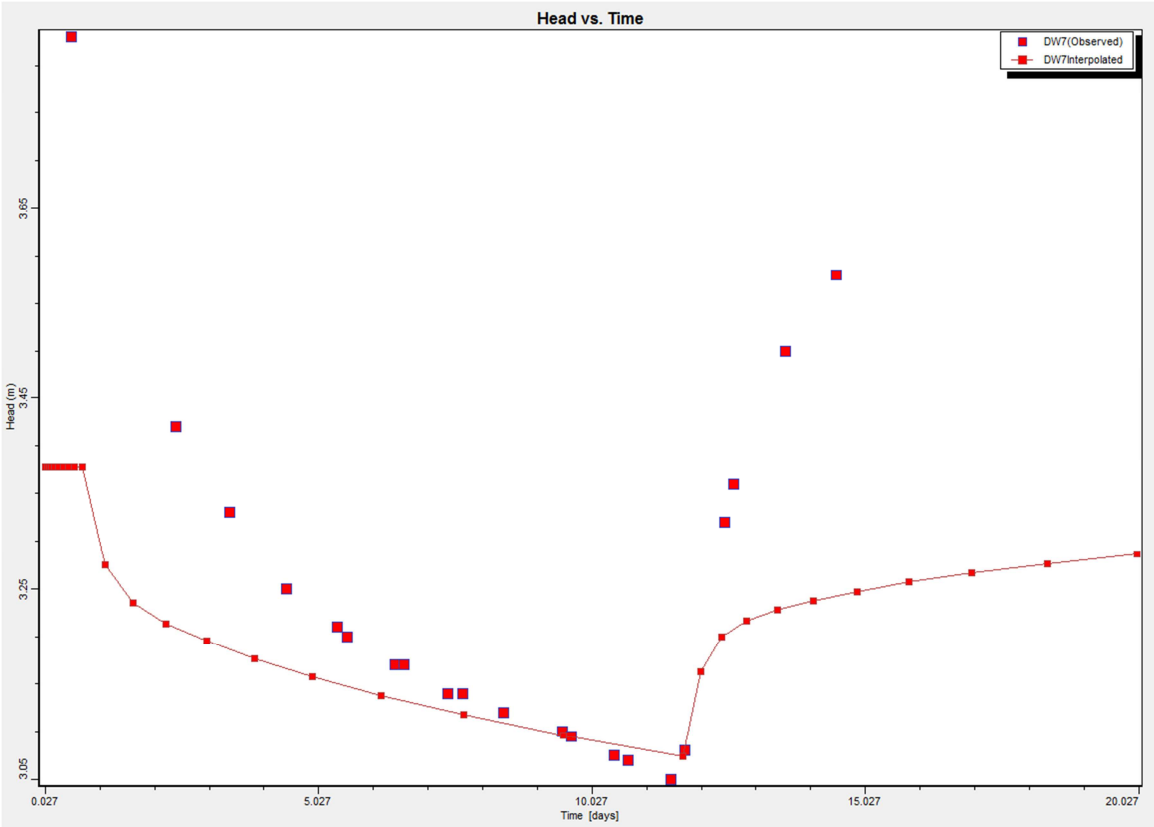
APPENDIX A

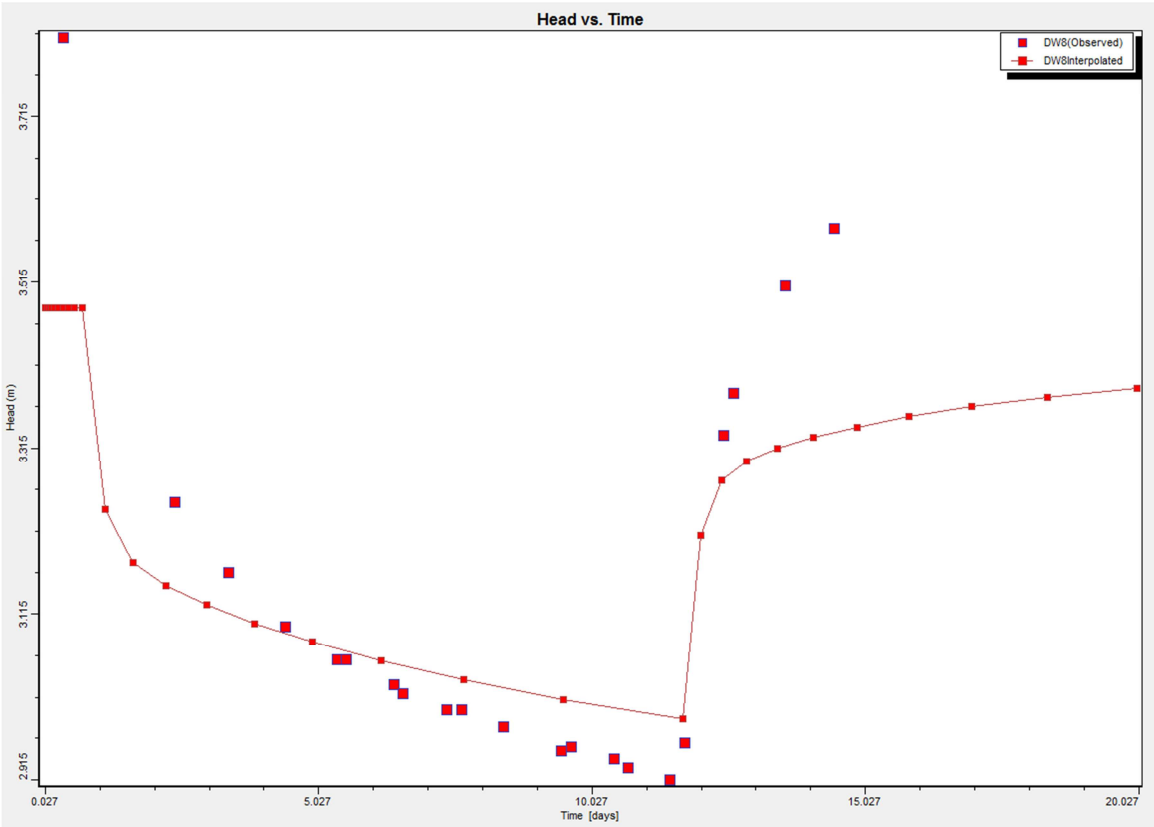
Calculated vs Observed Hydrographs at PW2 Pumping Test – Transient Model Calibration

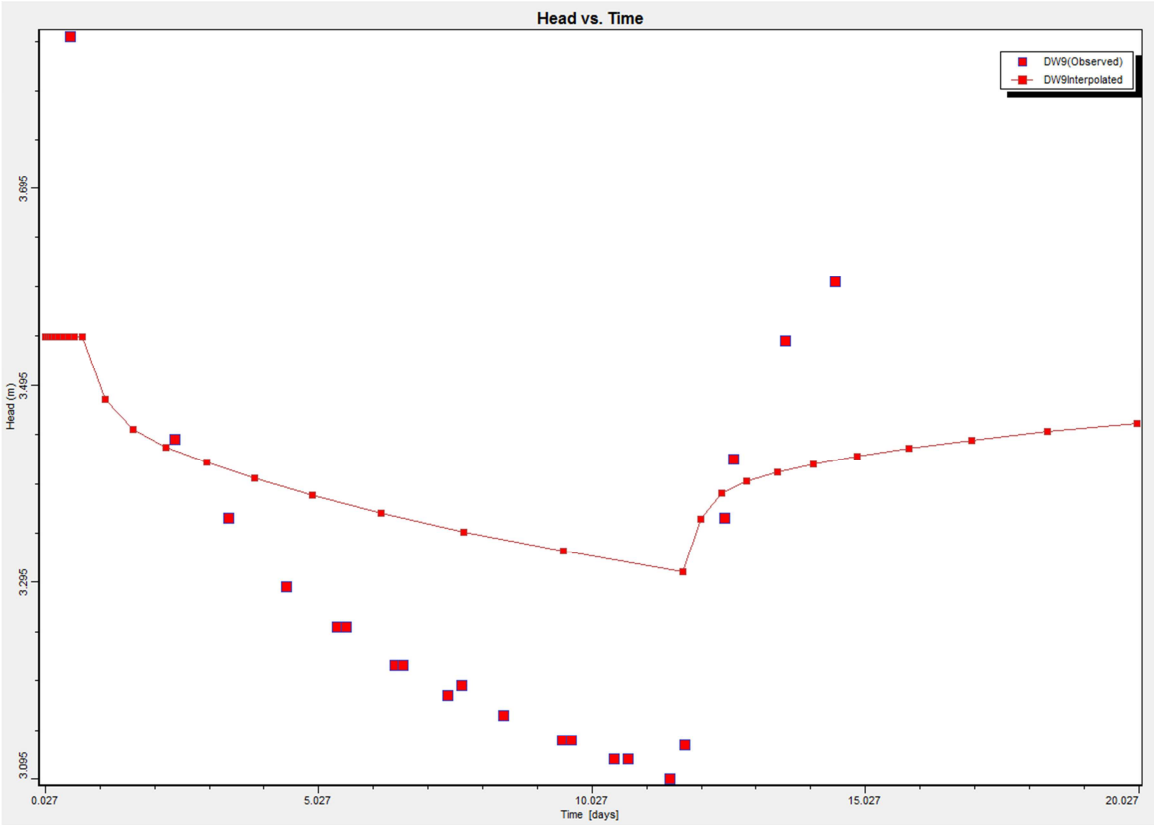

Head vs. Time
DW9(Observed)
DW9Interpolated
Head (m)
3.695
3.495
3.295
3.095
0.027
5.027
10.027
15.027
20.027
Time [days]


Head vs. Time
DW5(Observed)
DW5Interpolated
Head (m)
3.794
3.594
3.394
3.194
0.027
5.027
10.027
15.027
20.027
Time [days]


Head vs. Time
DW6(Observed)
DW6Interpolated
Head (m)
3.74
3.54
3.34
3.14
0.027
5.027
10.027
15.027
20.027
Time [days]

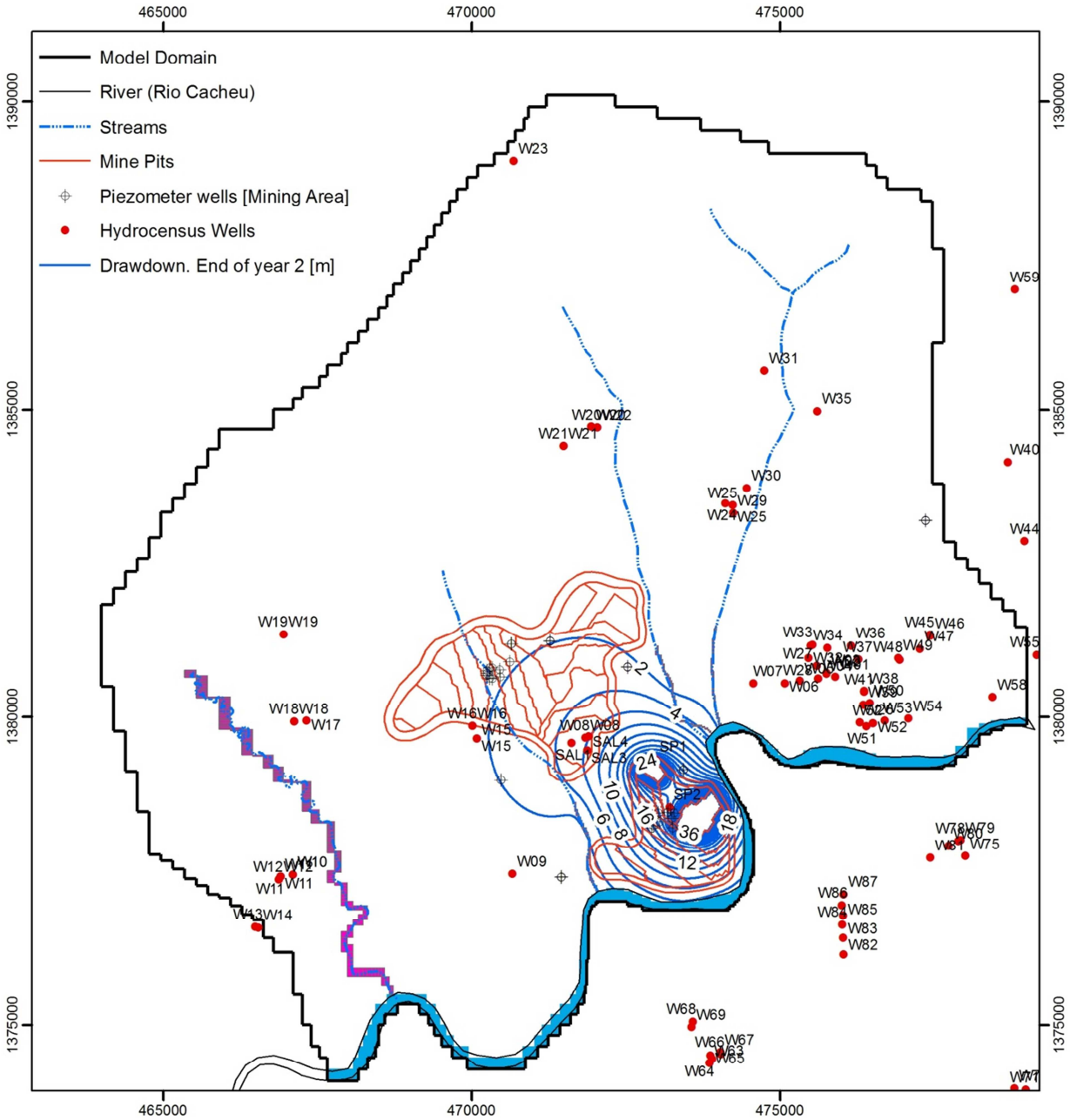

Head vs. Time
DW7(Observed)
DW7Interpolated
Head (m)
3.65
3.45
3.25
3.05
0.027
5.027
10.027
15.027
20.027
Time [days]

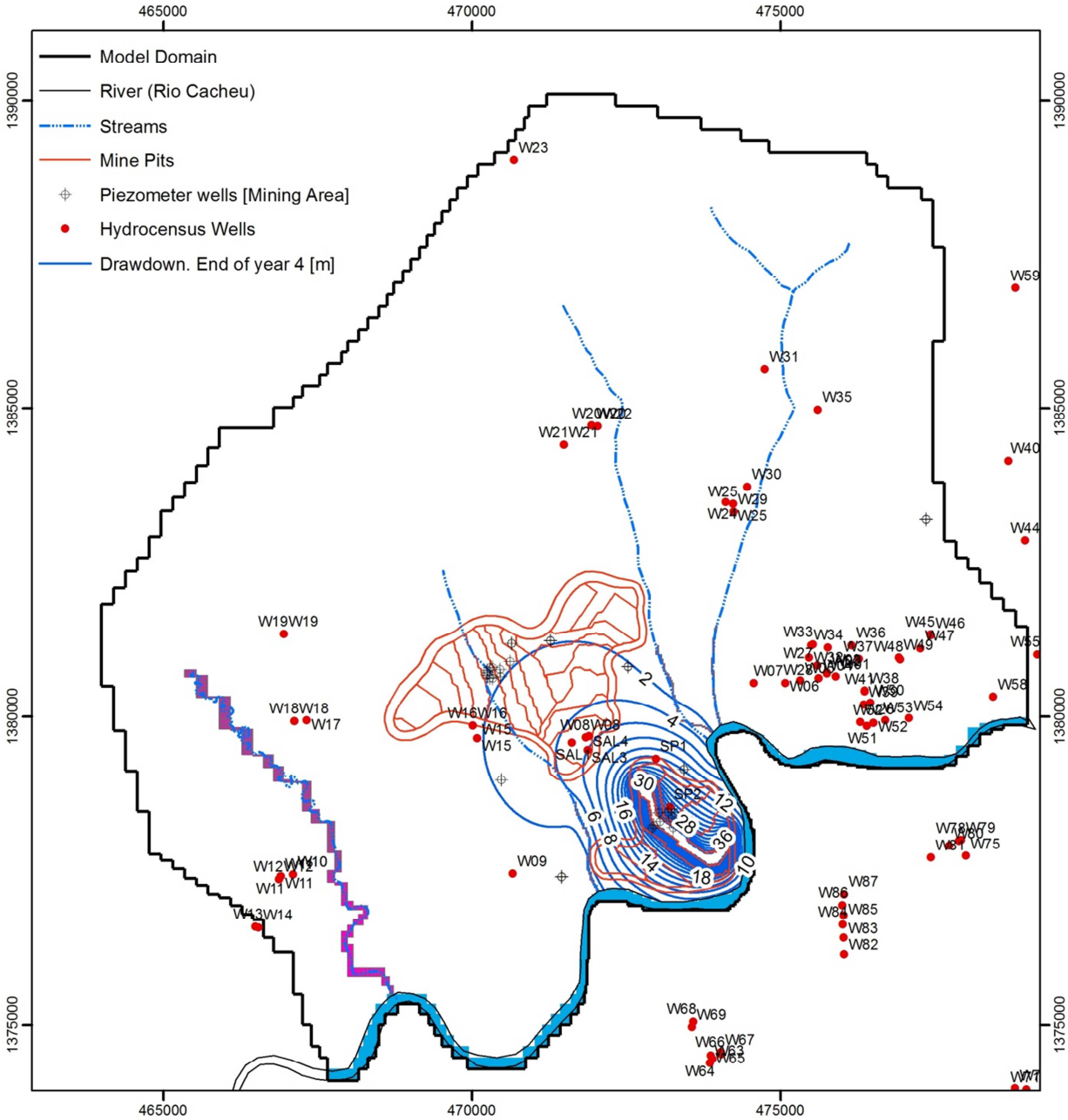

Head vs. Time
DW8(Observed)
DW8Interpolated
Head (m)
3.715
3.515
3.315
3.115
2.915
0.027
5.027
10.027
15.027
20.027
Time [days]

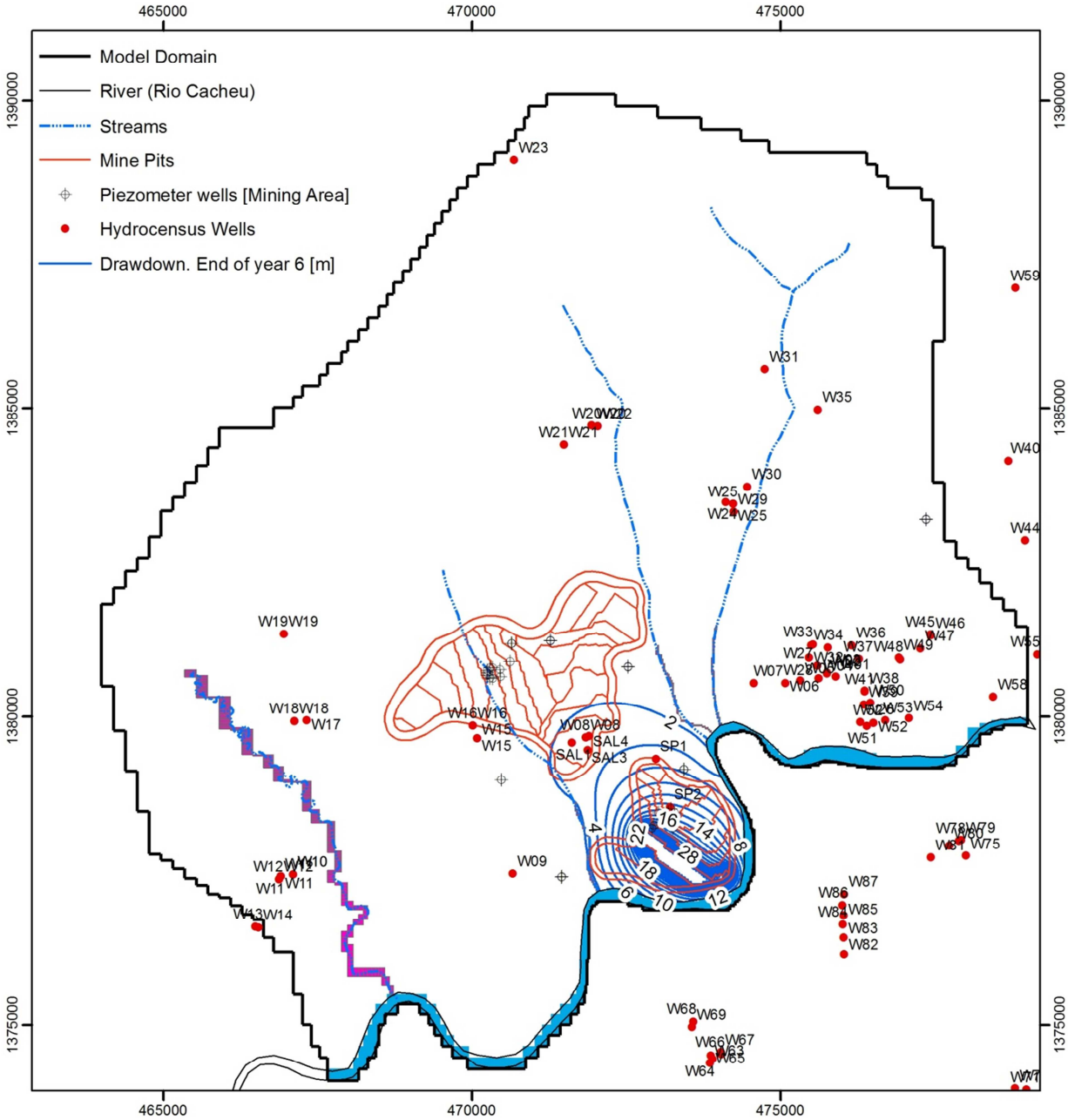

Head vs. Time
DW9(Observed)
DW9Interpolated
Head (m)
3.695
3.495
3.295
3.095
0.027
5.027
10.027
15.027
20.027
Time [days]

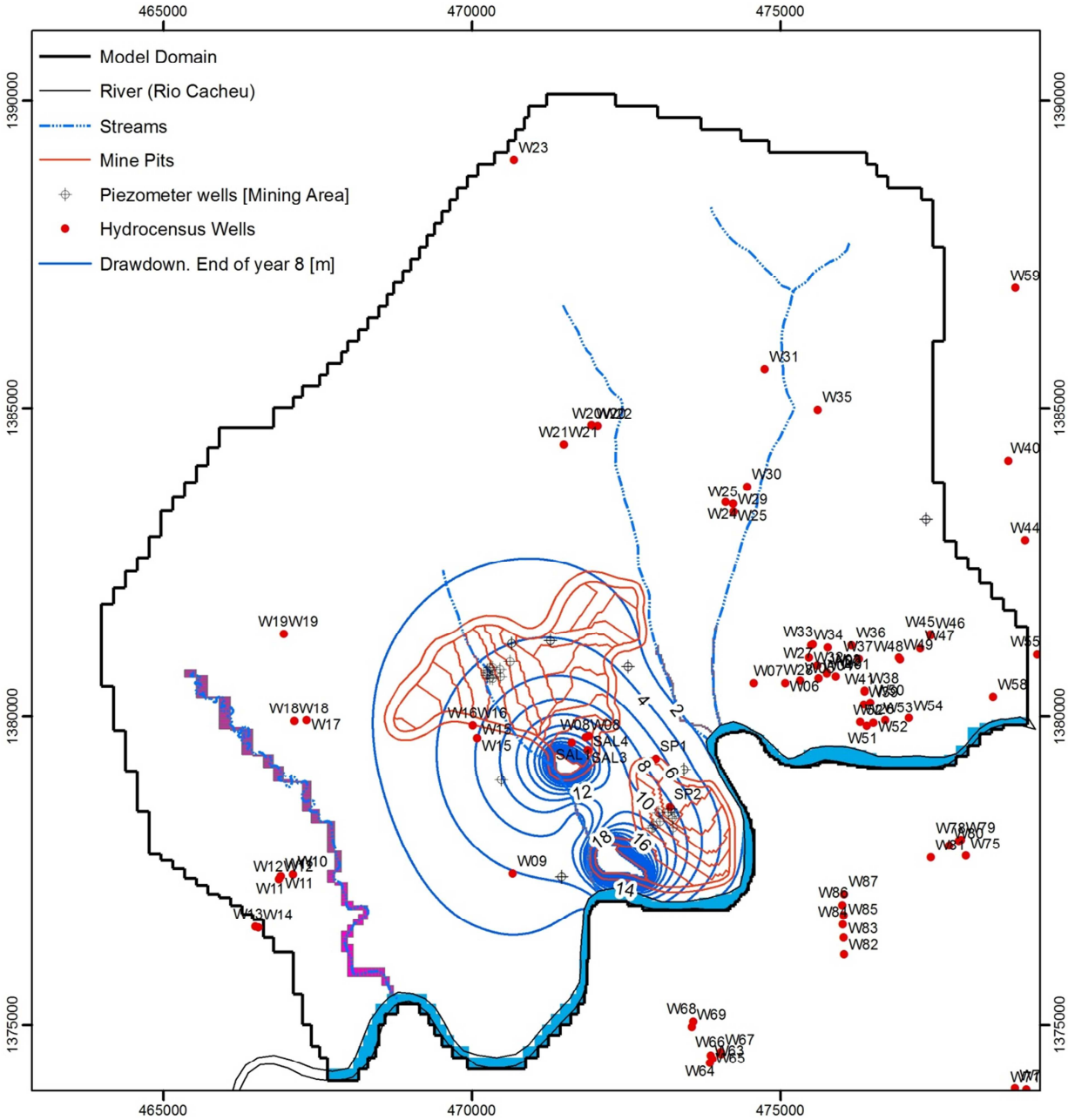
APPENDIX B

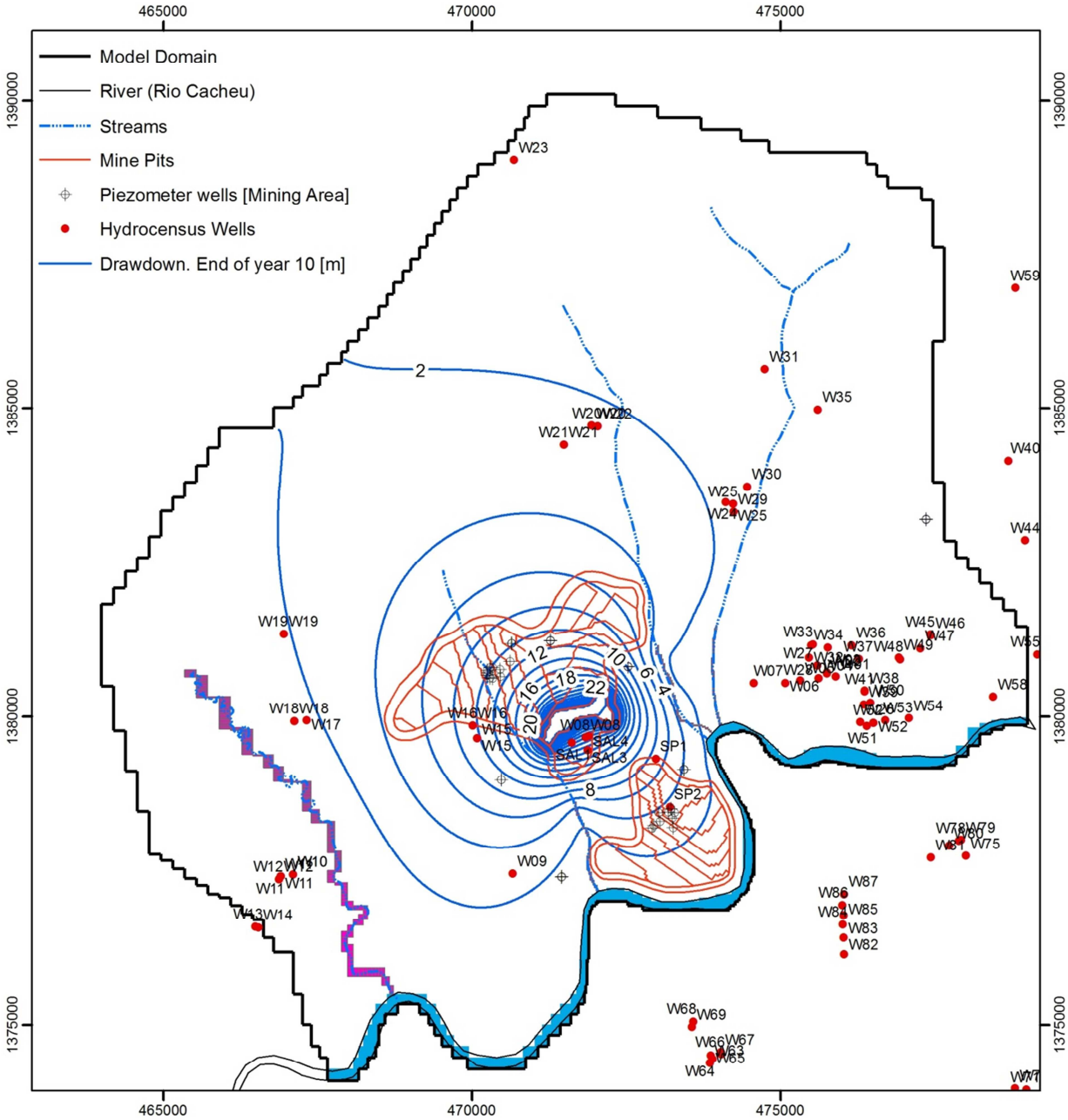
Water Level Drawdown Estimates

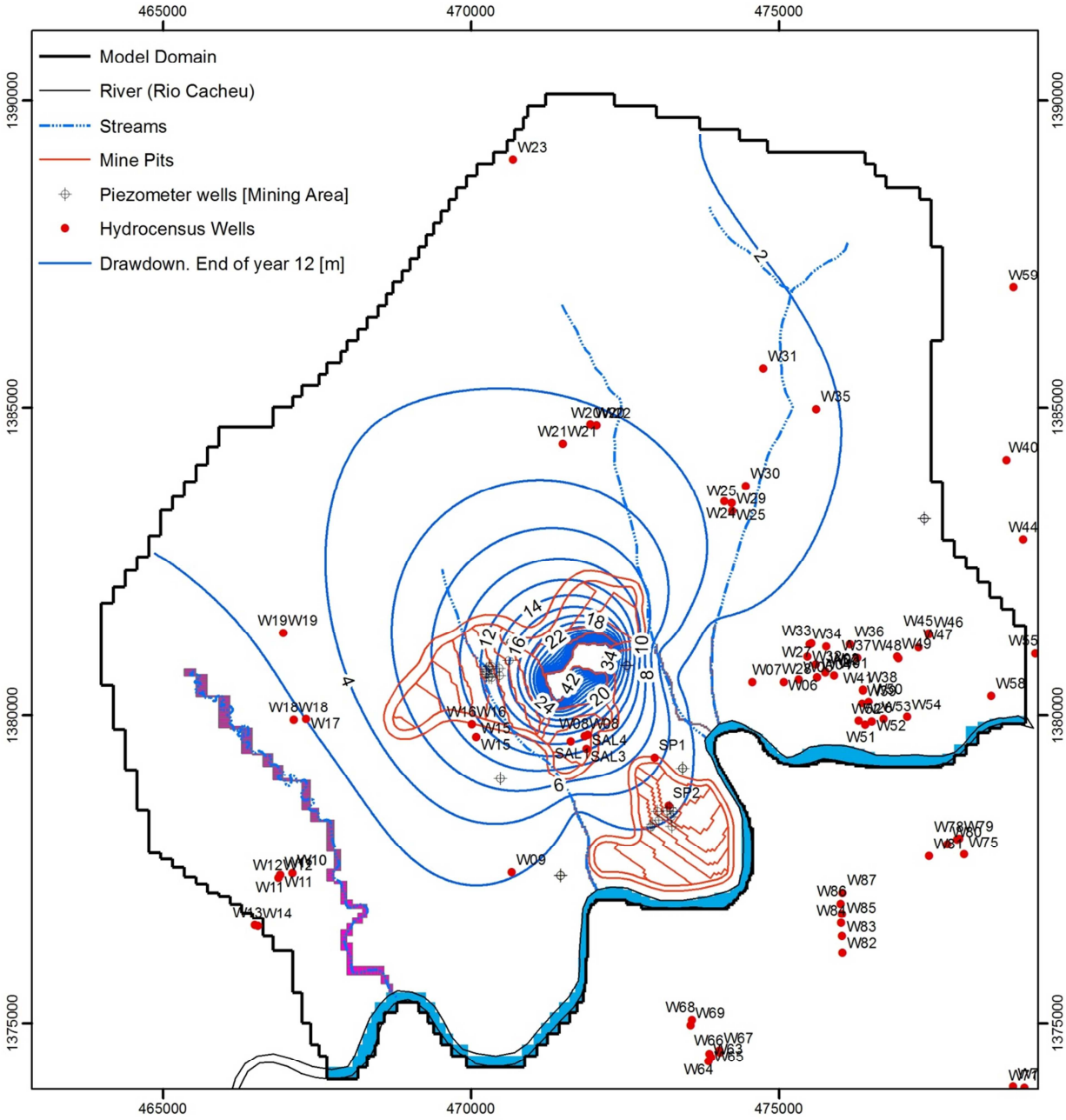

465000
470000
475000
1390000
1385000
1380000
1375000
Model Domain
River (Rio Cacheu)
Streams
Mine Pits
Piezometer wells [Mining Area]
Hydrocensus Wells
Drawdown. End of year 2 [m]
W23
W59
W31
W35
W40
W44
W30
W19W19
W18W18
W17
W16W16
W15
W08W08
SAL4
SAL1
SAL3
SP1
SP2
W09
W12
W11
W10
W43W14
W45W46
W47
W33
W34
W36
W37W48W49
W07
W06
W41
W38
W54
W52
W51
W58
W78W79
W75
W87
W86
W85
W83
W82
W68
W69
W66W67
W64
2
4
6
8
10
12
16
18
24
36


Model Domain
River (Rio Cacheu)
Streams
Mine Pits
Piezometer wells [Mining Area]
Hydrocensus Wells
Drawdown. End of year 4 [m]
465000
470000
475000
1390000
1385000
1380000
1375000
W23
W59
W31
W35
W40
W30
W44
W19
W18
W17
W16
W15
W08
SAL4
SAL1
SAL3
SP1
SP2
W09
W12
W11
W13
W14
W45
W46
W47
W33
W34
W36
W37
W48
W49
W55
W58
W07
W06
W41
W38
W54
W52
W51
W78
W79
W75
W87
W86
W85
W83
W82
W68
W69
W66
W67
W65
W64
2
4
6
8
10
12
14
16
18
28
30
36


Model Domain
River (Rio Cacheu)
Streams
Mine Pits
Piezometer wells [Mining Area]
Hydrocensus Wells
Drawdown. End of year 6 [m]
465000
470000
475000
1390000
1385000
1380000
1375000
W23
W59
W31
W35
W40
W30
W44
W19
W18
W17
W16
W15
W08
SAL4
SAL3
SP1
SP2
W09
W12
W11
W13
W14
W33
W34
W36
W45
W46
W47
W48
W49
W55
W58
W54
W52
W51
W78
W79
W75
W87
W86
W85
W83
W82
W68
W69
W66
W67
W65
W64
2
4
6
8
10
12
14
16
18
22
28


465000
470000
475000
1390000
1385000
1380000
1375000
Model Domain
River (Rio Cacheu)
Streams
Mine Pits
Piezometer wells [Mining Area]
Hydrocensus Wells
Drawdown. End of year 8 [m]
W23
W59
W31
W35
W40
W44
W30
W19W19
W18W18
W17
W16W16
W15
W09
SAL1
SAL3
SAL4
SP1
SP2
W51
W52
W54
W58
W87
W86
W85
W83
W82
W68
W69
W66W67
W64
2
4
6
8
10
12
14
16
18


465000
470000
475000
1390000
1385000
1380000
1375000
Model Domain
River (Rio Cacheu)
Streams
Mine Pits
Piezometer wells [Mining Area]
Hydrocensus Wells
Drawdown. End of year 10 [m]
2
4
6
8
10
12
16
18
20
22
SP1
SP2
SAL1
SAL2
SAL3
SAL4
W08
W09
W23
W31
W35
W59
W40
W44
W55
W58
W30
W25
W29
W24
W21
W20
W22
W19
W18
W17
W16
W15
W12
W11
W10
W13
W14
W33
W34
W36
W37
W48
W49
W45
W46
W47
W27
W07
W06
W41
W38
W39
W52
W53
W54
W51
W78
W79
W75
W87
W86
W85
W83
W82
W68
W69
W66
W67
W65
W64


Model Domain
River (Rio Cacheu)
Streams
Mine Pits
Piezometer wells [Mining Area]
Hydrocensus Wells
Drawdown. End of year 12 [m]
465000
470000
475000
1390000
1385000
1380000
1375000
W23
W59
W31
W35
W40
W44
W55
W58
W30
W25
W29
W24
W21
W19
W18
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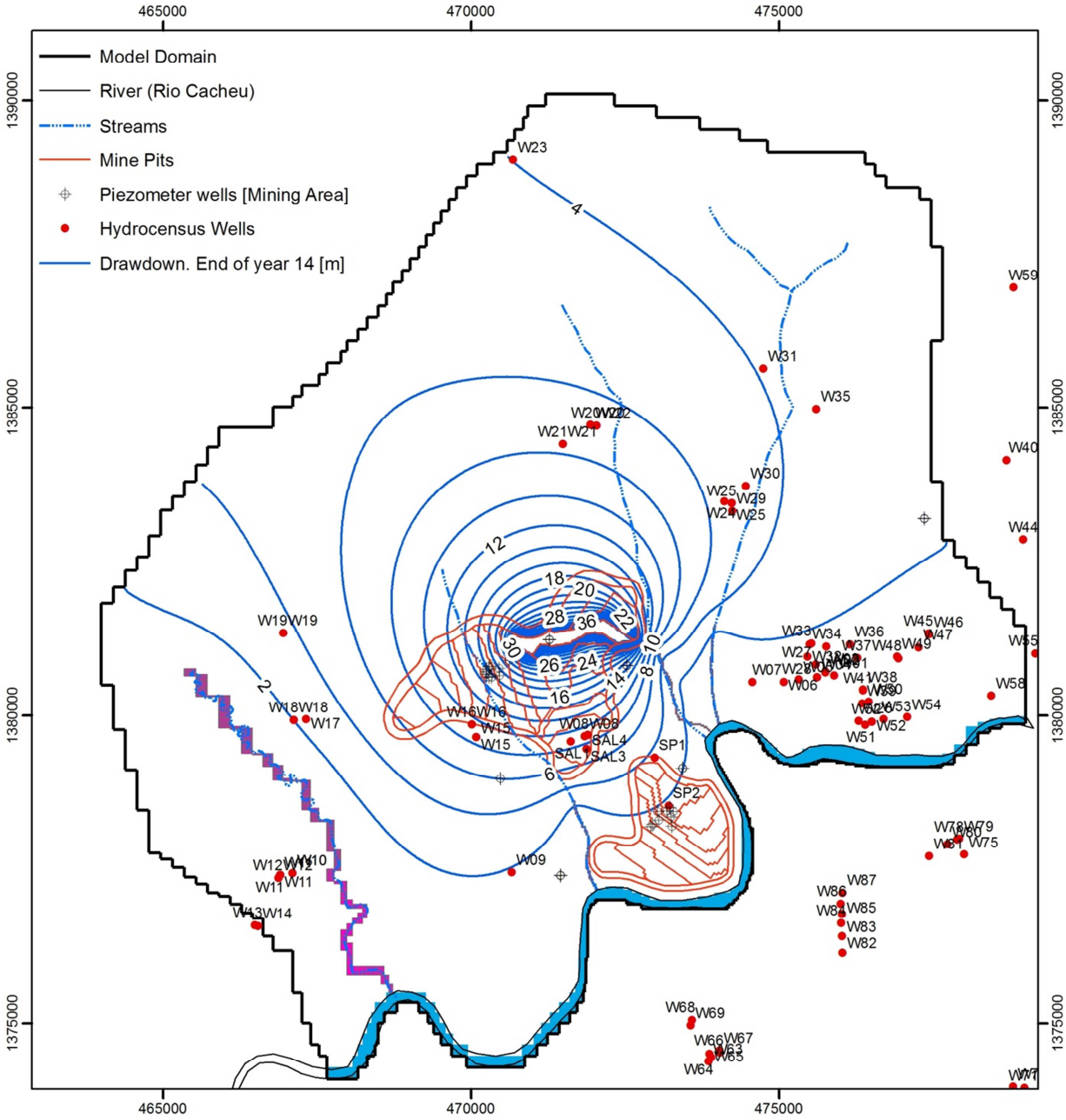
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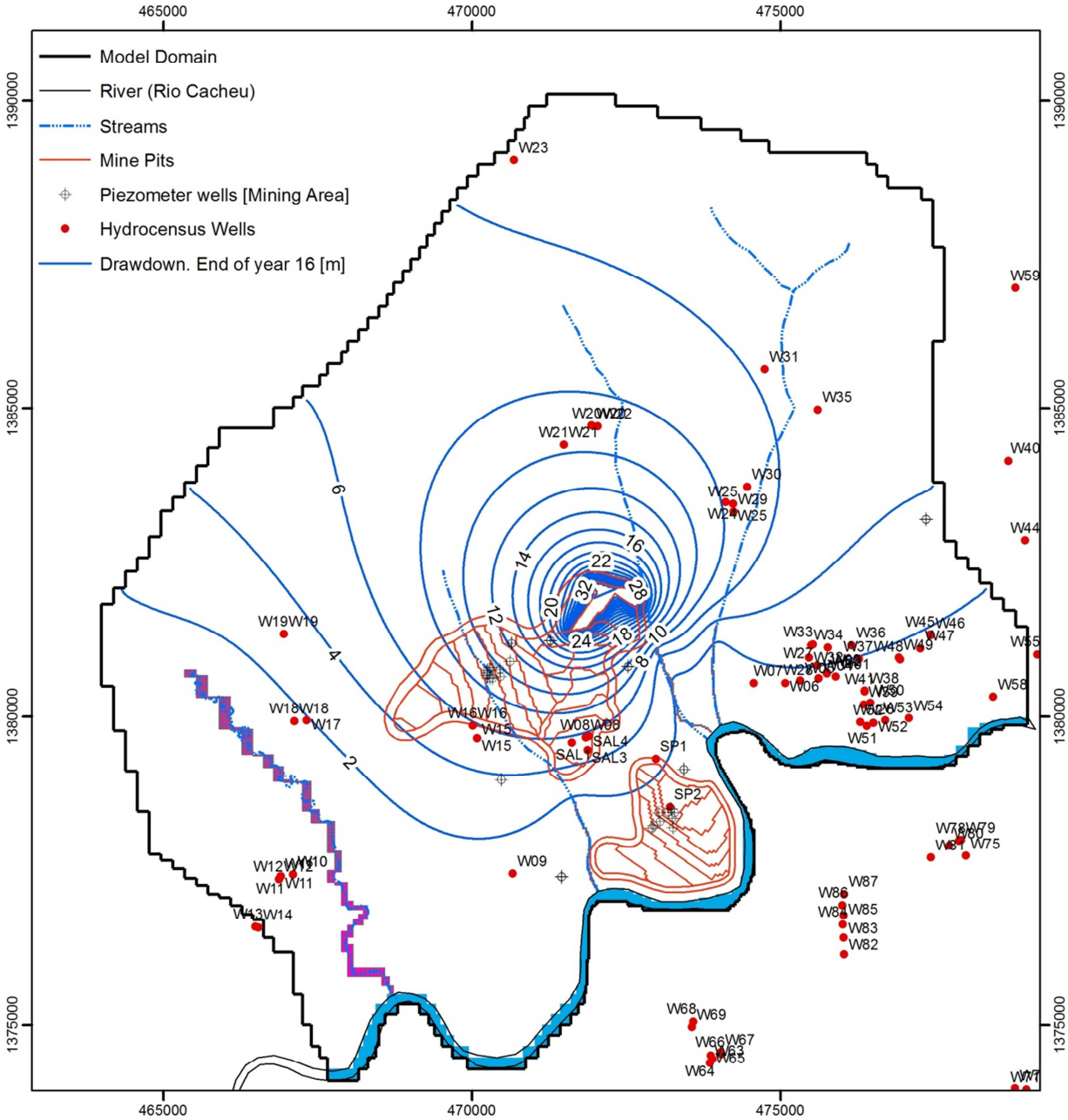
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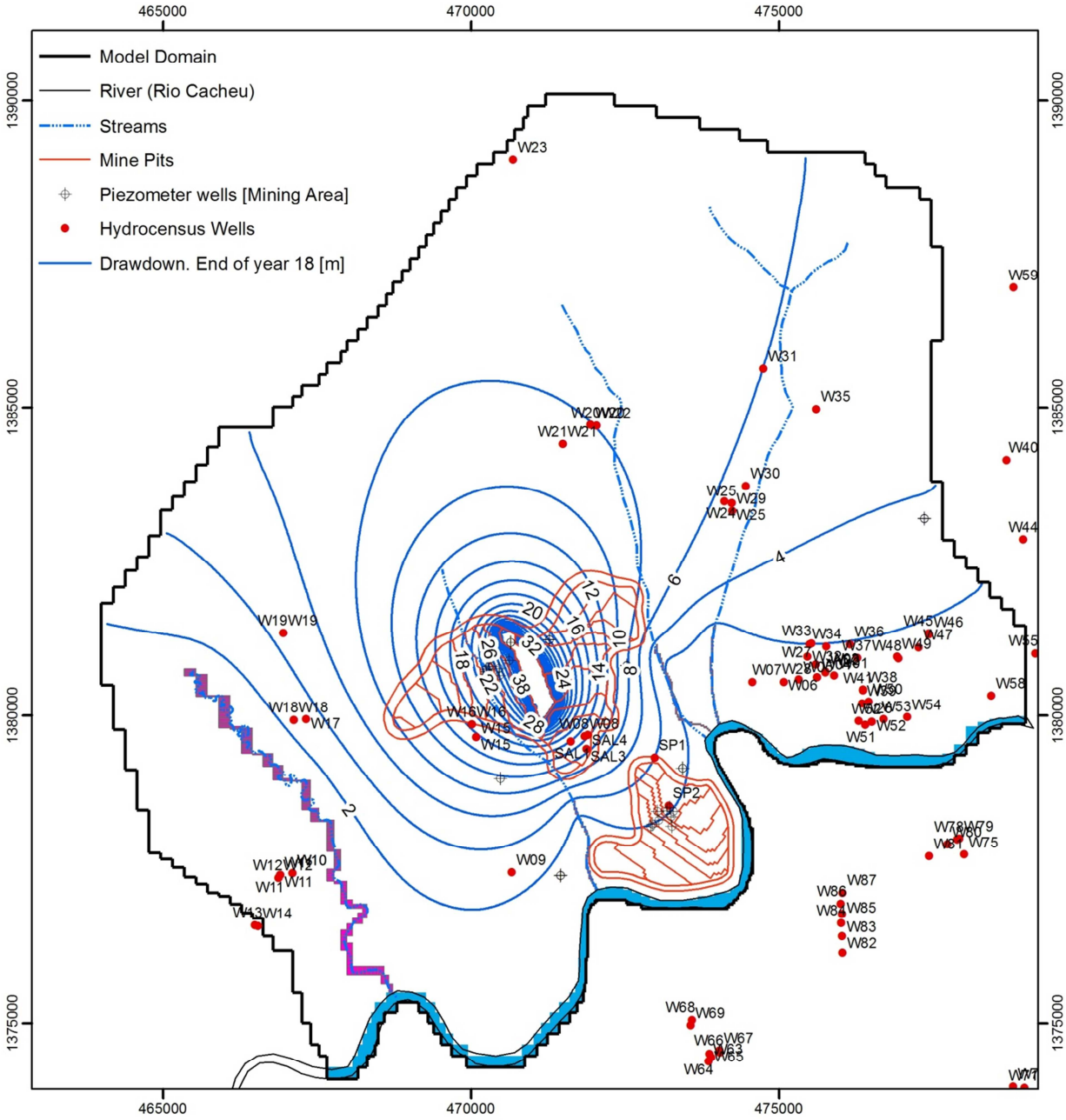
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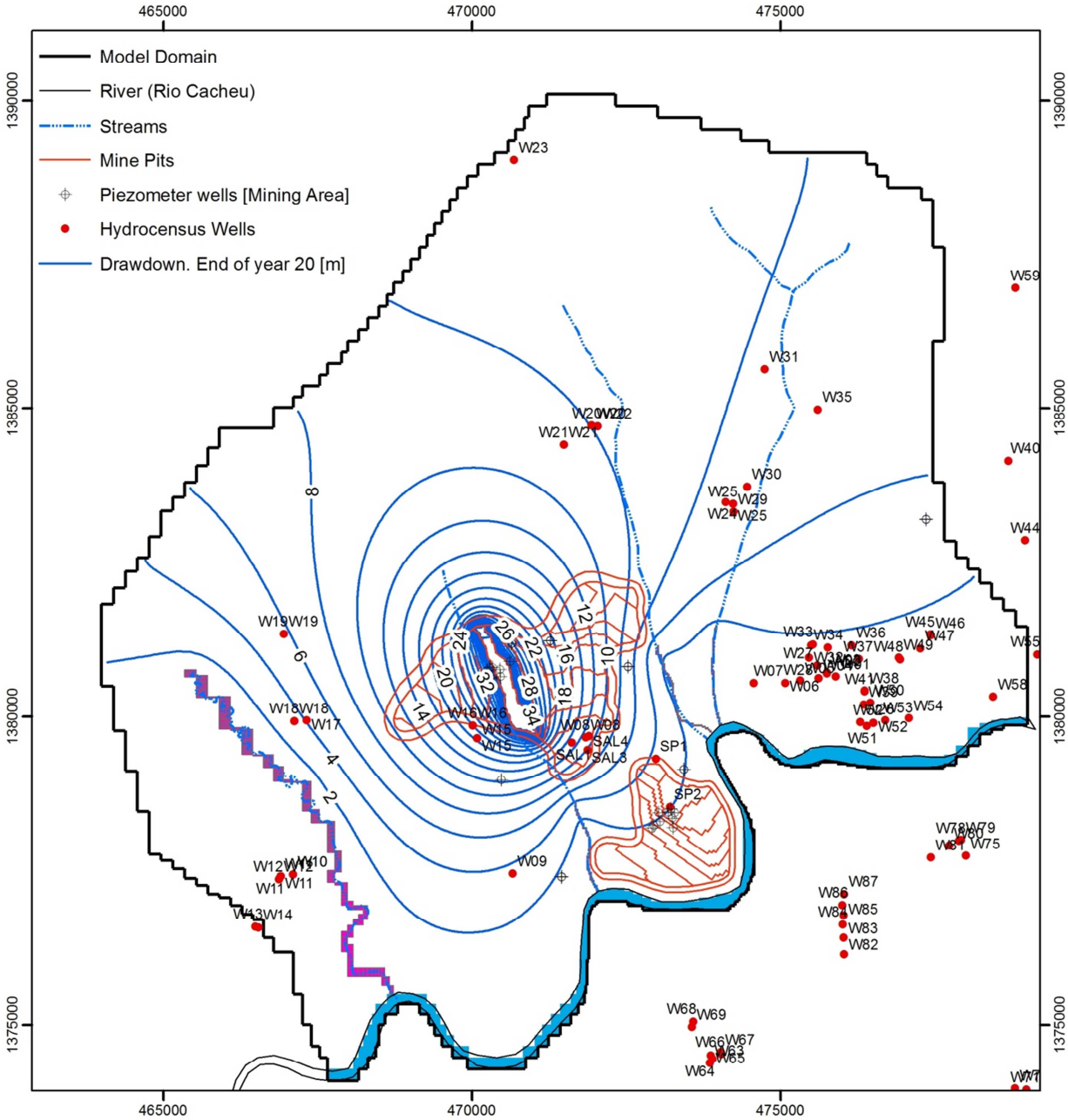
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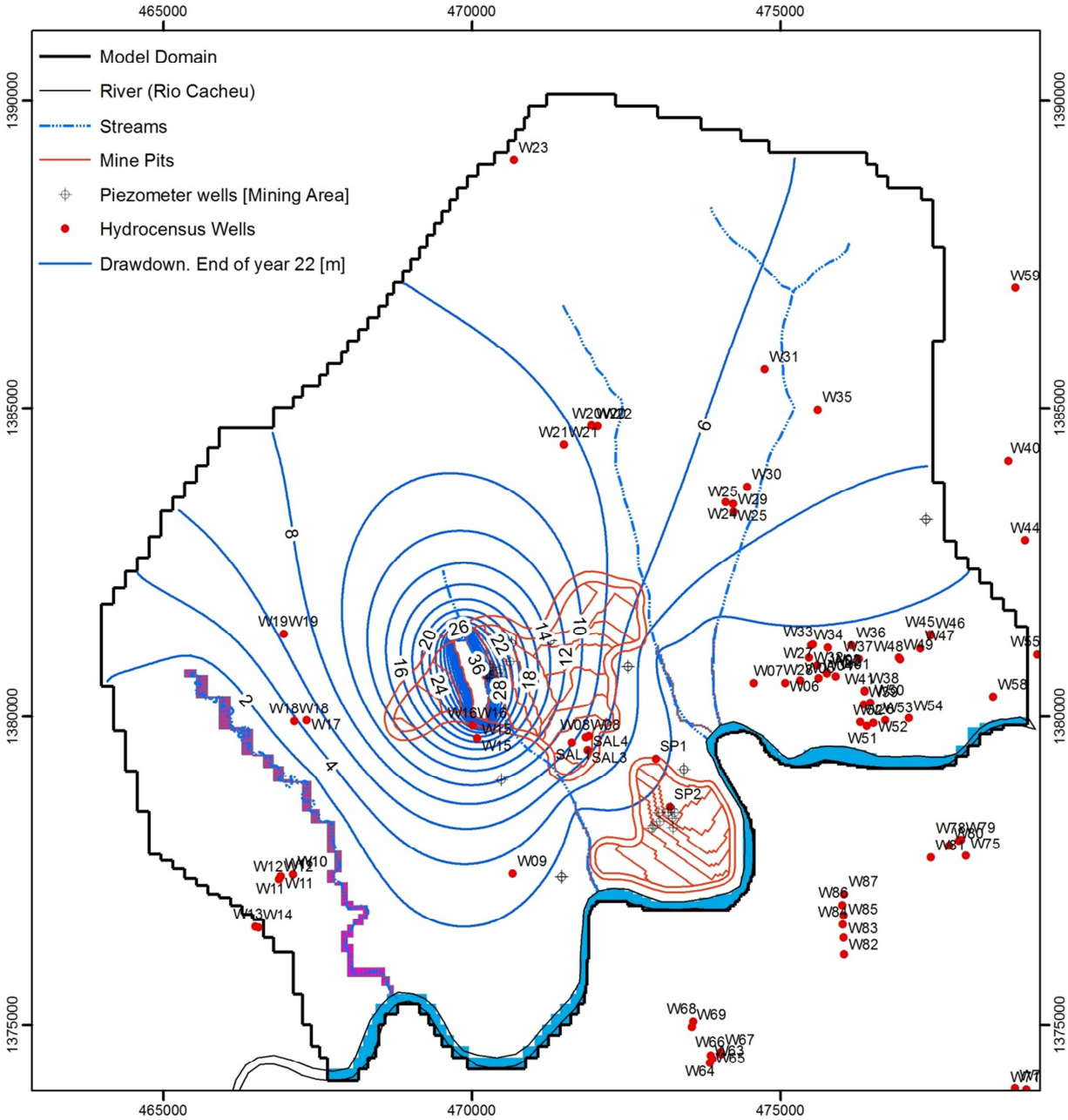
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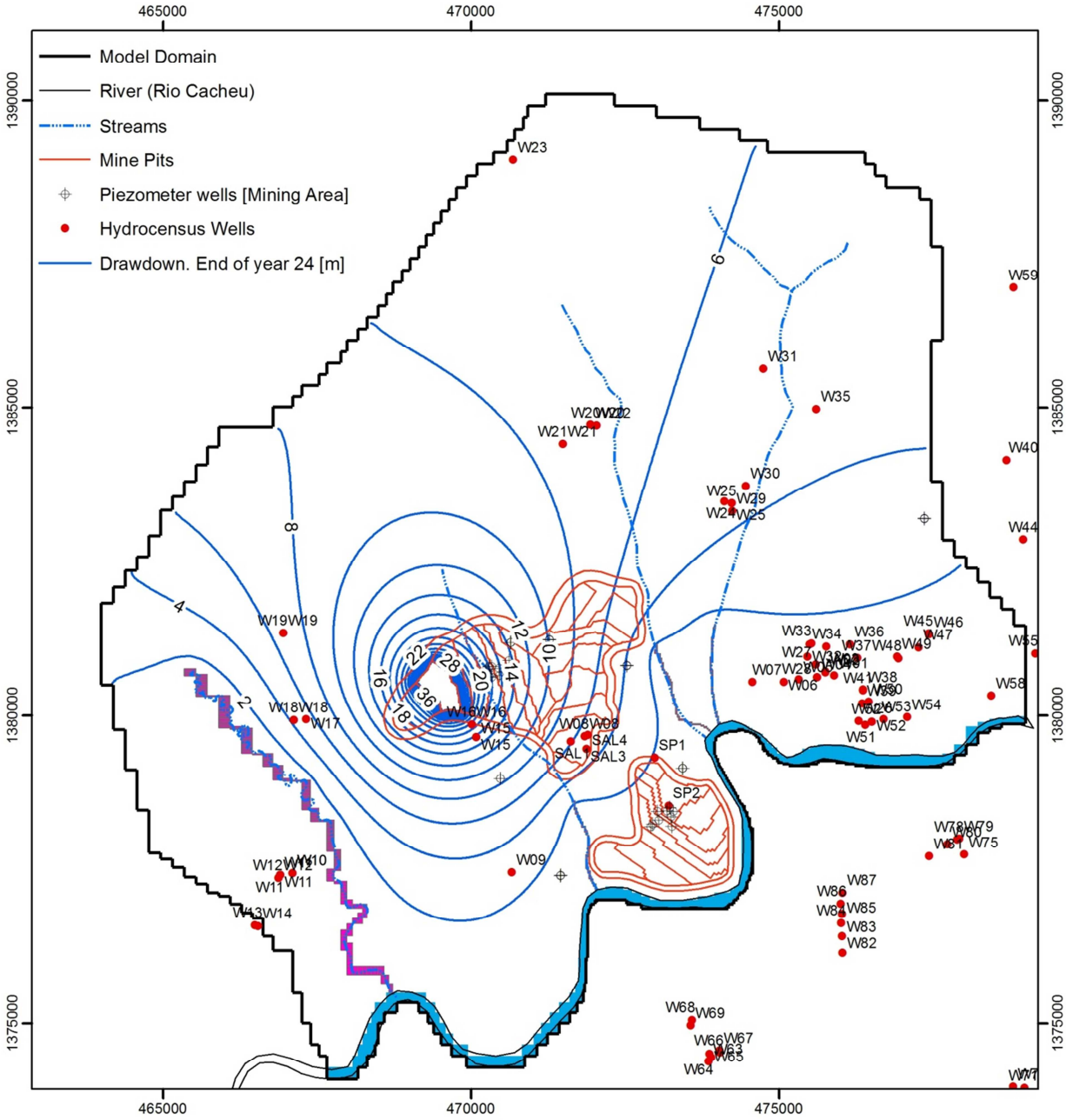
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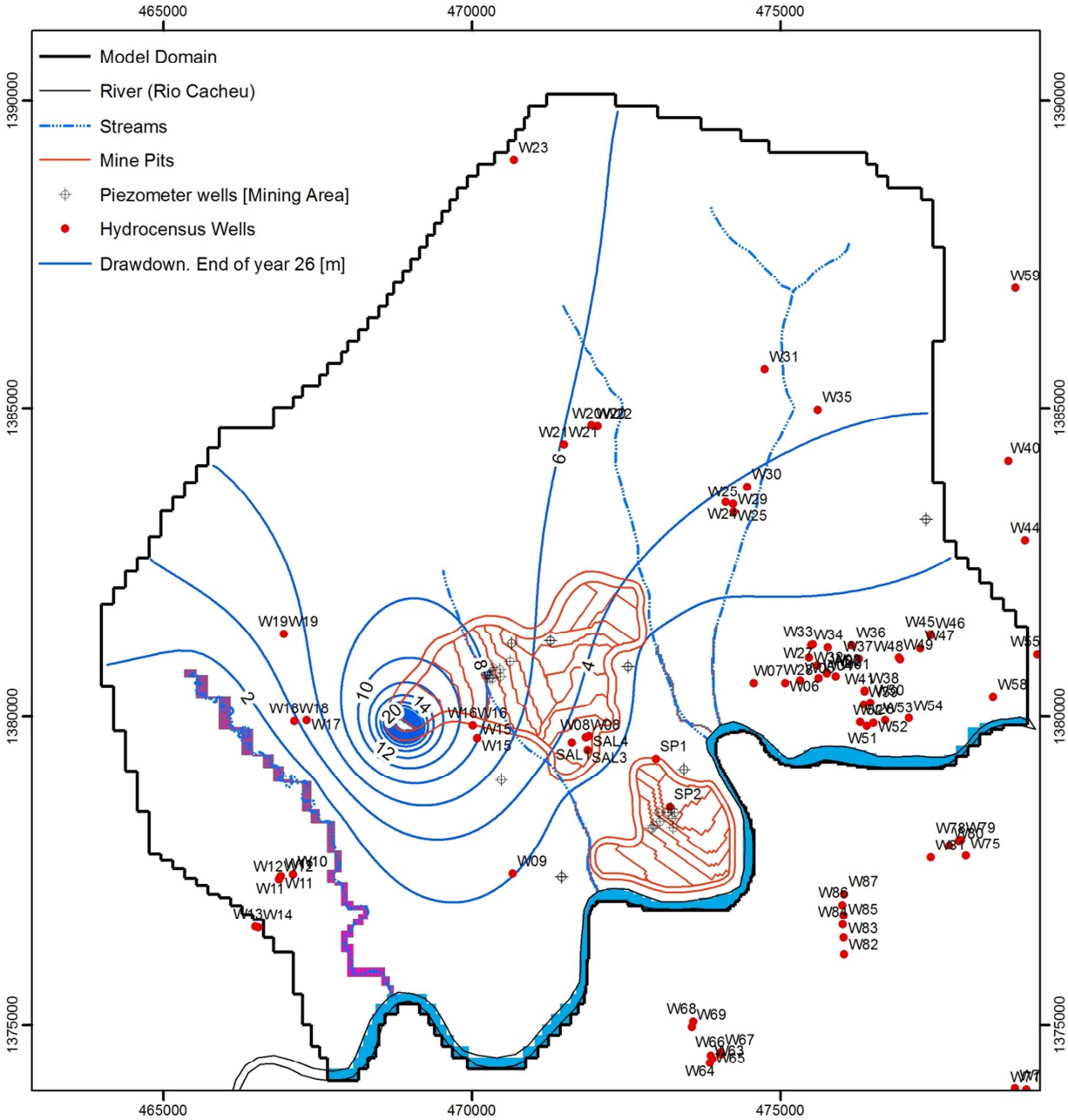
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MEMORANDUM

To:	Ms. Olga Kovalik	Date:	July 13, 2015
Copy To:	Christine Moore (Intrinsik)	File No.:	NB301-520/2-A.01
From:	Richard Cook	Cont. No.:	NB15-00186
Re:	Supplemental Terrestrial Soil Baseline Report - Farim Phosphate Project		

1 – INTRODUCTION

A supplemental soil sampling program was undertaken by Knight Piésold in support of the Environmental and Social Impact Assessment (ESIA) currently under preparation for the Farim Phosphate Project. Historic soil data are available for the Mine Site. However, incorrect analytical methods were used for baseline metals characterization (Golder, 2014). Additionally, soil quality data were not previously collected within the Port Site area. The following describes the field program undertaken by Knight Piésold in May 2015, the soil quality laboratory results, and provides a discussion of the results in relation to the Canadian Environmental Quality Guidelines (CEQG) - Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2015).

2 – FIELD PROGRAM

The sampling program was developed with the intent of understanding the baseline metals concentrations in the shallow / near surface soil mineral soils (the soil immediately beneath the topsoil layer) within various soil types and land uses at the Mine and Port sites. Port Site area samples were analyzed for additional parameters to provide an indication of nutrient levels and agricultural potential. Fifteen (15) soil samples were collected from within four land use types located adjacent to the Port Site development area (Figure 1) over the period of May 8 to 15, 2015. Similarly, 36 soil samples were collected from five land use types in the vicinity of the Mine Site (Figure 2). Table 1 summarizes the soil sample information collected at each of the project sites.

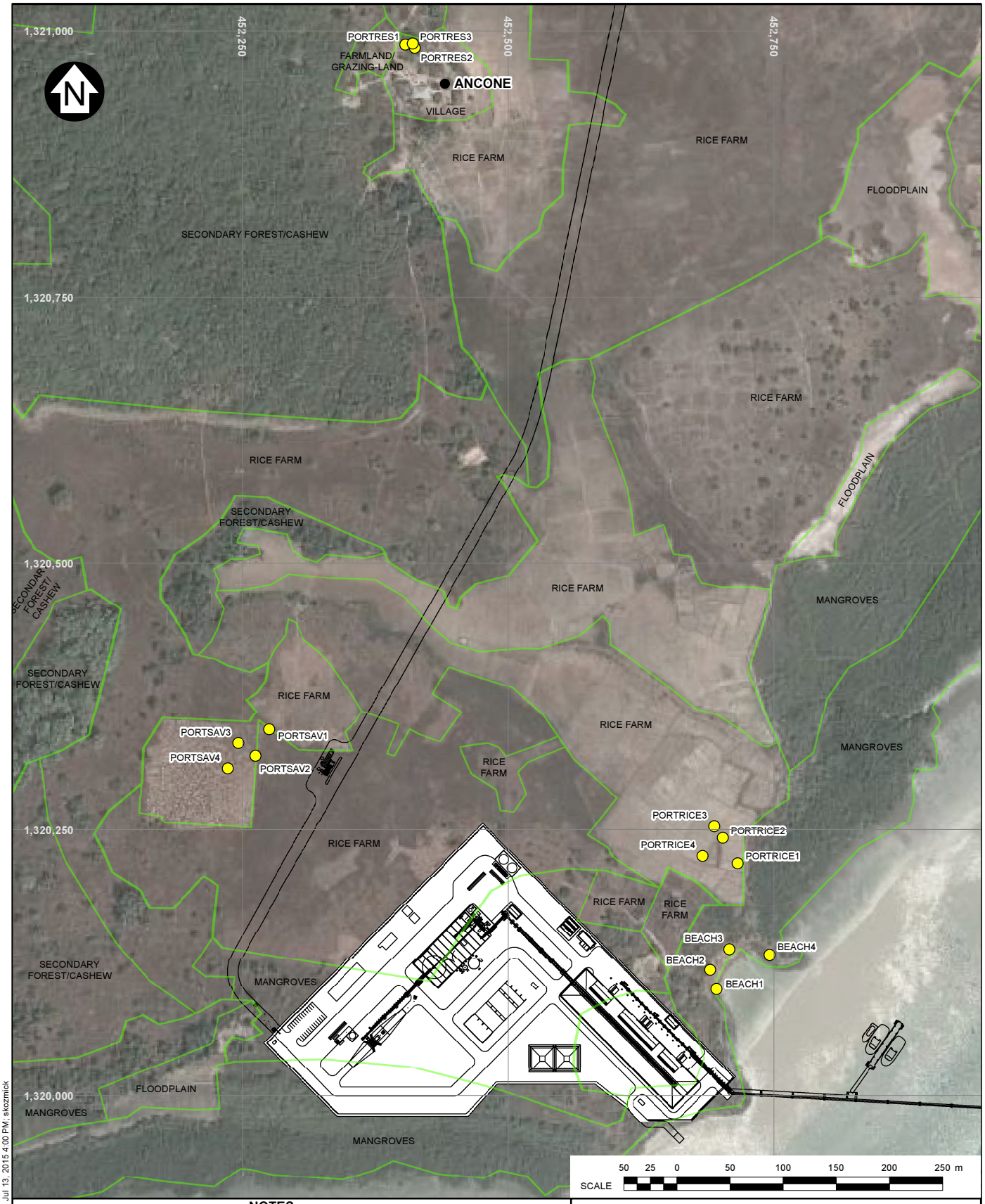
Sample collection involved the excavation of shallow test pits using a stainless steel trowel. Samples were placed in food-grade plastic bags (double-bagged), labelled with chain of custody forms completed, and stored in a cooler. Field notes were recorded on datasheets. Photographs of the shallow test pit profile were taken along with photographs of the surrounding area. Sample coordinates were recorded using a GPS unit. Photographs of the surrounding area were also recorded. Representative photographs of the soil sample locations and sample pits are presented in Appendix A.

The samples were transported in a cooler/container with ice packs to the shipping location, and were shipped to ALS located in Prague, Czech Republic for analysis. A metals scan was completed by ALS using atomic emission spectrometry with inductively coupled plasma. Eight (8) soil samples collected from the agricultural areas at the port were also analyzed for pH, total nitrogen, bulk density and electrical conductivity.

Delays in sample shipment from Guinea-Bissau as well as delays in customs clearance resulted in the soil samples arriving to the laboratory on June 15, 2015. As such, the ALS recommended holding times were exceeded for pH and electrical conductivity (7 days) as well as anions and cations (28 days).

Table 1 Soil Sample Summary

Land Use Area		Station ID	Number of Samples	Moisture		Colour	Comments
				Surface	Subsurface		
Port Site Area							
Rice Paddy		PortRice	4	Dry	Dry	Grey	Clay; see Photos 1 and 2.
Savannah		PortSav	4	Dry	Dry	Brown/Grey	Silty sand; see Photos 3 and 4. Sample PortSav1 was noted to appear be a periodically flooded wetland.
Fishing Beach		Beach	4	Dry	Wet-Dry	Grey	Beach, upland area and peninsula; see Photos 5 to 10. Beach 1 sample collected from stony beach material; stones covering clay. Beach2 was lose and stony.
Residential		PortRes	3	Dry	Dry	Brown/Grey	Soft sand over hard sand and red rock; see Photos 11 and 12.
Mine Site Area							
Rice Paddy	Canico	CanicoRice	3	Dry	Dry	Grey	Clay to sand; see Photo 13.
	Ponta Zeca	P.ZecaRice	3	Dry	Dry	Grey	Clay; see Photo 14.
	Farim	FarimAgric	3	Dry	Dry	Grey	Clay; see Photo 15.
Upland Agricultural	Saliquenhe	S.HedimCrop	3	Dry	Dry	Brown	Row crops, no rice.
	Canico	CanicoCrops	3	Dry	Dry	Brown-Grey	Sand.
	Ponta Zeca	P.ZecaCrops	3	Dry	Dry	Brown-Grey	No field notes recorded.
	Tambato	S.TambatoAgric	3	Dry	Dry	Grey	South of road, historic agriculture.
Residential	Saliquenhe	S.HedimRes	3	Dry	Dry	Brown	Abandoned area near road.
	Nema (NemaRes)		3	Dry	Dry	Brown	Sand; see Photo 16.
	Canico	CanicoRes	3	Dry	Dry	Grey	Sandy soils; samples collected opposite soccer pitch.
	Ponta Zeca	P.ZecaRes	3	Dry	Dry	Brown	No field notes recorded.
Fallow Agricultural	Truck Load-Out	TruckLoadArea	3	Dry	Dry	Grey-Black	Hard clay; samples collected from a former agricultural area now fallow.



LEGEND:

- ● COMMUNITY/RESIDENCE
- ● 2015 SOIL SAMPLE LOCATION (KP)
- PROPOSED INFRASTRUCTURE
- LANDUSE

NOTES:

1. PORT SITE INFRASTRUCTURE PROVIDED BY LYCOPODIUM MINERALS CANADA LTD. (MARCH 18, 2015). MODIFIED BY KNIGHT PIESOLD LTD. TO SHOW THE CORRECT GEOGRAPHIC LOCATION (JUNE 26, 2015).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: WGS 1984 UTM ZONE 28N.
3. IMAGERY GEOREFERENCED FROM GOOGLE EARTH (JULY 2015).

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FARIM PHOSPHATE PROJECT

PORT SITE
SOIL SAMPLE LOCATIONS

Knight Piésold CONSULTING

P/A NO. NB301-520/2 | REF NO. NB15-00186

FIGURE 1 | REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
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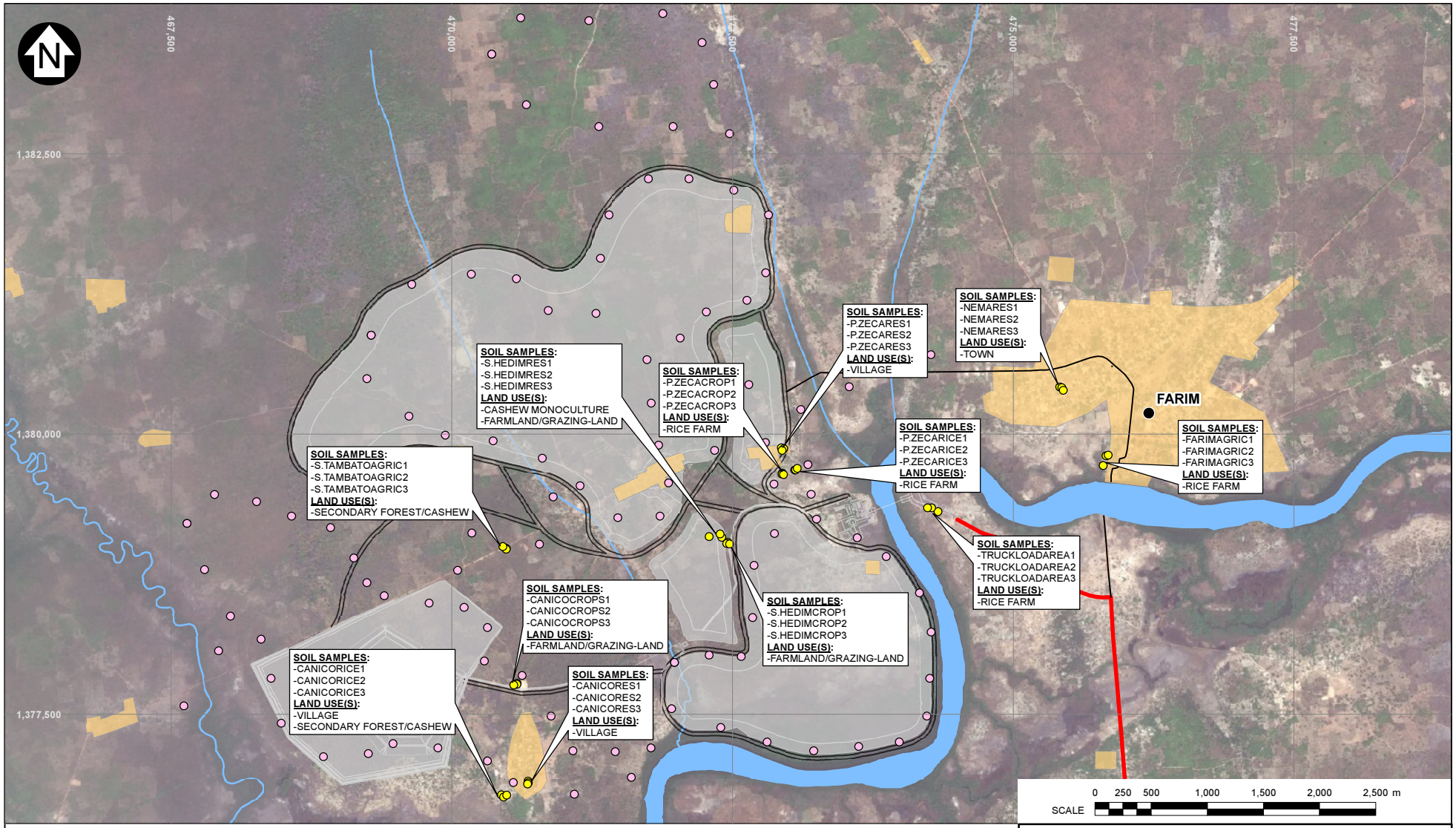

LEGEND:

- COMMUNITY
- 2015 SOIL SAMPLE LOCATION (KP)
- 2013 SOIL SAMPLE LOCATION (GOLDER)
- ROAD
- PROPOSED HAUL ROAD
- PROPOSED INFRASTRUCTURE
- PRODUCT TRANSPORT ROUTE
- RIVER/STREAM/DRAINAGE
- WATER
- POPULATED SETTLEMENT
- PROPOSED INFRASTRUCTURE

NOTES:

1. MINE INFRASTRUCTURE AND BASEMAP DATA PROVIDED BY LYCOPODIUM MINERALS CANADA LTD. (MARCH 18, 2015).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: WGS 1984 UTM ZONE 28N.
3. 2013 SOIL SAMPLE LOCATIONS FROM GOLDER (2014) MINE COMPONENT ENVIRONMENTAL AND SOCIAL BASELINE STUDIES.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	13JUL'15	ISSUED WITH REPORT	RAC	SWK	RAC

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

MINE SITE
SOIL SAMPLE LOCATIONS

Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF NO. NB15-00186

FIGURE 2

REV 0

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3 – RESULTS

3.1 REFERENCE GUIDELINES

The soil results were compared to the Canadian Environmental Quality Guidelines (CEQG) Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2015). These guidelines include concentration limits for agricultural, residential/parkland, commercial and industrial land uses. The laboratory results and corresponding guidelines are shown in Appendix B. Summaries of the guideline exceedances are provided below.

3.2 PORT SITE

The Port area soil samples were analyzed for total metals content. The rice paddy and savannah samples also included agricultural parameter analysis. The following exceedances of the CEQG guidelines were observed in the Port Site area soil samples:

- **Arsenic (As) -** The four rice paddy (PortRice1 to 4) and three of the four beach (Beach1 to 3) samples had arsenic concentrations above the CEQG guidelines (all land uses 12 mg/kg), with concentrations ranging between 12.30 mg/kg and 44.80 mg/kg. The highest concentrations were observed at the beach.
- **Cadmium (Cd) -** The four rice paddy (PortRice 1 to 4), two savannah (PortSav3 and PortSav4), and three beach (Beach1 to 3) samples had cadmium concentrations above the CEQG agricultural guideline (1.4 mg/kg DW) ranging between 1.72 mg/kg and 5.96 mg/kg. The highest concentrations were observed at the beach.
- **Molybdenum -** Two rice paddy (PortRice2 and PortRice4) and on beach (Beach3) samples had molybdenum concentrations above the CEQG guideline (5 mg/kg), with concentrations ranging between 6.29 mg/kg and 6.44 mg/kg. The highest concentration was observed at the beach.
- **Tin (Sn) -** One beach (Beach1) sample had a tin concentration of 7.6 mg/kg, above the CEQG agricultural guideline of 5 mg/kg.
- **Vanadium (V) -** Three of four beach (Beach1 to 3) samples had vanadium concentrations above the CEQG guidelines (all land uses 130 mg/kg), with concentrations ranging between 167 mg/kg and 352 mg/kg.
- **pH -** All pH values for the rice paddy and savannah samples were below the CEQG guidelines (all land uses suitable pH from 6 to 8), with measurements ranging between 5.1 and 5.9.
- **Electrical Conductivity (EC) -** All four soil samples collected within the rice paddy area next to the Port Site (PortRice1 to 4) had EC measurements above the CEQG agricultural and recreational/parkland guidelines (200 mS/m), with three of the four samples exceeding the CEQG commercial and industrial guideline (400 mS/m). EC measurements ranged between 304 mS/m and 1,480 mS/m.

The Port Site results are summarized by land use type as follows:

- **Residential -** No exceedances of any soil quality criteria were noted.
- **Rice Paddy -** Soils were slightly acidic (pH 5.1 to 5.9), with high electrical conductivity, and elevated concentrations of arsenic, cadmium and molybdenum that measured above one or more land use soil quality guidelines. Since the rice paddies are established in lower lying areas, it is likely that they have been flooded by the sea in the past.
- **Savannah -** The savannah area soil samples were acidic (pH 5.1 to 5.9) and two of four samples contained elevated concentrations of cadmium exceeding agricultural soil quality guidelines.
- **Fishing Beach Area -** Three of four soil samples exceeded at least the agricultural criteria for arsenic, cadmium and vanadium, and one of the four soil samples exceeded the agricultural criteria for molybdenum and tin.

The laboratory method detection limit (MDL) for selenium (2 mg/kg) was between the agricultural and residential/parkland soil quality limit for selenium (1 mg/kg) but was below the commercial and industrial soil quality criteria of 2.9 mg/kg. All results, however, were below the MDL.

3.3 MINE SITE

The Mine Site area soil samples were analyzed for total metals content, targeting multiple samples each within multiple land uses. The following exceedances of the CEQG guidelines were observed in the Mine Site area samples:

- **Beryllium (Be) -** The three Ponta Zeca rice paddy (P.ZecaRice1 to 3) samples had beryllium concentrations above the CEQG agricultural and residential/parkland guidelines (both 2 mg/kg).
- **Tin (Sn) -** One sample from the Saliquenhe crop area (S.HEDIMCrop2) had a tin concentration of 6.9 mg/kg, above the CEQG agricultural guideline of 5 mg/kg. The other two S.HEDIMCrop samples had tin concentrations of 2.4 mg/kg and 3.2 mg/kg.

As mentioned for the Port Site soils, the MDL for selenium is above the agricultural and residential/parkland soil quality criterion. However, selenium was not detected at concentrations above the MDL (2 mg/kg) at any of the Mine Site sampling locations.

The Mine Site results are summarized by land use type as follows:

- **Residential -** Four residential areas were targeted within and outside of the mine footprint, with three discrete soil samples collected at each location. This included the villages of Salinquenhe, Canico, Ponta Zeca and Nema. No exceedances of any soil quality criteria were noted.
- **Rice Paddy -** Rice paddies were sampled at Canico, Ponta Zeca and Farim. Only the soils collected from within the rice paddies at Ponta Zeca contained beryllium concentrations above the CEQG agricultural and residential/parkland guidelines.
- **Upland Agricultural Areas (Cashew Monoculture, Secondary Forest/Cashew, and Farming/Grazing Land -** Only one of three soil samples at the Saliquenhe area contained elevated concentration of tin above the CEQG agricultural guideline.
- **Truck Load-Out Area -** Three soil samples were collected from this area, believed to be rice paddy in fallow, and/or grazing area. No exceedances of any soil quality criteria were noted.

4 – DISCUSSION

The Port Site area samples showed parameter concentrations above several CEQG criteria as noted earlier. Most of the metals exceedances were detected in the beach and rice paddy sample areas. Concentrations of vanadium (V) and tin (Sn) above the CEQG criteria were only observed in the beach area. These metals originate from the ferricrete that outcrops along the coast in this area, as vanadium and other trace metals can be found at high concentrations in ferricrete (Konka et al., 2013).

The electrical conductivity measured in the rice paddy samples were also above CEQG criteria, likely due to increased salinity from seasonal flooding and potentially due to the close proximity of the River Geba.

The Mine site area samples showed metals concentrations mostly below the CEQG criteria, with the exception of Ponta Zeca rice paddy samples and one Saliquenhe crop area sample as noted earlier.

5 – REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR), 2015. Retrieved from: http://www.atsdr.cdc.gov/.

ALS Environmental, 2015. *Recommended Holding Times and Preservations for Soil and Air*. Version 2, July 2013.

Canadian Council of Ministers of the Environment (CCME), 2015. *Canadian Environmental Quality Guidelines (CEQG) Soil Quality Guidelines for the Protection of Environmental and Human Health*.

Golder Associates (UK) Ltd., 2014a. *Mine Component Environmental and Social Baseline Studies*. Report No. 13514950201.550.17/B.0, including Appendices/Drawings.

Konka, Bheemalingeswara, Solomon Gebreselassie and Ebrahim Nesro Hussen, 2013. Petrography and Geochemistry of Ferricrete Near Shire, Northern Ethiopia. *Momona Ethiopian Journal of Science*, Vol. 5(1): 32-50. Copyright Mekelle University. ISSN: 2220-184X.

6 – CLOSURE

Please do not hesitate to contact the undersigned with any questions.

Prepared: _____
Richard Cook, P.Geo.(Ltd.) - Senior Environmental Scientist | Associate

Reviewed: _____
Steven R. Aiken, P.Eng. - Manager, Environmental Services

Approval that this document adheres to Knight Piésold Quality Systems:

Attachments:

Appendix A	Soil Sample Location and Test Pit Photos
Appendix B	Chemical Analysis Results
Appendix C	Laboratory Reports

/dkk

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APPENDIX A

SOIL SAMPLE LOCATION AND TEST PIT PHOTOS

(Pages A-1 to A-4)

Photo 1 – Port Site rice paddy

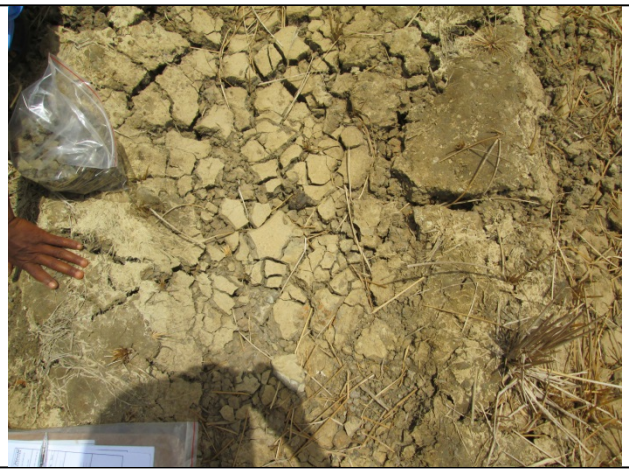

Photo 2 – Port Site rice paddy

Photo 3 – Port Site savannah

Photo 4 – Port Site savannah

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Photo 5 – Fishing beach area (test pit 1)

Photo 6 – Fishing beach area (test pit 1)

Photo 7 – Fishing beach area (test pit 2)

Photo 8 – Fishing beach area (test pit 2)

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Photo 9 – Fishing beach area - exposed ferricrete on the coast

Photo 10 – Fishing beach area - beach gravel test pit

Photo 11 – Port site residential area (test pit 1)

Photo 12 – Port site residential area (test pit 1)

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Photo 13 – Mine site – rice paddy at Canico

Photo 14 – Mine site – rice paddy at Ponta Zeca

Photo 15 – Mine site – Farim rice paddy

Photo 16 – Mine site – Nema residential area

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APPENDIX B

CHEMICAL ANALYSIS RESULTS

Table B.1 Chemical Analysis Results - Port Site Soil Samples
Table B.2 Chemical Analysis Results - Mine Site Soil Samples

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TABLE B.1

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SUPPLEMENTAL TERRESTRIAL SOIL BASELINE REPORT
CHEMICAL ANALYSIS RESULTS - PORT SITE SOIL SAMPLES

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Parameter	CEQG Soil Quality Guidelines for the Protection of Environmental and Human Health				MDL	SUMMARY STATISTICS			Port Site Area Soil Samples														
									Residential Samples (Ancone)			Rice Paddy				Upland Area				Fishing Beach			
	Agricultural	Residential/Parkland	Commercial	Industrial		MIN	MAX	MEAN	PortRes1	PortRes2	PortRes3	PortRice1	PortRice2	PortRice3	PortRice4	PortSav1	PortSav2	PortSav3	PortSav4	Beach1	Beach2	Beach3	Beach4
									15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015
Aluminium	-	-	-	-	1	4900	83100	37173	4900	7610	9490	36800	39300	43000	37400	67000	65800	79100	83100	33400	18000	22900	9800
Antimony	20	20	40	40	0.5	0.50	0.51	0.50	0.50	0.50	0.51	0.50	0.50	0.50	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51
Arsenic	12	12	12	12	0.5	0.50	44.80	13.80	0.50	2.24	2.94	***15.90***	***21.60***	***12.30***	***12.30***	3.98	2.73	8.13	8.20	***24.60***	***38.80***	***44.80***	8.00
Barium	750	500	2000	2000	0.2	10.50	113.00	44.69	10.50	17.20	24.20	25.10	27.40	29.20	26.10	95.70	102.00	113.00	107.00	31.80	18.70	19.90	22.60
Beryllium	4	4	8	8	0.01	0.097	3.980	1.386	0.097	0.207	0.159	1.210	1.360	1.350	1.370	1.790	2.240	3.690	3.980	1.100	1.000	1.010	0.224
Bismuth	-	-	-	-	1	1.0	6.0	1.6	1.0	1.0	1.0	1.0	3.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.4	6.0	1.0
Boron	2	-	-	-	1	1.0	26.0	12.1	1.0	2.7	1.7	20.2	23.3	26.0	25.2	3.4	3.9	6.4	6.9	25.9	12.6	19.9	2.2
Cadmium	1.4	10	22	22	0.4	0.40	5.96	2.20	0.40	0.45	0.77	**1.97**	**2.67**	**2.20**	**1.87**	1.36	0.98	**1.72**	**2.04**	**3.79**	**5.58**	**5.96**	1.18
Calcium	-	-	-	-	50	118	2580	848	666	1610	2580	633	1250	580	1170	348	301	259	118	615	1350	912	334
Chromium	-	-	-	-	0.5	20.90	302.00	114.11	20.90	29.80	29.00	108.00	117.00	121.00	109.00	94.00	93.90	95.40	90.20	191.00	236.00	302.00	74.40
Cobalt	40	50	300	300	0.2	2.57	12.80	8.21	2.81	2.57	3.29	9.04	10.90	11.00	10.80	12.80	10.80	11.30	12.70	6.90	8.89	6.72	2.57
Copper	63	63	91	91	1	2.9	11.6	8.5	3.2	5.7	7.0	11.6	9.0	9.0	8.9	11.2	11.6	9.1	8.3	9.1	10.8	10.7	2.9
Iron	-	-	-	-	10	6170	187000	60058	6170	11600	14700	58200	65700	53400	50400	38200	27500	49400	51800	96700	161000	187000	29100
Lead	70	140	260	600	1	3.9	46.2	23.9	3.9	18.5	8.6	24.8	26.0	23.3	26.6	26.7	19.0	13.4	13.1	36.9	36.3	35.1	46.2
Lithium	-	-	-	-	1	1.0	46.5	14.6	1.0	1.0	1.0	3.3	11.4	16.7	11.1	34.5	46.5	45.1	42.8	1.0	1.0	1.0	1.0
Magnesium	-	-	-	-	5	258	6670	2240	258	676	647	4530	5120	5100	6670	988	974	741	624	2450	1970	2100	756
Manganese	-	-	-	-	0.5	25	322	112	130	170	322	66	106	114	90	44	59	32	25	70	293	103	48
Mercury	6.6	6.6	24	50	0.2	0.20	0.29	0.21	0.20	0.20	0.20	0.29	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Molybdenum	5	10	40	40	0.4	0.88	6.44	3.56	0.88	4.14	2.58	4.45	**6.29**	3.37	**6.34**	2.52	1.82	2.08	1.67	4.51	4.40	**6.44**	1.98
Nickel	50	50	50	50	1	2.3	33.9	16.2	4.3	3.5	3.5	13.6	19.5	19.3	18.2	28.8	28.1	33.9	32.7	11.3	10.4	13.2	2.3
Phosphorus	-	-	-	-	5	656.00	860.00	749.75				725.00	820.00	673.00	656.00	744.00	860.00	830.00	690.00				
Potassium	-	-	-	-	5	357	4830	2023	357	858	806	4340	4460	4810	4830	825	986	1020	1150	2660	978	1800	467
Selenium	1	1	2.9	2.9	2	2	2	2	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***
Silicon	-	-	-	-	50	150	238	202	238	231	231	190	198	217	207	206	194	183	150	204	187	172	228
Silver	20	20	40	40	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium	-	-	-	-	15	101	17900	3250	168	209	101	4700	6300	6770	17900	426	257	405	364	5800	888	4260	203
Strontium	-	-	-	-	0.1	9.81	80.50	47.61	9.81	27.30	29.10	80.50	72.50	74.20	75.60	33.00	35.40	49.60	44.70	62.50	45.70	48.40	25.90
Thallium	1	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tin	5	50	300	300	1	1.0	7.6	3.8	1.9	4.6	3.0	1.2	2.6	4.3	4.5	3.8	3.7	4.9	5.0	**7.6**	5.0	1.0	4.2
Titanium	-	-	-	-	0.2	95	297	178	148	154	167	144	205	223	215	109	95	165	135	192	297	243	174
Uranium	23	23	33	300	0.1	0.456	18.500	5.082	0.456	0.671	0.750	3.030	2.890	2.420	2.570	6.160	10.900	14.900	18.500	3.240	4.080	4.310	1.350
Vanadium	130	130	130	130	0.1	15.10	352.00	93.01	15.10	20.80	23.50	54.50	66.10	56.70	54.20	54.80	51.90	59.30	59.00	***167.00***	***286.00***	***352.00***	74.20
Zinc	200	200	360	360	3	8.8	153.0	38.5	33.6	66.9	153.0	30.4	36.6	37.5	36.7	26.6	27.1	19.8	19.0	20.0	32.8	28.2	8.8
Dry matter @ 105°C (%)	-	-	-	-	0.1	81.4	99.0	91.4	99.0	97.7	97.6	93.3	93.9	85.6	90.3	88.5	84.6	86.2	85.4	81.4	97.5	94.5	96.0
Total Nitrogen as N	-	-	-	-	50	824	5260	2956	-	-	-	1140	952	824	1310	4820	5260	5020	4320	-	-	-	-
Active pH (pH units)	6 to 8	6 to 8	6 to 8	6 to 8	1	5.1	5.9	5.6	-	-	-	***5.6***	***5.9***	***5.7***	***5.1***	***5.5***	***5.1***	***5.9***	***5.6***	-	-	-	-
Electrical Conductivity @ 25°C (mS/m)	200	200	400	400	1	4	1480	362	-	-	-	***575***	***497***	***304***	***1480***	17	10.6	4.1	4.7	-	-	-	-
Laboratory compacted bulk density (g/L)	-	-	-	-	100	550	1130	843	-	-	-	1130	1110	1060	1110	610	590	550	580	-	-	-	-

\\NB4\Project$\3\01\00520\02\A\Correspondence\NB15-00186 - Soil Sampling Report\[Appendix B tables.xlsx]Table B1 - Port

NOTES:
1. CEQG - CANADIAN ENVIRONMENTAL QUALITY GUIDELINES.
2. MDL - METHOD DETECTION LIMIT PROVIDED BY ALS CZECH REPUBLIC, S.R.O.
3. ALL VALUES EXPRESSED AS MG/KG DRY WEIGHT UNLESS OTHERWISE NOTED.
4. RED FONT IDENTIFY RESULTS REPORTED BELOW THE LABORATORY METHOD DETECTION LIMIT.
5. BOLD, SHADED CELLS IDENTIFY VALUES GREATER THAN THE CEQG AGRICULTURAL GUIDELINE CONCENTRATION.
6. ITALICIZED, SHADED CELLS IDENTIFY VALUES GREATER THAN THE CEQG RESIDENTIAL/PARKLAND GUIDELINE CONCENTRATION.
7. UNDERLINED, SHADED CELLS IDENTIFY VALUES GREATER THAN THE CEQG COMMERCIAL AND/OR INDUSTRIAL GUIDELINE CONCENTRATION.
8. THE SELENIUM MDL (2 MG/KG DW) WAS ABOVE THE CEQG AGRICULTURAL AND RESIDENTIAL/PARKLAND GUIDELINE CONCENTRATION (1 MG/KG DW).

0	13JUL'15	ISSUED WITH MEMO NB15-00186	DKK	RAC
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE B.2

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTAL TERRESTRIAL SOIL BASELINE REPORT
CHEMICAL ANALYSIS RESULTS - MINE SITE SOIL SAMPLES

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Parameter	CEQG Soil Quality Guidelines for the Protection of Environmental and Human Health				MDL	MIN	MAX	MEAN	Residential												Rice Paddy								
									Canico			Nema			Ponta Zeca			Saliquenhe			Canico			Farim			Ponta Zeca		
									CanicoRes1	CanicoRes2	CanicoRes3	NemaRes1	NemaRes2	NemaRes3	P.ZecaRes1	P.ZecaRes2	P.ZecaRes3	S.HEDIMRes1	S.HEDIMRes2	S.HEDIMRes3	CanicoRice1	CanicoRice2	CanicoRice3	FarimAgric1	FarimAgric2	FarimAgric3	P.ZecaRice1	P.ZecaRice2	P.ZecaRice3
	Agricultural	Residential/Parkland	Commercial	Industrial					15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015
Aluminium	-	-	-	-	1	2070	34100	9175	3230	3580	2070	5700	3240	3010	3480	2150	2530	6420	4220	5720	3500	2490	2230	9950	9500	8010	21100	32400	32900
Antimony	20	20	40	40	0.5	0.50	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.50	0.50	0.50	0.50
Arsenic	12	12	12	12	0.5	0.50	7.13	1.30	0.50	0.50	0.50	0.50	0.67	0.50	1.21	0.50	0.97	1.28	1.09	0.84	0.63	0.50	0.50	2.74	1.62	2.02	2.78	5.36	7.13
Barium	750	500	2000	2000	0.2	4.21	73.00	22.60	8.49	7.42	7.08	6.95	4.21	4.72	12.30	5.23	8.08	11.10	7.84	10.60	18.30	10.80	7.14	55.40	36.80	33.70	49.10	43.60	48.00
Beryllium	4	4	8	8	0.01	0.044	6.130	0.824	0.062	0.052	0.044	0.087	0.050	0.060	0.136	0.055	0.064	0.098	0.047	0.082	0.312	0.187	0.103	0.644	0.724	0.517	***4.140***	***5.700***	***6.130***
Bismuth	-	-	-	-	1	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Boron	2	-	-	-	1	1.0	2.7	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.0	1.0	2.0	2.7	2.1
Cadmium	1.4	10	22	22	0.4	0.40	0.77	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Calcium	-	-	-	-	50	90	3830	752	622	541	476	291	90	258	286	223	317	551	910	698	1220	374	208	3830	2080	2010	1470	1240	1500
Chromium	-	-	-	-	0.5	8.15	46.00	20.37	9.55	9.99	8.45	12.20	15.20	10.30	12.60	9.43	10.30	17.00	14.70	16.10	12.50	8.97	8.15	34.30	35.20	30.10	35.30	38.00	37.80
Cobalt	40	50	300	300	0.2	0.20	6.70	1.70	1.04	0.81	0.77	1.05	0.92	0.78	0.78	0.20	0.70	1.61	1.79	2.34	1.23	0.87	0.69	2.52	1.98	1.55	3.82	5.80	6.70
Copper	63	63	91	91	1	1.5	16.5	5.3	2.7	5.0	2.1	2.5	1.5	1.9	3.0	1.9	1.9	2.5	2.8	2.1	6.2	2.4	1.5	13.8	10.5	11.7	13.9	15.2	16.5
Iron	-	-	-	-	10	2180	34000	8083	2920	2590	2180	4180	3020	2640	3060	2340	2460	5960	4720	5500	3240	2440	2520	17200	15000	13100	15500	27800	34000
Lead	70	140	260	600	1	3.0	29.6	8.2	3.9	3.6	3.0	4.5	4.0	4.2	6.2	5.4	5.2	4.7	4.4	4.6	5.4	4.1	3.4	29.6	20.1	25.8	15.6	16.2	16.0
Lithium	-	-	-	-	1	1.0	44.1	7.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	7.4	6.8	4.9	26.7	43.9	44.1
Magnesium	-	-	-	-	5	70	2000	538	210	203	150	146	70	118	193	132	173	283	330	302	329	187	134	1640	640	520	1510	1680	1800
Manganese	-	-	-	-	0.5	11	325	104	131	83	93	67	78	55	76	44	56	194	146	214	149	85	73	52	37	31	24	28	35
Mercury	6.6	6.6	24	50	0.2	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Molybdenum	5	10	40	40	0.4	0.40	1.29	0.58	0.40	0.40	0.40	0.40	0.40	0.40	0.52	0.40	0.57	1.12	0.40	0.83	0.40	0.40	0.40	0.40	0.48	0.40	0.93	1.08	1.00
Nickel	50	50	50	50	1	1.0	14.9	3.3	1.5	1.4	1.0	2.1	1.3	1.3	1.0	1.0	1.0	2.4	1.8	1.7	2.5	1.3	1.0	4.4	3.8	3.1	10.9	14.5	14.9
Potassium	-	-	-	-	5	60	2320	416	405	266	182	148	60	213	128	286	208	164	157	153	169	87	80	1230	562	458	1000	1230	1250
Selenium	1	1	2.9	2.9	2	2	2	2	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***
Silicon	-	-	-	-	50	130	278	219	239	239	257	228	278	245	243	266	239	248	254	236	216	220	253	172	195	180	186	156	130
Silver	20	20	40	40	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium	-	-	-	-	15	15	8360	1133	39	26	28	49	15	65	34	161	18	15	15	15	35	17	15	4030	1450	930	3090	2820	3270
Strontium	-	-	-	-	0.1	1.68	174.00	19.20	5.88	5.66	5.30	3.46	1.68	2.55	3.26	2.03	2.91	5.27	6.12	5.81	8.42	4.86	3.08	35.20	19.40	18.30	38.10	37.00	38.30
Thallium	1	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tin	5	50	300	300	1	1.0	6.9	1.6	1.0	1.0	1.0	1.0	1.0	1.0	2.4	1.0	1.1	2.8	2.5	3.0	1.0	1.0	1.0	2.6	1.0	1.0	1.0	1.0	1.2
Titanium	-	-	-	-	0.2	28	242	126	114	112	104	108	152	110	110	86	104	192	209	208	65	61	81	74	99	90	67	50	28
Uranium	23	23	33	300	0.1	0.189	6.170	1.293	0.279	0.299	0.189	0.345	0.203	0.240	0.398	0.205	0.237	0.355	0.270	0.342	0.589	0.493	0.251	2.340	2.120	1.400	4.400	4.000	3.710
Vanadium	130	130	130	130	0.1	6.60	50.40	21.00	9.19	8.84	6.60	13.40	10.80	9.17	9.80	6.86	7.04	17.00	13.10	15.80	12.70	11.10	8.64	42.30	39.60	35.90	47.60	48.70	50.40
Zinc	200	200	360	360	3	3.0	39.2	10.4	29.3	13.9	21.8	10.4	18.9	10.8	3.0	10.7	6.5	24.1	3.9	3.8	8.2	3.9	3.0	36.6	22.8	39.2	9.0	13.9	15.1
Dry matter @ 105°C (%)	-	-	-	-	0.1	91.9	99.9	97.9	98.8	99.3	99.5	99.3	99.9	99.5	99.4	99.5	99.6	98.7	99.4	99.2	99.0	99.2	99.5	93.5	97.6	97.1	96.2	94.7	94.2

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TABLE B.2

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTAL TERRESTRIAL SOIL BASELINE REPORT
CHEMICAL ANALYSIS RESULTS - MINE SITE SOIL SAMPLES

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Parameter	CEQG Soil Quality Guidelines for the Protection of Environmental and Human Health				MDL	MIN	MAX	MEAN	Upland Row Agriculture												Truck Loadout Area Soil Samples		
									Canico			Ponta Zeca			Tambato			Saliquenhe					
									CanicoCrops1	CanicoCrops2	CanicoCrops3	P.ZecaCrop1	P.ZecaCrop2	P.ZecaCrop3	S.TambatoAgric1	S.TambatoAgric2	S.TambatoAgric3	S.HEDIMCrop1	S.HEDIMCrop2	S.HEDIMCrop3	TruckLoadArea1	TruckLoadArea2	TruckLoadArea3
	Agricultural	Residential/Parkland	Commercial	Industrial					15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015	15/05/2015
Aluminium	-	-	-	-	1	2070	34100	9175	3690	4380	4760	5420	10600	13800	8700	6130	6840	5590	7420	6740	34100	20100	24600
Antimony	20	20	40	40	0.5	0.50	0.51	0.50	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.50	0.50	0.51	0.50	0.51
Arsenic	12	12	12	12	0.5	0.50	7.13	1.30	0.51	0.50	0.50	0.78	0.50	1.02	3.26	0.71	0.80	1.09	0.50	0.70	0.85	0.99	1.92
Barium	750	500	2000	2000	0.2	4.21	73.00	22.60	7.41	6.10	10.60	17.80	38.30	59.90	19.40	16.50	17.40	8.54	10.10	11.00	62.80	58.00	73.00
Beryllium	4	4	8	8	0.01	0.044	6.130	0.824	0.050	0.066	0.082	1.110	1.490	1.830	0.162	0.110	0.111	0.078	0.130	0.123	1.410	2.310	1.320
Bismuth	-	-	-	-	1	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Boron	2	-	-	-	1	1.0	2.7	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.0	1.0
Cadmium	1.4	10	22	22	0.4	0.40	0.77	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.77	0.40	0.40	0.40	0.41	0.40	0.40	0.40	0.40
Calcium	-	-	-	-	50	90	3830	752	399	146	421	222	439	528	884	826	815	260	261	327	790	963	605
Chromium	-	-	-	-	0.5	8.15	46.00	20.37	11.20	10.70	10.20	15.70	32.00	34.20	23.80	14.40	19.10	14.00	14.90	14.40	45.20	41.40	46.00
Cobalt	40	50	300	300	0.2	0.20	6.70	1.70	1.39	1.55	2.22	1.00	0.71	2.26	1.82	2.36	1.76	1.41	0.92	0.83	1.60	1.95	1.50
Copper	63	63	91	91	1	1.5	16.5	5.3	2.3	2.1	2.8	3.5	6.2	8.0	4.0	3.0	3.4	2.1	2.4	2.3	7.9	8.5	10.0
Iron	-	-	-	-	10	2180	34000	8083	3730	3540	4010	7950	10800	13300	17000	4950	7040	4170	4790	4650	11300	12600	8780
Lead	70	140	260	600	1	3.0	29.6	8.2	3.2	3.3	3.7	6.4	9.9	13.5	6.5	6.8	5.7	3.8	4.0	5.5	9.4	10.2	13.4
Lithium	-	-	-	-	1	1.0	44.1	7.6	1.0	1.0	1.0	3.2	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	36.0	33.9	40.0
Magnesium	-	-	-	-	5	70	2000	538	200	163	279	205	287	363	398	347	431	193	233	226	1580	2000	1720
Manganese	-	-	-	-	0.5	11	325	104	104	128	208	11	19	29	325	302	312	137	164	186	18	35	21
Mercury	6.6	6.6	24	50	0.2	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Molybdenum	5	10	40	40	0.4	0.40	1.29	0.58	0.40	0.40	0.40	0.40	0.40	1.29	0.84	0.49	0.40	0.61	0.80	0.92	0.46	0.72	0.52
Nickel	50	50	50	50	1	1.0	14.9	3.3	1.7	2.0	2.3	2.0	4.1	5.8	2.7	3.6	2.3	1.8	2.3	1.7	4.0	5.7	4.6
Potassium	-	-	-	-	5	60	2320	416	85	94	105	73	197	199	245	202	232	115	205	166	2320	845	1440
Selenium	1	1	2.9	2.9	2	2	2	2	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***	***2***
Silicon	-	-	-	-	50	130	278	219	224	244	214	195	207	193	217	230	227	271	208	235	181	179	194
Silver	20	20	40	40	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium	-	-	-	-	15	15	8360	1133	15	15	15	596	1300	644	30	15	15	15	15	15	8360	5750	7840
Strontium	-	-	-	-	0.1	1.68	174.00	19.20	4.24	2.62	5.16	4.44	7.88	8.78	8.69	7.60	7.21	3.95	4.52	4.81	174.00	108.00	86.80
Thallium	1	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tin	5	50	300	300	1	1.0	6.9	1.6	1.0	1.0	1.0	1.0	1.3	3.1	2.4	1.0	1.0	3.2	**6.9**	2.4	1.0	1.0	1.0
Titanium	-	-	-	-	0.2	28	242	126	166	184	200	89	101	92	211	206	219	242	203	217	56	57	77
Uranium	23	23	33	300	0.1	0.189	6.170	1.293	0.249	0.265	0.395	1.050	1.790	2.100	0.574	0.332	0.438	0.240	0.471	0.399	5.500	3.920	6.170
Vanadium	130	130	130	130	0.1	6.60	50.40	21.00	11.80	11.40	12.10	20.00	30.80	32.30	33.20	14.50	19.40	13.00	14.50	14.40	37.80	32.40	34.00
Zinc	200	200	360	360	3	3.0	39.2	10.4	3.0	3.0	3.2	3.0	3.0	4.6	6.7	4.9	5.2	3.0	3.6	3.6	5.0	7.9	5.3
Dry matter @ 105°C (%)	-	-	-	-	0.1	91.9	99.9	97.9	99.2	99.5	99.3	98.2	96.0	97.5	97.3	99.0	98.6	99.5	99.3	99.4	92.5	94.8	91.9

\\NB4\Project$\3\01\00520\02\A\Correspondence\NB15-00186 - Soil Sampling Report\[Appendix B tables.xlsx]Table B2 - Mine

NOTES:

1. CEQG - CANADIAN ENVIRONMENTAL QUALITY GUIDELINES (CCME, 2015).
2. MDL - METHOD DETECTION LIMIT PROVIDED BY ALS LABS.
3. ALL VALUES EXPRESSED AS MG/KG DRY WEIGHT UNLESS OTHERWISE NOTED.
4. RED FONT IDENTIFY RESULTS REPORTED BELOW THE LABORATORY METHOD DETECTION LIMIT.
5. BOLD, SHADED CELLS IDENTIFY VALUES GREATER THAN THE CEQG AGRICULTURAL GUIDELINE CONCENTRATION.
6. ITALICIZED, SHADED CELLS IDENTIFY VALUES GREATER THAN THE CEQG RESIDENTIAL/PARKLAND GUIDELINE CONCENTRATION.
7. UNDERLINED, SHADED CELLS IDENTIFY VALUES GREATER THAN THE CEQG COMMERCIAL AND/OR INDUSTRIAL GUIDELINE CONCENTRATION.
8. THE SELENIUM MDL (2 MG/KG) WAS ABOVE THE CEQG AGRICULTURAL AND RESIDENTIAL/PARKLAND GUIDELINE CONCENTRATION (1 MG/KG).

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	13JUL'15	ISSUED WITH MEMO NB15-00186	DKK	RAC

Knight Piésold
CONSULTING

APPENDIX C

LABORATORY REPORTS

(Pages C-1 to C-16)

CERTIFICATE OF ANALYSIS

Work Order	: **PR1537599**	Issue Date	: 24-JUN-2015
Client	: **Knight Piesold Ltd.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Mr. Richard Cook	Contact	: Client Service
Address	: 1650 Main Street West North Bay Ontario Canada P1B 8G5	Address	: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00
E-mail	: rcook@knightpiesold.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Facsimile	: ----	Facsimile	: +420 284 081 635
Project	: FARIM PROJECT NB301-520 02	Page	: 1 of 16
Order number	: NB-728	Date Samples Received	: 15-JUN-2015
C-O-C number	: ----	Quote number	: PR2015KNIPI-CA0004 (PT-300-15-0473)
Site	: ----	Date of test	: 17-JUN-2015 - 24-JUN-2015
Sampled by	: client S.Tarlton	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples.

Responsible for accuracy

Signatories	*Position*
Zdenek Jirak	Environmental Business Unit Manager

Testing Laboratory Accredited by CAI

ZKUŠEBNÍ LABORATOR AKREDITOVANÁ ČIA ALS Czech Republic s.r.o. č. 1163

ilac-MRA

L 1163

Analytical Results

Sub-Matrix: SOIL			Client sample ID	CanicoRes1		CanicoRes2		CanicoRes3	
			Laboratory sample ID	PR1537599001		PR1537599002		PR1537599003	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	98.8	±6.0 %	99.3	±6.0 %	99.5	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	3230	±20.0 %	3580	±20.0 %	2070	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Barium	S-METAXHB1	0.20	mg/kg DW	8.49	±20.0 %	7.42	±20.0 %	7.08	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.062	±20.0 %	0.052	±20.0 %	0.044	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	622	±20.0 %	541	±20.0 %	476	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	9.55	±20.0 %	9.99	±20.0 %	8.45	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.04	±20.0 %	0.81	±20.0 %	0.77	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	2.7	±20.0 %	5.0	±20.0 %	2.1	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	2920	±20.0 %	2590	±20.0 %	2180	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	3.9	±20.0 %	3.6	±20.0 %	3.0	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	210	±20.0 %	203	±20.0 %	150	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	131	±20.0 %	82.5	±20.0 %	92.5	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Nickel	S-METAXHB1	1.0	mg/kg DW	1.5	±20.0 %	1.4	±20.0 %	<1.0	----
Potassium	S-METAXHB2	5.0	mg/kg DW	405	±20.0 %	266	±20.0 %	182	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	239	±20.0 %	239	±20.0 %	257	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	39	±20.0 %	26	±20.0 %	28	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	5.88	±20.0 %	5.66	±20.0 %	5.30	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	114	±20.0 %	112	±20.0 %	104	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.279	±20.0 %	0.299	±20.0 %	0.189	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	9.19	±20.0 %	8.84	±20.0 %	6.60	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	29.3	±20.0 %	13.9	±20.0 %	21.8	±20.0 %

Sub-Matrix: SOIL			Client sample ID	CanicoRice1		CanicoRice2		CanicoRice3	
			Laboratory sample ID	PR1537599004		PR1537599005		PR1537599006	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.0	±6.0 %	99.2	±6.0 %	99.5	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	3500	±20.0 %	2490	±20.0 %	2230	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	0.63	±20.0 %	<0.50	----	<0.50	----
Barium	S-METAXHB1	0.20	mg/kg DW	18.3	±20.0 %	10.8	±20.0 %	7.14	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.312	±20.0 %	0.187	±20.0 %	0.103	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----

Sub-Matrix: SOIL			Client sample ID	CanicoRice1		CanicoRice2		CanicoRice3	
			Laboratory sample ID	PR1537599004		PR1537599005		PR1537599006	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	1220	±20.0 %	374	±20.0 %	208	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	12.5	±20.0 %	8.97	±20.0 %	8.15	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.23	±20.0 %	0.87	±20.0 %	0.69	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	6.2	±20.0 %	2.4	±20.0 %	1.5	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	3240	±20.0 %	2440	±20.0 %	2520	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	5.4	±20.0 %	4.1	±20.0 %	3.4	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	1.2	±20.0 %	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	329	±20.0 %	187	±20.0 %	134	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	149	±20.0 %	85.3	±20.0 %	73.1	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Nickel	S-METAXHB1	1.0	mg/kg DW	2.5	±20.0 %	1.3	±20.0 %	1.0	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	169	±20.0 %	86.8	±20.0 %	80.2	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	216	±20.0 %	220	±20.0 %	253	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	35	±20.0 %	17	±20.0 %	<15	----
Strontium	S-METAXHB1	0.10	mg/kg DW	8.42	±20.0 %	4.86	±20.0 %	3.08	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	65.4	±20.0 %	60.8	±20.0 %	81.1	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.589	±20.0 %	0.493	±20.0 %	0.251	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	12.7	±20.0 %	11.1	±20.0 %	8.64	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	8.2	±20.0 %	3.9	±20.0 %	<3.0	----

Sub-Matrix: SOIL			Client sample ID	CanicoCrops1		CanicoCrops2		CanicoCrops3	
			Laboratory sample ID	PR1537599007		PR1537599008		PR1537599009	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.2	±6.0 %	99.5	±6.0 %	99.3	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	3690	±20.0 %	4380	±20.0 %	4760	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.51	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	<0.51	----	<0.50	----	<0.50	----
Barium	S-METAXHB1	0.20	mg/kg DW	7.41	±20.0 %	6.10	±20.0 %	10.6	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.050	±20.0 %	0.066	±20.0 %	0.082	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	399	±20.0 %	146	±20.0 %	421	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	11.2	±20.0 %	10.7	±20.0 %	10.2	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.39	±20.0 %	1.55	±20.0 %	2.22	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	2.3	±20.0 %	2.1	±20.0 %	2.8	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	3730	±20.0 %	3540	±20.0 %	4010	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	3.2	±20.0 %	3.3	±20.0 %	3.7	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	200	±20.0 %	163	±20.0 %	279	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	104	±20.0 %	128	±20.0 %	208	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----

Sub-Matrix: SOIL			Client sample ID	CanicoCrops1		CanicoCrops2		CanicoCrops3	
			Laboratory sample ID	PR1537599007		PR1537599008		PR1537599009	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Molybdenum	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Nickel	S-METAXHB1	1.0	mg/kg DW	1.7	±20.0 %	2.0	±20.0 %	2.3	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	85.2	±20.0 %	94.3	±20.0 %	105	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	224	±20.0 %	244	±20.0 %	214	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	<15	----	<15	----	<15	----
Strontium	S-METAXHB1	0.10	mg/kg DW	4.24	±20.0 %	2.62	±20.0 %	5.16	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	166	±20.0 %	184	±20.0 %	200	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.249	±20.0 %	0.265	±20.0 %	0.395	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	11.8	±20.0 %	11.4	±20.0 %	12.1	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	<3.0	----	<3.0	----	3.2	±20.0 %

Sub-Matrix: SOIL			Client sample ID	NemaRes1		NemaRes2		NemaRes3	
			Laboratory sample ID	PR1537599010		PR1537599011		PR1537599012	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.3	±6.0 %	99.9	±6.0 %	99.5	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	5700	±20.0 %	3240	±20.0 %	3010	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	<0.50	----	0.67	±20.0 %	<0.50	----
Barium	S-METAXHB1	0.20	mg/kg DW	6.95	±20.0 %	4.21	±20.0 %	4.72	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.087	±20.0 %	0.050	±20.0 %	0.060	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	291	±20.0 %	90	±20.0 %	258	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	12.2	±20.0 %	15.2	±20.0 %	10.3	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.05	±20.0 %	0.92	±20.0 %	0.78	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	2.5	±20.0 %	1.5	±20.0 %	1.9	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	4180	±20.0 %	3020	±20.0 %	2640	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	4.5	±20.0 %	4.0	±20.0 %	4.2	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	146	±20.0 %	70.2	±20.0 %	118	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	66.5	±20.0 %	78.2	±20.0 %	54.5	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Nickel	S-METAXHB1	1.0	mg/kg DW	2.1	±20.0 %	1.3	±20.0 %	1.3	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	148	±20.0 %	60.2	±20.0 %	213	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	228	±20.0 %	278	±20.0 %	245	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	49	±20.0 %	<15	----	65	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	3.46	±20.0 %	1.68	±20.0 %	2.55	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	108	±20.0 %	152	±20.0 %	110	±20.0 %

Sub-Matrix: SOIL			Client sample ID	NemaRes1		NemaRes2		NemaRes3	
			Laboratory sample ID	PR1537599010		PR1537599011		PR1537599012	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Uranium	S-METMSHB3	0.100	mg/kg DW	0.345	±20.0 %	0.203	±20.0 %	0.240	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	13.4	±20.0 %	10.8	±20.0 %	9.17	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	10.4	±20.0 %	18.9	±20.0 %	10.8	±20.0 %

Sub-Matrix: SOIL			Client sample ID	TruckLoadArea1		TruckLoadArea2		TruckLoadArea3	
			Laboratory sample ID	PR1537599013		PR1537599014		PR1537599015	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	92.5	±6.0 %	94.8	±6.0 %	91.9	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	34100	±20.0 %	20100	±20.0 %	24600	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.51	----	<0.50	----	<0.51	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	0.85	±20.0 %	0.99	±20.0 %	1.92	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	62.8	±20.0 %	58.0	±20.0 %	73.0	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	1.41	±20.0 %	2.31	±20.0 %	1.32	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	1.8	±20.0 %	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	790	±20.0 %	963	±20.0 %	605	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	45.2	±20.0 %	41.4	±20.0 %	46.0	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.60	±20.0 %	1.95	±20.0 %	1.50	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	7.9	±20.0 %	8.5	±20.0 %	10.0	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	11300	±20.0 %	12600	±20.0 %	8780	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	9.4	±20.0 %	10.2	±20.0 %	13.4	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	36.0	±20.0 %	33.9	±20.0 %	40.0	±20.0 %
Magnesium	S-METAXHB2	5.0	mg/kg DW	1580	±20.0 %	2000	±20.0 %	1720	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	18.0	±20.0 %	35.2	±20.0 %	20.5	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	0.46	±20.0 %	0.72	±20.0 %	0.52	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	4.0	±20.0 %	5.7	±20.0 %	4.6	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	2320	±20.0 %	845	±20.0 %	1440	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	181	±20.0 %	179	±20.0 %	194	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	8360	±20.0 %	5750	±20.0 %	7840	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	174	±20.0 %	108	±20.0 %	86.8	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	56.2	±20.0 %	56.7	±20.0 %	76.9	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	5.50	±20.0 %	3.92	±20.0 %	6.17	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	37.8	±20.0 %	32.4	±20.0 %	34.0	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	5.0	±20.0 %	7.9	±20.0 %	5.3	±20.0 %

Sub-Matrix: SOIL			Client sample ID	FarimAgric1		FarimAgric2		FarimAgric3	
			Laboratory sample ID	PR1537599016		PR1537599017		PR1537599018	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	93.5	±6.0 %	97.6	±6.0 %	97.1	±6.0 %

Sub-Matrix: SOIL			Client sample ID	FarimAgric1		FarimAgric2		FarimAgric3	
			Laboratory sample ID	PR1537599016		PR1537599017		PR1537599018	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	9950	±20.0 %	9500	±20.0 %	8010	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.51	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	2.74	±20.0 %	1.62	±20.0 %	2.02	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	55.4	±20.0 %	36.8	±20.0 %	33.7	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.644	±20.0 %	0.724	±20.0 %	0.517	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	1.4	±20.0 %	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	3830	±20.0 %	2080	±20.0 %	2010	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	34.3	±20.0 %	35.2	±20.0 %	30.1	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	2.52	±20.0 %	1.98	±20.0 %	1.55	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	13.8	±20.0 %	10.5	±20.0 %	11.7	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	17200	±20.0 %	15000	±20.0 %	13100	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	29.6	±20.0 %	20.1	±20.0 %	25.8	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	7.4	±20.0 %	6.8	±20.0 %	4.9	±20.0 %
Magnesium	S-METAXHB2	5.0	mg/kg DW	1640	±20.0 %	640	±20.0 %	520	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	51.8	±20.0 %	37.1	±20.0 %	31.1	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	<0.40	----	0.48	±20.0 %	<0.40	----
Nickel	S-METAXHB1	1.0	mg/kg DW	4.4	±20.0 %	3.8	±20.0 %	3.1	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	1230	±20.0 %	562	±20.0 %	458	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	172	±20.0 %	195	±20.0 %	180	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	4030	±20.0 %	1450	±20.0 %	930	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	35.2	±20.0 %	19.4	±20.0 %	18.3	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	2.6	±20.0 %	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	73.6	±20.0 %	99.2	±20.0 %	89.5	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	2.34	±20.0 %	2.12	±20.0 %	1.40	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	42.3	±20.0 %	39.6	±20.0 %	35.9	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	36.6	±20.0 %	22.8	±20.0 %	39.2	±20.0 %

Sub-Matrix: SOIL			Client sample ID	P.ZecaRice1		P.ZecaRice2		P.ZecaRice3	
			Laboratory sample ID	PR1537599019		PR1537599020		PR1537599021	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	96.2	±6.0 %	94.7	±6.0 %	94.2	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	21100	±20.0 %	32400	±20.0 %	32900	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	2.78	±20.0 %	5.36	±20.0 %	7.13	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	49.1	±20.0 %	43.6	±20.0 %	48.0	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	4.14	±20.0 %	5.70	±20.0 %	6.13	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	1.0	±20.0 %
Boron	S-METAXHB2	1.0	mg/kg DW	2.0	±20.0 %	2.7	±20.0 %	2.1	±20.0 %
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	1470	±20.0 %	1240	±20.0 %	1500	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	35.3	±20.0 %	38.0	±20.0 %	37.8	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	3.82	±20.0 %	5.80	±20.0 %	6.70	±20.0 %

Sub-Matrix: SOIL			Client sample ID	P.ZecaRice1		P.ZecaRice2		P.ZecaRice3	
			Laboratory sample ID	PR1537599019		PR1537599020		PR1537599021	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Copper	S-METAXHB1	1.0	mg/kg DW	13.9	±20.0 %	15.2	±20.0 %	16.5	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	15500	±20.0 %	27800	±20.0 %	34000	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	15.6	±20.0 %	16.2	±20.0 %	16.0	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	26.7	±20.0 %	43.9	±20.0 %	44.1	±20.0 %
Magnesium	S-METAXHB2	5.0	mg/kg DW	1510	±20.0 %	1680	±20.0 %	1800	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	23.9	±20.0 %	28.0	±20.0 %	34.8	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	0.93	±20.0 %	1.08	±20.0 %	1.00	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	10.9	±20.0 %	14.5	±20.0 %	14.9	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	1000	±20.0 %	1230	±20.0 %	1250	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	186	±20.0 %	156	±20.0 %	130	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	3090	±20.0 %	2820	±20.0 %	3270	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	38.1	±20.0 %	37.0	±20.0 %	38.3	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	1.2	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	67.4	±20.0 %	50.1	±20.0 %	28.4	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	4.40	±20.0 %	4.00	±20.0 %	3.71	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	47.6	±20.0 %	48.7	±20.0 %	50.4	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	9.0	±20.0 %	13.9	±20.0 %	15.1	±20.0 %

Sub-Matrix: SOIL			Client sample ID	P.ZecaCrop1		P.ZecaCrop2		P.ZecaCrop3	
			Laboratory sample ID	PR1537599022		PR1537599023		PR1537599024	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	98.2	±6.0 %	96.0	±6.0 %	97.5	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	5420	±20.0 %	10600	±20.0 %	13800	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	0.78	±20.0 %	<0.50	----	1.02	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	17.8	±20.0 %	38.3	±20.0 %	59.9	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	1.11	±20.0 %	1.49	±20.0 %	1.83	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	1.3	±20.0 %	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	0.40	±20.0 %
Calcium	S-METAXHB2	50	mg/kg DW	222	±20.0 %	439	±20.0 %	528	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	15.7	±20.0 %	32.0	±20.0 %	34.2	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.00	±20.0 %	0.71	±20.0 %	2.26	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	3.5	±20.0 %	6.2	±20.0 %	8.0	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	7950	±20.0 %	10800	±20.0 %	13300	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	6.4	±20.0 %	9.9	±20.0 %	13.5	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	3.2	±20.0 %	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	205	±20.0 %	287	±20.0 %	363	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	11.4	±20.0 %	18.7	±20.0 %	29.2	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	1.29	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	2.0	±20.0 %	4.1	±20.0 %	5.8	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	73.4	±20.0 %	197	±20.0 %	199	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----

Sub-Matrix: SOIL			Client sample ID	P.ZecaCrop1		P.ZecaCrop2		P.ZecaCrop3	
			Laboratory sample ID	PR1537599022		PR1537599023		PR1537599024	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Silicon	S-METAXHB2	50	mg/kg DW	195	±20.0 %	207	±20.0 %	193	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	596	±20.0 %	1300	±20.0 %	644	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	4.44	±20.0 %	7.88	±20.0 %	8.78	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	<1.0	----	1.3	±20.0 %	3.1	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	89.1	±20.0 %	101	±20.0 %	92.3	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	1.05	±20.0 %	1.79	±20.0 %	2.10	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	20.0	±20.0 %	30.8	±20.0 %	32.3	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	<3.0	----	<3.0	----	4.6	±20.0 %

Sub-Matrix: SOIL			Client sample ID	P.ZecaRes1		P.ZecaRes2		P.ZecaRes3	
			Laboratory sample ID	PR1537599025		PR1537599026		PR1537599027	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.4	±6.0 %	99.5	±6.0 %	99.6	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	3480	±20.0 %	2150	±20.0 %	2530	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	1.21	±20.0 %	<0.50	----	0.97	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	12.3	±20.0 %	5.23	±20.0 %	8.08	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.136	±20.0 %	0.055	±20.0 %	0.064	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	286	±20.0 %	223	±20.0 %	317	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	12.6	±20.0 %	9.43	±20.0 %	10.3	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	0.78	±20.0 %	<0.20	----	0.70	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	3.0	±20.0 %	1.9	±20.0 %	1.9	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	3060	±20.0 %	2340	±20.0 %	2460	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	6.2	±20.0 %	5.4	±20.0 %	5.2	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	193	±20.0 %	132	±20.0 %	173	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	76.3	±20.0 %	44.0	±20.0 %	56.3	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	0.52	±20.0 %	<0.40	----	0.57	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Potassium	S-METAXHB2	5.0	mg/kg DW	128	±20.0 %	286	±20.0 %	208	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	243	±20.0 %	266	±20.0 %	239	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	34	±20.0 %	161	±20.0 %	18	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	3.26	±20.0 %	2.03	±20.0 %	2.91	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	2.4	±20.0 %	<1.0	----	1.1	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	110	±20.0 %	85.8	±20.0 %	104	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.398	±20.0 %	0.205	±20.0 %	0.237	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	9.80	±20.0 %	6.86	±20.0 %	7.04	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	<3.0	----	10.7	±20.0 %	6.5	±20.0 %

Sub-Matrix: SOIL			Client sample ID	S.TambatoAgric1		S.TambatoAgric2		S.TambatoAgric3	
			Laboratory sample ID	PR1537599028		PR1537599029		PR1537599030	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	97.3	±6.0 %	99.0	±6.0 %	98.6	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	8700	±20.0 %	6130	±20.0 %	6840	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	3.26	±20.0 %	0.71	±20.0 %	0.80	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	19.4	±20.0 %	16.5	±20.0 %	17.4	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.162	±20.0 %	0.110	±20.0 %	0.111	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	0.77	±20.0 %	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	884	±20.0 %	826	±20.0 %	815	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	23.8	±20.0 %	14.4	±20.0 %	19.1	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.82	±20.0 %	2.36	±20.0 %	1.76	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	4.0	±20.0 %	3.0	±20.0 %	3.4	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	17000	±20.0 %	4950	±20.0 %	7040	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	6.5	±20.0 %	6.8	±20.0 %	5.7	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	1.2	±20.0 %	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	398	±20.0 %	347	±20.0 %	431	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	325	±20.0 %	302	±20.0 %	312	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	0.84	±20.0 %	0.49	±20.0 %	<0.40	----
Nickel	S-METAXHB1	1.0	mg/kg DW	2.7	±20.0 %	3.6	±20.0 %	2.3	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	245	±20.0 %	202	±20.0 %	232	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	217	±20.0 %	230	±20.0 %	227	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	30	±20.0 %	<15	----	<15	----
Strontium	S-METAXHB1	0.10	mg/kg DW	8.69	±20.0 %	7.60	±20.0 %	7.21	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	2.4	±20.0 %	<1.0	----	<1.0	----
Titanium	S-METAXHB2	0.20	mg/kg DW	211	±20.0 %	206	±20.0 %	219	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.574	±20.0 %	0.332	±20.0 %	0.438	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	33.2	±20.0 %	14.5	±20.0 %	19.4	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	6.7	±20.0 %	4.9	±20.0 %	5.2	±20.0 %

Sub-Matrix: SOIL			Client sample ID	S.HEDIMRes1		S.HEDIMRes2		S.HEDIMRes3	
			Laboratory sample ID	PR1537599031		PR1537599032		PR1537599033	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	98.7	±6.0 %	99.4	±6.0 %	99.2	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	6420	±20.0 %	4220	±20.0 %	5720	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	1.28	±20.0 %	1.09	±20.0 %	0.84	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	11.1	±20.0 %	7.84	±20.0 %	10.6	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.098	±20.0 %	0.047	±20.0 %	0.082	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	<0.40	----	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	551	±20.0 %	910	±20.0 %	698	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	17.0	±20.0 %	14.7	±20.0 %	16.1	±20.0 %

Sub-Matrix: SOIL			Client sample ID	S.HEDIMRes1		S.HEDIMRes2		S.HEDIMRes3	
			Laboratory sample ID	PR1537599031		PR1537599032		PR1537599033	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.61	±20.0 %	1.79	±20.0 %	2.34	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	2.5	±20.0 %	2.8	±20.0 %	2.1	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	5960	±20.0 %	4720	±20.0 %	5500	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	4.7	±20.0 %	4.4	±20.0 %	4.6	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	283	±20.0 %	330	±20.0 %	302	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	194	±20.0 %	146	±20.0 %	214	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	1.12	±20.0 %	<0.40	----	0.83	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	2.4	±20.0 %	1.8	±20.0 %	1.7	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	164	±20.0 %	157	±20.0 %	153	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	248	±20.0 %	254	±20.0 %	236	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	<15	----	<15	----	<15	----
Strontium	S-METAXHB1	0.10	mg/kg DW	5.27	±20.0 %	6.12	±20.0 %	5.81	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	2.8	±20.0 %	2.5	±20.0 %	3.0	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	192	±20.0 %	209	±20.0 %	208	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.355	±20.0 %	0.270	±20.0 %	0.342	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	17.0	±20.0 %	13.1	±20.0 %	15.8	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	24.1	±20.0 %	3.9	±20.0 %	3.8	±20.0 %

Sub-Matrix: SOIL			Client sample ID	S.HEDIMCrop1		S.HEDIMCrop2		S.HEDIMCrop3	
			Laboratory sample ID	PR1537599034		PR1537599035		PR1537599036	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.5	±6.0 %	99.3	±6.0 %	99.4	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	5590	±20.0 %	7420	±20.0 %	6740	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.51	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	1.09	±20.0 %	<0.50	----	0.70	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	8.54	±20.0 %	10.1	±20.0 %	11.0	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.078	±20.0 %	0.130	±20.0 %	0.123	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	0.41	±20.0 %	<0.40	----
Calcium	S-METAXHB2	50	mg/kg DW	260	±20.0 %	261	±20.0 %	327	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	14.0	±20.0 %	14.9	±20.0 %	14.4	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	1.41	±20.0 %	0.92	±20.0 %	0.83	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	2.1	±20.0 %	2.4	±20.0 %	2.3	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	4170	±20.0 %	4790	±20.0 %	4650	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	3.8	±20.0 %	4.0	±20.0 %	5.5	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	193	±20.0 %	233	±20.0 %	226	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	137	±20.0 %	164	±20.0 %	186	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	0.61	±20.0 %	0.80	±20.0 %	0.92	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	1.8	±20.0 %	2.3	±20.0 %	1.7	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	115	±20.0 %	205	±20.0 %	166	±20.0 %

Sub-Matrix: SOIL			Client sample ID	S.HEDIMCrop1		S.HEDIMCrop2		S.HEDIMCrop3	
			Laboratory sample ID	PR1537599034		PR1537599035		PR1537599036	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	271	±20.0 %	208	±20.0 %	235	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	<15	----	<15	----	<15	----
Strontium	S-METAXHB1	0.10	mg/kg DW	3.95	±20.0 %	4.52	±20.0 %	4.81	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	3.2	±20.0 %	6.9	±20.0 %	2.4	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	242	±20.0 %	203	±20.0 %	217	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	0.240	±20.0 %	0.471	±20.0 %	0.399	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	13.0	±20.0 %	14.5	±20.0 %	14.4	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	<3.0	----	3.6	±20.0 %	3.6	±20.0 %

Sub-Matrix: SOIL			Client sample ID	PortRice1		PortRice2		PortRice3	
			Laboratory sample ID	PR1537599037		PR1537599038		PR1537599039	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Active pH	S-PHAC-ELE	1.0	-	5.6	±2.7 %	5.9	±2.5 %	5.7	±2.6 %
Electrical Conductivity @ 25°C	S-CON-ELE	1.0	mS/m	575	±20.0 %	497	±20.0 %	304	±20.0 %
Laboratory compacted bulk density	S-LCBD-GR	100	g/L	1130	±15.0 %	1110	±15.0 %	1060	±15.0 %
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	93.3	±6.0 %	93.9	±6.0 %	85.6	±6.0 %
Nonmetallic Inorganic Parameters									
Total Nitrogen as N	S-NTOT-PHO	50	mg/kg DW	1140	±20.2 %	952	±20.3 %	824	±20.4 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	36800	±20.0 %	39300	±20.0 %	43000	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	15.9	±20.0 %	21.6	±20.0 %	12.3	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	25.1	±20.0 %	27.4	±20.0 %	29.2	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	1.21	±20.0 %	1.36	±20.0 %	1.35	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	3.3	±20.0 %	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	20.2	±20.0 %	23.3	±20.0 %	26.0	±20.0 %
Cadmium	S-METAXHB1	0.40	mg/kg DW	1.97	±20.0 %	2.67	±20.0 %	2.20	±20.0 %
Calcium	S-METAXHB2	50	mg/kg DW	633	±20.0 %	1250	±20.0 %	580	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	108	±20.0 %	117	±20.0 %	121	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	9.04	±20.0 %	10.9	±20.0 %	11.0	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	11.6	±20.0 %	9.0	±20.0 %	9.0	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	58200	±20.0 %	65700	±20.0 %	53400	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	24.8	±20.0 %	26.0	±20.0 %	23.3	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	3.3	±20.0 %	11.4	±20.0 %	16.7	±20.0 %
Magnesium	S-METAXHB2	5.0	mg/kg DW	4530	±20.0 %	5120	±20.0 %	5100	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	66.4	±20.0 %	106	±20.0 %	114	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	0.29	±20.0 %	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	4.45	±20.0 %	6.29	±20.0 %	3.37	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	13.6	±20.0 %	19.5	±20.0 %	19.3	±20.0 %
Phosphorus	S-METAXHB1	5.0	mg/kg DW	725	±20.0 %	820	±20.0 %	673	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	4340	±20.0 %	4460	±20.0 %	4810	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	190	±20.0 %	198	±20.0 %	217	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	4700	±20.0 %	6300	±20.0 %	6770	±20.0 %

Sub-Matrix: SOIL			Client sample ID	PortRice1		PortRice2		PortRice3	
			Laboratory sample ID	PR1537599037		PR1537599038		PR1537599039	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Strontium	S-METAXHB1	0.10	mg/kg DW	80.5	±20.0 %	72.5	±20.0 %	74.2	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	1.2	±20.0 %	2.6	±20.0 %	4.3	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	144	±20.0 %	205	±20.0 %	223	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	3.03	±20.0 %	2.89	±20.0 %	2.42	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	54.5	±20.0 %	66.1	±20.0 %	56.7	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	30.4	±20.0 %	36.6	±20.0 %	37.5	±20.0 %

Sub-Matrix: SOIL			Client sample ID	PortRice4		PortSav1		PortSav2	
			Laboratory sample ID	PR1537599040		PR1537599041		PR1537599042	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Active pH	S-PHAC-ELE	1.0	-	5.1	±2.9 %	5.5	±2.7 %	5.1	±2.9 %
Electrical Conductivity @ 25°C	S-CON-ELE	1.0	mS/m	1480	±20.0 %	17.0	±20.4 %	10.6	±21.0 %
Laboratory compacted bulk density	S-LCBD-GR	100	g/L	1110	±15.0 %	610	±15.0 %	590	±15.0 %
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	90.3	±6.0 %	88.5	±6.0 %	84.6	±6.0 %
Nonmetallic Inorganic Parameters									
Total Nitrogen as N	S-NTOT-PHO	50	mg/kg DW	1310	±20.2 %	4820	±20.0 %	5260	±20.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	37400	±20.0 %	67000	±20.0 %	65800	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.51	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	12.3	±20.0 %	3.98	±20.0 %	2.73	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	26.1	±20.0 %	95.7	±20.0 %	102	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	1.37	±20.0 %	1.79	±20.0 %	2.24	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	25.2	±20.0 %	3.4	±20.0 %	3.9	±20.0 %
Cadmium	S-METAXHB1	0.40	mg/kg DW	1.87	±20.0 %	1.36	±20.0 %	0.98	±20.0 %
Calcium	S-METAXHB2	50	mg/kg DW	1170	±20.0 %	348	±20.0 %	301	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	109	±20.0 %	94.0	±20.0 %	93.9	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	10.8	±20.0 %	12.8	±20.0 %	10.8	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	8.9	±20.0 %	11.2	±20.0 %	11.6	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	50400	±20.0 %	38200	±20.0 %	27500	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	26.6	±20.0 %	26.7	±20.0 %	19.0	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	11.1	±20.0 %	34.5	±20.0 %	46.5	±20.0 %
Magnesium	S-METAXHB2	5.0	mg/kg DW	6670	±20.0 %	988	±20.0 %	974	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	90.1	±20.0 %	44.1	±20.0 %	58.6	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	6.34	±20.0 %	2.52	±20.0 %	1.82	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	18.2	±20.0 %	28.8	±20.0 %	28.1	±20.0 %
Phosphorus	S-METAXHB1	5.0	mg/kg DW	656	±20.0 %	744	±20.0 %	860	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	4830	±20.0 %	825	±20.0 %	986	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	207	±20.0 %	206	±20.0 %	194	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	17900	±20.0 %	426	±20.0 %	257	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	75.6	±20.0 %	33.0	±20.0 %	35.4	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	4.5	±20.0 %	3.8	±20.0 %	3.7	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	215	±20.0 %	109	±20.0 %	95.2	±20.0 %

Sub-Matrix: SOIL			Client sample ID	PortRice4		PortSav1		PortSav2	
			Laboratory sample ID	PR1537599040		PR1537599041		PR1537599042	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Extractable Metals / Major Cations - Continued									
Uranium	S-METMSHB3	0.100	mg/kg DW	2.57	±20.0 %	6.16	±20.0 %	10.9	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	54.2	±20.0 %	54.8	±20.0 %	51.9	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	36.7	±20.0 %	26.6	±20.0 %	27.1	±20.0 %

Sub-Matrix: SOIL			Client sample ID	PortSav3		PortSav4		Beach1	
			Laboratory sample ID	PR1537599043		PR1537599044		PR1537599045	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Active pH	S-PHAC-ELE	1.0	-	5.9	±2.5 %	5.6	±2.7 %	----	----
Electrical Conductivity @ 25°C	S-CON-ELE	1.0	mS/m	4.1	±25.0 %	4.7	±24.5 %	----	----
Laboratory compacted bulk density	S-LCBD-GR	100	g/L	550	±15.0 %	580	±15.0 %	----	----
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	86.2	±6.0 %	85.4	±6.0 %	81.4	±6.0 %
Nonmetallic Inorganic Parameters									
Total Nitrogen as N	S-NTOT-PHO	50	mg/kg DW	5020	±20.0 %	4320	±20.0 %	----	----
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	79100	±20.0 %	83100	±20.0 %	33400	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	8.13	±20.0 %	8.20	±20.0 %	24.6	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	113	±20.0 %	107	±20.0 %	31.8	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	3.69	±20.0 %	3.98	±20.0 %	1.10	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	6.4	±20.0 %	6.9	±20.0 %	25.9	±20.0 %
Cadmium	S-METAXHB1	0.40	mg/kg DW	1.72	±20.0 %	2.04	±20.0 %	3.79	±20.0 %
Calcium	S-METAXHB2	50	mg/kg DW	259	±20.0 %	118	±20.0 %	615	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	95.4	±20.0 %	90.2	±20.0 %	191	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	11.3	±20.0 %	12.7	±20.0 %	6.90	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	9.1	±20.0 %	8.3	±20.0 %	9.1	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	49400	±20.0 %	51800	±20.0 %	96700	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	13.4	±20.0 %	13.1	±20.0 %	36.9	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	45.1	±20.0 %	42.8	±20.0 %	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	741	±20.0 %	624	±20.0 %	2450	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	32.4	±20.0 %	25.4	±20.0 %	69.9	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	2.08	±20.0 %	1.67	±20.0 %	4.51	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	33.9	±20.0 %	32.7	±20.0 %	11.3	±20.0 %
Phosphorus	S-METAXHB1	5.0	mg/kg DW	830	±20.0 %	690	±20.0 %	----	----
Potassium	S-METAXHB2	5.0	mg/kg DW	1020	±20.0 %	1150	±20.0 %	2660	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	183	±20.0 %	150	±20.0 %	204	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	405	±20.0 %	364	±20.0 %	5800	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	49.6	±20.0 %	44.7	±20.0 %	62.5	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	4.9	±20.0 %	5.0	±20.0 %	7.6	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	165	±20.0 %	135	±20.0 %	192	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	14.9	±20.0 %	18.5	±20.0 %	3.24	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	59.3	±20.0 %	59.0	±20.0 %	167	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	19.8	±20.0 %	19.0	±20.0 %	20.0	±20.0 %

Sub-Matrix: SOIL			Client sample ID	Beach2		Beach3		Beach4	
			Laboratory sample ID	PR1537599046		PR1537599047		PR1537599048	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	97.5	±6.0 %	94.5	±6.0 %	96.0	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	18000	±20.0 %	22900	±20.0 %	9800	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.51	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	38.8	±20.0 %	44.8	±20.0 %	8.00	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	18.7	±20.0 %	19.9	±20.0 %	22.6	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	1.00	±20.0 %	1.01	±20.0 %	0.224	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	3.4	±20.0 %	6.0	±20.0 %	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	12.6	±20.0 %	19.9	±20.0 %	2.2	±20.0 %
Cadmium	S-METAXHB1	0.40	mg/kg DW	5.58	±20.0 %	5.96	±20.0 %	1.18	±20.0 %
Calcium	S-METAXHB2	50	mg/kg DW	1350	±20.0 %	912	±20.0 %	334	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	236	±20.0 %	302	±20.0 %	74.4	±20.0 %
Cobalt	S-METAXHB1	0.20	mg/kg DW	8.89	±20.0 %	6.72	±20.0 %	2.57	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	10.8	±20.0 %	10.7	±20.0 %	2.9	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	161000	±20.0 %	187000	±20.0 %	29100	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	36.3	±20.0 %	35.1	±20.0 %	46.2	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	1970	±20.0 %	2100	±20.0 %	756	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	293	±20.0 %	103	±20.0 %	47.6	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	4.40	±20.0 %	6.44	±20.0 %	1.98	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	10.4	±20.0 %	13.2	±20.0 %	2.3	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	978	±20.0 %	1800	±20.0 %	467	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	187	±20.0 %	172	±20.0 %	228	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	888	±20.0 %	4260	±20.0 %	203	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	45.7	±20.0 %	48.4	±20.0 %	25.9	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	5.0	±20.0 %	<1.0	----	4.2	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	297	±20.0 %	243	±20.0 %	174	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	4.08	±20.0 %	4.31	±20.0 %	1.35	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	286	±20.0 %	352	±20.0 %	74.2	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	32.8	±20.0 %	28.2	±20.0 %	8.8	±20.0 %

Sub-Matrix: SOIL			Client sample ID	PortRes1		PortRes2		PortRes3	
			Laboratory sample ID	PR1537599049		PR1537599050		PR1537599051	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.0	±6.0 %	97.7	±6.0 %	97.6	±6.0 %
Extractable Metals / Major Cations									
Aluminium	S-METAXHB2	1.0	mg/kg DW	4900	±20.0 %	7610	±20.0 %	9490	±20.0 %
Antimony	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.51	----
Arsenic	S-METAXHB1	0.50	mg/kg DW	<0.50	----	2.24	±20.0 %	2.94	±20.0 %
Barium	S-METAXHB1	0.20	mg/kg DW	10.5	±20.0 %	17.2	±20.0 %	24.2	±20.0 %
Beryllium	S-METAXHB1	0.010	mg/kg DW	0.097	±20.0 %	0.207	±20.0 %	0.159	±20.0 %
Bismuth	S-METAXHB2	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Boron	S-METAXHB2	1.0	mg/kg DW	<1.0	----	2.7	±20.0 %	1.7	±20.0 %
Cadmium	S-METAXHB1	0.40	mg/kg DW	<0.40	----	0.45	±20.0 %	0.77	±20.0 %
Calcium	S-METAXHB2	50	mg/kg DW	666	±20.0 %	1610	±20.0 %	2580	±20.0 %
Chromium	S-METAXHB1	0.50	mg/kg DW	20.9	±20.0 %	29.8	±20.0 %	29.0	±20.0 %

Sub-Matrix: **SOIL**			Client sample ID	PortRes1		PortRes2		PortRes3	
			Laboratory sample ID	PR1537599049		PR1537599050		PR1537599051	
			Client sampling date / time	15-MAY-2015 00:00		15-MAY-2015 00:00		15-MAY-2015 00:00	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**	**Result**	**MU**	**Result**	**MU**
Extractable Metals / Major Cations - Continued									
Cobalt	S-METAXHB1	0.20	mg/kg DW	**2.81**	±20.0 %	**2.57**	±20.0 %	**3.29**	±20.0 %
Copper	S-METAXHB1	1.0	mg/kg DW	**3.2**	±20.0 %	**5.7**	±20.0 %	**7.0**	±20.0 %
Iron	S-METAXHB1	10	mg/kg DW	**6170**	±20.0 %	**11600**	±20.0 %	**14700**	±20.0 %
Lead	S-METAXHB1	1.0	mg/kg DW	**3.9**	±20.0 %	**18.5**	±20.0 %	**8.6**	±20.0 %
Lithium	S-METAXHB1	1.0	mg/kg DW	<1.0	----	<1.0	----	<1.0	----
Magnesium	S-METAXHB2	5.0	mg/kg DW	**258**	±20.0 %	**676**	±20.0 %	**647**	±20.0 %
Manganese	S-METAXHB1	0.50	mg/kg DW	**130**	±20.0 %	**170**	±20.0 %	**322**	±20.0 %
Mercury	S-METAXHB1	0.20	mg/kg DW	<0.20	----	<0.20	----	<0.20	----
Molybdenum	S-METAXHB1	0.40	mg/kg DW	**0.88**	±20.0 %	**4.14**	±20.0 %	**2.58**	±20.0 %
Nickel	S-METAXHB1	1.0	mg/kg DW	**4.3**	±20.0 %	**3.5**	±20.0 %	**3.5**	±20.0 %
Potassium	S-METAXHB2	5.0	mg/kg DW	**357**	±20.0 %	**858**	±20.0 %	**806**	±20.0 %
Selenium	S-METAXHB2	2.0	mg/kg DW	<2.0	----	<2.0	----	<2.0	----
Silicon	S-METAXHB2	50	mg/kg DW	**238**	±20.0 %	**231**	±20.0 %	**231**	±20.0 %
Silver	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Sodium	S-METAXHB2	15	mg/kg DW	**168**	±20.0 %	**209**	±20.0 %	**101**	±20.0 %
Strontium	S-METAXHB1	0.10	mg/kg DW	**9.81**	±20.0 %	**27.3**	±20.0 %	**29.1**	±20.0 %
Thallium	S-METAXHB1	0.50	mg/kg DW	<0.50	----	<0.50	----	<0.50	----
Tin	S-METAXHB1	1.0	mg/kg DW	**1.9**	±20.0 %	**4.6**	±20.0 %	**3.0**	±20.0 %
Titanium	S-METAXHB2	0.20	mg/kg DW	**148**	±20.0 %	**154**	±20.0 %	**167**	±20.0 %
Uranium	S-METMSHB3	0.100	mg/kg DW	**0.456**	±20.0 %	**0.671**	±20.0 %	**0.750**	±20.0 %
Vanadium	S-METAXHB1	0.10	mg/kg DW	**15.1**	±20.0 %	**20.8**	±20.0 %	**23.5**	±20.0 %
Zinc	S-METAXHB1	3.0	mg/kg DW	**33.6**	±20.0 %	**66.9**	±20.0 %	**153**	±20.0 %

If the client does not specify the date and time of sample collection, the laboratory will specify the date on sample delivery in parentheses, instead. If the time of sample collection is specified as 0:00 it means that the client did specify the date but not the time. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.
Key: LOR = Limit of reporting; MU = Measurement Uncertainty

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Bendlova 1687/7 Ceska Lipa Czech Republic 470 01	
S-CON-ELE	CZ_SOP_D06_07_126 (CSN EN 13038) Determination of electrical conductivity.
S-DRY-GRCI	CZ_SOP_D06_01_045, CZ_SOP_D06_07_046 (CSN ISO 11465) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.
*S-LCBD-GR	CSN EN 13040 Soil improvers and growing media - Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density.
S-NTOT-PHO	CZ_SOP_D06_07_102 (CSN ISO 11261) Determination of total nitrogen by modified Kjeldahl method by spectrophotometry.
S-PHAC-ELE	CZ_SOP_D06_07_113 (CSN ISO 10390, CSN EN 12176, CSN 46 5735, L 1086-1) Determination of pH electrochemically in the soil suspension in water, KCl, CaCl2, BaCl2.
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
S-DRY-GRCI	CZ_SOP_D06_01_045, CZ_SOP_D06_07_046 (CSN ISO 11465) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.
S-METAXHB1	CZ_SOP_D06_02_001 (US EPA 200.7, ISO 11885, US EPA 6010, SM 3120, samples prepared as per CZ_SOP_D06_02_J02 (US EPA 3050) chap. 10.3 to 10.16, 10.17.5, 10.17.6, 10.17.9 to 10.17.14), Determination of elements by atomic emission spectrometry with inductively coupled plasma and stoichiometric calculations of compounds concentration from measured values. Sample was homogenized and mineralized by aqua regia prior to analysis.
S-METAXHB2	CZ_SOP_D06_02_001 (US EPA 200.7, ISO 11885, US EPA 6010, SM 3120, samples prepared as per CZ_SOP_D06_02_J02 (US EPA 3050) chap. 10.3 to 10.16, 10.17.5, 10.17.6, 10.17.9 to 10.17.14), Determination of elements by atomic emission spectrometry with inductively coupled plasma and stoichiometric calculations of compounds concentration from measured values. Sample was homogenized and mineralized by aqua regia prior to analysis.

Analytical Methods	*Method Descriptions*
S-METMSHB3	CZ_SOP_D06_02_002 (US EPA 200.8, CSN EN ISO 17294-2, US EPA 6020A, samples prepared as per CZ_SOP_D06_02_J02 chap. 10.3 to 10.16, 10.17.5, 10.17.6, 10.17.9 to 10.17.14) Determination of elements by mass spectrometry with inductively coupled plasma and stoichiometric calculations of compounds concentration from measured values. Sample was homogenized and mineralized by aqua regia prior to analysis.
Preparation Methods	*Method Descriptions*
Location of test performance: Bendlova 1687/7 Ceska Lipa Czech Republic 470 01	
* S-PPHOM2	Drying and sieving of sample on the grain size < 2 mm
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
* S-PPHOM2	Drying and sieving of sample on the grain size < 2 mm

A `*` symbol preceeding any method indicates non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information.
The calculation methods of summation parameters are available on request in the client service.

GB MINERALS LIMITED
FARIM PHOSPHATE PROJECT

TAILINGS GEOCHEMICAL CHARACTERISATION REPORT

PREPARED FOR:

Lycopodium Minerals Canada Ltd.
5060 Spectrum Way, Suite 302,
Mississauga,
ON L4W 5N5
CANADA

PREPARED BY:

Knight Piésold Pty Limited
Level 1, 184 Adelaide Terrace
East Perth, WA 6004, AUSTRALIA
p. +61 9223 6300 • f. +61 9223 6399

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Knight Piésold
CONSULTING
www.knightpiesold.com

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LYCOPODIUM MINERALS CANADA LTD

FARIM PHOSPHATE PROJECT

TAILINGS GEOCHEMICAL CHARACTERISATION REPORT

KP Project No.: PE301-00520/04

KP Report No.: PE301-00520/05

CONTRACT

DOCUMENT INFORMATION

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Tailings Geochemical Characterisation – Preliminary Report

APPENDIX B
Laboratory Certificates

DEFINITION OF TECHNICAL TERMS

Acronym or Symbol	Parameter	Brief Description	Determination / Source	Unit
ACA	Average Crustal Abundance	Average concentration of a particular element in Earth's crust.	References	ppm
AFP	Acid Formation Potential	The potential of a material to form acid.	Calculation	N/A
ANC	Acid Neutralising Capacity	A materials ability to neutralise acid generally through mineral dissolution.	Analysis Result	kg H_2SO_4/tonne
ARD	Acid Rock Drainage	Acid metal rich leachate resulting from sulfide oxidation.		N/A
C_n	Element Concentration	Measure of concentration of an element in a particular sample.	Analysis Result	ppm or %
CRS	Chromium Reducible Sulfur	A laboratory test to determine the sulfide content of a sample	Analysis Result	ppm or %
EC	Electrical Conductivity	A measure of electrical current transported by the ions in solution.	Analysis Result	mS/cm
GAI	Geochemical Abundance Index	A scale of enrichment based on C_n and ACA.	Calc.(GAI = Log_2 (C_n / (1.5 x ACA))	None
MPA	Maximum Potential Acidity	The max. amount of acid which can be produced by oxidisation of contained sulfides.	Calc.(MPA = Sulfide-S x 30.6)	kg H_2SO_4/tonne
NAF	Non Acid Forming	Material does not produce acid either as a result of low sulfide contents or due to excess acid neutralising capacity.	Calculation	N/A
NAG	Net Acid Generation	A direct measure of acid production under extreme oxidising conditions.	Analysis Result	kg H_2SO_4/tonne
NAPP	Net Acid Producing Potential	The balance between MPA and ANC.	Calc.(NAPP = ANC – MPA)	kg H_2SO_4/tonne
HCl	Hydrochloric Acid	A mineral acid.		N/A
H_2O_2	Hydrogen Peroxide	A strong oxidising agent.		N/A
H_2SO_4	Sulfuric Acid	A mineral acid.		N/A
PAF	Potentially Acid Forming	Material has potential to produce acid through sulfide oxidation.	Calculation	N/A
Sulfate-S	Sulfate Sulfur	The sulfur present in the oxidised state.	Result	%
Sulfide-S	Sulfide Sulfur	The sulfur present in the reduced state.	Calc.(Sulfide-S = Total-S – Sulfate-S)	%
TDS	Total Dissolved Solids	A measure of the total amount of material dissolved in a solution.	Analysis Result	ppm
Total-S	Total Sulfur	The total amount of sulfur present.	Analysis Result	%

1. INTRODUCTION

1.1 GENERAL

The Farim Phosphate Project is being developed by GB Minerals Ltd (GBML). Knight Piésold Pty Ltd (KP) was engaged by Lycopodium Minerals Canada Ltd. (Lyco) to provide engineering services as part of the feasibility study (FS), comprising geotechnical site investigations and assessment of the proposed sites of the tailings storage facility and process plant, geotechnical assessment of the proposed port site, feasibility level design of the tailings storage facility, an hydrogeological and de-watering assessment for the open pits, a waste rock geochemical assessment study, and surface water management design for the project site.

A preliminary study of the tailings geochemistry was conducted on a limited size dry tailings sample which was received by KP in April 2015. Due to the small sample size, only a limited suite of testing could be conducted at that time. The assessment was reported in May 2015 (Ref. 1) and a copy of the report is included herein as Appendix A.

A comprehensive assessment of the tailings geochemistry has been carried out on a full-size and representative sample of tailings slurry received by KP in August 2015. This report presents details of the scope and findings of the geochemical assessment carried out on the full-size representative tailings sample.

1.2 PROJECT DESCRIPTION AND GEOLOGY

The Farim project site is located in the north of Guinea-Bissau, approximately 25 km south of the Senegal border, 5 km west of the town of Farim and 120 km north-east of Bissau, the capital of Guinea-Bissau. The project will comprise an open pit mining operation with two separate pits.

A summary of the geology is taken from Golder Associates Report No. 11514950096.515/B.0 (full reference not known), as follows:

"The project comprises a high grade phosphate deposit which occurs within the Middle Eocene Lutetian Formation in a Cenozoic sedimentary basin that extends from Morocco in the north through Mauritania, Senegal, Guinea-Bissau and into Guinea to the south. The basin hosts a number of important phosphate deposits and accounts for almost 25% of world production. Three phosphate-bearing horizons have been identified at the Farim phosphate deposit. These are referred to as the FPO, FPA and FPB. The FPO is a clayey dolomitic limestone that is weakly phosphatic with limited economic potential. The FPA underlies the FPO and is a soft, poorly cemented unit of phosphatic sand, which includes phosphatised shell and bone material, teeth, faecal

pellets and crustacean coprolites. The unit is beige to brown and lies in a generally reducing environment below the oxidised interval. The FPA unit is the identified potentially economic phosphate bed. The FPB underlies the FPA and is a calcareous phosphate unit comprising a much harder phosphatic limestone than the FPA unit. The FPB member is of less economic interest due to the low phosphate and high limestone content. The phosphate deposit is underlain by a soft, white and porous limestone unit.

The phosphate bearing strata are unconformably overlain by a sandy-argillaceous sequence comprising soft alternating sandy, clayey and sandy-clay layers with a blue/green soft clay or black lignitic clay at the base."

An overview of the site stratigraphy is summarised in Table 1.1.

Table 1.1: Indicative site stratigraphy

Age	Unit	Description	Approx. Thickness (m)
Post Eocene	Sandy/Argillaceous Overburden	Alternating sandy, clayey and sandy clayey layers	27 to 58
	Basal Clay Overburden	Blue/green soft clay and black lignitic clay (anoxic depositional environment)	
Eocene	Sand including FPO (phosphatic interval)	Grey/white fine grained sand including phosphate bearing clayey dolomitic limestone (FPO)	7 (single intercept)
	Upper Dolomitic Limestone	Clayey limestone	>2 [1] (single intercept)
	Decarbonised Phosphate Unit (FPA)	Ore zone comprising beige to brown, poorly cemented very fine grained phosphatic sand.	1 to 11
	Calcareous Phosphate Unit FPB	Cemented phosphatic limestone	2 to 8
	Limestone	Soft, white and porous limestone	>6 to 17 [1]

[1] Base of unit not encountered

The actual stratigraphy recorded in the recent drilling to provide geotechnical data and geochemical waste rock samples appears to be highly variable, with the indicative stratigraphic column provided in Table 1.1 rarely clearly definable and certain strata not always present.

2. TESTING METHODS

2.1 ACID BASE ACCOUNTING

Acid base accounting (ABA) assesses a sample's potential to form acid from the oxidation of sulfides and the ability to neutralise acid by the dissolution of minerals, particularly carbonates, contained in the sample.

Total sulfur, total carbon and total inorganic carbon were determined by Leco induction furnace, with infrared detection. Sulfate sulfur was determined by ICP following a hydrochloric acid digest. The testing methods specified are based on the ABA methodology defined in the Mine Environment Neutral Drainage (MEND) Acid Rock Drainage Prediction Manual (Ref. 2) and Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Ref. 3).

Acid Neutralising Capacity (ANC) was determined by digestion in a standard solution of HCl, followed by back titration with NaOH to determine the amount of acid consumed. The technique used was based on Sobek et al (Ref. 4), with a siderite correction step added to the standard procedure.

The results of the ABA testing are used to calculate the Maximum Potential Acidity (MPA), which is a measure of the maximum amount of sulfuric acid which can be produced from the total oxidation of all sulfides within the sample, assuming all sulfides are present as pyrite.

The Net Acid Producing Potential (NAPP) is the balance between the MPA and ANC. A negative NAPP indicates that there is an excess neutralising capacity and a positive NAPP indicates there is excess potential acidity.

2.2 NET ACID GENERATION (NAG)

Net Acid Generation (NAG) testing provides a direct measure of a sample's ability to produce acid through sulfide oxidation. The addition of hydrogen peroxide to samples causes rapid oxidation of the contained sulfides to produce sulfuric acid.

The specified procedure is based on the Static NAG Test (Ref. 5 and 6). The static NAG test involves the addition of 250 mL of 15 per cent hydrogen peroxide to 2.5 g of pulverised sample. The sample is allowed to react overnight prior to heating for a period of three hours. Once the sample has cooled the pH of the sample is measured prior to titration back to pH 4.5 and 7 to determine the acidity produced by the oxidisation reactions.

Organic acids may be generated in the NAG test when organic carbon is present due to partial oxidation of the carbonaceous material. This can lead to low NAG pH values which are not due to acid generation from sulfides. Organic acid effects can, therefore,

result in misleading NAG values and misclassification of the acid formation potential of samples which contain significant organic carbon. The extended boil NAG test (Ref. 7) can be used to account for the organic acidity and this method was applied to the tailings sample in addition to the standard static NAG test.

2.3 ACID FORMING POTENTIAL

The acid formation potential of a sample is calculated based on the acid base accounting, i.e. the balance between a sample's ability to produce acid from the oxidisation of sulfide minerals (MPA) and neutralise acid by the dissolution of alkaline minerals (ANC).

Historically a safety margin was applied to ratio between the ANC and MPA to allow for variability in the rates of acid production and neutralisation processes and the potential for geographic separation of the acid producing and acid neutralising phases. This safety margin was generally set by industry at 2 in North America and 3 in Australia.

With recent advances in the understanding and acceptance of the NAG test there has been a move away from this method of classifying materials based solely on the ANC and MPA as these calculated parameters do not take into consideration the true availability of acid producing and acid neutralising phases.

KP prefers to utilise the results of the acid base accounting in combination with the NAG testing results to classify the acid formation potential of materials. KP's classification system, as summarised in Table 2.1, is based on the Australian guidelines on Managing Acidic and Metalliferous Drainage (Ref. 8) and is broadly similar to the classification system contained within the AMIRA ARD Test Handbook (Ref. 9), which is advocated by the Global Acid Rock Drainage Guidelines (Ref. 10).

Table 2.1: Acid Formation Potential Classification System

Acid Formation Potential Class	NAPP (kg H_2SO_4 /t)	NAG pH
Potentially Acid Forming (PAF)	>10	<4.5
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than -100	≥4.5
Uncertain (UC)	Positive	≥4.5
	Negative	<4.5

2.4 MULTI-ELEMENT ANALYSIS

2.4.1 Element Enrichment

Multi-element analysis was conducted to assess elemental enrichments within the samples. The specified four acid digestion method results in near total digestion of the samples to assess the whole rock geochemistry.

Multi-element analysis results are compared to the average crustal abundance to determine geochemical abundance indices. The Geochemical Abundance Index (GAI) quantifies an assay result for a particular element in terms of average crustal abundance.

The GAI is calculated from the following formula:

$$\mathbf{GAI = Log_2 (C_n / (1.5 \times B_n))}$$

Where:

C_n = measured concentration of element in sample

B_n = average crustal abundance (Bowen, Ref. 11)

The GAI is expressed on a scale of 0 to 6, with 0 indicating that the element concentration is less than or similar to average crustal abundance, and a GAI of 6 indicating an element concentration of more than 96 times the average crustal abundance. The enrichment ranges for GAIs are as follows:

- GAI = 0 represents <3 times crustal abundance.
- GAI = 1 represents 3 to 6 times crustal abundance.
- GAI = 2 represents 6 to 12 times crustal abundance.
- GAI = 3 represents 12 to 24 times crustal abundance.
- GAI = 4 represents 24 to 48 times crustal abundance.
- GAI = 5 represents 48 to 96 times crustal abundance.
- GAI = 6 represents more than 96 times crustal abundance.

KP has assigned an arbitrary scale to the GAI, with indices of 0 and 1 being classified as “not enriched”, an index of 2 being classed as “slightly enriched”, indices of 3 and 4 being classed as “significantly enriched” and indices of 5 and 6 being classified as “highly enriched”.

2.4.2 Soil Quality Screening for Closure Planning

The multi-element analysis results were also compared to guideline concentrations for soil quality based on risk to human health and ecology for preliminary assessment of possible closure requirements, such as construction of engineered cover systems or limiting land use / access.

The Australian National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (Ref. 12) has been used to assess risk to human health, based on an assumed ‘recreational’ closure land use. This assumes the final landform will comprise public open space such as parks and playing fields rather than undeveloped public open space where the potential for exposure will be lower. However, these values assume that no planting of crops for human consumption will occur.

To assess ecological risk, the U.S. Environmental Protection Agency Ecological Soil Screening Levels (Eco-SSLs) (Ref. 13) have been applied. These values apply to sites where terrestrial organisms may be exposed directly or indirectly to contaminated soil. The Eco-SSL values for mammalian wildlife have been adopted for this study. The Eco-SSLs do not provide guideline values for sulfur, sulfate or phosphorous. Therefore, the former National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999) (Ref. 14) ecological investigation levels for these substances have been included for reference purposes in the absence of other more applicable ecological assessment criteria.

The Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) has developed a series of soil-screening values for contaminated sites as part of the Dutch Soil Protection Act (VROM 2000) (Ref. 15). Soil quality is assessed and managed using target and intervention values which are independent of land use. Soils with contaminant concentrations below target values are considered to be at no risk and no restrictions on their use have been set. Soils with contaminant concentrations exceeding the intervention values require remediation as a matter of urgency, as the functional properties of the soil for humans, plant and animal life is seriously impaired or threatened. Therefore, for preliminary screening purposes, the intervention values have been applied in this study. For certain substances where intervention values have

not been set, so-called “indicative levels for serious contamination” have been provided. These have also been included in this study, where appropriate.

The establishment of these soil quality screening values is to allow for evaluation only and it is not implied by production of these values that the Farim project will be required to meet these reference levels or that these reference levels should be used as the regulatory framework. The regulatory requirements for the project will be determined by the relevant regulatory authorities during the environmental design phase of the project.

2.5 RADIOMETRIC ANALYSIS OF SOLIDS

Radiometric analysis of the solid samples was conducted to assess and quantify the various radionuclides present in the Uranium-238 and Thorium-232 decay chain within the sample. The radiometric analysis was conducted by SGS (formerly Western Radiation Services), Perth. The samples were pulverized for homogeneity and sealed in a fixed geometry counting container. High resolution gamma spectrometry was used for the counting and analysis of different radionuclides present in the Uranium-238 and Thorium-238 decay chains, specifically Radium-226, Ra-228 and Pb-210, with gas flow proportional counting used for determining gross alpha and beta. Inductively Coupled Plasma Mass Spectrometry was used for the quantification of total uranium (U-234, U-235 and U-238) and Thorium-232.

The results of the radiometric analysis have been compared to the Canadian Guidelines for the Management of Naturally Occurring Radioactive Material (NORM) (Ref. 16). The Canadian Guidelines provide limits at which NORM may be released with no radiological restrictions. These limits, provided in Table 2.2 below, have been calculated to ensure that the associated radiation dose to the public would be no more than 0.3 mSv per annum. The radioactive hazard associated with this dose is considered insignificant, and no further controls on the material are necessary on radiological protection grounds. Where the activity exceeds the devised release limits for diffuse naturally occurring radioactive material, a site-specific radiation dose assessment needs to be carried out to estimate the doses to workers and members of the public, and to determine appropriate radiation protection measures.

Table 2.2: Derived release limits - diffuse NORM sources

NORM Radionuclide	Derived Release Limit (Bq/g)
Uranium-238 Series (all progeny)	0.3
Thorium-232	10
Radium-226 (in equilibrium with its progeny)	0.3
Radium-228 (in equilibrium with Ac-228)	0.3
Lead-210 (in equilibrium with Bi-210 and Po-210)	0.3

The ^{238}U and ^{232}Th results can also be compared to a wider array of international guidelines and legislation which specify different definitions of radioactive material to assess whether the tailings are likely to be classified as radioactive. The guideline values provided by the International Atomic Energy Agency (IAEA) (Ref. 17), Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (Ref. 18), Radiation Safety Act (Ref. 19) and Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM) (Ref. 16) are summarised in Table 2.3.

Table 2.3: Guideline Values for Classification of Radioactive Material

Guideline	^{238}U (All Progeny) Bq/g	^{232}Th (All Progeny) Bq/g
IAEA (International)	1	1
ARPANSA (Australia)	1	1
Radiation Safety Act (WA, Australia)	30	30
Management of NORM (Canada)	0.3	0.3

2.6 SUPERNATANT WATER QUALITY

Characterisation of the tailings supernatant has been conducted to assess the potential for the supernatant to cause environmental impacts to surface water or groundwater.

The pH and the conductivity of the tailings supernatant were measured and the bottles left to stand for a minimum of three hours. The supernatant was then filtered through 0.45 µm membrane before preservation of the solution by acid addition prior to analysis. The analysis was by ICP-MS or ICP-OES, depending on the element being analysed and the detection limits required.

The results have been compared to three sets of reference water quality standards, which are discussed in Section 2.7.

2.7 REFERENCE WATER QUALITY STANDARDS

To allow assessment of the results of the supernatant analysis a set of reference values has been established. These reference values were compiled from internationally accepted guidelines for water quality for release from mining operations (IFC environmental, health and safety guidelines (Ref. 20 and 21) and the ANZECC water quality guideline for livestock drinking water (Ref. 22)). The use of several guidelines is required as no single guideline contains target concentrations for all parameters. Where a target concentration for a specific element is at different levels in various guidelines, the lowest concentration has been adopted. These reference values are summarised in Table 2.4. The water quality results of the supernatant analysis have also been compared to Australian drinking water guidelines (Ref. 23) with the Australia drinking water guideline values provided in Table 2.5. Another useful assessment is to compare the supernatant results to baseline surface water and groundwater monitoring data. A summary of the baseline data, which is taken from the environmental and social baseline studies report (Ref. 24) is presented in Table 2.6.

The establishment of these reference water quality values is to allow for evaluation only and it is not implied by production of the reference water quality values that the Farim project will be required to meet these reference levels or that these reference levels should be used as the regulatory framework. The regulatory requirements for the project will be determined by the relevant regulatory authorities during the environmental design phase of the project.

Table 2.4: Reference Guidelines for Water Release and Livestock Drinking Water

Parameter	Units	ANZECC Livestock	IFC 2004	IFC 2007	Adopted Reference Level
pH	pH Units		6 to 9	6 to 9	6 to 9
TDS	mg/kg	2000			2000
Aluminum	mg/L	5			5
Antimony	mg/L				N/G
Arsenic	mg/L	0.5	0.1	0.1	0.1
Barium	mg/L				N/G
Boron	mg/L	5			5
Cadmium	mg/L	0.01	0.1	0.05	0.01
Calcium	mg/L	1000			1000
Chloride	mg/L				N/G
Chromium	mg/L	1			1
Cobalt	mg/L	1			1
Copper	mg/L	0.4	0.5	0.3	0.3
Fluoride	mg/L	2	20		2
Iron	mg/L		3.5	2	2
Lead	mg/L	0.1	0.1	0.2	0.1
Magnesium	mg/L	2000			2000
Manganese	mg/L				N/G
Mercury	mg/L	0.002	0.01	0.002	0.002
Molybdenum	mg/L	0.15			0.15
Nickel	mg/L	1	0.5	0.5	0.5
Phosphate	mg/L				N/G
Selenium	mg/L	0.02	0.1		0.02
Silver	mg/L		0.5		0.5
Sodium	mg/L				N/G
Sulfate	mg/L	1000			1000
Tin	mg/L				N/G
Uranium	mg/L	0.2			0.2
Vanadium	mg/L				N/G
Zinc	mg/L	20	2	0.5	0.5

N/G – No guideline

Table 2.5: Australian Drinking Water Guidelines

Parameter	Units	Health	Aesthetic	Adopted Reference Level
pH	pH Units		6.5 to 8.5	6.5 to 8.5
TDS	mg/kg		600	600
Aluminum	mg/L		0.2	0.2
Antimony	mg/L	0.003		0.003
Arsenic	mg/L	0.01		0.01
Barium	mg/L	2.0		2.0
Boron	mg/L	4		4
Cadmium	mg/L	0.002		0.002
Calcium	mg/L			N/G
Chloride	mg/L		250	250
Chromium	mg/L			N/G
Cobalt	mg/L			N/G
Copper	mg/L	2	1	1
Fluoride	mg/L	1.5		1.5
Iron	mg/L		0.3	0.3
Lead	mg/L	0.01		0.01
Magnesium	mg/L			N/G
Manganese	mg/L	0.5	0.1	0.1
Mercury	mg/L	0.001		0.001
Molybdenum	mg/L	0.05		0.05
Nickel	mg/L	0.02		0.02
Phosphate	mg/L			N/G
Selenium	mg/L	0.01		0.01
Silver	mg/L	0.1		0.1
Sodium	mg/L		180	180
Sulfate	mg/L	500	250	250
Tin	mg/L			N/G
Uranium	mg/L	0.02		0.02
Vanadium	mg/L			N/G
Zinc	mg/L		3	3

N/G – No guideline

Table 2.6: Average Surface Water and Groundwater Quality

Parameter	Units	Surface Water	Groundwater
pH	pH Units	7.1	6.4
TDS	ppm	2527	293
EC	µS/cm	3905	1334
Arsenic	mg/L	0.001	0.002
Calcium	mg/L	41	45
Cadmium	mg/L	0.0001	0.0002
Chloride	mg/L	1337	96
Chromium	mg/L	0.002	0.001
Copper	mg/L	0.005	0.01
Iron	mg/L	0.20	1.3
Mercury	mg/L	0.00002	N/M
Potassium	mg/L	25	2.8
Magnesium	mg/L	78	15.9
Manganese	mg/L	0.05	0.34
Sodium	mg/L	769	42
Nickel	mg/L	0.002	0.002
Lead	mg/L	0.002	0.001
Phosphate	mg/L	0.14	0.15
Sulfate	mg/L	120	28
Zinc	mg/L	0.01	0.06

N/M – Not measured

3. TAILINGS GEOCHEMICAL RESULTS

3.1 INTRODUCTION

Laboratory test certificates for the tailings analytical testing conducted are provided in Appendix B. The results are presented and discussed in the following sections. As part of the quality control and assurance programme conducted by Intertek Genalysis, duplicates of all tests were conducted on the tailings sample. In addition, duplicate analysis of chromium, copper, nickel and zinc were conducted using an ICP-OES instrument in addition to the ICP-MS instrument specified. SGS also conducted duplicate analysis of radium-226, radium-228, gross alpha and gross beta on the tailings sample. The results presented in the following sections are the average of the original and duplicate tests.

It should be noted that this assessment of the tailings geochemistry does not include assessment of residual process chemicals which may be present within the tailings slurry. However, should it be foreseeable under normal operating conditions that release of tailings slurry or supernatant into any waterways could occur, a detailed assessment of the residual process chemicals is recommended. This detailed assessment will require input from the process chemical supplier to determine the most appropriate laboratory methods to analyse for the specific process chemicals to be used in ore beneficiation.

3.2 ACID BASE ACCOUNTING

Total sulfur content of the tailings was determined by LECO combustion. In addition, the sample was analysed for HCl soluble sulfate. The difference between these two values was assumed to be equal to the sulfide content of the sample. The results of the analysis indicate a high sulfur content of 1.09% and moderate sulfate concentration of 0.49%. Consequently, the sulfide content was calculated as 0.61% and the maximum potential acidity (MPA) at 18.5 kg H_2SO_4 / tonne of tailings, which is high.

The acid neutralising capacity (ANC) of the sample was determined along with the carbonate content. The two results can be used as a check against one another and to identify the contribution of ANC from carbonates and other non-carbonate minerals. The results of the analysis indicate a very high carbonate content of 6.7%. Accordingly the ANC values were also very high, although the measured ANC was found to be approximately twice that of the ANC calculated as being available from carbonate minerals. This indicates that additional buffering capacity may be available from non-carbonate minerals or residual alkalinity in the tailings solids.

The Net Acid Producing Potential (NAPP) of the tailings was calculated from the MPA and the ANC along with the ANC/MPA ratio. The net acid producing potential was

strongly negative (-110 kg H_2SO_4 / t) with an ANC/MPA ratio of 7, indicating significant excess neutralising capacity. Further, the ratio of carbonate ANC to MPA was 3.5, indicating that carbonate minerals alone would likely provide excess neutralising capacity.

All acid base accounting results are presented in Table 3.1.

3.3 NET ACID GENERATION

The net acid generation (NAG) test aids in interpretation of the acid formation potential. It also identifies whether the sulfides and neutralising minerals contained in the samples are readily available to produce or consume acid.

The results of the NAG test are given in Table 3.1 and indicate that following extreme oxidising conditions, the final pH of the NAG solution was pH 4.7. This is only marginally above the Potentially Acid Forming (PAF) cut-off of pH 4.5, which does not correlate well with the acid base accounting results which indicate significant excess neutralising capacity is available from both carbonate and non-carbonate minerals. However, the results indicate that the sample contains around 0.37% organic carbon. Therefore, organic acids may be being generating due to partial oxidation of carbonaceous materials when exposed to hydrogen peroxide. To verify this interference from organic carbon, an extended boil NAG test was conducted. This extended boil NAG includes a secondary boiling step to overcome the effects of organic carbon. The extended NAG test indicated a final pH after additional boiling of 5.4, which provides a better fit with the acid base accounting results. As such, the results of the extended boil NAG test suggest the presence of organic carbon did lead to overestimation of the pyrite derived acidity using the standard test procedure. Therefore, caution should be applied if the standard static NAG test is to be used to characterise tailings at the project in future studies or during operations.

3.4 ACID FORMATION POTENTIAL

The acid formation potential of the sample is determined based on the acid base accounting results and the NAG test. The tailings recorded a strongly negative net acid producing potential of -110 kg H_2SO_4 / t and NAG pH value of 4.7. Therefore, the tailings would be classified as Acid Consuming, given the very low NAPP, as shown in Figure 3.1. However, it would be unusual for an acid consuming sample to have a NAG pH as low as 4.7. Conversely, when adopting the results from the extended boil NAG test, the final NAG pH was 5.4, which indicates that the acid consuming classification is indeed correct. This classification based on the extended boil NAG is also shown in Figure 3.1.

Table 3.1: Tailings Acid Base Accounting and NAG Results

Sulfur Species			Paste pH	ANC	Carbon Species				Calculations			NAG			AFP
Total-S	Sulfate-S	Sulfide-S			Total C	TIC	Calcite Equivalent	$CaCO_3$-ANC	MPA	ANC/MPA	NAPP	NAG (7.0)	NAG pH	NAG $_{ExB}$ pH	
%	%	%	None	kg H_2SO_4/t	%	%	%	kg H_2SO_4/t	kg H_2SO_4/t	N/A	kg H_2SO_4/t	kg H_2SO_4/t	None	None	
1.09	0.49	0.61	7	129	1.17	0.80	6.67	65	18.5	7	-110	1	4.7	5.4	AC

3.5 MULTI-ELEMENT RESULTS

3.5.1 Element Enrichments

Whole rock multi-element analysis of the tailings solids was conducted to assess elemental enrichments within the solid fraction of the tailings material. Multi-element analysis results were compared to the average crustal abundance to give the geochemical abundance indices. The Geochemical Abundance Index (GAI) quantifies an assay result for a particular element in terms of average crustal abundance.

The assay results, average crustal abundance (ACA) and corresponding geochemical abundance indices (GAI) are provided in Table 3.2. The results of the analysis indicate the tailings to have moderate levels of enrichment, with cadmium, phosphorous and selenium found to be highly enriched. In addition, silver, fluoride, sulfur, antimony and uranium were found to be significantly enriched, with arsenic, bismuth, chromium and lead slightly enriched.

3.5.2 Preliminary Soil Quality Screening

The results of the analysis have also been compared to a set of soil quality screening guidelines for human health and ecology and are summarised in Table 3.3.

The multi-element results met the human health criteria for recreational land use, indicating that the TSF could likely be rehabilitated as undeveloped public space without posing an unacceptable risk to human health. However, the tailings did not meet the ecological guideline values for antimony, cadmium, chromium, copper, lead, nickel, phosphorous, selenium, sulfur, sulfate, vanadium and zinc. Further, the concentrations of cadmium, chromium and vanadium exceeded the intervention values for soil, indicating that an engineered cover system will be required on closure to isolate the tailings from the environment. This is discussed further in Section 4.

Table 3.2: Tailings Multi-Element Results and Geochemical Abundance Indices

Element	Unit	Multi-Element Analysis Results	Average Crustal Abundance	Geochemical Abundance Index
Ag	ppm	1.5	0.07	3
Al	ppm	30080	82000	0
As	ppm	15.5	1.5	2
B	ppm	50	10	1
Ba	ppm	55	500	0
Be	ppm	2.5	2.6	0
Bi	ppm	0.4	0.048	2
Ca	ppm	243155	41000	1
Cd	ppm	21.65	0.11	6
Cl	ppm	200	130	0
Co	ppm	32.5	20	0
Cr	ppm	1077	100	2
Cu	ppm	78	50	0
F	ppm	25061	950	4
Fe	ppm	20800	41000	0
Hg	ppm	0.07	0.05	0
K	ppm	1448	21000	0
Mg	ppm	2450	23000	0
Mn	ppm	198	950	0
Mo	ppm	4.1	1.5	0
Na	ppm	1309.5	23000	0
Ni	ppm	172	80	0
P	ppm	104569	1000	6
Pb	ppm	111	14	2
S	ppm	10900	260	4
Sb	ppm	7.0	0.2	4
Se	ppm	21.7	0.05	6
Sn	ppm	0.8	2.2	0
Sr	ppm	1060	370	0
Th	ppm	13.7	12	0
U	ppm	107	2.4	4
V	ppm	529	160	1
Zn	ppm	422	75	1

Not Enriched
Slightly Enriched
Significantly Enriched
Highly Enriched

Table 3.3: Tailings Multi-Element Results and Soil Screening Guidelines

Element	Human Health-Based Investigation Levels [1] (ppm)	Ecological Soil Screening Levels [2,3] (ppm)	Soil Remediation Intervention Values [4] (ppm)	Multi-Element Analysis Results (ppm)
Antimony		**0.27**	15	7.0
Arsenic	300	46	55	15.5
Barium		2000	625	54.7
Beryllium	90	21	30	2.5
Boron	20,000			50
Cadmium	90	**0.36**	**12**	21.65
Chromium III		**34**	**380**	1077
Chromium IV	300	130		0.2
Cobalt	300	230	240	32.5
Copper	17,000	**49**	190	78
Lead	600	**56**	530	111
Manganese	19,000	4000		198
Mercury	80		10	0.07
Molybdenum			200	4.1
Nickel	1,200	**130**	210	172
Phosphorus		**2000**		104569
Selenium	700	**0.63**	100	21.7
Silver		14	15	1.5
Sulfur		**600**		10900
Sulfate		**2000**		4850
Tin			900	0.8
Vanadium		**280**	**250**	529
Zinc	30,000	**79**	720	422

Notes:

[1] National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1). Health Investigation Levels for Soil Contaminants, Generic Land Use HIL C – Recreational.

[2] United States Environmental Protection Agency (U.S. EPA) Ecological Soil Screening Levels (Eco-SSLs), http://www.epa.gov/ecotox/ecossl/ (mammalian wildlife).

[3] Ecological guideline values for phosphorous, sulfur and sulfate are based on National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999). These former Australian ecological investigation levels for urban areas have been included for reference purposes in the absence of other more applicable ecological assessment criteria.

[4] Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) 2000. Circular on Target Values and Intervention Values for Soil Remediation, Reference DBO/1999226863. Soil remediation intervention values. In the absence of intervention values for beryllium, selenium, silver, tin and vanadium, "indicative levels for serious soil contamination" have been applied.

Values in red bold indicate where a guideline value has been exceeded.

3.6 RADIOMETRIC RESULTS OF TAILINGS SOLIDS

The results of the tailings solids radiometric analyses are summarised in tables 3.4 and 3.5 and indicate that the tailings exceeded the NORM guideline levels for uranium (U-

238 series) and radium-226 activity. However, comparing the uranium and thorium data to a wider range of guidelines for the classification of radioactive materials, only the Canadian NORM guidelines are exceeded. Therefore, the classification of tailings material in terms of radioactive risk will likely depend on the guidelines adopted for environmental permitting. This is discussed further in Section 4.

Table 3.4: Tailings Solids Radiometric Results Compared to NORM Guidelines

Parameter	Unit	Guideline Values	Activity
Gross Alpha	(Bq/g)	N/G	0.275 (+/- 0.030)
Gross Beta	(Bq/g)	N/G	8.02 (+/- 0.56)
Ra-226	(Bq/g)	0.3	**0.735** (+/- 0.058)
Ra-228	(Bq/g)	0.3	0.055 (+/- 0.009)
Pb-210	(Bq/g)	0.3	0.127 (+/- 0.009)
Th-228	(Bq/g)	N/G	0.033 (+/- 0.005)
Total U[1]	(Bq/g)	0.3	**0.738** (+/- 0.56)
Total Th[2]	(Bq/g)	10	0.061 (+/- 0.017)

Notes:
[1]Total uranium represents U-234, U-235 and U-238 calculated from ICPMS data.
[2]Total thorium represents Th-232 calculated from ICPMS data.
N/G: No guideline.

Table 3.5: Tailings Solids Radiometric Results Compared Guideline Values for Classification of Radioactive Material

Parameter	Units	Assay Result	IAEA (International)	ARPANSA (Australia)	Radiation Safety Act (WA)	Management of NORM (Canada)
^{238}U (All Progeny)	Bq/g	0.738 (+/- 0.56)	1	1	30	**0.3**
^{232}Th (All Progeny)	Bq/g	0.061 (+/- 0.017)	1	1	30	0.3

Notes:
[1]Assay result for uranium represents U-234, U-235 and U-238 calculated from ICPMS data.
[2]Assay result for thorium represents Th-232 calculated from ICPMS data.

3.7 SUPERNATANT RESULTS

The results of the supernatant analysis compared to various reference values are provided in the following sections.

3.7.1 Comparison to Guidelines for Release and Livestock Drinking Water

The results of the supernatant testing have been compared to a reference set of water quality guidelines as a means of assessing the risk to surface waters from supernatant

release. However, comparison to background surface water quality data should also be considered, as provided in Section 3.7.3.

As shown in Table 3.6, the supernatant water quality was found to meet the reference water quality values for surfaces waters, indicating that the supernatant may be of a suitable quality to be released from site without treatment, subject to baseline surface water quality. This is discussed further in Section 4.4.

In the absence of a release guideline value for phosphorous or phosphate, the results have also been compared to the ANZECC guidelines for aquatic protection (Ref. 22) in relation to total phosphorous and filterable reactive phosphate. The most applicable values are those for lowland rivers in tropical regions with slightly disturbed ecosystems. The guideline trigger values for aquatic protection for total phosphorous and filterable reactive phosphate (FRP) are 0.01 mg/L and 0.004 mg/L respectively, compared to measured supernatant values of between <0.05 mg/L and 0.08 mg/L for total phosphorous and <0.005 mg/L for FRP. Based on these results the concentration of total phosphorous in the supernatant may have a negative impact on lowland rivers, depending on the degree of dilution which occurs. This is discussed further in Section 4.

3.7.2 Comparison to Australian Drinking Water Guidelines

The results of the analysis have also been compared to Australian drinking water standards. These can be used to assess risk to groundwater and any nearby abstractions from supernatant release. However, comparison to background groundwater quality data should also be considered, as discussed in Section 3.7.3.

The results indicate that TDS, iron, manganese, nickel and sulfate exceed the drinking water guidelines, as shown in Table 3.7. The element recording the highest exceedance was nickel followed by manganese. Based on these results, the TSF will require controls to limit seepage flows from entering groundwater or surface water bodies where abstraction for drinking water is occurring. This is discussed further in Section 4.

3.7.3 Comparison to Baseline Surface Water and Groundwater Quality

The supernatant assay results have also been compared to baseline data for surface water and groundwater, as shown in Table 3.8. The results of this comparison indicate that the supernatant is of a poor quality compared to baseline conditions and, as such, the TSF will require seepage control measures and sufficient flood storage capacity to limit supernatant release. This is discussed further in Section 4.

Table 3.6: Supernatant Results Compared to Reference Surface Water Guidelines

Parameter	Units	Reference Release Value	Assay Results
pH	pH Units	6 – 9	7.6
TDS	mg/L	2000	605
Aluminium	mg/L	5	0.01
Antimony	mg/L	N/G	0.0004
Arsenic	mg/L	0.1	0.001
Barium	mg/L	N/G	0.03
Boron	mg/L	5	0.01
Cadmium	mg/L	0.01	0.001
Calcium	mg/L	1000	145
Chloride	mg/L	N/G	20.5
Chromium	mg/L	1	0.01
Cobalt	mg/L	1	0.12
Copper	mg/L	0.3	0.01
Fluoride	mg/L	2	0.4
Iron	mg/L	2	0.37
Lead	mg/L	0.1	0.002
Magnesium	mg/L	2000	13
Manganese	mg/L	N/G	0.60
Mercury	mg/L	0.002	0.0001
Molybdenum	mg/L	0.15	0.001
Nickel	mg/L	0.5	0.33
Phosphorus[1]	mg/L	0.01	**0.07**
FRP[1]	mg/L	0.004	**0.005**
Selenium	mg/L	0.02	0.001
Silver	mg/L	0.5	0.00001
Sodium	mg/L	N/G	21.7
Sulfate[2]	mg/L	1000	326
Tin	mg/L	N/G	0.00
Uranium	mg/L	0.2	0.002
Vanadium	mg/L	N/G	0.01
Zinc	mg/L	0.5	0.06

Notes:

N/G - no guideline value.

[1] Guideline values for total phosphorous and filterable reactive phosphate based on ANZECC guidelines for aquatic protection (Ref. 22).

[2] Assay results for sulfate estimated based on sulfur.

Table 3.7: Supernatant Results Compared to Australian Drinking Water Guidelines

Parameter	Units	Drinking Water Guideline	Assay Results
pH	pH Units	8.5	7.6
TDS	mg/L	2000	**605**
Aluminium	mg/L	0.2	0.01
Antimony	mg/L	0.003	0.0004
Arsenic	mg/L	0.01	0.001
Barium	mg/L	2	0.03
Boron	mg/L	4	0.01
Cadmium	mg/L	0.002	0.001
Calcium	mg/L	N/G	145
Chloride	mg/L	250	20.5
Chromium	mg/L	N/G	0.01
Cobalt	mg/L	N/G	0.12
Copper	mg/L	1	0.01
Fluoride	mg/L	1.5	0.4
Iron	mg/L	0.3	**0.37**
Lead	mg/L	0.01	0.002
Magnesium	mg/L	N/G	13
Manganese	mg/L	0.1	**0.60**
Mercury	mg/L	0.001	0.0001
Molybdenum	mg/L	0.05	0.001
Nickel	mg/L	0.02	**0.33**
Phosphorus	mg/L	N/G	0.07
Selenium	mg/L	0.01	0.001
Silver	mg/L	0.1	0.00001
Sodium	mg/L	180	21.7
Sulfate[1]	mg/L	250	**326**
Tin	mg/L	N/G	0.00
Uranium	mg/L	0.017	0.002
Vanadium	mg/L	N/G	0.01
Zinc	mg/L	3	0.06

Notes:

N/G - no guideline value.

[1] Assay results for sulfate estimated based on sulfur.

Table 3.8: Supernatant Results Compared to Surface Water and Groundwater Quality

Parameter	Units	Surface Water	Groundwater	Assay Results
pH	pH Units	7.1	6.4	7.6
TDS	ppm	2527	**293**	605
EC	µS/cm	3905	1334	780
Arsenic	mg/L	0.0009	0.0018	0.0007
Calcium	mg/L	**40.8**	**45.3**	145
Cadmium	mg/L	**0.0001**	**0.0002**	0.0005
Chloride	mg/L	1337	96	20.5
Chromium	mg/L	**0.002**	**0.001**	0.01
Copper	mg/L	**0.005**	0.015	0.01
Iron	mg/L	**0.20**	1.30	0.37
Mercury	mg/L	**0.00002** [3]	N/M	0.0001
Potassium	mg/L	25.3	**2.8**	2.9
Magnesium	mg/L	77.5	15.9	12.6
Manganese	mg/L	**0.05**	**0.34**	0.60
Sodium	mg/L	769	42	22
Nickel	mg/L	**0.002**	**0.002**	0.33
Lead	mg/L	**0.0003** [3]	**0.001**	0.002
Phosphate [1]	mg/L	0.14	0.15	0.005
Sulfate [2]	mg/L	**120**	**28**	326
Zinc	mg/L	**0.01**	**0.06**	0.06

Notes:

N/M – Not Measured.

Values in red bold indicate where a baseline concentration has been exceeded.

[1] Assay result for phosphate based on filterable reactive phosphate test.

[2] Assay result for sulfate estimated based on sulfur.

[3] Not measured above detection limit.

4. IMPLICATIONS FOR TAILINGS MANAGEMENT

4.1 ACID FORMING POTENTIAL

The tailings were found to be Acid Consuming. This is based on a very high ANC, despite being high in sulfide sulfur, resulting in a strongly negative NAPP and final pH in the NAG test of 4.7. Further, the extended boil NAG indicates that the NAG pH resulting from pyrite oxidation alone (i.e. without interference from organic acids) is likely to be around pH 5.4. This indicates that sufficient neutralising capacity exists under circum neutral pH conditions to buffer any acid formed from sulfide oxidation. As such, there is no perceived risk from acidification of the tailings and there are no specific controls required. However, the high sulfide content of the tailings has the potential to lead to high sulfate and saline drainage. This has been considered in the design of seepage protection measures outlined in Section 4.4, although long term leach tests would be required to fully assess this risk.

4.2 MULTI-ELEMENT ENRICHMENT

The results of the analysis indicate that the tailings have moderate levels of element enrichment, with cadmium, phosphorous and selenium found to be highly enriched. In addition, silver, fluoride, sulfur, antimony and uranium were found to be significantly enriched, with arsenic, bismuth, chromium and lead slightly enriched.

The tailings did not meet the ecological soil screening guidelines, with several metals also exceeding the remediation intervention values. Therefore, during operations the facility must be designed and operated in such a way as to fully contain the tailings solids and minimise dusting. On closure, a cover system will be required to isolate the tailings from the environment. From a multi-element perspective, this would likely comprise a basic store and release cover, consisting of a coarse rockfill layer to form a capillary break and prevent upward migration of salts, overlain by rock mulch for storage of rain water and capped with a growth medium to aid re-vegetation. The closure cover system should also be domed such that once the rock mulch storage layer is fully saturated, excess water will flow towards and over the spillway rather than through the consolidated tailings. However, consideration must also be given to the radiometric results.

4.3 TAILINGS RADIOMETRICS

The tailings solids radiometric analyses indicated that the activity of certain radionuclides exceed the activity guidelines set out in the NORM guidelines and, therefore, a site-specific radiation dose assessment is recommended to determine whether radiation control measures are required during operations and post closure. This radiation dose assessment should consider external gamma and beta irradiation

(including skin contamination), inhalation of dust and gases such as radon and/or thoron and ingestion of tailings solids. The dose to both site personnel and local residents should be assessed in the study.

On closure it is envisaged that the store and release cover system outlined in Section 4.2 will also require a basal low permeability layer constructed of low permeability soils (placed at a high moisture content and compacted to minimise gas diffusion) or a geomembrane with low gas permeability to attenuate radon/thoron release into the upper cover layers and atmosphere. However, detailed cover design should be conducted based on the results of the radiation dose assessment.

It is also envisaged that operating procedures that reduce dust formation should be adopted for the tailings storage facility. This will most likely entail a deposition strategy designed to allow the tailings to dry but limit the amount of desiccation to a level above which dust generation from the tailings beach surface starts to occur. The effectiveness of these operational controls should be verified with dust monitoring around the tailings storage facility. Detailed design of the operational procedures and monitoring should be based on the results of the radiation dose assessment.

4.4 SUPERNATANT QUALITY

The supernatant sample was found to be of a reasonable quality, but did not meet all guideline concentrations and was found to exceed baseline surface water and groundwater concentrations for several parameters. As such, the tailings storage facility will require controls to limit seepage to surface water and groundwater. This will likely comprise an engineered low permeability liner across the base and sides of the facility, and a storage capacity sufficient to contain all stormwater run-off within the adopted design standard. An underdrainage system constructed over the basal liner will also reduce the hydraulic head acting on the liner to further reduce seepage.

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this geochemical study, the following conclusions and recommendations are made:

5.1 CONCLUSIONS

- There is no perceived risk from acidification of the tailings.
- The results of the analysis indicate that the tailings have moderate levels of element enrichment, with cadmium, phosphorous and selenium found to be highly enriched.
- The tailings did not meet the ecological soil screening guidelines, with several metals also exceeding the remediation intervention values.
- The tailings solids radiometric analyses indicated that the activity of certain radionuclides exceed the activity guidelines set out in the NORM guidelines.
- The supernatant sample was found to be of a reasonable quality, but did not meet all guideline concentrations and was found to exceed baseline surface water and groundwater concentrations for several parameters.

5.2 RECOMMENDATIONS

- There are no specific controls required for the control of acid generations within the tailings, although the high sulfide content has the potential to lead to high sulfate and saline drainage, which has been considered in the design of seepage protection measures.
- Based on the multi-element and radiometric results, operating procedures that reduce dust formation should be adopted for the tailings storage facility.
- On closure, it is envisaged that a store and release cover system will be required to isolate the high metal concentrations recorded in the tailings solids from the environment. Also, given the radiometric results, the cover system will require a basal low permeability layer constructed to attenuate radon/thoron release into the upper cover layers and atmosphere.
- A site-specific radiation dose assessment is recommended to allow detailed design of the operational and closure control measures with regards to radiation risk to site personnel and local residents.
- An engineered low permeability liner is recommended across the base and sides of the facility to limit seepage, together with an above-liner underdrainage system across the base. The storage capacity of the facility should be sufficient to contain all stormwater run-off resulting from the design rainfall event.

6. REFERENCES

1. Knight Piésold (2015). Tailings Geochemical Characterisation – Preliminary Report. Document Ref. PE301-00520/05 Rev. A issued 15th May 2015.
2. Mine Environment Neutral Drainage (MEND) Program (1991). Acid Rock Drainage Prediction Manual. Mend Project 1.16.16.
3. British Columbia Ministry of Energy and Mines (August 1998). Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia.
4. Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M. (1978). Field and laboratory methods applicable to overburden and mine soils, EPA 600/2-78-054.
5. Miller, S., Robertson A., Donohue, T. (1997). Advances in acid drainage prediction using the net acid generation test. In Proceedings of the Forth International Conference on Acid Rock Drainage (Vancouver B.C.) pp 535 - 547.
6. Stewart, W., Miller, S., Smart, R., Gerson, A., Thomas, J., Skinner, W., Levay, G. and Schumann, R. (2003). Evaluation of the Net Acid Generation (NAG) Test for Assessing the Acid Generating Capacity of Sulfide Minerals. In Proceeding of the Sixth international conference on Acid Rock Drainage (Cairns, Australia) pp 617 - 625.
7. Environmental Geochemistry International (June 2008). Extended Boil and Calculated Net Acid Generation (Calculated NAG) Test Procedure for Coal Washery Wastes.
8. Australian Government, Department of Industry, Tourism and Resources (February 2007). Managing Acid and Metalliferous Drainage.
9. AMIRA International (May 2002). ARD Test Handbook.
10. The International Network for Acid Prevention (INAP) (2009). Global Acid Rock Drainage Guide (GARD Guide). http://www.gardguide.com/
11. Bowen, H.J.M. (1979). Environmental Chemistry of the Elements. Academic Press, New York.
12. Australian Government (2013). National Environment Protection (Assessment of Site Contamination) Amendment Measure.
13. United States Environmental Protection Agency (U.S. EPA) Ecological Soil Screening Levels (Eco-SSLs), http://www.epa.gov/ecotox/ecossl/.

14. NEPC (1999). National Environment Protection (Assessment of Site Contamination) Measure.

15. VROM (2000), Circular on Target Values and Intervention Values for Soil Remediation, Reference DBO/1999226863, Ministry of Housing, Spatial Planning and the Environment, Bilthoven, Netherlands.

16. Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM), October 2000. Prepared by the Canadian NORM Working Group of the Federal Provincial Territorial Radiation Protection Committee.

17. International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources, Safety Series No.115, International Atomic Energy Agency (IAEA), Vienna, 1996.

18. Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Minerals Processing, Radiation Protection Series Publication No.9, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2005.

19. The Radiation Safety Act, 1975. Western Australian Legislation.

20. IFC (2004). IFC Environmental, Health and Safety Guidelines for Precious Metal Mining (Draft).

21. IFC (2007) IFC Environmental, Health and Safety Guidelines for Mining.

22. ANZECC / ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

23. NHMRC, NRMMC (2011). Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

24. Golder Associates (2014). Mine Component Environmental and Social Baseline Studies. Report No. 13514950200.550-1/B.0. Issued 21 February 2014.

FIGURE

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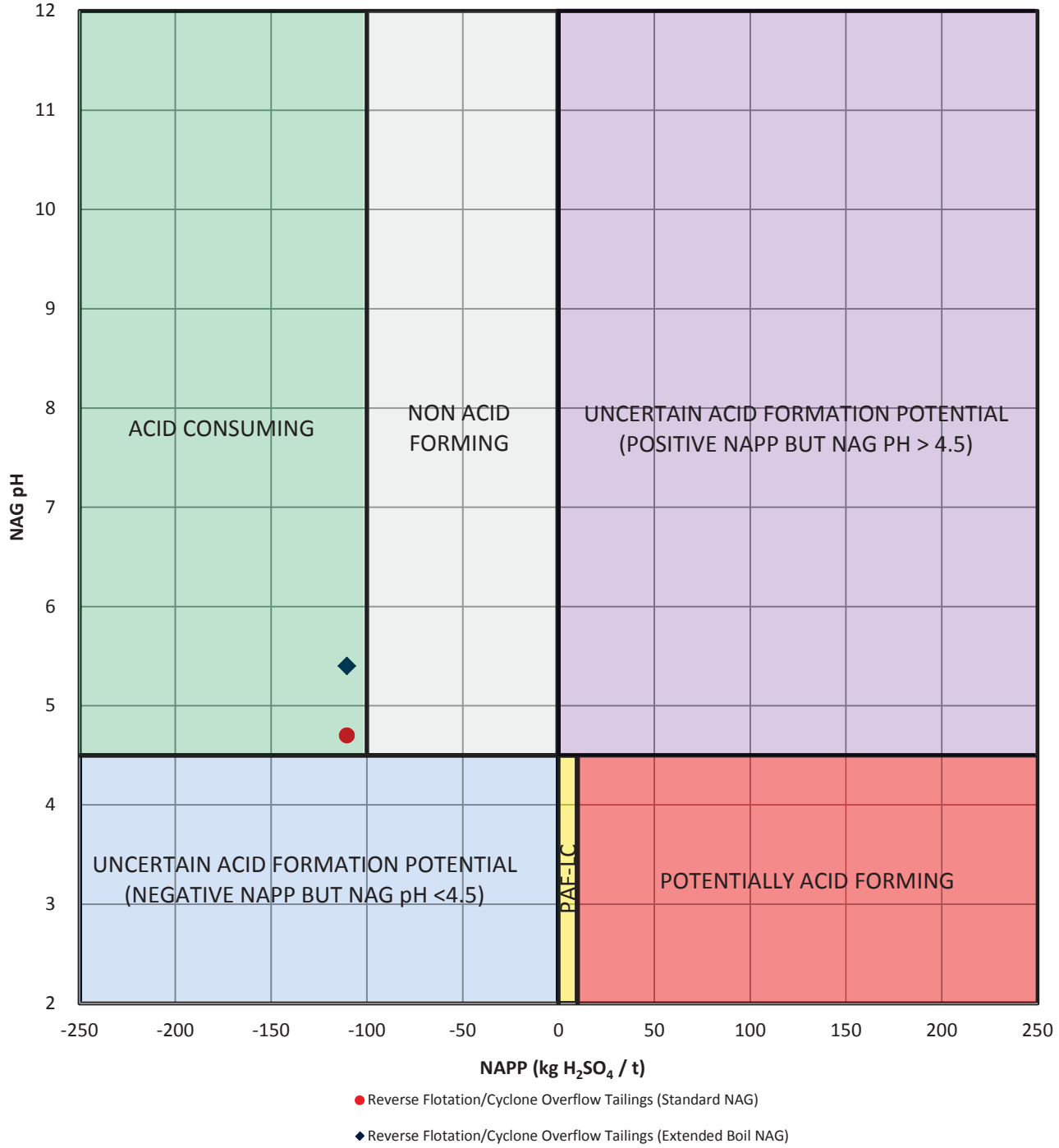
Acid Formation Potential



Acid Formation Potential	NAPP (kg H_2SO_4 / t)	NAG pH
Potentially Acid Forming (PAF)	>10	<4.5
Potentially Acid Forming - Low Capacity (PAF - LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than - 100	≥4.5
Uncertain	Positive	≥4.5
	Negative	<4.5

APPENDIX A

Tailings Geochemical Characterisation – Preliminary Report

Knight Piésold
CONSULTING

GB MINERALS LIMITED
FARIM PHOSPHATE PROJECT

TAILINGS GEOCHEMICAL CHARACTERISATION PRELIMINARY REPORT

PREPARED FOR:

Lycopodium Minerals Canada Ltd.
5060 Spectrum Way, Suite 302,
Mississauga,
ON L4W 5N5
CANADA

PREPARED BY:

Knight Piésold Pty Limited
Level 1, 184 Adelaide Terrace
East Perth, WA 6004, AUSTRALIA
p. +61 9223 6300 • f. +61 9223 6399

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Knight Piésold
CONSULTING
www.knightpiesold.com

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LYCOPODIUM MINERALS CANADA LTD

FARIM PHOSPHATE PROJECT

TAILINGS GEOCHEMICAL CHARACTERISATION PRELIMINARY REPORT

KP Project No.: PE301-00520/04

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Intertek Genalysis Laboratory Certificates

DEFINITION OF TECHNICAL TERMS

Acronym or Symbol	Parameter	Brief Description	Determination / Source	Unit
ACA	Average Crustal Abundance	Average concentration of a particular element in Earth's crust.	References	ppm
AFP	Acid Formation Potential	The potential of a material to form acid.	Calculation	N/A
ANC	Acid Neutralising Capacity	A materials ability to neutralise acid generally through mineral dissolution.	Analysis Result	kg H_2SO_4/tonne
ARD	Acid Rock Drainage	Acid metal rich leachate resulting from sulphide oxidation.		N/A
C_n	Element Concentration	Measure of concentration of an element in a particular sample.	Analysis Result	ppm or %
CRS	Chromium Reducible Sulphur	A laboratory test to determine the sulphide content of a sample	Analysis Result	ppm or %
EC	Electrical Conductivity	A measure of electrical current transported by the ions in solution.	Analysis Result	mS/cm
GAI	Geochemical Abundance Index	A scale of enrichment based on C_n and ACA.	Calc.(GAI = Log_2 (C_n / (1.5 x ACA))	None
MPA	Maximum Potential Acidity	The max. amount of acid which can be produced by oxidisation of contained sulphides.	Calc.(MPA = Sulphide-S x 30.6)	kg H_2SO_4/tonne
NAF	Non Acid Forming	Material does not produce acid either as a result of low sulphide contents or due to excess acid neutralising capacity.	Calculation	N/A
NAG	Net Acid Generation	A direct measure of acid production under extreme oxidising conditions.	Analysis Result	kg H_2SO_4/tonne
NAPP	Net Acid Producing Potential	The balance between MPA and ANC.	Calc.(NAPP = ANC – MPA)	kg H_2SO_4/tonne
HCl	Hydrochloric Acid	A mineral acid.		N/A
H_2O_2	Hydrogen Peroxide	A strong oxidising agent.		N/A
H_2SO_4	Sulphuric Acid	A mineral acid.		N/A
PAF	Potentially Acid Forming	Material has potential to produce acid through sulphide oxidation.	Calculation	N/A
Sulphate-S	Sulphate Sulphur	The sulphur present in the oxidised state.	Result	%
Sulphide-S	Sulphide Sulphur	The sulphur present in the reduced state.	Calc.(Sulphide-S = Total-S – Sulphate-S)	%
TDS	Total Dissolved Solids	A measure of the total amount of material dissolved in a solution.	Analysis Result	ppm
Total-S	Total Sulphur	The total amount of sulphur present.	Analysis Result	%

1. INTRODUCTION

1.1 GENERAL

The Farim Phosphate Project is being developed by GB Minerals Ltd (GBML). Knight Piésold Pty Ltd (KP) was engaged by Lycopodium Minerals Canada Ltd. (Lyco) to provide engineering services as part of the feasibility study (FS), comprising geotechnical site investigations and assessment of the proposed sites of the tailings storage facility and process plant, geotechnical assessment of the proposed port site, feasibility level design of the tailings storage facility, an hydrogeological and de-watering assessment for the south open pit, a waste rock geochemical assessment study, and surface water management design for the project site.

This report presents the findings of the preliminary tailings geochemical assessment.

1.2 PROJECT DESCRIPTION AND GEOLOGY

The Farim project site is located in the north of Guinea-Bissau, approximately 25 km south of the Senegal border, 5 km west of the town of Farim and 120 km north-east of Bissau, the capital of Guinea-Bissau. The project will comprise an open pit mining operation with two separate pits.

A summary of the geology is taken from Golder Associates Report No. 11514950096.515/B.0, as follows:

“The project comprises a high grade phosphate deposit which occurs within the Middle Eocene Lutetian Formation in a Cenozoic sedimentary basin that extends from Morocco in the north through Mauritania, Senegal, Guinea-Bissau and into Guinea to the south. The basin hosts a number of important phosphate deposits and accounts for almost 25% of world production. Three phosphate-bearing horizons have been identified at the Farim phosphate deposit. These are referred to as the FPO, FPA and FPB. The FPO is a clayey dolomitic limestone that is weakly phosphatic with limited economic potential. The FPA underlies the FPO and is a soft, poorly cemented unit of phosphatic sand, which includes phosphatised shell and bone material, teeth, faecal pellets and crustacean coprolites. The unit is beige to brown and lies in a generally reducing environment below the oxidised interval. The FPA unit is the identified potentially economic phosphate bed. The FPB underlies the FPA and is a calcareous phosphate unit comprising a much harder phosphatic limestone than the FPA unit. The FPB member is of less economic interest due to the low phosphate and high limestone content. The phosphate deposit is underlain by a soft, white and porous limestone unit.

The phosphate bearing strata are unconformably overlain by a sandy-argillaceous sequence comprising soft alternating sandy, clayey and sandy-clay layers with a blue/green soft clay or black lignitic clay at the base."

An overview of the site stratigraphy is summarised in Table 1.1.

Table 1.1: Indicative site stratigraphy

Age	Unit	Description	Approx. Thickness (m)
Post Eocene	Sandy/Argillaceous Overburden	Alternating sandy, clayey and sandy clayey layers	27 to 58
	Basal Clay Overburden	Blue/green soft clay and black lignitic clay (anoxic depositional environment)	
Eocene	Sand including FPO (phosphatic interval)	Grey/white fine grained sand including phosphate bearing clayey dolomitic limestone (FPO)	7 (single intercept)
	Upper Dolomitic Limestone	Clayey limestone	>2 [1] (single intercept)
	Decarbonised Phosphate Unit (FPA)	Ore zone comprising beige to brown, poorly cemented very fine grained phosphatic sand.	1 to 11
	Calcareous Phosphate Unit FPB	Cemented phosphatic limestone	2 to 8
	Limestone	Soft, white and porous limestone	>6 to 17 [1]

[1] Base of unit not encountered

2. TESTING METHODS

2.1 ACID BASE ACCOUNTING

Acid base accounting (ABA) assesses a sample's potential to form acid from the oxidation of sulphides and the ability to neutralise acid by the dissolution of minerals, particularly carbonates, contained in the sample.

Total sulphur, total carbon and total inorganic carbon were determined by Leco induction furnace, with infrared detection. Sulphate sulphur was determined by ICP following a hydrochloric acid digest. The testing methods specified are based on the ABA methodology defined in the Mine Environment Neutral Drainage (MEND) Acid Rock Drainage Prediction Manual (Ref. 1) and Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Ref. 2).

Acid Neutralising Capacity (ANC) was determined by digestion in a standard solution of HCl, followed by back titration with NaOH to determine the amount of acid consumed. The technique used was based on Sobek et al (Ref. 3), with a siderite correction step added to the standard procedure.

The results of the ABA testing are used to calculate the Maximum Potential Acidity (MPA), which is a measure of the maximum amount of sulphuric acid which can be produced from the total oxidation of all sulphides within the sample, assuming all sulphides are present as pyrite.

The Net Acid Producing Potential (NAPP) is the balance between the MPA and ANC. A negative NAPP indicates that there is an excess neutralising capacity and a positive NAPP indicates there is excess potential acidity.

2.2 NET ACID GENERATION (NAG)

Net Acid Generation (NAG) testing provides a direct measure of a sample's ability to produce acid through sulphide oxidation. The addition of hydrogen peroxide to samples causes rapid oxidation of the contained sulphides to produce sulphuric acid.

The specified procedure is based on the Static NAG Test (Refs. 4 and 5). The static NAG test involves the addition of 250 mL of 15 per cent hydrogen peroxide to 2.5 g of pulverised sample. The sample is allowed to react overnight prior to heating for a period of three hours. Once the sample has cooled the pH of the sample is measured prior to titration back to pH 4.5 and 7 to determine the acidity produced by the oxidisation reactions.

2.3 ACID FORMING POTENTIAL

The acid formation potential of a sample is calculated based on the acid base accounting, i.e. the balance between a sample's ability to produce acid from the oxidisation of sulphide minerals (MPA) and neutralise acid by the dissolution of alkaline minerals (ANC).

Historically a safety margin was applied to ratio between the ANC and MPA to allow for variability in the rates of acid production and neutralisation processes and the potential for geographic separation of the acid producing and acid neutralising phases. This safety margin was generally set by industry at 2 in North America and 3 in Australia.

With recent advances in the understanding and acceptance of the NAG test there has been a move away from this method of classifying materials based solely on the ANC and MPA as these calculated parameters do not take into consideration the true availability of acid producing and acid neutralising phases.

KP prefers to utilise the results of the acid base accounting in combination with the NAG testing results to classify the acid formation potential of materials. KP's classification system, as summarised in Table 2.1, is based on the Australian guidelines on Managing Acidic and Metalliferous Drainage (Ref. 6) and is broadly similar to the classification system contained within the AMIRA ARD Test Handbook (Ref. 7), which is advocated by the Global Acid Rock Drainage Guidelines (Ref. 8).

Table 2.1: Acid Formation Potential Classification System

Acid Formation Potential Class	NAPP (kg H_2SO_4 /t)	NAG pH
Potentially Acid Forming (PAF)	>10	<4.5
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than -100	≥4.5
Uncertain (UC)	Positive	≥4.5
	Negative	<4.5

2.4 MULTI-ELEMENT ANALYSIS

2.4.1 Element Enrichment

Multi-element analysis was conducted to assess elemental enrichments within the samples. The specified four acid digestion method results in near total digestion of the samples to assess the whole rock geochemistry.

Multi-element analysis results are compared to the average crustal abundance to determine geochemical abundance indices. The Geochemical Abundance Index (GAI)

quantifies an assay result for a particular element in terms of average crustal abundance.

The GAI is calculated from the following formula:

$$\mathbf{GAI = Log_2 (C_n / (1.5 \times B_n))}$$

Where:

C_n = measured concentration of element in sample

B_n = average crustal abundance (Bowen, Ref. 9)

The GAI is expressed on a scale of 0 to 6, with 0 indicating that the element concentration is less than or similar to average crustal abundance, and a GAI of 6 indicating an element concentration of more than 96 times the average crustal abundance. The enrichment ranges for GAIs are as follows:

- GAI = 0 represents <3 times crustal abundance
- GAI = 1 represents 3 to 6 times crustal abundance
- GAI = 2 represents 6 to 12 times crustal abundance
- GAI = 3 represents 12 to 24 times crustal abundance
- GAI = 4 represents 24 to 48 times crustal abundance
- GAI = 5 represents 48 to 96 times crustal abundance
- GAI = 6 represents more than 96 times crustal abundance

KP has assigned an arbitrary scale to the GAI, with indices of 0 and 1 being classified as “not enriched”, an index of 2 being classed as “slightly enriched”, indices of 3 and 4 being classed as “significantly enriched” and indices of 5 and 6 being classified as “highly enriched”.

2.4.2 Soil Quality Screening for Closure Planning

The multi-element analysis results were also compared to guideline concentrations for soil quality based on risk to human health and ecology for preliminary assessment of possible closure requirements, such as construction of engineered cover systems or limiting land use / access.

The Australian National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (Ref. 10) has been used to assess risk to human health, based on an assumed ‘recreational’ closure land use. This assumes the final landform will comprise public open space such as parks and playing fields rather than undeveloped public open space where the potential for exposure will be lower.

However, these values assume that no planting of crops for human consumption will occur.

To assess ecological risk, the U.S. Environmental Protection Agency Ecological Soil Screening Levels (Eco-SSLs) (Ref. 11) have been applied. These values apply to sites where terrestrial organisms may be exposed directly or indirectly to contaminated soil. The Eco-SSL values for mammalian wildlife have been adopted for this study. The Eco-SSLs do not provide guideline values for sulphur, sulphate or phosphorous. Therefore, the former National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999) (Ref. 12) ecological investigation levels for these substances have been included for reference purposes in the absence of other more applicable ecological assessment criteria.

The Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) has developed a series of soil-screening values for contaminated sites as part of the Dutch Soil Protection Act (VROM 2000) (Ref. 13). Soil quality is assessed and managed using target and intervention values which are independent of land use. Soils with contaminant concentrations below target values are considered to be at no risk and no restrictions on their use have been set. Soils with contaminant concentrations exceeding the intervention values require remediation as a matter of urgency, as the functional properties of the soil for humans, plant and animal life is seriously impaired or threatened. Therefore, for preliminary screening purposes, the intervention values have been applied in this study. For certain substances where intervention values have not been set, so-called “indicative levels for serious contamination” have been provided. These have also been included in this study, where appropriate.

The establishment of these soil quality screening values is to allow for evaluation only and it is not implied by production of these values that the Farim project will be required to meet these reference levels or that these reference levels should be used as the regulatory framework. The regulatory requirements for the project will be determined by the relevant regulatory authorities during the environmental design phase of the project.

2.5 SUPERNATANT WATER QUALITY

The tailings were supplied as a dry sample with no supernatant. In order to conduct the physical tests, Perth tap water was added to the tailings to create a slurry at a nominal design percent solids. Following the physical tests, a sample of the supernatant was sampled and sent for analysis for preliminary geochemical assessment. The results of this analysis have been compared to a set of reference water quality standards, which are discussed in Section 2.6.

2.6 REFERENCE WATER QUALITY STANDARDS

To allow assessment of the results of the supernatant analysis a set of reference values has been established. These reference values were compiled from internationally accepted guidelines for water quality for release from mining operations (IFC environmental, health and safety guidelines (Ref. 14 and 15) and the ANZECC water quality guideline for livestock drinking water (Ref. 16)). The use of several guidelines is required as no single guideline contains target concentrations for all parameters. Where a target concentration for a specific element is at different levels in various guidelines, the lowest concentration has been adopted. These reference values are summarised in Table 2.2. The water quality results of the supernatant analysis have also been compared to Australian drinking water guidelines (Ref. 16) with the Australia drinking water guideline provided in Table 2.3. Another useful assessment is to compare the supernatant results to baseline surface water and groundwater monitoring data. A summary of the baseline data, which is taken from the environmental and social baseline studies report (Ref. 17) is presented in Table 2.4.

The establishment of these reference water quality values is to allow for evaluation only and it is not implied by production of the reference water quality values that the Farim project will be required to meet these reference levels or that these reference levels should be used as the regulatory framework. The regulatory requirements for the project will be determined by the relevant regulatory authorities during the environmental design phase of the project.

Table 2.2: Reference Guidelines for Water Release and Livestock Drinking Water

Parameter	Units	ANZECC Livestock	IFC 2004	IFC 2007	Adopted Reference Level
pH	pH Units		6 to 9	6 to 9	6 to 9
TDS	mg/kg	2000			2000
Aluminum	mg/L	5			5
Antimony	mg/L				N/G
Arsenic	mg/L	0.5	0.1	0.1	0.1
Barium	mg/L				N/G
Boron	mg/L	5			5
Cadmium	mg/L	0.01	0.1	0.05	0.01
Calcium	mg/L	1000			1000
Chloride	mg/L				N/G
Chromium	mg/L	1			1
Cobalt	mg/L	1			1
Copper	mg/L	0.4	0.5	0.3	0.3
Fluoride	mg/L	2	20		2
Iron	mg/L		3.5	2	2
Lead	mg/L	0.1	0.1	0.2	0.1
Magnesium	mg/L	2000			2000
Manganese	mg/L				N/G
Mercury	mg/L	0.002	0.01	0.002	0.002
Molybdenum	mg/L	0.15			0.15
Nickel	mg/L	1	0.5	0.5	0.5
Phosphate	mg/L				N/G
Selenium	mg/L	0.02	0.1		0.02
Silver	mg/L		0.5		0.5
Sodium	mg/L				N/G
Sulfate	mg/L	1000			1000
Tin	mg/L				N/G
Uranium	mg/L	0.2			0.2
Vanadium	mg/L				N/G
Zinc	mg/L	20	2	0.5	0.5

N/G – No guideline

Table 2.3: Australian Drinking Water Guidelines

Parameter	Units	Health	Aesthetic	Adopted Reference Level
pH	pH Units		6.5 to 8.5	6.5 to 8.5
TDS	mg/kg		600	600
Aluminum	mg/L		0.2	0.2
Antimony	mg/L	0.003		0.003
Arsenic	mg/L	0.01		0.01
Barium	mg/L	2.0		2.0
Boron	mg/L	4		4
Cadmium	mg/L	0.002		0.002
Calcium	mg/L			N/G
Chloride	mg/L		250	250
Chromium	mg/L			N/G
Cobalt	mg/L			N/G
Copper	mg/L	2	1	1
Fluoride	mg/L	1.5		1.5
Iron	mg/L		0.3	0.3
Lead	mg/L	0.01		0.01
Magnesium	mg/L			N/G
Manganese	mg/L	0.5	0.1	0.1
Mercury	mg/L	0.001		0.001
Molybdenum	mg/L	0.05		0.05
Nickel	mg/L	0.02		0.02
Phosphate	mg/L			N/G
Selenium	mg/L	0.01		0.01
Silver	mg/L	0.1		0.1
Sodium	mg/L		180	180
Sulfate	mg/L	500	250	250
Tin	mg/L			N/G
Uranium	mg/L	0.02		0.02
Vanadium	mg/L			N/G
Zinc	mg/L		3	3

N/G – No guideline

Table 2.4: Average Surface Water and Groundwater Quality

Parameter	Units	Surface Water	Groundwater
pH	pH Units	7.1	6.4
TDS	ppm	2527	293
EC	µS/cm	3905	1334
Arsenic	mg/L	0.001	0.002
Calcium	mg/L	41	45
Cadmium	mg/L	0.0001	0.0002
Chloride	mg/L	1337	96
Chromium	mg/L	0.002	0.001
Copper	mg/L	0.005	0.01
Iron	mg/L	0.20	1.3
Mercury	mg/L	0.00002	N/M
Potassium	mg/L	25	2.8
Magnesium	mg/L	78	15.9
Manganese	mg/L	0.05	0.34
Sodium	mg/L	769	42
Nickel	mg/L	0.002	0.002
Lead	mg/L	0.002	0.001
Phosphate	mg/L	0.14	0.15
Sulphate	mg/L	120	28
Zinc	mg/L	0.01	0.06

N/M – Not measured

3. TAILINGS GEOCHEMICAL RESULTS

3.1 INTRODUCTION

Laboratory test certificates for the tailings analytical testing conducted by Intertek Genalysis are provided in Appendix A. The results are presented and discussed in the following sections. As part of the quality control and assurance programme conducted by Intertek Genalysis, duplicates of all tests were conducted on the tailings sample. The results presented in the following sections are the average of the original and duplicate tests.

It should be noted that this assessment of the tailings geochemistry does not include assessment of residual process chemicals which may be present within the tailings slurry. However, should it be foreseeable under normal operating conditions that release of tailings slurry or supernatant into any waterways could occur, a detailed assessment of the residual process chemicals is recommended. This detailed assessment will require input from the process chemical supplier to determine the most appropriate laboratory methods to analyse for the specific process chemicals to be used in ore beneficiation.

3.2 ACID BASE ACCOUNTING

Total sulphur content of the tailings was determined by LECO combustion. In addition, the samples were analysed for HCl soluble sulphate. The difference between these two values was assumed to be equal to the sulphide content of the samples. The results of the analysis are given in Table 3.1 and indicate a high sulphur content of 1.07% and low sulphate concentration of 0.09%. Consequently, the sulphide content was calculated as 0.98% and the maximum potential acidity (MPA) at 30 kg H_2SO_4 / tonne of tailings, which is high.

The acid neutralising capacity (ANC) of the samples was determined along with the carbonate content. The two results can be used as a check against one another and to identify the contribution of ANC from carbonates and other non-carbonate minerals. The results of the analysis are given in Table 3.1 and indicate a very high carbonate content of 5%. Accordingly the ANC values were also very high, although the measured ANC was found to be approximately 2.5 times higher than the ANC calculated as being available from carbonate minerals. This indicates that additional buffering capacity may be available from non-carbonate minerals or residual alkalinity in the tailings solids.

The Net Acid Producing Potential (NAPP) of the tailings was calculated from the MPA and the ANC and is given in Table 3.1 along with the ANC/MPA ratio. The net acid producing potential was strongly negative (-96 kg H_2SO_4 / t) with an ANC/MPA ratio of

4, indicating significant excess neutralising capacity. Further, the ratio of carbonate ANC to MPA was 1.6, indicating that carbonates alone will provide 60% excess neutralising capacity.

3.3 NET ACID GENERATION

The net acid generation (NAG) test aids in interpretation of the acid formation potential. It also identifies whether the sulphides and neutralising minerals contained in the samples are readily available to produce or consume acid.

The results of the net acid generation test are given in Table 3.1 and indicate that under extreme oxidising conditions, the acidity produced by the tailings was adequately buffered by the neutralising minerals, with the pH of the NAG solution recorded at pH 5.7 at the end of the test. This is one pH unit lower (i.e. ten times more acidity) than the tailings paste pH of 6.7, but still within a Non Acid Forming range, indicating that the neutralising minerals are available to buffer acidity produced by sulphide oxidation under circum neutral pH conditions.

3.4 ACID FORMATION POTENTIAL

The acid formation potential of the sample is determined based on the acid base accounting results and the NAG test. The tailings recorded a strongly negative net acid producing potential of -96 kg H_2SO_4 / t and NAG pH value of 5.7. Therefore, the tailings are classified as Non Acid Forming, as shown in Figure 3.1.

Table 3.1: Tailings Acid Base Accounting and NAG Results

Sulfur Species			Paste pH	ANC	Carbon Species			Calculations			NAG		AFP
S	Sulfate S	Sulfide S			TIC	Calcite Equivalent	$CaCO_3$-ANC	MPA	ANC/MPA	NAPP	NAG (7.0)	NAG pH	
%	%	%	pH Units	kg H_2SO_4/t	%	%	kg H_2SO_4/t	kg H_2SO_4/t		kg H_2SO_4/t	kg H_2SO_4/t	NONE	
1.07	0.09	0.98	6.7	126	0.60	5.0	49	29.8	4	-96	0	5.7	NAF

3.5 MULTI-ELEMENT RESULTS

3.5.1 Element Enrichments

Whole rock multi-element analysis of the tailings solids was conducted to assess elemental enrichments within the solid fraction of the tailings material. Multi-element analysis results were compared to the average crustal abundance to give the geochemical abundance indices. The Geochemical Abundance Index (GAI) quantifies an assay result for a particular element in terms of average crustal abundance.

The assay results, average crustal abundance (ACA) and corresponding geochemical abundance indices (GAI) are provided in Table 3.2. The results of the analysis indicate the tailings to have high levels of enrichment, with bismuth, cadmium, phosphorous and selenium found to be highly enriched. In addition, silver, arsenic, fluoride, sulphur, antimony and uranium were found to be significantly enriched, with calcium and chromium slightly enriched.

3.5.2 Preliminary Soil Quality Screening

The results of the analysis have also been compared to a set of soil quality screening guidelines for human health and ecology and are summarised in Table 3.3.

The multi-element results met the human health criteria for recreational land use, indicating that the TSF could likely be rehabilitated as undeveloped public space without posing an unacceptable risk to human health. However, the tailings did not meet the ecological guideline values for antimony, cadmium, chromium, copper, nickel, phosphorous, selenium, sulphur, vanadium and zinc. Further, the concentrations of cadmium, chromium and vanadium exceeded the intervention values for soil, indicating that an engineered cover system will be required on closure to isolate the tailings from the environment. This is discussed further in Section 4.

Table 3.2: Tailings Multi-Element Results and Geochemical Abundance Indices

Element	Unit	Multi-Element Analysis Results	Average Crustal Abundance	Geochemical Abundance Index
Ag	ppm	1.1	0.07	3
Al	ppm	23616	82000	0
As	ppm	37	1.5	4
B	ppm	50	10	1
Ba	ppm	49	500	0
Be	ppm	2	2.6	0
Bi	ppm	6.6	0.048	6
Ca	ppm	289525	41000	2
Cd	ppm	17.3	0.11	6
Cl	ppm	300	130	0
Co	ppm	32.3	20	0
Cr	ppm	963	100	2
Cu	ppm	155	50	1
F	ppm	24765	950	4
Fe	ppm	18100	41000	0
Hg	ppm	0.09	0.05	0
K	ppm	1054	21000	0
Mg	ppm	3333	23000	0
Mn	ppm	201	950	0
Mo	ppm	3.6	1.5	0
Na	ppm	1514	23000	0
Ni	ppm	171	80	0
P	ppm	93246	1000	5
Pb	ppm	36	14	0
S	ppm	10650	260	4
Sb	ppm	3.1	0.2	3
Se	ppm	20.7	0.05	6
Sn	ppm	2.5	2.2	0
Sr	ppm	1114	370	1
Th	ppm	14.1	12	0
U	ppm	115	2.4	4
V	ppm	492	160	1
Zn	ppm	296	75	1

Not Enriched
Slightly Enriched
Significantly Enriched
Highly Enriched

Table 3.3: Tailings Multi-Element Results and Soil Screening Guidelines

Element	Human Health-Based Investigation Levels [1] (ppm)	Ecological Soil Screening Levels [2,3] (ppm)	Soil Remediation Intervention Values [4] (ppm)	Multi-Element Analysis Results (ppm)
Antimony		**0.27**	15	3.1
Arsenic	300	46	55	37
Barium		2000	625	49.1
Beryllium	90	21	30	2
Boron	20,000			50
Cadmium	90	**0.36**	**12**	17.3
Chromium		**34**	**380**	963
Cobalt	300	230	240	32.3
Copper	17,000	**49**	190	155
Lead	600	56	530	36
Manganese	19,000	4000		201
Mercury	80		10	0.09
Molybdenum			200	3.6
Nickel	1,200	**130**	210	171
Phosphorus		**2,000**		93246
Selenium	700	**0.63**	100	20.7
Silver		14	15	1.1
Sulfur		**60**		10650
Sulfate		2,000		900
Tin			900	2.5
Vanadium		**280**	**250**	492
Zinc	30,000	**79**	720	296

Notes:

[1] National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1). Health Investigation Levels for Soil Contaminants, Generic Land Use HIL C – Recreational.

[2] United States Environmental Protection Agency (U.S. EPA) Ecological Soil Screening Levels (Eco-SSLs), http://www.epa.gov/ecotox/ecossl/ (mammalian wildlife).

[3] Ecological guideline values for phosphorous, sulphur and sulphate are based on National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999). These former Australian ecological investigation levels for urban areas have been included for reference purposes in the absence of other more applicable ecological assessment criteria.

[4] Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) 2000. Circular on Target Values and Intervention Values for Soil Remediation, Reference DBO/1999226863. Soil remediation intervention values. In the absence of intervention values for beryllium, selenium, silver, tin and vanadium, "indicative levels for serious soil contamination" have been applied.

Values in red bold indicate where a guideline value has been exceeded.

3.6 SUPERNATANT RESULTS

It should be noted that the tailings were provided as a dry sample with no supernatant. The dry tailings were then slurried using Perth tap water in order to conduct physical

testing. A sample of this liquor was extracted by KP and submitted to Intertek Genalysis for analysis as a preliminary assessment of soluble metals which may also be present within the supernatant. However, a sample of actual tailings supernatant should be tested when available.

3.6.1 Comparison to Guidelines for Release and Livestock Drinking Water

The results of the supernatant testing have been compared to a reference set of water quality guidelines as a means of assessing the risk to surface waters from supernatant release. However, comparison should also be made to background surface water quality data.

Only nickel and selenium were found to exceed the reference water quality values, both of which measured at approximately twice the published guideline limit (Table 3.4). As such, it is anticipated that the supernatant will not be of a suitable quality to be released to the environment and controls will be required to minimise seepage and spillway discharge. This is discussed further in Section 4.

3.6.2 Comparison to Australian Drinking Water Guidelines

The results of the analysis have also been compared to Australian drinking water standards. These can be used to assess risk to groundwater and any nearby abstractions from supernatant release. However, comparison should also be made to background groundwater quality data.

The results indicate that cadmium, manganese, nickel, selenium and sulphate exceed the drinking water guidelines (Table 3.5). There was insufficient sample to conduct TDS analysis, but based on the EC measurement of 2249 µS/cm the supernatant would be considered saline and unsuitable for use as drinking water. As such, the TSF will require controls to limit seepage flows entering groundwater. This is discussed further in Section 4.

3.6.3 Comparison to Baseline Surface Water and Groundwater Quality

The supernatant assay results have also been compared to baseline data for surface water and groundwater (Table 3.6). The results of this comparison indicate that the supernatant is of a poor quality compared to baseline conditions and, as such, the TSF will require seepage control measures and sufficient flood storage capacity to limit supernatant release. This is discussed further in Section 4.

Table 3.4: Supernatant Results Compared to Reference Surface Water Guidelines

Parameter	Units	Reference Release Value	Assay Results
pH	pH Units	9	6.9
Aluminium	mg/L	5	0.02
Antimony	mg/L	N/G	0.001
Arsenic	mg/L	0.1	0.001
Barium	mg/L	N/G	0.06
Boron	mg/L	5	0.2
Cadmium	mg/L	0.01	0.006
Calcium	mg/L	1000	313
Chloride	mg/L	N/G	250
Chromium	mg/L	1	0.01
Cobalt	mg/L	1	0.14
Copper	mg/L	0.3	0.01
Fluoride	mg/L	2	0.55
Iron	mg/L	2	0.03
Lead	mg/L	0.1	0.002
Magnesium	mg/L	2000	81
Manganese	mg/L	N/G	0.86
Mercury	mg/L	0.002	0.0001
Molybdenum	mg/L	0.15	0.003
Nickel	mg/L	0.5	**0.91**
Phosphorus	mg/L	N/G	0.5
Selenium	mg/L	0.02	**0.05**
Silver	mg/L	0.5	0.00004
Sodium	mg/L	N/G	87
Sulphate*	mg/L	1000	768
Tin	mg/L	N/G	0.33
Uranium	mg/L	0.2	0.004
Vanadium	mg/L	N/G	0.01
Zinc	mg/L	0.5	0.24

Notes:

N/G - no guideline value

* Assay results for sulphate estimated based on sulphur

Table 3.5: Supernatant Results Compared to Australian Drinking Water Guidelines

Parameter	Units	Drinking Water Guideline	Assay Results
pH	pH Units	8.5	6.9
Aluminium	mg/L	0.2	0.02
Antimony	mg/L	0.003	0.001
Arsenic	mg/L	0.01	0.001
Barium	mg/L	2	0.06
Boron	mg/L	4	0.2
Cadmium	mg/L	0.002	**0.006**
Calcium	mg/L	N/G	313
Chloride	mg/L	250	250
Chromium	mg/L	N/G	0.01
Cobalt	mg/L	N/G	0.14
Copper	mg/L	1	0.01
Fluoride	mg/L	1.5	0.55
Iron	mg/L	0.3	0.03
Lead	mg/L	0.01	0.002
Magnesium	mg/L	N/G	81
Manganese	mg/L	0.1	**0.86**
Mercury	mg/L	0.001	0.0001
Molybdenum	mg/L	0.05	0.003
Nickel	mg/L	0.02	**0.91**
Phosphorus	mg/L	N/G	0.5
Selenium	mg/L	0.01	**0.05**
Silver	mg/L	0.1	0.00004
Sodium	mg/L	180	87
Sulphate*	mg/L	250	**768**
Tin	mg/L	N/G	0.33
Uranium	mg/L	0.017	0.004
Vanadium	mg/L	N/G	0.01
Zinc	mg/L	3	0.24

Notes:

N/G - no guideline value

* Assay results for sulphate estimated based on sulphur

Table 3.6: Supernatant Results Compared to Surface Water and Groundwater Quality

Parameter	Units	Surface Water	Groundwater	Assay Results
pH	pH Units	7.1	6.4	6.85
TDS	ppm	2527	293	N/M
EC	µS/cm	3905	**1334**	2249
Arsenic	mg/L	**0.0009**	0.0018	0.001
Calcium	mg/L	**40.8**	**45.3**	313
Cadmium	mg/L	**0.0001**	**0.0002**	0.006
Chloride	mg/L	1337	**96**	250
Chromium	mg/L	**0.002**	**0.001**	0.01 [3]
Copper	mg/L	**0.005**	0.015	0.01 [3]
Iron	mg/L	0.20	1.30	0.025
Mercury	mg/L	**0.00002** [3]	N/M	0.0001 [3]
Potassium	mg/L	25.3	**2.8**	15.5
Magnesium	mg/L	**77.5**	**15.9**	81.5
Manganese	mg/L	**0.05**	**0.34**	0.86
Sodium	mg/L	769	**42**	87
Nickel	mg/L	**0.002**	**0.002**	0.91
Lead	mg/L	**0.0003** [3]	**0.001**	0.002 [3]
Phosphate [1]	mg/L	**0.14**	**0.15**	1.5
Sulphate [2]	mg/L	**120**	**28**	768
Zinc	mg/L	**0.01**	**0.06**	0.24

Notes:

N/M – Not Measured

Values in red bold indicate where a baseline concentration has been exceeded.

[1] Assay result for phosphate estimated based on phosphorous

[2] Assay result for sulphate estimated based on sulphur

[3] Not measured above detection limit

4. IMPLICATIONS FOR TAILINGS MANAGEMENT

4.1 ACID FORMING POTENTIAL

The tailings were found to be Non Acid Forming. This is based on a very high ANC, despite being high in sulphide sulphur, resulting in a strongly negative NAPP and final pH in the NAG test of 5.7. This indicates that sufficient neutralising capacity exists under circum neutral pH conditions to buffer any acid formed from sulphide oxidation. As such, there is no perceived risk from acidification of the tailings and there are no specific controls required. However, the high sulphide content of the tailings has the potential to lead to high sulphate and saline drainage. Long term leach tests would be required to assess this risk.

4.2 MULTI-ELEMENT ENRICHMENT

The results of the analysis indicate that the tailings have high levels of element enrichment, with bismuth, cadmium, phosphorous and selenium found to be highly enriched. In addition, silver, arsenic, fluoride, sulphur, antimony and uranium were found to be significantly enriched, with calcium and chromium slightly enriched. Further, the tailings did not meet the ecological soil screening guidelines, with several metals also exceeding the remediation intervention values. Therefore, during operations the facility must be designed and operated in such a way as to fully contain the tailings solids and minimise dusting. On closure, a cover system will be required to isolate the tailings from the environment. This would likely comprise a basic store and release cover, consisting of a coarse rockfill layer to form a capillary break and prevent upward migration of salts, overlain by rock mulch for storage of rain water and capped with a growth medium to aid re-vegetation.

4.3 SUPERNATANT QUALITY

The supernatant created by slurrying the dry tailings sample was found to be of a reasonable quality, but did not meet all guideline concentrations and was found to exceed baseline surface water and groundwater concentrations for several parameters. As such, the TSF will require controls to limit seepage to surface water and groundwater. This will likely comprise an engineered low permeability liner across the base and sides of the facility, and a storage capacity sufficient to contain all stormwater run-off within the adopted design standard. The closure cover system should also be domed such that once the rock mulch storage layer is fully saturated, excess water will flow towards and over the spillway rather than through the consolidated tailings. However, these recommendations should be reviewed following analysis of an actual supernatant sample created from metallurgical testing. This analysis should include measurement of total dissolved solids (TDS) and phosphate speciation, which was not

possible during this preliminary assessment due to the very limited volume of liquor which could be extracted from the tailings slurry.

5. REFERENCES

1. Mine Environment Neutral Drainage (MEND) Program (1991). Acid Rock Drainage Prediction Manual. Mend Project 1.16.16.
2. British Columbia Ministry of Energy and Mines (August 1998). Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia.
3. Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M. (1978). Field and laboratory methods applicable to overburden and mine soils, EPA 600/2-78-054.
4. Miller, S., Robertson A., Donohue, T. (1997). Advances in acid drainage prediction using the net acid generation test. In Proceedings of the Forth International Conference on Acid Rock Drainage (Vancouver B.C.) pp 535 - 547.
5. Stewart, W., Miller, S., Smart, R., Gerson, A., Thomas, J., Skinner, W., Levay, G. and Schumann, R. (2003). Evaluation of the Net Acid Generation (NAG) Test for Assessing the Acid Generating Capacity of Sulfide Minerals. In Proceeding of the Sixth international conference on Acid Rock Drainage (Cairns, Australia) pp 617 - 625.
6. Australian Government, Department of Industry, Tourism and Resources (February 2007). Managing Acid and Metalliferous Drainage.
7. AMIRA International (May 2002). ARD Test Handbook.
8. International Network for Acid Prevention Limited (December 2008). Global Acid Rock Drainage Guide (Version 0.7).
9. Bowen, H.J.M. (1979). Environmental Chemistry of the Elements. Academic Press, New York.
10. Australian Government (2013). National Environment Protection (Assessment of Site Contamination) Amendment Measure.
11. United States Environmental Protection Agency (U.S. EPA) Ecological Soil Screening Levels (Eco-SSLs), http://www.epa.gov/ecotox/ecossl/.
12. NEPC (1999). National Environment Protection (Assessment of Site Contamination) Measure.
13. VROM (2000), Circular on Target Values and Intervention Values for Soil Remediation, Reference DBO/1999226863, Ministry of Housing, Spatial Planning and the Environment, Bilthoven, Netherlands.

14. IFC (2004). IFC Environmental, Health and Safety Guidelines for Precious Metal Mining (Draft).

15. IFC (2007) IFC Environmental, Health and Safety Guidelines for Mining.

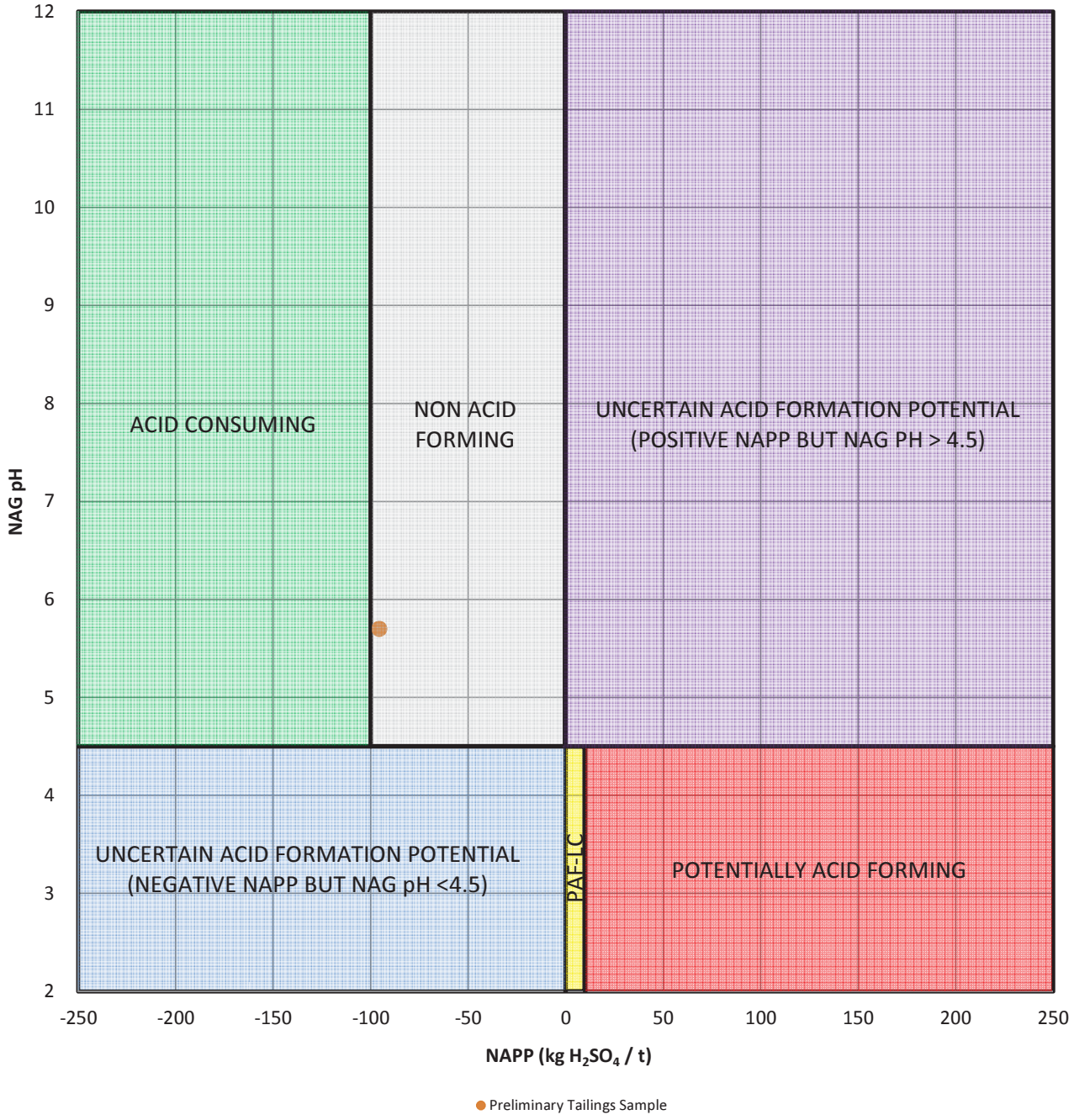
16. ANZECC / ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

17. Golder Associates (2014). Mine Component Environmental and Social Baseline Studies. Report No. 13514950200.550-1/B.0. Issued 21 February 2014.

FIGURE

Knight Piésold
CONSULTING

Acid Formation Potential



Acid Formation Potential	NAPP (kg H_2SO_4 / t)	NAG pH
Potentially Acid Forming (PAF)	>10	<4.5
Potentially Acid Forming - Low Capacity (PAF - LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than - 100	≥4.5
Uncertain	Positive	≥4.5
	Negative	<4.5

APPENDIX A

Intertek Genalysis Laboratory Certificates

ANALYTICAL REPORT

T. ROWLES
KNIGHT PIESOLD PTY LIMITED
PO Box 6837
EAST PERTH, W.A. 6892
AUSTRALIA

JOB INFORMATION

JOB CODE	: 752.0/1504834
No. of SAMPLES	: 1
No. of ELEMENTS	: 45
CLIENT O/N	: P13706 (Job 1 of 2)
SAMPLE SUBMISSION No.	: PE301-00520/04 SS15001
PROJECT	: FARIM PHOSPHATE
STATE	: Solid
DATE RECEIVED	: 20/04/2015
DATE COMPLETED	: 05/05/2015
DATE PRINTED	: 05/05/2015
ANALYSING LABORATORY	: Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

MAIN OFFICE AND LABORATORY

15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY

11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY

43 Malcolm Moodie Crescent,
Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

TOWNSVILLE LABORATORY

9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818
Tel: +61 7 4774 3655 Fax: +61 7 4774 4692

Results are not intended for commercial settlement purposes

SAMPLE DETAILS

DISCLAIMER

Intertek Genalysis wishes to make the following disclaimer pertaining to the accompanying analytical results.

All work is performed in accordance with the Intertek Minerals Standard Terms and Conditions of work http://www.intertek.com/terms/

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report.

The results provided are not intended for commercial settlement purposes.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Intertek Genalysis accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of $4.00 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at $150.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

NOTES

1. Note: Detection Limit only apply when TDS <100mg/l for MS and TDS<5000mg/l for OES except when indicated in spreadsheet

ANALYSIS

ELEMENTS	Ag	Al	ANC	As	B	Ba
UNITS	ppm	ppm	kgH2SO4/t	ppm	ppm	ppm
DETECTION LIMIT	0.1	50	1	1	50	0.1
DIGEST	4AB/	4AB/	ANCx/	4AB/	FP1/	4AB/
ANALYTICAL FINISH	MS	OE	VOL	MS	OE	MS
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	1.0	2.36%	126	37	X	49.2
CHECKS						
0001 Preliminary Tailings Sample	1.1	2.36%	125	37	X	49.0
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0341						
0003 HgSTD-5						
0004 MA-3a						
0005 MPL-5	27.3	3.17%		1000		561.6
0006 OREAS 25a					68	
0007 OREAS 97.01						
0008 PD-1						
BLANKS						
0001 Control Blank	X	X		X	X	X

ANALYSIS

ELEMENTS	Be	Bi	C	Ca	Cd	Cl
UNITS	ppm	ppm	%	ppm	ppm	%
DETECTION LIMIT	0.1	0.01	0.01	50	0.1	0.02
DIGEST	4AB/	4AB/		4AB/	4AB/	CL1/
ANALYTICAL FINISH	MS	MS	/CSA	OE	MS	COL
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	2.0	6.62	1.03	28.91%	17.4	0.03
CHECKS						
0001 Preliminary Tailings Sample	2.0	6.64	1.03	28.99%	17.2	0.03
STANDARDS						
0001 0.5%NaCl						0.31
0002 AMIS0341						
0003 HgSTD-5						
0004 MA-3a			2.49			
0005 MPL-5	21.0	38.13		4.10%	2.8	
0006 OREAS 25a						
0007 OREAS 97.01						
0008 PD-1						
BLANKS						
0001 Control Blank	X	X		X	X	

ANALYSIS

ELEMENTS	Coolour	Change	Cr	Cu	EC	F
UNITS	ppm	NONE	ppm	ppm	mS/cm	ppm
DETECTION LIMIT	0.1	0	5	1	0.01	50
DIGEST	4AB/	ANCx/	4AB/	4AB/	Paste/	FC7/
ANALYTICAL FINISH	MS	QUAL	OE	OE	MTR	SIE
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	32.4	No	961	152	2025.00	2.57%
CHECKS						
0001 Preliminary Tailings Sample	32.1	No	964	157	2035.00	2.38%
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0341						3556
0003 HgSTD-5						
0004 MA-3a						
0005 MPL-5	131.7		344	1782		
0006 OREAS 25a						
0007 OREAS 97.01						
0008 PD-1						
BLANKS						
0001 Control Blank	X		X	X		56

ANALYSIS

ELEMENTS	Fe	Final-pH	Fizz-Rate	Hg	K	Mg
UNITS	%	NONE	NONE	ppm	ppm	ppm
DETECTION LIMIT	0.01	0.1	0	0.01	20	20
DIGEST	4AB/	ANCx/	ANCx/	HG1/	4AB/	4AB/
ANALYTICAL FINISH	OE	MTR	QUAL	CV	OE	OE
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	1.81	1.8	2	0.09	1066	3345
CHECKS						
0001 Preliminary Tailings Sample	1.81	1.8	2	0.09	1042	3320
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0341						
0003 HgSTD-5				0.85		
0004 MA-3a						
0005 MPL-5	3.51				1.08%	8317
0006 OREAS 25a						
0007 OREAS 97.01						
0008 PD-1						
BLANKS						
0001 Control Blank	X			0.01	39	X

ANALYSIS

ELEMENTS	Mn	Mo	Na	NAG	NAGpH	NAG(4.5)
UNITS	ppm	ppm	ppm	kgH2SO4/t	NONE	kgH2SO4/t
DETECTION LIMIT	1	0.1	20	1	0.1	1
DIGEST	4AB/	4AB/	4AB/	NAGx/	NAGx/	NAGx/
ANALYTICAL FINISH	OE	MS	OE	VOL	MTR	VOL
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	202	3.6	1532	0	5.7	0
CHECKS						
0001 Preliminary Tailings Sample	200	3.5	1496	0	5.7	0
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0341						
0003 HgSTD-5						
0004 MA-3a						
0005 MPL-5	2183	19.8	5413			
0006 OREAS 25a						
0007 OREAS 97.01						
0008 PD-1						
BLANKS						
0001 Control Blank	X	X	22			

ANALYSIS

ELEMENTS	Ni	P	Pb	pH	S	S-SO4
UNITS	ppm	ppm	ppm	NONE	%	%
DETECTION LIMIT	1	50	2	0.1	0.01	0.01
DIGEST	4AB/	4AB/	4AB/	Paste/		S71/
ANALYTICAL FINISH	OE	OE	MS	MTR	/CSA	OE
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	170	9.20%	36	6.6	1.07	0.10
CHECKS						
0001 Preliminary Tailings Sample	171	9.45%	36	6.7	1.06	0.08
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0341						
0003 HgSTD-5						
0004 MA-3a					1.10	
0005 MPL-5	2356	681	2104			
0006 OREAS 25a						
0007 OREAS 97.01						
0008 PD-1						4.43
BLANKS						
0001 Control Blank	X	X	X			X

ANALYSIS

ELEMENTS	Sb	Se	Sn	Sr	Th	TIC
UNITS	ppm	ppm	ppm	ppm	ppm	%
DETECTION LIMIT	0.05	0.01	0.1	0.05	0.01	0.01
DIGEST	4AB/	SE1/	4AB/	4AB/	4AB/	C72/
ANALYTICAL FINISH	MS	MS	MS	MS	MS	CSA
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	2.84	20.63	2.6	1115.72	14.00	0.60
CHECKS						
0001 Preliminary Tailings Sample	3.31	20.83	2.3	1112.14	14.13	0.60
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0341						
0003 HgSTD-5						
0004 MA-3a						
0005 MPL-5	307.74		9.2	420.58	93.40	
0006 OREAS 25a						
0007 OREAS 97.01		0.62				
0008 PD-1						
BLANKS						
0001 Control Blank	X	X	X	X	0.01	

ANALYSIS

ELEMENTS	U	V	Zn
UNITS	ppm	ppm	ppm
DETECTION LIMIT	0.01	2	1
DIGEST	4AB/	4AB/	4AB/
ANALYTICAL FINISH	MS	OE	OE
SAMPLE NUMBERS			
0001 Preliminary Tailings Sample	114.61	494	297
CHECKS			
0001 Preliminary Tailings Sample	114.42	489	294
STANDARDS			
0001 0.5%NaCl			
0002 AMIS0341			
0003 HgSTD-5			
0004 MA-3a			
0005 MPL-5	11.08	197	1299
0006 OREAS 25a			
0007 OREAS 97.01			
0008 PD-1			
BLANKS			
0001 Control Blank	X	X	1

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
/CSA	Intertek Genalysis Perth	
Induction Furnace Analysed by Infrared Spectrometry		
4AB/MS	Intertek Genalysis Perth	**4AB/ : MPL_W001, MS : ICP_W003**
Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Beakers. Analysed by Inductively Coupled Plasma Mass Spectrometry.		
4AB/OE	Intertek Genalysis Perth	**4AB/ : MPL_W001, OE : ICP_W004**
Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Beakers. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		
ANCx/MTR	Intertek Genalysis Perth	
Acid Neutralizing Capacity Digestion Procedure. Analysed with Electronic Meter Measurement		
ANCx/QUAL	Intertek Genalysis Perth	
Acid Neutralizing Capacity Digestion Procedure. Analysed by Qualitative Inspection		
ANCx/VOL	Intertek Genalysis Perth	
Acid Neutralizing Capacity Digestion Procedure. Analysed by Volumetric Technique.		
C72/CSA	Intertek Genalysis Perth	**ENV_W017, CSA : ENV_W017**
Digestion by hot acid(s) Analysed by Infrared Spectrometry		
CL1/COL	Intertek Genalysis Perth	**ENV_W014, COL : ENV_W014**
Carbonate leach specific for Chlorine. Analysed by UV-Visible Spectrometry.		
FC7/SIE	Intertek Genalysis Perth	**ENV_W012, SIE : ENV_W012**
Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.		
FP1/OE	Intertek Genalysis Perth	**FP1/ : MPL_W011, OE : ICP_W004**
Sodium peroxide fusion (Zirconia crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		
HG1/CV	Intertek Genalysis Perth	
Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.		
NAGx/MTR	Intertek Genalysis Perth	
Net Acid Generation Extraction of samples with H2O2 Analysed with Electronic Meter Measurement		
NAGx/VOL	Intertek Genalysis Perth	
Net Acid Generation Extraction of samples with H2O2 Analysed by Volumetric Technique.		
Paste/MTR	Intertek Genalysis Perth	
Water Extraction using a specific sample:water ratio. Analysed with Electronic Meter Measurement		
S71/OE	Intertek Genalysis Perth	
Digestion to eliminate sulphides. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
SE1/MS	Intertek Genalysis Perth	

Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled Plasma Mass Spectrometry.

ANALYTICAL REPORT

KNIGHT PIESOLD PTY LIMITED
PO Box 6837
EAST PERTH, W.A. 6892
AUSTRALIA

JOB INFORMATION

JOB CODE	:	752.0/1504835
No. of SAMPLES	:	1
No. of ELEMENTS	:	35
CLIENT O/N	:	P13706 (Job 2 of 2)
SAMPLE SUBMISSION No.	:	PE301-00520/04 SS15001
PROJECT	:	FARIM PHOSPHATE
STATE	:	Solutions
DATE RECEIVED	:	30/04/2015
DATE COMPLETED	:	07/05/2015
DATE PRINTED	:	07/05/2015
ANALYSING LABORATORY	:	Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

MAIN OFFICE AND LABORATORY

15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY

11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY

43 Malcolm Moodie Crescent,
Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

TOWNSVILLE LABORATORY

9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818
Tel: +61 7 4774 3655 Fax: +61 7 4774 4692

Results are not intended for commercial settlement purposes

SAMPLE DETAILS

DISCLAIMER

Intertek Genalysis wishes to make the following disclaimer pertaining to the accompanying analytical results.

All work is performed in accordance with the Intertek Minerals Standard Terms and Conditions of work http://www.intertek.com/terms/

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report.

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SIGNIFICANT FIGURES

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SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

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SAMPLE STORAGE OF SOLUTIONS

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NOTES

1. Note: Detection Limit only apply when TDS <100mg/l for MS and TDS<5000mg/l for OES except when indicated in spreadsheet

ANALYSIS

ELEMENTS	Ag	Al	As	B	Ba	Be
UNITS	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l
DETECTION LIMIT	0.01	0.01	0.1	0.01	0.05	0.1
DIGEST						
ANALYTICAL FINISH	/MS	/OE	/MS	/OE	/MS	/MS
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	0.04	0.02	0.9	0.20	61.45	X
CHECKS						
0001 Preliminary Tailings Sample	0.03	0.02	1.0	0.20	62.77	X
STANDARDS						
0001 Alcoa12-OES		2.11		0.99		
0002 SOLN-001						
0003 TMDW	2.06		80.0		50.16	21.0
BLANKS						
0001 Control Blank	X	X	X	X	0.08	X

ANALYSIS

ELEMENTS	Bi	Ca	Cd	Cl	Co	Cr
UNITS	ug/l	mg/l	ug/l	mg/l	ug/l	mg/l
DETECTION LIMIT	0.005	0.01	0.5	2	0.1	0.01
DIGEST						
ANALYTICAL FINISH	/MS	/OE	/MS	/COL	/MS	/OE
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	0.010	320.64	5.8	250	140.6	X
CHECKS						
0001 Preliminary Tailings Sample	0.010	305.80	5.9	250	141.6	X
STANDARDS						
0001 Alcoa12-OES		57.61				0.51
0002 SOLN-001						
0003 TMDW	9.800		9.9		24.3	
BLANKS						
0001 Control Blank	X	X	X		X	X

ANALYSIS

ELEMENTS	Cu	EC	F	Fe-Sol	Hg	K
UNITS	mg/l	uS/cm	mg/l	mg/l	ug/l	mg/l
DETECTION LIMIT	0.01	10	0.1	0.01	0.1	0.1
DIGEST						
ANALYTICAL FINISH	/OE	/MTR	/SIE	/OE	/MS	/OE
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	X	2231	0.6	0.02	X	15.9
CHECKS						
0001 Preliminary Tailings Sample	X	2267	0.5	0.03	X	15.0
STANDARDS						
0001 Alcoa12-OES	0.46			2.16		3.8
0002 SOLN-001			1.0			
0003 TMDW					X	
BLANKS						
0001 Control Blank	X		X	X	X	X

ANALYSIS

ELEMENTS	Mg	Mn	Mo	Na	Ni	P
UNITS	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
DETECTION LIMIT	0.01	0.01	0.05	0.1	0.01	0.1
DIGEST						
ANALYTICAL FINISH	/OE	/OE	/MS	/OE	/OE	/OE
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	81.74	0.86	2.80	89.0	0.90	0.5
CHECKS						
0001 Preliminary Tailings Sample	81.25	0.86	2.90	85.0	0.91	0.5
STANDARDS						
0001 Alcoa12-OES	52.78	0.52		236.4	0.51	1.0
0002 SOLN-001						
0003 TMDW			102.71			
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ANALYSIS

ELEMENTS	Pb	pH	S	Sb	Se	Sn
UNITS	ug/l	NONE	mg/l	ug/l	ug/l	ug/l
DETECTION LIMIT	2	0.1	0.1	0.01	0.5	0.1
DIGEST						
ANALYTICAL FINISH	/MS	/MTR	/OE	/MS	/MS	/MS
SAMPLE NUMBERS						
0001 Preliminary Tailings Sample	X	6.8	255.9	1.16	45.1	329.6
CHECKS						
0001 Preliminary Tailings Sample	X	6.9	256.9	1.22	46.4	337.0
STANDARDS						
0001 Alcoa12-OES			19.4			
0002 SOLN-001						
0003 TMDW	40			10.43	10.0	1.0
BLANKS						
0001 Control Blank	X		0.1	0.02	X	X

ANALYSIS

ELEMENTS	Sr	Th	U	V	Zn
UNITS	ug/l	ug/l	ug/l	mg/l	mg/l
DETECTION LIMIT	0.02	0.005	0.005	0.01	0.01
DIGEST					
ANALYTICAL FINISH	/MS	/MS	/MS	/OE	/OE
SAMPLE NUMBERS					
0001 Preliminary Tailings Sample	1073.57	0.050	4.114	X	0.24
CHECKS					
0001 Preliminary Tailings Sample	1076.13	0.055	4.169	X	0.24
STANDARDS					
0001 Alcoa12-OES				0.51	0.53
0002 SOLN-001					
0003 TMDW	251.20	X	10.042		
BLANKS					
0001 Control Blank	X	X	X	X	X

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
/COL	Intertek Genalysis Perth	

No digestion or other pre-treatment undertaken. Analysed by UV-Visible Spectrometry.

/MS Intertek Genalysis Perth

No digestion or other pre-treatment undertaken. Analysed by Inductively Coupled Plasma Mass Spectrometry.

/MTR Intertek Genalysis Perth

No digestion or other pre-treatment undertaken. Analysed with Electronic Meter Measurement

/OE Bauxite Laboratory at Church Rd

Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

/SIE Intertek Genalysis Perth

No digestion or other pre-treatment undertaken. Analysed by Specific Ion Electrode.

APPENDIX B

Laboratory Certificates

Knight Piésold
CONSULTING

ANALYTICAL REPORT

KNIGHT PIESOLD PTY LIMITED
PO Box 6837
EAST PERTH, W.A. 6892
AUSTRALIA

JOB INFORMATION

JOB CODE	:	752.0/1510894
No. of SAMPLES	:	1
No. of ELEMENTS	:	45
CLIENT O/N	:	PE301-00520/04 (Job 1 of 1)
SAMPLE SUBMISSION No.	:	PE301-00520/04 SS15002
PROJECT	:	FARIUM PHOSPHATE
STATE	:	Slurry
DATE RECEIVED	:	17/08/2015
DATE COMPLETED	:	26/08/2015
DATE PRINTED	:	26/08/2015
ANALYSING LABORATORY	:	Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

MAIN OFFICE AND LABORATORY

15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY

11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY

43 Malcolm Moodie Crescent,
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SAMPLE DETAILS

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SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

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SAMPLE STORAGE OF SOLUTIONS

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NOTES

1. Note: Detection Limit only apply when TDS <100mg/l for MS and TDS<5000mg/l for OES except when indicated in spreadsheet

ANALYSIS

ELEMENTS	Ag	Al	ANC	As	B	Ba
UNITS	ppm	ppm	kgH2SO4/t	ppm	ppm	ppm
DETECTION LIMIT	0.1	50	1	1	50	0.1
DIGEST	4AB/	4AB/	ANCx/	4AB/	FP1/	4AB/
ANALYTICAL FINISH	MS	OE	VOL	MS	OE	MS
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	1.4	3.02%	129	17	X	53.9
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	1.6	3.00%	129	14	X	55.5
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167	0.9	1.27%		153		85.2
0003 AMIS0343						
0004 AMIS0401					X	
0005 HgSTD-5						
0006 OREAS 45d						
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1						
BLANKS						
0001 Control Blank	X	X		X	X	X
0002 Control Blank	X	64		X	X	0.2

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Be	Bi	C	Ca	Cd	Cl
UNITS	ppm	ppm	%	ppm	ppm	%
DETECTION LIMIT	0.1	0.01	0.01	50	0.1	0.02
DIGEST	4AB/	4AB/		4AB/	4AB/	CL1/
ANALYTICAL FINISH	MS	MS	/CSA	OE	MS	COL
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	2.5	0.22	1.17	24.38%	21.2	X
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	2.5	0.53	1.16	24.25%	22.1	X
STANDARDS						
0001 0.5%NaCl						0.33
0002 AMIS0167	0.4	1.01		980	0.4	
0003 AMIS0343						
0004 AMIS0401						
0005 HgSTD-5						
0006 OREAS 45d			1.03			
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1						
BLANKS						
0001 Control Blank	X	0.02	X	X	X	X
0002 Control Blank	X	X		78	X	X

ANALYSIS

ELEMENTS	Coolour	Change	Cr	Cr	Cu	Cu
UNITS	ppm	NONE	ppm	ppm	ppm	ppm
DETECTION LIMIT	0.1	0	0.5	5	0.2	1
DIGEST	4AB/	ANCx/	4AB/	4AB/	4AB/	4AB/
ANALYTICAL FINISH	MS	QUAL	MS	OE	MS	OE
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	32.7	No	1098.4	1065	80.0	84
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	32.2	No	1093.6	1050	72.6	77
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167	39.1		345.5	374	60.4	60
0003 AMIS0343						
0004 AMIS0401						
0005 HgSTD-5						
0006 OREAS 45d						
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1						
BLANKS						
0001 Control Blank	X		X	X	0.5	2
0002 Control Blank	0.2		4.4	6	X	1

ANALYSIS

ELEMENTS	EC	F	Fe	Final-pH	Fizz-Rate	Hg
UNITS	uS/cm	ppm	%	NONE	NONE	ppm
DETECTION LIMIT	10	50	0.01	0.1	0	0.01
DIGEST	Paste/	FC7/	4AB/	ANCx/	ANCx/	HG1/
ANALYTICAL FINISH	MTR	SIE	OE	MTR	QUAL	CV
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	910	2.51%	2.03	1.7	2.0000000	0.08
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	910	2.50%	2.13	1.7	2.0000000	0.06
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167			2.44			
0003 AMIS0343		2332				
0004 AMIS0401						
0005 HgSTD-5						0.84
0006 OREAS 45d						
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1						
BLANKS						
0001 Control Blank	X	X	0.02			X
0002 Control Blank			0.01			X

ANALYSIS

ELEMENTS	K	Mg	Mn	Mo	Na	NAG
UNITS	ppm	ppm	ppm	ppm	ppm	kgH2SO4/t
DETECTION LIMIT	20	20	1	0.1	20	1
DIGEST	4AB/	4AB/	4AB/	4AB/	4AB/	NAGx/
ANALYTICAL FINISH	OE	OE	OE	MS	OE	VOL
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	1449	2460	199	4.1	1316	1
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	1447	2439	197	4.0	1303	1
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167	3982	1369	173	3.5	609	
0003 AMIS0343						
0004 AMIS0401						
0005 HgSTD-5						
0006 OREAS 45d						
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1						
BLANKS						
0001 Control Blank	X	23	1	X	29	4
0002 Control Blank	X	27	1	0.6	28	

ANALYSIS

ELEMENTS	NAGpH	NAG(4.5)	Ni	Ni	P	Pb
UNITS	NONE	kgH2SO4/t	ppm	ppm	ppm	ppm
DETECTION LIMIT	0.1	1	0.1	1	50	2
DIGEST	NAGx/	NAGx/	4AB/	4AB/	4AB/	4AB/
ANALYTICAL FINISH	MTR	VOL	MS	OE	OE	MS
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	4.7	0	181.6	170	10.52%	113
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	4.7	0	176.1	162	10.40%	109
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167			92.2	92	162	229
0003 AMIS0343						
0004 AMIS0401						
0005 HgSTD-5						
0006 OREAS 45d						
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1						
BLANKS						
0001 Control Blank	4.5	0	X	X	X	X
0002 Control Blank			9.3	10	X	X

ANALYSIS

ELEMENTS	pH	S	S-SO4	Sb	Se	Sn
UNITS	NONE	%	%	ppm	ppm	ppm
DETECTION LIMIT	0.1	0.01	0.01	0.05	0.01	0.1
DIGEST	Paste/		S71/	4AB/	SE1/	4AB/
ANALYTICAL FINISH	MTR	/CSA	OE	MS	MS	MS
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	7.0	1.11	0.48	7.22	21.34	0.7
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	7.0	1.07	0.49	6.75	22.01	0.8
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167				6.43		1.3
0003 AMIS0343						
0004 AMIS0401						
0005 HgSTD-5						
0006 OREAS 45d		0.05				
0007 OREAS 97.01					0.63	
0008 PD-1			4.33			
0009 TOC-1						
BLANKS						
0001 Control Blank		X	X	X	X	0.1
0002 Control Blank			X	X		X

ANALYSIS

ELEMENTS	Sr	Th	TIC	U	V	Zn
UNITS	ppm	ppm	%	ppm	ppm	ppm
DETECTION LIMIT	0.05	0.01	0.01	0.01	2	0.5
DIGEST	4AB/	4AB/	C72/	4AB/	4AB/	4AB/
ANALYTICAL FINISH	MS	MS	CSA	MS	OE	MS
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	1056.66	13.58	0.80	107.02	533	433.1
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	1062.50	13.88	0.80	106.17	525	451.7
STANDARDS						
0001 0.5%NaCl						
0002 AMIS0167	18.66	46.59		454.94	57	152.7
0003 AMIS0343						
0004 AMIS0401						
0005 HgSTD-5						
0006 OREAS 45d						
0007 OREAS 97.01						
0008 PD-1						
0009 TOC-1			1.60			
BLANKS						
0001 Control Blank	X	X	X	X	X	X
0002 Control Blank	0.80	0.02		0.05	X	X

ANALYSIS

ELEMENTS	Zn
UNITS	ppm
DETECTION LIMIT	1
DIGEST	4AB/
ANALYTICAL FINISH	OE
SAMPLE NUMBERS	
0001 Reverse Flotation/Cyclone Overflow	398

CHECKS	
0001 Reverse Flotation/Cyclone Overflow	406

STANDARDS	
0001 0.5%NaCl	
0002 AMIS0167	156
0003 AMIS0343	
0004 AMIS0401	
0005 HgSTD-5	
0006 OREAS 45d	
0007 OREAS 97.01	
0008 PD-1	
0009 TOC-1	

BLANKS	
0001 Control Blank	3
0002 Control Blank	3

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
/CSA	Intertek Genalysis Perth	
Induction Furnace Analysed by Infrared Spectrometry		
4AB/MS	Intertek Genalysis Perth	**4AB/ : MPL_W001, MS : ICP_W003**
Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Beakers. Analysed by Inductively Coupled Plasma Mass Spectrometry.		
4AB/OE	Intertek Genalysis Perth	**4AB/ : MPL_W001, OE : ICP_W004**
Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Beakers. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		
ANCx/MTR	Intertek Genalysis Perth	
Acid Neutralizing Capacity Digestion Procedure. Analysed with Electronic Meter Measurement		
ANCx/QUAL	Intertek Genalysis Perth	
Acid Neutralizing Capacity Digestion Procedure. Analysed by Qualitative Inspection		
ANCx/VOL	Intertek Genalysis Perth	
Acid Neutralizing Capacity Digestion Procedure. Analysed by Volumetric Technique.		
C72/CSA	Intertek Genalysis Perth	**ENV_W017, CSA : ENV_W017**
Digestion by hot acid(s) Analysed by Infrared Spectrometry		
CL1/COL	Intertek Genalysis Perth	**ENV_W014, COL : ENV_W014**
Carbonate leach specific for Chlorine. Analysed by UV-Visible Spectrometry.		
FC7/SIE	Intertek Genalysis Perth	**ENV_W012, SIE : ENV_W012**
Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.		
FP1/OE	Intertek Genalysis Perth	**FP1/ : MPL_W011, OE : ICP_W004**
Sodium peroxide fusion (Zirconia crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		
HG1/CV	Intertek Genalysis Perth	
Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.		
NAGx/MTR	Intertek Genalysis Perth	
Net Acid Generation Extraction of samples with H2O2 Analysed with Electronic Meter Measurement		
NAGx/VOL	Intertek Genalysis Perth	
Net Acid Generation Extraction of samples with H2O2 Analysed by Volumetric Technique.		
Paste/MTR	Intertek Genalysis Perth	
Water Extraction using a specific sample:water ratio. Analysed with Electronic Meter Measurement		
S71/OE	Intertek Genalysis Perth	
Digestion to eliminate sulphides. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
SE1/MS	Intertek Genalysis Perth	

Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled Plasma Mass Spectrometry.

ANALYTICAL REPORT

KNIGHT PIESOLD PTY LIMITED
PO Box 6837
EAST PERTH, W.A. 6892
AUSTRALIA

JOB INFORMATION

JOB CODE	:	752.0/1510895
No. of SAMPLES	:	1
No. of ELEMENTS	:	37
CLIENT O/N	:	PE301-00520/04 (Job 1 of 1)
SAMPLE SUBMISSION No.	:	PE301-00520/04 SS15002
PROJECT	:	FARIUM PHOSPHATE
STATE	:	Solutions
DATE RECEIVED	:	17/08/2015
DATE COMPLETED	:	25/08/2015
DATE PRINTED	:	25/08/2015
ANALYSING LABORATORY	:	Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

MAIN OFFICE AND LABORATORY

15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY

11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY

43 Malcolm Moodie Crescent,
Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

TOWNSVILLE LABORATORY

9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818
Tel: +61 7 4774 3655 Fax: +61 7 4774 4692

Results are not intended for commercial settlement purposes

SAMPLE DETAILS

DISCLAIMER

Intertek Genalysis wishes to make the following disclaimer pertaining to the accompanying analytical results.

All work is performed in accordance with the Intertek Minerals Standard Terms and Conditions of work http://www.intertek.com/terms/

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report.

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SIGNIFICANT FIGURES

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SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of $4.00 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at $150.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

NOTES

1. Note: Detection Limit only apply when TDS <100mg/l for MS and TDS<5000mg/l for OES except when indicated in spreadsheet

ANALYSIS

ELEMENTS	Ag	Al	As	B	Ba	Be
UNITS	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l
DETECTION LIMIT	0.01	0.01	0.1	0.01	0.05	0.1
DIGEST						
ANALYTICAL FINISH	/MS	/OE	/MS	/OE	/MS	/MS
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	0.01	X	0.7	X	29.11	X
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	X	X	0.6	X	30.01	X
STANDARDS						
0001 MSC-5						
0002 SOLN-001						
0003 TAP + Spike		1.99		0.75		
0004 TMDW	2.12		80.1		50.75	17.5
BLANKS						
0001 Control Blank	X	X	X	X	X	0.1

ANALYSIS

ELEMENTS	Bi	Ca	Cd	Cl	Co	Cr
UNITS	ug/l	mg/l	ug/l	mg/l	ug/l	mg/l
DETECTION LIMIT	0.005	0.01	0.5	2	0.1	0.01
DIGEST						
ANALYTICAL FINISH	/MS	/OE	/MS	/COL	/MS	/OE
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	X	145.84	X	21	116.2	X
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	X	143.89	X	20	115.2	X
STANDARDS						
0001 MSC-5						
0002 SOLN-001						
0003 TAP + Spike		19.75				1.98
0004 TMDW	10.051		10.1		26.5	
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ANALYSIS

ELEMENTS	Cu	EC	F	Fe-Sol	Hg	K
UNITS	mg/l	uS/cm	mg/l	mg/l	ug/l	mg/l
DETECTION LIMIT	0.01	10	0.1	0.01	0.1	0.1
DIGEST						
ANALYTICAL FINISH	/OE	/MTR	/SIE	/OE	/MS	/OE
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	X	780	0.4	0.37	X	2.9
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	X	780	0.4	0.36	X	2.9
STANDARDS						
0001 MSC-5						
0002 SOLN-001			1.0			
0003 TAP + Spike	0.91			19.86		4.4
0004 TMDW					X	
BLANKS						
0001 Control Blank	X	X	X	X	0.1	X

ANALYSIS

ELEMENTS	Mg	Mn	Mo	Na	Ni	P
UNITS	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
DETECTION LIMIT	0.01	0.001	0.05	0.1	0.01	0.05
DIGEST						
ANALYTICAL FINISH	/OE	/OE	/MS	/OE	/OE	/OE
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	12.68	0.604	1.01	21.3	0.33	X
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	12.53	0.595	1.01	22.1	0.33	0.08
STANDARDS						
0001 MSC-5						
0002 SOLN-001						
0003 TAP + Spike	6.95	0.793		75.2	0.78	1.93
0004 TMDW			101.15			
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ANALYSIS

ELEMENTS	P-PO4	Pb	pH	S	Sb	Se
UNITS	mg/l	ug/l	NONE	mg/l	ug/l	ug/l
DETECTION LIMIT	0.005	2	0.1	0.05	0.01	0.5
DIGEST						
ANALYTICAL FINISH	/COL	/MS	/MTR	/OE	/MS	/MS
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	X	X	7.5	108.58	0.43	0.7
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	X	X	7.6	109.04	0.40	0.7
STANDARDS						
0001 MSC-5						
0002 SOLN-001						
0003 TAP + Spike				7.54		
0004 TMDW		40			10.05	9.9
BLANKS						
0001 Control Blank	X	X		X	0.01	X

ANALYSIS

ELEMENTS	Sn	Sr	TDSEva	Th	U	V
UNITS	ug/l	ug/l	mg/Kg	ug/l	ug/l	mg/l
DETECTION LIMIT	0.1	0.02	20	0.005	0.005	0.01
DIGEST						
ANALYTICAL FINISH	/MS	/MS	/GR	/MS	/MS	/OE
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow	1.7	368.21	612	X	2.384	X
CHECKS						
0001 Reverse Flotation/Cyclone Overflow	1.7	370.75	598	X	2.426	X
STANDARDS						
0001 MSC-5			764			
0002 SOLN-001						
0003 TAP + Spike						0.80
0004 TMDW	0.1	251.54		X	10.006	
BLANKS						
0001 Control Blank	X	0.05	X	X	X	X

ANALYSIS

ELEMENTS	Zn
UNITS	mg/l
DETECTION LIMIT	0.01
DIGEST	
ANALYTICAL FINISH	/OE
SAMPLE NUMBERS	
0001 Reverse Flotation/Cyclone Overflow	0.06

CHECKS	
0001 Reverse Flotation/Cyclone Overflow	0.06

STANDARDS	
0001 MSC-5	
0002 SOLN-001	
0003 TAP + Spike	0.80
0004 TMDW	

BLANKS	
0001 Control Blank	X

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
/COL	Intertek Genalysis Perth	

No digestion or other pre-treatment undertaken. Analysed by UV-Visible Spectrometry.

/GR	Intertek Genalysis Perth	

Analysed by Gravimetric Technique.

/MS	Intertek Genalysis Perth	

No digestion or other pre-treatment undertaken. Analysed by Inductively Coupled Plasma Mass Spectrometry.

/MTR	Intertek Genalysis Perth	

No digestion or other pre-treatment undertaken. Analysed with Electronic Meter Measurement

/OE	Intertek Genalysis Perth	

Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

/SIE	Intertek Genalysis Perth	

No digestion or other pre-treatment undertaken. Analysed by Specific Ion Electrode.

ANALYTICAL REPORT

KNIGHT PIESOLD PTY LIMITED
PO Box 6837
EAST PERTH, W.A. 6892
AUSTRALIA

JOB INFORMATION

JOB CODE	: 752.0/1511771
No. of SAMPLES	: 2
No. of ELEMENTS	: 5
CLIENT O/N	: P14151 (Job 1 of 1)
SAMPLE SUBMISSION No.	: PE301-00520/04
PROJECT	: FARIUM PHOSPHATE
STATE	: Ex-Pulp
DATE RECEIVED	: 02/09/2015
DATE COMPLETED	: 04/09/2015
DATE PRINTED	: 04/09/2015
ANALYSING LABORATORY	: Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
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*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
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MAIN OFFICE AND LABORATORY

15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY

11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY

43 Malcolm Moodie Crescent,
Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

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9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818

Tel: +61 7 4774 3655 Fax: +61 7 4774 4692

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SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

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SAMPLE STORAGE OF SOLUTIONS

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NOTES

1. Note: Detection Limit only apply when TDS <100mg/l for MS and TDS<5000mg/l for OES except when indicated in spreadsheet

ANALYSIS

ELEMENTS	Cr6+	Cr6+	NAGpHfnl	NAG	NAGpH	NAG(4.5)
UNITS	mg/l	mg/Kg	NONE	kgH2SO4/t	NONE	kgH2SO4/t
DETECTION LIMIT	0.01	0.2	0.1	0.5	0.1	1
DIGEST		Ws/	NAGx/	NAGx/	NAGx/	NAGx/
ANALYTICAL FINISH	/COL	COL	MTR	VOL	MTR	VOL
SAMPLE NUMBERS						
0001 Reverse Flotation/Cyclone Overflow		X	5.5	0.4	4.1	0
0002 Reverse Flotation/Cyclone Overflow soln	X					
CHECKS						
0001 Reverse Flotation/Cyclone Overflow		X	5.5	0.4	4.1	0
BLANKS						
0001 Control Blank	X	X				

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory	NATA Scope of Accreditation
/COL	Intertek Genalysis Perth	

No digestion or other pre-treatment undertaken. Analysed by UV-Visible Spectrometry.

NAGx/MTR	Intertek Genalysis Perth	

Net Acid Generation Extraction of samples with H2O2 Analysed with Electronic Meter Measurement

NAGx/VOL	Intertek Genalysis Perth	

Net Acid Generation Extraction of samples with H2O2 Analysed by Volumetric Technique.

Ws/COL	Intertek Genalysis Perth	

Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed by UV-Visible Spectrometry.

SGS

NATA
Accredited Laboratory
No. 14174

Western Radiation Services
analytical laboratory & consulting

ABN: 44 000 964 278

3 September 2015

Ref: 9397
Order No: P14111

Knight Piesold
Level 1, 184 Adelaide Terrace
EAST PERTH WA 6004

Attn: Simon Smith

ANALYTICAL REPORT

The results (to 95%, 2σ, confidence level) for Radium-226, Radium-228, Thorium-28, Lead-210 and Gross Alpha and Beta of one (1) slurry/solid samples, as received at our laboratory on 17 August are detailed on page two of this report.

The results of Uranium-238 and Thorium-232 analyses by ICPMS are provided as an attachment to this report. For those methods and MDL's please refer to the report of the originating laboratory.

MDL:	Radium-226	0.03 Bq/g	Radium-228	0.03 Bq/g
	Thorium-228	0.03 Bq/g	Lead-210	0.03 Bq/g
	Uranium (Total)	0.03 Bq/g	Thorium (Total)	0.03 Bq/g
	Alpha	0.03 Bq/g	Beta	0.03 Bq/g

Method:	LTP No. 4(a)	Gamma Spectrometry Analysis
	LTP No. 6	Gross Alpha/Beta Analysis Gas Flow Proportional Counting

Madassar A. Qureshi
Authorised Signatory

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Perth Office: 24 Brennan Way, Belmont W.A. 6104
Tel: 61 8 9475 0099 | **Fax:** 61 8 9475 0165
Email: AU.radiation.perth.lab@sgs.com

WRS No.	Client Sample ID	Gross Alpha (Bq/g)	Gross Beta (Bq/g)
9397-1	PE301-520	0.275 ± 0.030	8.02 ± 0.56

WRS No.	Client Sample ID	Ra-226 (Bq/g)	Ra-228 (Bq/g)
9397-1	PE301-520	0.735 ± 0.058	0.055 ± 0.009

WRS No.	Client Sample ID	Th-228 (Bq/g)	Pb-210 (Bq/g)
9397-1	PE301-520	0.033 ± 0.005	0.127 ± 0.009

WRS No.	Client Sample ID	Uranium* (Total) (Bq/g)	Thorium* (Total) (Bq/g)
9397-1	PE301-520	0.738 ± 0.061	0.061 ± 0.017

*calculated

Gamma Spectrometry

The reported expanded uncertainty of measurement is stated as the standard uncertainty of the measurement ± 5.6 %, multiplied by the coverage factor k=2, which corresponds to a coverage probability of approximately 95%.

Gross Alpha and Beta

The reported expanded uncertainty of measurement is stated as the standard uncertainty of the measurement ± 5.7 %, multiplied by the coverage factor k=2, which corresponds to a coverage probability of approximately 95%.

Perth Office: 24 Brennan Way, Belmont W.A. 6104
Tel: 61 8 9475 0099 | **Fax:** 61 8 9475 0165
Email: AU.radiation.perth.lab@sgs.com

SGS

Ros Ma

SGS Environmental Services

10 Reid Road
Perth International Airport
Newburn, WA 6105
Australia

Lab Ref	WM165012
Client Ref	**PE101303**
Project	*
Cost Code	NA
Status	Final
Received	27/08/15
Reported	31/08/15
Samples	1
First Sample	PE101303.001 9397-1
Last Sample	PE101303.001 9397-1
Pages	3

Copy

Notes

Authorised by *On behalf of:*

Graeme Farrant
Laboratory Manager

The results in this analytical report pertain to the samples provided to this laboratory for preparation and/or analysis as requested by the client. This document is issued by the company subject to its General Conditions of Services (www.sgs.com/generalconditions). Attention is drawn to the limitations of liability, indemnification and justifications issues established therein.

Lab Ref	WM165012
Client Ref	**PE101303**
Project	*
Reported	31/08/15
Status	Final
Page	Page 2 of 3

ANALYTICAL REPORT

Scheme	IMS84V	IMS84V
Units	PPB	PPB
Detection Limit	1	1
Upper Limit	10000	10000
	U	Th
PE101303.001 9397-1	6170	830

- not analysed / -- element not determined / I.S. insufficient sample / L.N.R. listed not received

Results are not intended for commercial settlement purposes.

DESCRIPTION

ENV01 : Environmental Levy

IMS84V : ICPMS Solutions and Brines

SRT01 : Sorting of samples prior to preparation

GB MINERALS LIMITED
FARIM PHOSPHATE PROJECT

WASTE ROCK GEOCHEMICAL CHARACTERISATION REPORT

PREPARED FOR:

Lycopodium Minerals Canada Ltd.
5060 Spectrum Way, Suite 302,
Mississauga,
ON L4W 5N5
CANADA

PREPARED BY:

Knight Piésold Pty Limited
Level 1, 184 Adelaide Terrace
East Perth, WA 6004, AUSTRALIA
p. +61 9223 6300 • f. +61 9223 6399

Knight Piésold
CONSULTING
www.knightpiesold.com

PE301-00520/06
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September 2015

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LYCOPODIUM MINERALS CANADA LTD

FARIM PHOSPHATE PROJECT

WASTE ROCK GEOCHEMICAL CHARACTERISATION REPORT

KP Project No.: PE301-00520/04

KP Report No.: PE301-00520/06

CONTRACT

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A	Lycopodium Minerals Canada Ltd, 5060 Spectrum Way, Suite 302, Mississauga, ON L4W 5N5, Canada	-	1

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DEFINITION OF TECHNICAL TERMS

Acronym or Symbol	Parameter	Brief Description	Determination / Source	Unit
ACA	Average Crustal Abundance	Average concentration of a particular element in Earth's crust.	References	ppm
AFP	Acid Formation Potential	The potential of a material to form acid.	Calculation	N/A
ANC	Acid Neutralising Capacity	A materials ability to neutralise acid generally through mineral dissolution.	Analysis Result	kg H_2SO_4/tonne
ARD	Acid Rock Drainage	Acid metal rich leachate resulting from sulfide oxidation.		N/A
C_n	Element Concentration	Measure of concentration of an element in a particular sample.	Analysis Result	ppm or %
CRS	Chromium Reducible Sulfur	A laboratory test to determine the sulfide content of a sample	Analysis Result	ppm or %
EC	Electrical Conductivity	A measure of electrical current transported by the ions in solution.	Analysis Result	mS/cm
GAI	Geochemical Abundance Index	A scale of enrichment based on C_n and ACA.	Calc.(GAI = Log_2 (C_n / (1.5 x ACA))	None
MPA	Maximum Potential Acidity	The max. amount of acid which can be produced by oxidisation of contained sulfides.	Calc.(MPA = Sulfide-S x 30.6)	kg H_2SO_4/tonne
NAF	Non Acid Forming	Material does not produce acid either as a result of low sulfide contents or due to excess acid neutralising capacity.	Calculation	N/A
NAG	Net Acid Generation	A direct measure of acid production under extreme oxidising conditions.	Analysis Result	kg H_2SO_4/tonne
NAPP	Net Acid Producing Potential	The balance between MPA and ANC.	Calc.(NAPP = ANC – MPA)	kg H_2SO_4/tonne
HCl	Hydrochloric Acid	A mineral acid.		N/A
H_2O_2	Hydrogen Peroxide	A strong oxidising agent.		N/A
H_2SO_4	Sulfuric Acid	A mineral acid.		N/A
PAF	Potentially Acid Forming	Material has potential to produce acid through sulfide oxidation.	Calculation	N/A
Sulfate-S	Sulfate Sulfur	The sulfur present in the oxidised state.	Result	%
Sulfide-S	Sulfide Sulfur	The sulfur present in the reduced state.	Calc.(Sulfide-S = Total-S – Sulfate-S)	%
TDS	Total Dissolved Solids	A measure of the total amount of material dissolved in a solution.	Analysis Result	ppm
Total-S	Total Sulfur	The total amount of sulfur present.	Analysis Result	%

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1. INTRODUCTION

1.1 GENERAL

The Farim Phosphate Project is being developed by GB Minerals Ltd (GBML). Knight Piésold Pty Ltd (KP) was engaged by Lycopodium Minerals Canada Ltd. (Lycopodium) to provide engineering services as part of the feasibility study (FS), comprising geotechnical site investigations and assessment of the proposed sites of the tailings storage facility and process plant, geotechnical assessment of the proposed port site, feasibility level design of the tailings storage facility, an hydrogeological and de-watering assessment for the open pits, a waste rock geochemical assessment study, and surface water management design for the project site.

A previous study of the waste rock geochemistry was conducted by Golder Associates (Golders) in 2012 (Refs. 1 and 2), details of which are provided in Section 1.3. KP developed preliminary recommendations for waste rock management based on a review of the previous geochemical information, as reported in Memorandum No. PE15-00483 (Ref. 3).

This report presents details of the scope and findings of a waste rock geochemical assessment conducted by KP, with revised recommendations for waste rock management.

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1.2 PROJECT DESCRIPTION AND GEOLOGY

The Farim project site is located in the north of Guinea-Bissau, approximately 25 km south of the Senegal border, 5 km west of the town of Farim and 120 km north-east of Bissau, the capital of Guinea-Bissau. The project will comprise an open pit mining operation with two separate pits.

A summary of the geology is taken from Golders Report No. 11514950096.515/B.0 (full reference not known), as follows:

> *"The project comprises a high grade phosphate deposit which occurs within the Middle Eocene Lutetian Formation in a Cenozoic sedimentary basin that extends from Morocco in the north through Mauritania, Senegal, Guinea-Bissau and into Guinea to the south. The basin hosts a number of important phosphate deposits and accounts for almost 25% of world production. Three phosphate-bearing horizons have been identified at the Farim phosphate deposit. These are referred to as the FPO, FPA and FPB. The FPO is a clayey dolomitic limestone that is weakly phosphatic with limited economic potential. The FPA underlies the FPO and is a soft, poorly cemented unit of phosphatic sand, which includes phosphatised shell and bone material, teeth, faecal pellets and crustacean*

coprolites. The unit is beige to brown and lies in a generally reducing environment below the oxidised interval. The FPA unit is the identified potentially economic phosphate bed. The FPB underlies the FPA and is a calcareous phosphate unit comprising a much harder phosphatic limestone than the FPA unit. The FPB member is of less economic interest due to the low phosphate and high limestone content. The phosphate deposit is underlain by a soft, white and porous limestone unit.

The phosphate bearing strata are unconformably overlain by a sandy-argillaceous sequence comprising soft alternating sandy, clayey and sandy-clay layers with a blue/green soft clay or black lignitic clay at the base."

An overview of the site stratigraphy is summarised in Table 1.1.

Table 1.1: Indicative site stratigraphy

Age	Unit	Description	Approx. Thickness (m)
Post Eocene	Sandy/Argillaceous Overburden	Alternating sandy, clayey and sandy clayey layers	27 to 58
	Basal Clay Overburden	Blue/green soft clay and black lignitic clay (anoxic depositional environment)	
Eocene	Sand including FPO (phosphatic interval)	Grey/white fine grained sand including phosphate bearing clayey dolomitic limestone (FPO)	7 (single intercept)
	Upper Dolomitic Limestone	Clayey limestone	>2 [1] (single intercept)
	Decarbonised Phosphate Unit (FPA)	Ore zone comprising beige to brown, poorly cemented very fine grained phosphatic sand.	1 to 11
	Calcareous Phosphate Unit FPB	Cemented phosphatic limestone	2 to 8
	Limestone	Soft, white and porous limestone	>6 to 17 [1]

[1] Base of unit not encountered

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The actual stratigraphy recorded in the recent drilling to provide geotechnical data and geochemical waste rock samples appears to be highly variable, with the indicative stratigraphic column provided in Table 1.1 rarely clearly defined and certain strata not always present.

1.3 PREVIOUS STUDIES

Geochemical testing of twenty composite samples of overburden comprising clay, sand and mudstone was undertaken by Golders in 2012. KP have not sighted this data nor the original geochemical characterisation report(s), but have been provided with a copy of a memorandum report prepared by Golders (Ref. 1) which presents a summary of the investigation findings. Additional details were also available within the ESIA baseline report (Ref. 2). However, the ESIA baseline report provided to KP did not include appendices of raw geochemical data or laboratory certificates. Therefore, KP has not been able to independently verify the summaries prepared by Golders.

All twenty samples selected by Golders were submitted for whole rock analyses (XRF and 3 acid digest), semi-quantitative XRD, acid base accounting, single addition NAG and shake flask extract. Two duplicate samples were also analysed. Below is a summary of the investigation findings, as reported by Golders.

The static testing is reported to have indicated a low acid generation potential and low neutralisation potential. As such, it was concluded that the potential for acid generation through the oxidation of waste rock was expected to be low.

The mineralogy results indicate that pyrite was the only sulfide mineral detected and found to be present in just over a third of samples with concentrations ranging from 0.3% to 3.5% by weight. Calcite was only encountered within one sample constituting 0.6%. The iron carbonate mineral siderite was present in just under one third of samples with concentrations ranging from 0.5% to 11%. However, Golders applied a modified ANC test method to account for the presence of siderite and prevent overestimation. Two phosphate minerals were also identified; cranulite (at 9.5% in one sample) and fluorapatite (in two samples at 1.8% and 12%).

It is reported that trace metal concentrations within the overburden waste are typically at or below crustal abundances. However, silver, arsenic, molybdenum, selenium and uranium are reported to exceed the crustal abundance by a factor of six in one or more samples. It is not clear whether this exceedance refers to Global Abundance Indices, whereby this would be indicative of highly enriched elements, or simple multiplication which would infer low levels of enrichment. For clarity, the method applied by KP (and accepted industry practice) to assess enrichment of trace metals is set out in Section 2.6.1.

Distilled water extract testing was undertaken and compared to surface water data for the River Cacheu and WHO drinking water guidelines. The results indicated that phosphate, ammonia, ammonium, sulfate, arsenic, cadmium, chromium, iron,

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manganese, nickel, lead and zinc exceed the reference surface water data with cadmium and nickel exceeding the WHO drinking water guidelines.

1.4 WASTE ROCK SAMPLE SELECTION

Waste rock samples for geochemical analysis were made available from a series of boreholes drilled within the footprints of the North and South Pits in June and July 2015 under the direction of GBML. KP was provided with basic logs (written in Portuguese) for five boreholes from which to nominate sampling intervals. KP made recommendations for sampling based on the data provided and the selected samples were sent to the laboratory of Maxxam Analytics in Burnaby, Canada for testing. The target number of samples from each unit and actual number selected are summarised in Table 1.2, and a complete list of as-sampled intervals is detailed in Table 1.3.

Table 1.2: Target and Actual Sampling of Lithographic Units

Unit	Target No. of Samples	No. Samples Selected
Overburden Samples	21	20
Basal Clay / Lignite samples	7	10
Eocene sand + FPO	7	6
Eocene Clayey Limestone	7	2
Total	42	38

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Table 1.3: Sampling Intervals

Sample No.	Sample ID	Lithology (as logged)
1	NP-15-2, 15 m	Sandy clay
2	NP-15-2, 15 m	Sandy clay
3	NP-15-2, 17 m	Fine Sand
4	NP-15-2, 17 m	Fine Sand
5	NP-15-2, 36 m	Plastic clay
6	NP-15-2, 38.5 m	Plastic clay
7	NP-15-2, 54.5 m	Sand with lignite
8	NP-15-2, 54.5 m	Sand with lignite
9	NP-15-2, 57.5 m	Grey phosphate clay
10	NP-15-2, 57.5 m	Grey phosphate clay
11	SP-15-3, 21.5 m	Clay
12	SP-15-3, 21.5 m	Clay
13	SP-15-3, 33 m	Fine Sand
14	SP-15-3, 33 m	Fine Sand
15	SP-15-3, 34.5 m	Clayey sand
16	SP-15-1, 15 m	Sandy clay/plastic clay
17	SP-15-1, 19.5 m	Sandy clay/plastic clay
18	SP-15-1, 19.5 m	Sandy clay/plastic clay
19	SP-15-1, 24.5 m	Sandy clay/plastic clay
20	SP-15-1, FPA.CO m	Sand/FPA
21	SP-15-1, FPA.CO m	Sand/FPA
22	SP-15-2, 16 m	Clay sandy
23	SP-15-2, 21 m	Clay sandy
24	SP-15-2, 21 m	Clay sandy
25	SP-15-2, 26 m	Clay sandy
26	SP-15-2, 26 m	Clay sandy
27	SP-15-2, 27.5 m	Sand with lignite
28	SP-15-2, 27.5 m	Sand with lignite
29	NP-15-4, 15.5 m	Clay
30	NP-15-4, 15.5 m	Clay
31	NP-15-4, 26 m	Fine sand, sandy clay
32	NP-15-4, 26 m	Fine sand, sandy clay
33	NP-15-4, 32 m	Plastic clay
34	NP-15-4, 32 m	Plastic clay
35	NP-15-4, 33.5 m	Fine sand, plastic clay
36	NP-15-4, 33.5 m	Fine sand, plastic clay
37	NP-15-4, 45 m	Fine sand
38	NP-15-4, 45 m	Fine sand

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2. TESTING METHODS

2.1 ACID BASE ACCOUNTING

Acid base accounting (ABA) assesses a sample's potential to form acid from the oxidation of sulfides and the ability to neutralise acid by the dissolution of minerals, particularly carbonates, contained in the sample.

Total sulfur, total carbon and total inorganic carbon were determined by Leco induction furnace, with infrared detection. Sulfate sulfur was determined by ICP following a hydrochloric acid digest. The testing methods specified are based on the ABA methodology defined in the Mine Environment Neutral Drainage (MEND) Acid Rock Drainage Prediction Manual (Ref. 4) and Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Ref. 5).

Acid Neutralising Capacity (ANC) was determined by digestion in a standard solution of HCl, followed by back titration with NaOH to determine the amount of acid consumed. The technique used was based on Sobek et al (Ref. 6), with a siderite correction step added to the standard procedure.

The results of the ABA testing are used to calculate the Maximum Potential Acidity (MPA), which is a measure of the maximum amount of sulfuric acid which can be produced from the total oxidation of all sulfides within the sample, assuming all sulfides are present as pyrite.

The Net Acid Producing Potential (NAPP) is the balance between the MPA and ANC. A negative NAPP indicates that there is an excess neutralising capacity and a positive NAPP indicates there is excess potential acidity.

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2.2 NET ACID GENERATION (NAG)

Net Acid Generation (NAG) testing provides a direct measure of a sample's ability to produce acid through sulfide oxidation. The addition of hydrogen peroxide to samples causes rapid oxidation of the contained sulfides to produce sulfuric acid.

The specified procedure is based on the Static NAG Test (Ref. 7 and 8). The static NAG test involves the addition of 250 mL of 15 per cent hydrogen peroxide to 2.5 g of pulverised sample. The sample is allowed to react overnight prior to heating for a period of three hours. Once the sample has cooled the pH of the sample is measured prior to titration back to pH 4.5 and 7 to determine the acidity produced by the oxidisation reactions.

Organic acids may be generated in the NAG test when organic carbon is present due to partial oxidation of the carbonaceous material. This can lead to low NAG pH values which are not due to acid generation from sulfides. Organic acid effects can, therefore,

result in misleading NAG values and misclassification of the acid formation potential of samples which contain significant organic carbon. The extended boil NAG test (Ref. 9) can be used to account for the organic acidity and this method was applied to four samples logged as containing lignite.

2.3 ACID FORMING POTENTIAL

The acid formation potential of a sample is calculated based on the acid base accounting, i.e. the balance between a sample's ability to produce acid from the oxidisation of sulfide minerals (MPA) and neutralise acid by the dissolution of alkaline minerals (ANC).

Historically a safety margin was applied to ratio between the ANC and MPA to allow for variability in the rates of acid production and neutralisation processes and the potential for geographic separation of the acid producing and acid neutralising phases. This safety margin was generally set by industry at 2 in North America and 3 in Australia.

With recent advances in the understanding and acceptance of the NAG test there has been a move away from this method of classifying materials based solely on the ANC and MPA as these calculated parameters do not take into consideration the true availability of acid producing and acid neutralising phases.

KP prefers to utilise the results of the acid base accounting in combination with the NAG testing results to classify the acid formation potential of materials. KP's classification system, as summarised in Table 2.1, is based on the Australian guidelines on Managing Acidic and Metalliferous Drainage (Ref. 10) and is broadly similar to the classification system contained within the AMIRA ARD Test Handbook (Ref. 11), which is advocated by the Global Acid Rock Drainage Guidelines (Ref. 12).

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Table 2.1: Acid Formation Potential Classification System

Acid Formation Potential Class	NAPP (kg H_2SO_4 /t)	NAG pH
Potentially Acid Forming (PAF)	>10	<4.5
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than -100	≥4.5
Uncertain (UC)	Positive	≥4.5
	Negative	<4.5

2.4 MULTI-ELEMENT ANALYSIS

2.4.1 Element Enrichment

Multi-element analysis was conducted to assess elemental enrichments within the samples. The specified four acid digestion method results in near total digestion of the samples to assess the whole rock geochemistry.

Multi-element analysis results are compared to the average crustal abundance to determine geochemical abundance indices. The Geochemical Abundance Index (GAI) quantifies an assay result for a particular element in terms of average crustal abundance.

The GAI is calculated from the following formula:

$$\mathbf{GAI = Log_2 (C_n / (1.5 \times B_n))}$$

Where:

C_n = measured concentration of element in sample

B_n = average crustal abundance (Bowen, Ref. 13)

The GAI is expressed on a scale of 0 to 6, with 0 indicating that the element concentration is less than or similar to average crustal abundance, and a GAI of 6 indicating an element concentration of more than 96 times the average crustal abundance. The enrichment ranges for GAIs are as follows:

- GAI = 0 represents <3 times crustal abundance.
- GAI = 1 represents 3 to 6 times crustal abundance.
- GAI = 2 represents 6 to 12 times crustal abundance.
- GAI = 3 represents 12 to 24 times crustal abundance.
- GAI = 4 represents 24 to 48 times crustal abundance.
- GAI = 5 represents 48 to 96 times crustal abundance.
- GAI = 6 represents more than 96 times crustal abundance.

KP has assigned an arbitrary scale to the GAI, with indices of 0 and 1 being classified as “not enriched”, an index of 2 being classed as “slightly enriched”, indices of 3 and 4 being classed as “significantly enriched” and indices of 5 and 6 being classified as “highly enriched”.

2.4.2 Soil Quality Screening for Closure Planning

The multi-element analysis results were also compared to guideline concentrations for soil quality based on risk to human health and ecology for preliminary assessment of possible closure requirements, such as construction of engineered cover systems or limiting land use / access.

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The Australian National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (Ref. 14) has been used to assess risk to human health, based on an assumed 'recreational' closure land use. This assumes the final landform will comprise public open space such as parks and playing fields rather than undeveloped public open space where the potential for exposure will be lower. However, these values assume that no planting of crops for human consumption will occur.

To assess ecological risk, the U.S. Environmental Protection Agency Ecological Soil Screening Levels (Eco-SSLs) (Ref. 15) have been applied. These values apply to sites where terrestrial organisms may be exposed directly or indirectly to contaminated soil. The Eco-SSL values for mammalian wildlife have been adopted for this study. The Eco-SSLs do not provide guideline values for sulfur, sulfate or phosphorous. Therefore, the former National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999) (Ref. 16) ecological investigation levels for these substances have been included for reference purposes in the absence of other more applicable ecological assessment criteria.

The Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) has developed a series of soil-screening values for contaminated sites as part of the Dutch Soil Protection Act (VROM 2000) (Ref. 17). Soil quality is assessed and managed using target and intervention values which are independent of land use. Soils with contaminant concentrations below target values are considered to be at no risk and no restrictions on their use have been set. Soils with contaminant concentrations exceeding the intervention values require remediation as a matter of urgency, as the functional properties of the soil for humans, plant and animal life is seriously impaired or threatened. Therefore, for preliminary screening purposes, the intervention values have been applied in this study. For certain substances where intervention values have not been set, so-called "indicative levels for serious contamination" have been provided. These have also been included in this study, where appropriate.

The establishment of these soil quality screening values is to allow for evaluation only and it is not implied by production of these values that the Farim project will be required to meet these reference levels or that these reference levels should be used as the regulatory framework. The regulatory requirements for the project will be determined by the relevant regulatory authorities during the environmental design phase of the project.

2.5 RADIOMETRIC ANALYSIS

Radiometric analysis of fourteen samples was conducted to assess and quantify the various nuclides present in the Uranium-238 and Thorium-232 decay chain within the sample. The radiometric analysis was conducted by SGS (formerly Western Radiation Services) in Perth. The samples were pulverised for homogeneity and sealed in a fixed geometry counting container. High resolution gamma spectrometry was used for the counting and analysis of different nuclides present in the Uranium-238 and Thorium-238 decay chains, specifically Radium-226, Ra-228 and Pb-210, with gas flow proportional counting used for determining gross alpha and beta. Neutron activation was used for the quantification of Uranium-238 and Thorium-232.

The results of the radiometric analysis have been compared to the Canadian Guidelines for the Management of Naturally Occurring Radioactive Material (NORM) (Ref. 18). The Canadian Guidelines provide limits at which NORM may be released with no radiological restrictions. These limits, provided in Table 2.2 below, have been calculated to ensure that the associated radiation dose to the public would be no more than 0.3 mSv per annum. The radioactive hazard associated with this dose is considered insignificant, and no further controls on the material are necessary on radiological protection grounds. Where the activity exceeds the devised release limits for diffuse naturally occurring radioactive material, a site-specific radiation dose assessment needs to be carried out to estimate the doses to workers and members of the public, and to determine appropriate radiation protection measures.

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Table 2.2: Derived release limits - diffuse NORM sources

NORM Radionuclide	Derived Release Limit (Bq/g)
Uranium-238 Series (all progeny)	0.3
Uranium-238 (U-238, Th-234, Pa-234m, U-234)	10
Thorium-230	10
Radium-226 (in equilibrium with its progeny)	0.3
Lead-210 (in equilibrium with Bi-210 and Po-210)	0.3
Thorium-232 Series (all progeny)	0.3
Thorium-232	10
Radium-228 (in equilibrium with Ac-228)	0.3
Thorium-228 (in equilibrium with all its progeny)	0.3
Potassium-40	17

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The ^{238}U and ^{232}Th results can also be compared to a wider array of international guidelines and legislation which specify different definitions of radioactive material to assess whether the waste rock is likely to be classified as radioactive. The guideline values provided by the International Atomic Energy Agency (IAEA) (Ref. 19), Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (Ref. 20), Radiation Safety Act (Ref. 21) and Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM) (Ref. 18) are summarised in Table 2.3.

Table 2.3: Guideline Values for Classification of Radioactive Material

Guideline	^{238}U (All Progeny) Bq/g	^{232}Th (All Progeny) Bq/g
IAEA (International)	1	1
ARPANSA (Australia)	1	1
Radiation Safety Act (WA, Australia)	30	30
Management of NORM (Canada)	0.3	0.3

2.6 QUANTITATIVE MINERALOGY

Twelve of the samples were submitted for quantitative phase analysis using the Rietveld method and X-ray powder diffraction (XRD) data.

The samples were reduced to the optimum grain-size range for quantitative X-ray analysis (<10 μm) by grinding under ethanol in a vibratory McCrone Micronizing Mill for 10 minutes. Continuous-scan X-ray powder-diffraction data were collected over a range 3-80°2 θ with CoKα radiation on a Bruker D8 Advance Bragg-Brentano diffractometer equipped with an Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye-XE detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

The X-ray diffractograms were analysed using the International Centre for Diffraction Database PDF-4 and Search-Match software by Bruker. X-ray powder-diffraction data of the samples were refined with Rietveld program Topas 4.2 (Bruker AXS).

2.7 DISTILLED WATER EXTRACT

Distilled water extract tests were conducted on nineteen samples to assess the potential for leaching of environmentally significant elements, which could have a detrimental effect on the seepage water quality. The procedure specified is based on the Shake Flask Method as described in the Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Ref. 5), as described below.

Initially 50 grams of each sample was mixed with 150 mL of deionized water. The mixtures were then bottle rolled for 24 hours. The pH and the conductivity of the solutions were measured and the bottles left to stand for a minimum of three hours. The solution was then siphoned off and filtered through a 0.45 µm membrane before preservation of the solution by acid addition prior to analysis. The analysis was typically by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) depending on the element being analysed and the detection limits required.

The results have been compared to three sets of reference water quality standards, which are discussed in Section 2.8.

2.8 REFERENCE WATER QUALITY STANDARDS

To allow assessment of the results of the distilled water extract analysis a set of reference values has been established. These reference values were compiled from internationally accepted guidelines for water quality for release from mining operations (IFC environmental, health and safety guidelines (Ref. 22 and 23) and the ANZECC water quality guideline for livestock drinking water (Ref. 24)). The use of several guidelines is required as no single guideline contains target concentrations for all parameters. Where a target concentration for a specific element is at different levels in various guidelines, the lowest concentration has been adopted. These reference values

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are summarised in Table 2.4. The water quality results of the supernatant analysis have also been compared to Australian drinking water guidelines (Ref. 25) with the Australia drinking water guideline values provided in Table 2.5. Another useful assessment is to compare the supernatant results to baseline surface water and groundwater monitoring data. A summary of the baseline data, which is taken from the environmental and social baseline studies report (Ref. 2) is presented in Table 2.6.

The establishment of these reference water quality values is to allow for evaluation only and it is not implied by production of the reference water quality values that the Farim project will be required to meet these reference levels or that these reference levels should be used as the regulatory framework. The regulatory requirements for the project will be determined by the relevant regulatory authorities during the environmental design phase of the project.

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Table 2.4: Reference Guidelines for Water Release and Livestock Drinking Water

Parameter	Units	ANZECC Livestock	IFC 2004	IFC 2007	Adopted Reference Level
pH	pH Units		6 to 9	6 to 9	6 to 9
TDS	mg/kg	2000			2000
Aluminum	mg/L	5			5
Antimony	mg/L				N/G
Arsenic	mg/L	0.5	0.1	0.1	0.1
Barium	mg/L				N/G
Boron	mg/L	5			5
Cadmium	mg/L	0.01	0.1	0.05	0.01
Calcium	mg/L	1000			1000
Chloride	mg/L				N/G
Chromium	mg/L	1			1
Cobalt	mg/L	1			1
Copper	mg/L	0.4	0.5	0.3	0.3
Fluoride	mg/L	2	20		2
Iron	mg/L		3.5	2	2
Lead	mg/L	0.1	0.1	0.2	0.1
Magnesium	mg/L	2000			2000
Manganese	mg/L				N/G
Mercury	mg/L	0.002	0.01	0.002	0.002
Molybdenum	mg/L	0.15			0.15
Nickel	mg/L	1	0.5	0.5	0.5
Phosphate	mg/L				N/G
Selenium	mg/L	0.02	0.1		0.02
Silver	mg/L		0.5		0.5
Sodium	mg/L				N/G
Sulfate	mg/L	1000			1000
Tin	mg/L				N/G
Uranium	mg/L	0.2			0.2
Vanadium	mg/L				N/G
Zinc	mg/L	20	2	0.5	0.5

N/G – No guideline

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Table 2.5: Australian Drinking Water Guidelines

Parameter	Units	Health	Aesthetic	Adopted Reference Level
pH	pH Units		6.5 to 8.5	6.5 to 8.5
TDS	mg/kg		600	600
Aluminum	mg/L		0.2	0.2
Antimony	mg/L	0.003		0.003
Arsenic	mg/L	0.01		0.01
Barium	mg/L	2.0		2.0
Boron	mg/L	4		4
Cadmium	mg/L	0.002		0.002
Calcium	mg/L			N/G
Chloride	mg/L		250	250
Chromium	mg/L			N/G
Cobalt	mg/L			N/G
Copper	mg/L	2	1	1
Fluoride	mg/L	1.5		1.5
Iron	mg/L		0.3	0.3
Lead	mg/L	0.01		0.01
Magnesium	mg/L			N/G
Manganese	mg/L	0.5	0.1	0.1
Mercury	mg/L	0.001		0.001
Molybdenum	mg/L	0.05		0.05
Nickel	mg/L	0.02		0.02
Phosphate	mg/L			N/G
Selenium	mg/L	0.01		0.01
Silver	mg/L	0.1		0.1
Sodium	mg/L		180	180
Sulfate	mg/L	500	250	250
Tin	mg/L			N/G
Uranium	mg/L	0.02		0.02
Vanadium	mg/L			N/G
Zinc	mg/L		3	3

N/G – No guideline

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Table 2.6: Average Surface Water and Groundwater Quality

Parameter	Units	Surface Water	Groundwater
pH	pH Units	7.1	6.4
TDS	ppm	2527	293
EC	µS/cm	3905	1334
Arsenic	mg/L	0.001	0.002
Calcium	mg/L	41	45
Cadmium	mg/L	0.0001	0.0002
Chloride	mg/L	1337	96
Chromium	mg/L	0.002	0.001
Copper	mg/L	0.005	□.01
Iron	mg/L	0.20	1.3
Mercury	mg/L	0.00002	N/M
Potassium	mg/L	25	2.8
Magnesium	mg/L	78	15.9
Manganese	mg/L	0.05	0.34
Sodium	mg/L	769	42
Nickel	mg/L	0.002	0.002
Lead	mg/L	0.002	0.001
Phosphate	mg/L	0.14	0.15
Sulfate	mg/L	120	28
Zinc	mg/L	0.01	0.06

N/M – Not measured

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3. WASTE ROCK GEOCHEMICAL RESULTS

3.1 INTRODUCTION

Laboratory test certificates for the analytical testing conducted are provided in Appendix A. The results are presented and discussed in the following sections. As part of the quality control and assurance programme conducted by Maxxam Analytics, duplicates of certain analyses were conducted on selected samples. The results presented in the following sections are the average of the original and duplicate tests.

3.2 ACID BASE ACCOUNTING

Total sulfur content of the tailings was determined by LECO combustion. In addition, the samples were analysed for HCl soluble sulfate. The difference between these two values was assumed to be equal to the sulfide content of the sample. The results of the analysis are given in Table 3.1 and indicate sulfur contents of between <0.02% and 5.23% at an average of 0.46% which is moderate. Twenty one samples recorded low sulfur contents of 0.03% or less, with only five samples recording very high sulfur contents of more than 1%.

Sulfate contents were typically low, varying from <0.01% to 0.13% at an average of 0.03%, indicating the majority of sulfur to be present as sulfide. Consequently, the sulfide contents were calculated as being similar to the total sulfur results, varying from negligible to 5.1% at an average of 0.43% which is moderate. Twenty six samples recorded low sulfide concentrations of 0.03% or less, with five sample recording very high concentrations of more than 1%.

The maximum potential acidity (MPA) was calculated based on the sulfide contents from negligible to 156 kg H_2SO_4 / tonne of waste rock at an average of 13 kg H_2SO_4 / t which is moderate.

The acid neutralising capacity (ANC) of the samples was determined along with the carbonate content. The two results can be used as a check against one another and to identify the contribution of ANC from carbonates and other non-carbonate minerals. The ANC was typically found to be very low varying from negligible to 5.9 kg H_2SO_4 / t at an average of 2.9 kg H_2SO_4 / t. However, six samples recorded high ANC values between 24.5 and 62.7 kg H_2SO_4 / t. Four of these were from phosphate bearing strata below the overburden, with two from the “sand/lignite” zone at the base of the overburden. Two samples also recorded extremely high ANC values greater than 800 kg H_2SO_4 / t, which are interpreted to represent the clayey dolomitic limestone in the phosphate bearing strata.

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The carbonate contents were typically very low, with twenty four samples recording inorganic carbon contents below the limit of detection. As such, these samples are essentially devoid of carbonate minerals, with any neutralising capacity derived from non-carbonate minerals. A further six samples recorded carbonate-ANC values significantly higher than the measured ANC, indicating the possible presence of siderite. These samples were from the basal overburden zone and phosphate bearing strata. This is discussed further in Section 3.5.

As would be expected, the two samples of clayey dolomitic limestone recorded near identical calculated carbonate-ANC results and measured ANC values.

The Net Acid Producing Potential (NAPP) of the samples was calculated from the MPA and the ANC along with the ANC/MPA ratio. When excluding the dolomitic limestone samples from the data, the NAPP values were found to vary from -46 to 108 kg H_2SO_4 / t at an average of 2.8 kg H_2SO_4 / t, indicating marginally greater acid producing potential. Conversely, the ANC/MPA ratios varied from zero to 19 at an average of 6.6 (dolomitic limestone samples excluded), indicating excess neutralising capacity. However, this confliction is because twenty six samples recorded MPA values less than one, with many reported at 0.31 kg H_2SO_4 / t due to negligible sulfide sulfur contents. As such, even when the ANC values were low at say 1 kg H_2SO_4 / t, this results in an ANC/MPA ratio of 3.2. Therefore, in cases where many samples record both low ANC and MPA values, ANC/MPA ratios can be exaggerated and misleading.

All acid base accounting results are presented in Table 3.1.

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3.3 NET ACID GENERATION

The net acid generation (NAG) test aids in interpretation of the acid formation potential. It also identifies whether the sulfides and neutralising minerals contained in the samples are readily available to produce or consume acid.

The results of the NAG test are given in Table 3.1 and indicate that following extreme oxidising conditions, the final pH of the NAG solutions varied significantly from 2.3 to 11.1, with seven samples recording NAG pH values less than 4.5. The acidity produced by the samples varied from zero to 39.8 kg H_2SO_4 / t at an average of 3.8 kg H_2SO_4 / t. As such, certain samples have the potential to produce significant volumes of acid, assuming complete oxidation of all sulfide minerals.

Given the presence of lignite noted in the logs for four samples, it was assumed that these samples may be high in organic carbon. As such, these samples were submitted for extended boil NAG testing to account for organic acids which may be generated during the standard NAG test due to partial oxidation of carbonaceous materials when

exposed to hydrogen peroxide. The extended boil NAG includes a secondary boiling step to allow the relative proportions of pyrite derived acidity and organic acidity to be determined. At the time of writing, the extended boil NAG results were not available.

3.4 ACID FORMATION POTENTIAL

The acid formation potential of the sample is determined based on the acid base accounting results and the NAG test, with the findings summarised as follows:

- Two samples of clayey dolomitic limestone classified as Acid Consuming (AC).
- Twenty seven samples (71%) classed as Non Acid Forming (NAF).
- Two samples classified as having an Uncertain (UC) acid forming potential due to conflicting NAPP and NAG results.
- One sample classified as Potential Acid Forming – Low Capacity (PAF-LC).
- Six samples classified as Potential Acid Forming (PAF).

These acid forming classifications are shown in figures 3.1 and 3.2.

It should be noted that the acid formation classification for four samples submitted for extended boil NAG testing may be modified following receipt of the results. This will be discussed in a subsequent revision of this report.

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Table 3.1: Tailings Acid Base Accounting and NAG Results

BH ID and Sample Depth	Maxxam Sample No.	Sample Description	KP Interpreted Lithology	Sulfur Species			Carbon Species				ANC	Paste pH	Paste EC	Calculations			Net Acid Generation			AFP
				S	Sulfate-S	Sulfide S	TOC	CO_2	$CaCO_3$ Equivalent	$CaCO_3$-ANC				MPA	ANC/MPA	NAPP	NAG (4.5)	NAG (7.0)	NAGpH	
				wt%	wt%	wt%	wt%	wt%	wt%	kg H_2SO_4/t	kg H_2SO_4/t	pH Units	uS/cm	kg H_2SO_4/t	None	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	pH Units	
1-NP-15-2, 15 M	MY2656	Sandy clay	OB	0.02	0.01	0.01		0.02	0.05	0.45	1.96	9.11	212	0.31	6.41	-1.65	0.00	2.50	6.27	NAF
2-NP-15-2, 15 M	MY2657	Sandy clay	OB	0.02	0.01	0.01		0.02	0.05	0.45	3.72	9.04	258	0.31	12.17	-3.42	0.00	2.50	6.25	NAF
3-NP-15-2, 17 M	MY2658	Fine Sand	OB	0.02	0.01	0.01		0.02	0.05	0.45	2.45	5.42	64	0.31	8.01	-2.14	0.00	0.90	5.84	NAF
4-NP-15-2, 17 M	MY2659	Fine Sand	OB	0.02	0.01	0.01		0.02	0.05	0.45	1.27	5.20	128	0.31	4.16	-0.97	0.00	0.70	5.94	NAF
5-NP-15-2, 36 M	MY2660	Plastic clay	BL	0.02	0.01	0.01		0.02	0.05	0.45	2.25	8.87	245	0.31	7.37	-1.95	0.00	2.10	6.23	NAF
6-NP-15-2, 38.5 M	MY2661	Plastic clay	BL	0.02	0.01	0.01		0.02	0.05	0.45	2.45	6.43	215	0.31	8.01	-2.14	0.00	1.40	6.13	NAF
7-NP-15-2, 54.5 M	MY2662	Sand with lignite	LIG	2.12	0.05	2.07	0.94	11.58	26.34	258	24.50	6.26	1560	63.34	0.39	38.84	1.00	17.20	3.74	PAF
8-NP-15-2, 54.5 M	MY2663	Sand with lignite	LIG	2.60	0.13	2.47	1.15	8.48	19.29	189	62.72	6.96	1210	75.58	0.83	12.86	0.00	9.80	5.24	UC
9-NP-15-2, 57.5 M	MY2664	Grey phosphate clay	PHOS	0.44	0.08	0.36		36.81	83.71	820	808.50	7.84	1300	11.02	73.39	-797.48	0.00	0.00	10.90	AC
10-NP-15-2, 57.5 M	MY2665	Grey phosphate clay	PHOS	0.40	0.06	0.34		38.43	87.40	856	859.46	7.88	1350	10.40	82.61	-849.06	0.00	0.00	11.10	AC
1-SP-15-3, 21.5 M	MY2666	Clay	OB	0.02	0.01	0.01		0.03	0.07	0.67	5.88	9.38	371	0.31	19.22	-5.57	0.00	0.00	7.14	NAF
2-SP-15-3, 21.5 M	MY2667	Clay	OB	0.02	0.01	0.01		0.02	0.05	0.45	2.45	8.36	569	0.31	8.01	-2.14	0.00	1.70	6.31	NAF
3-SP-15-3, 33 M	MY2668	Fine Sand	OB	0.49	0.03	0.46		0.02	0.05	0.45	0.49	7.11	1040	14.08	0.03	13.59	5.10	5.90	2.77	PAF
4-SP-15-3, 33 M	MY2669	Fine Sand	OB	0.58	0.07	0.51		0.02	0.05	0.45	0.00	3.98	1470	15.61	0.00	15.61	4.53	7.40	2.69	PAF
5-SP-15-3, 34.5 M	MY2670	Clayey sand	BL	1.54	0.08	1.46		0.02	0.05	0.45	0.98	3.98	1600	44.68	0.02	43.70	19.60	20.80	2.26	PAF
1-SP-15-1, 15 M	MY2671	Sandy clay/plastic clay	OB	0.07	0.04	0.03		0.02	0.05	0.45	2.74	4.38	10	0.92	2.99	-1.83	0.00	1.20	4.57	NAF
2-SP-15-1, 19.5 M	MY2672	Sandy clay/plastic clay	OB	0.09	0.06	0.03		0.02	0.05	0.45	2.45	4.48	929	0.92	2.67	-1.53	0.10	0.90	4.46	UC
3-SP-15-1, 19.5 M	MY2673	Sandy clay/plastic clay	OB	0.02	0.02	0.00		0.02	0.05	0.45	1.76	4.95	854	0.00	N/C	-1.76	0.00	1.80	5.17	NAF
4-SP-15-1, 24.5 M	MY2674	Sandy clay/plastic clay	BL	0.02	0.01	0.01		0.02	0.05	0.45	1.27	5.21	956	0.31	4.16	-0.97	0.00	1.70	5.60	NAF
5-SP-15-1, FPA.CO M	MY2675	Sand/FPA	PHOS	1.19	0.07	1.12		1.15	2.62	26	26.12	5.76	2240	34.27	0.76	8.16	5.50	10.30	2.89	PAF-LC
6-SP-15-1, FPA.CO M	MY2676	Sand/FPA	PHOS	5.23	0.13	5.10		2.96	6.73	66	47.82	5.69	2080	156.06	0.31	108.24	25.30	39.80	2.30	PAF
1-SP-15-2, 16 M	MY2677	Clay sandy	OB	0.02	0.01	0.01		0.02	0.05	0.45	3.43	8.02	2880	0.31	11.21	-3.12	0.00	0.60	6.74	NAF
2-SP-15-2, 21 M	MY2678	Clay sandy	OB	0.02	0.01	0.01		0.02	0.05	0.45	3.72	8.05	2360	0.31	12.17	-3.42	0.00	1.50	6.50	NAF
3-SP-15-2, 21 M	MY2679	Clay sandy	OB	0.02	0.01	0.01		0.04	0.09	0.89	3.43	7.70	2920	0.31	11.21	-3.12	0.00	0.20	6.92	NAF
4-SP-15-2, 26 M	MY2680	Clay sandy	OB	0.02	0.01	0.01		0.05	0.11	1.11	4.90	8.47	3060	0.31	16.01	-4.59	0.00	0.20	6.91	NAF
5-SP-15-2, 26 M	MY2681	Clay sandy	OB	0.07	0.05	0.02		0.05	0.11	1.11	3.72	6.57	2530	0.61	6.08	-3.11	0.00	0.50	6.59	NAF
6-SP-15-2, 27.5 M	MY2682	Sand with lignite	LIG	0.04	0.02	0.02	0.02	0.02	0.05	0.45	4.70	5.21	1580	0.61	7.69	-4.09	0.00	0.00	7.22	NAF
7-SP-15-2, 27.5 M	MY2683	Sand with lignite	LIG	0.03	0.01	0.02	0.02	0.03	0.06	0.56	3.92	7.88	1790	0.61	6.41	-3.31	0.00	0.00	7.37	NAF
1-NP-15-4, 15.5 M	MY2684	Clay	BL	0.03	0.02	0.01		0.02	0.05	0.45	2.94	4.95	1430	0.31	9.61	-2.63	0.00	1.00	5.70	NAF
2-NP-15-4, 15.5 M	MY2685	Clay	BL	0.02	0.01	0.01		0.02	0.05	0.45	4.17	5.10	124	0.31	13.61	-3.86	0.00	0.90	5.84	NAF
3-NP-15-4, 26 M	MY2686	Fine sand, sandy clay	OB	0.02	0.01	0.01		0.02	0.05	0.45	3.43	5.76	119	0.31	11.21	-3.12	0.00	1.60	5.76	NAF
4-NP-15-4, 26 M	MY2687	Fine sand, sandy clay	OB	0.02	0.01	0.01		0.02	0.05	0.45	5.39	5.45	160	0.31	17.61	-5.08	0.00	0.20	6.34	NAF
5-NP-15-4, 32 M	MY2688	Plastic clay	OB	0.04	0.02	0.02		0.02	0.05	0.45	1.96	6.93	87	0.61	3.20	-1.35	0.00	0.40	6.40	NAF

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Table 3.1 (cont'd): Tailings Acid Base Accounting and NAG Results

BH ID and Sample Depth	Maxxam Sample No.	Sample Description	KP Interpreted Lithology	Sulfur Species			Carbon Species				ANC	Paste pH	Paste EC	Calculations			Net Acid Generation			AFP
				S	Sulfate-S	Sulfide S	TOC	CO_2	$CaCO_3$ Equivalent	$CaCO_3$-ANC				MPA	ANC/MPA	NAPP	NAG (4.5)	NAG (7.0)	NAGpH	
				wt%	wt%	wt%	wt%	wt%	wt%	kg H_2SO_4/t	kg H_2SO_4/t	pH Units	uS/cm	kg H_2SO_4/t	None	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	pH Units	
6-NP-15-4, 32 M	MY2689	Plastic clay	OB	0.02	0.01	0.01		0.02	0.05	0.45	2.45	6.04	96	0.31	8.01	-2.14	0.00	0.10	6.72	NAF
7-NP-15-4, 33.5 M	MY2690	Fine sand, plastic clay	BL	0.97	0.03	0.94		1.39	3.16	31	13.23	5.95	1640	28.76	0.46	15.53	7.10	9.40	2.77	PAF
8-NP-15-4, 33.5 M	MY2691	Fine sand, plastic clay	BL	0.03	0.01	0.02		0.02	0.05	0.45	2.94	5.98	164	0.61	4.80	-2.33	0.00	0.20	6.50	NAF
9-NP-15-4, 45 M	MY2692	Fine sand	PHOS	0.59	0.07	0.52		16.10	36.61	359	53.41	7.71	581	15.91	3.36	-37.50	0.00	0.00	7.25	NAF
10-NP-15-4, 45 M	MY2693	Fine sand	PHOS	0.53	0.05	0.48		21.37	48.60	476	60.91	7.77	1070	14.54	4.19	-46.37	0.00	0.00	8.43	NAF
		Minimum		0.02	0.01	0.00	0.02	0.02	0.05	0.45	0.00	3.98	10.00	0.00	0.00	-849.06	0.00	0.00	2.26	
		Maximum		5.23	0.13	5.10	1.15	38.43	87.40	856.50	859.46	9.38	3060	156.06	82.61	108.24	25.30	39.80	11.10	
		Average		0.46	0.03	0.43	0.53	3.66	8.32	81.49	53.68	6.57	1086	13.02	10.50	-40.67	1.80	3.83	5.89	

Abbreviated Lithologies	
OB	Overburden
BL	Basal Sand/Clay
LIG	Lignite
PHOS	Phosphate Bearing Strata

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3.5 QUANTITATIVE MINERALOGY

The results of XRD analysis are summarised in Table 3.2 and indicate that quartz was present in all samples comprising an average of 58.3%. Calcite was only present in two samples; at 0.2% in a sample of overburden and at 91.1% in the dolomitic limestone. The overall lack of calcite reported (with the exception of the dolomitic limestone) correlates well with the acid base accounting results.

Siderite was present in four samples at contents of between 0.1% and 52.8% at an average of 18.9%. This correlates well with the acid base accounting which indicated certain samples to contain siderite based on the discrepancy between calculated carbonate-ANC and measured (siderite corrected) ANC. Siderite ($FeCO_3$) is an important mineral in acid base accounting as it does not provide any neutralising benefit. This is because the acid consumed during dissolution is re-released upon oxidation of aqueous iron and precipitation of iron oxyhydroxides. However, the presence of siderite is overcome in the ANC test specified by KP by applying a siderite correction step in the method. The highest siderite contents were encountered in the basal overburden layer (one sample) and sandy phosphate bearing strata (two samples).

Pyrite was evident in eleven of twelve samples tested between 0.1% and 9.7% at an average of 1.7%. Three samples contained pyrite greater than 2%, two of which were from the basal overburden layer and one from a sandy phosphate bearing stratum (logged as comprising FPA) which had the highest pyrite content of almost 10%.

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Table 3.2: Summary of XRD Results

Mineral	Ideal Formula	No. Samples Containing Mineral	Minimum Content (%)	Average Content (%)	Maximum Content (%)
Quartz	SiO_2	12	1.4	58.3	95.0
Pyrite	FeS_2	11	0.1	1.7	9.7
Kaolinite	$Al_2Si_2O_5(OH)_4$	10	4.4	20.5	49.2
Anatase	TiO_2	10	0.1	0.3	0.8
Illite-smectite/smectite	Varies	9	N.R.	N.R.	N.R.
Hematite	Fe_2O_3	7	0.1	0.3	0.5
Orthoclase (K-feldspar)	$KAlSi_3O_8$	5	0.7	1.0	1.3
Siderite	$Fe^{2+}CO_3$	4	0.1	18.9	52.8
Calcite	$CaCO_3$	2	0.2	45.7	91.1
Fluorapatite	$Ca_5(PO_4,CO_3)_3(F,O)$	1	7.1	26.9	44.6
Topaz	$Al_2SiO_4(OH,F)_2$	1	0.7	0.7	0.7
Gypsum	$CaSO_4{\cdot}2H_2O$	1	0.3	0.3	0.3
Alunite	$K_2Al_6(SO_4)_4(OH)_{12}$	1	0.2	0.2	0.2

N.R. – Not Reported.

3.6 MULTI-ELEMENT RESULTS

3.6.1 Element Enrichments

Whole rock multi-element analysis of the waste rock samples was conducted to assess elemental enrichments. Multi-element analysis results were compared to the average crustal abundance to give the geochemical abundance indices. The Geochemical Abundance Index (GAI) quantifies an assay result for a particular element in terms of average crustal abundance.

Complete tables of assay results, average crustal abundance (ACA) and corresponding geochemical abundance indices (GAI) are provided in Appendix B, with a summary provided in Table 3.3. The results of the analysis indicate the samples to have low levels of enrichment, with phosphorous, selenium and tellurium the only elements found to be highly enriched. The four samples logged as sand / FPA typically have higher levels of element enrichment than the overburden samples.

It should be noted that rhenium, selenium and tellurium were only detected above the limits of detection in a limited number of samples. However, where an element is not measured above the detection limit, KP conservatively assumes that the element is present at the detection limit. The detection limits for rhenium and selenium is equivalent to a significantly enriched classification, with the detection limit for tellurium equivalent to a highly enriched classification. As the GAIs of these elements cannot be determined when measured below the detection limit, KP has highlighted such instances in Appendix B with “DL” to indicate that the result is below the limit of detection. A summary is also included in Table 3.3.

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Table 3.3: Summary of Element Enrichments

Element	Non Enriched	Slightly Enriched	Significantly Enriched	Highly Enriched	Below Detection*
Ag	35	2	1	0	N/A
Al	38	0	0	0	N/A
As	13	11	14	0	N/A
B	36	2	0	0	N/A
Ba	38	0	0	0	N/A
Be	38	0	0	0	N/A
Bi	31	7	0	0	N/A
Ca	36	2	0	0	N/A
Cd	32	0	6	0	N/A
Ce	38	0	0	0	N/A
Co	38	0	0	0	N/A
Cr	38	0	0	0	N/A
Cu	38	0	0	0	N/A
Fe	38	0	0	0	N/A
Hf	38	0	0	0	N/A
Hg	38	0	0	0	N/A
In	38	0	0	0	N/A
K	38	0	0	0	N/A
La	38	0	0	0	N/A
Li	38	0	0	0	N/A
Mg	38	0	0	0	N/A
Mn	38	0	0	0	N/A
Mo	38	0	0	0	N/A
Na	38	0	0	0	N/A
Nb	38	0	0	0	N/A
Ni	38	0	0	0	N/A
P	32	2	3	1	N/A
Pb	38	0	0	0	N/A
Rb	38	0	0	0	N/A
Re*	0	0	2	0	36
S	35	2	1	0	N/A
Sb	35	1	2	0	N/A
Sc	38	0	0	0	N/A
Se*	0	0	5	3	30
Sn	38	0	0	0	N/A
Sr	38	0	0	0	N/A
Ta	38	0	0	0	N/A
Te*	0	0	0	2	36
Th	38	0	0	0	N/A
Ti	38	0	0	0	N/A
Tl	38	0	0	0	N/A
U	34	0	4	0	N/A
V	38	0	0	0	N/A
W	38	0	0	0	N/A
Y	38	0	0	0	N/A
Zn	38	0	0	0	N/A
Zr	38	0	0	0	N/A

*Detection limits equivalent to a significantly or highly enriched classification for Re, Se and Te

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3.6.2 Preliminary Soil Quality Screening

The results of the multi-element analysis have also been compared to a set of soil quality screening guidelines for human health and ecology. The results indicated that all samples met the criteria for human health and soil remediation/intervention. However, no samples met the ecological criteria. This has implications for post closure land use, as discussed in Section 4.

Complete tabulated assay results compared to the soil screening criteria are presented in Appendix C.

3.7 RADIOMETRIC RESULTS

The results of the radiometric testing are presented in Table 3.4 and indicate that the overburden and clayey dolomitic limestone would not require any special controls in relation to radioactive risk, with these samples recording low gross alpha and beta activities and most measured radionuclides below the limit of detection. However, the two samples logged as comprising sand / FPA recorded Lead-210 and Radium-226 above NORM guidelines. As such, it appears that radiation risk is limited to the ore zone which will need to be considered in ore handling and processing procedures. This is discussed further in Section 4.

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Table 3.4: Radiometric Test Results

RADIONUCLIDE	UNITS	NORM Guideline	AWI740	AWI763	AWI764	AWI765	AWI766	AWI767	AWI768
			1-NP-15-2, 15M	3-NP-15-2, 17M	6-NP-15-2, 38.5M	7-NP-15-2, 54.5M	9-NP-15-2, 57.5M	1-SP-15-3, 21.5M	5-SP-15-3, 34.5M
Gross Alpha	Bq/g	N/G	0.1	0.7	0.1	0.6	0.9	0.1	0.4
Gross Beta	Bq/g	N/G	0.1	0.6	0.3	0.4	0.7	0.1	0.3
Lead-210	Bq/g	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Potassium-40	Bq/g	17	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Radium-226	Bq/g	0.3	0.1	0.1	0.1	0.1	0.11	0.1	0.1
Radium-228	Bq/g	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Thorium-228	Bq/g	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Thorium-230	Bq/g	10	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Thorium-234	Bq/g	N/G	0.05	0.06	0.05	0.05	0.11	0.05	0.05
Uranium-235	Bq/g	N/G	0.1	0.1	0.1	0.1	0.1	0.1	0.1

RADIONUCLIDE	UNITS	NORM Guideline	AWI769	AWI770	AWI771	AWI772	AWI773	AWI774	AWI775
			4-SP-15-1, 24.5M	6-SP-15-1, FPA.COM	2-SP-15-2, 21M	6-SP-15-2, 27.5M	1-NP-15-4, 15.5M	5-NP-15-4, 32M	9-NP-15-4, 45M
Gross Alpha	Bq/g	N/G	0.1	0.6	0.3	0.4	0.7	0.1	0.3
Gross Beta	Bq/g	N/G	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lead-210	Bq/g	0.3	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Potassium-40	Bq/g	17	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Radium-226	Bq/g	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Radium-228	Bq/g	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Thorium-228	Bq/g	0.3	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Thorium-230	Bq/g	10	0.05	0.06	0.05	0.05	0.11	0.05	0.05
Thorium-234	Bq/g	N/G	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Uranium-235	Bq/g	N/G	0	0	0	0	0	0	0

Note: Table to be updated with data for Uranium-238 and Thorium-232 when available.

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3.8 DISTILLED WATER EXTRACT RESULTS

The results of the distilled water extract analysis compared to various reference values are provided in the following sections, with the implications for waste rock management discussed in Section 4.

3.8.1 Comparison to Guidelines for Release and Livestock Drinking Water

The distilled water extract results were found to be of a reasonable quality compared to reference surface water guidelines, with exceedances noted for the following:

- pH in 47% of samples (the pH in two samples was too high while the pH in seven samples was too low).
- Cobalt in 5% of samples (i.e. one sample).
- Iron in 5% of samples (i.e. one sample).
- Nickel in 5% of samples (i.e. one sample).
- Selenium in 16% of samples.
- Zinc in 5% of samples (i.e. one sample).

In the absence of a release guideline value for phosphorous or phosphate, the results have also been compared to the ANZECC guidelines for aquatic protection (Ref. 24) in relation to total phosphorous and filterable reactive phosphate. The most applicable values are those for lowland rivers in tropical regions with slightly disturbed ecosystems. The guideline trigger values for aquatic protection for total phosphorous and filterable reactive phosphate (FRP) are 0.01 mg/L and 0.004 mg/L respectively. The guideline for total phosphorous was exceeded in 95% of samples and FRP in 100%, indicating that these concentrations may have a negative impact on lowland rivers, depending on the degree of dilution which occurs. This is discussed further in Section 4.

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3.8.2 Comparison to Australian Drinking Water Guidelines

The distilled water extract results were found to be of a relatively poor quality compared to reference drinking water standards, with exceedances noted for the following:

- pH in 63% of samples (the pH in two samples was too high while the pH in ten samples was too low).
- TDS in 21% of samples.
- Aluminium in 26% of samples.
- Arsenic in 5% of samples (i.e. one sample).
- Cadmium in 11% of samples.
- Iron in 11% of samples.

- Manganese in 26% of samples.
- Nickel in 21% of samples.
- Manganese in 26% of samples.
- Selenium in 16% of samples.
- Sodium in 11% of samples.
- Sulfate in 11% of samples.
- Uranium in 5% of samples (i.e. one sample).

3.8.3 Comparison to Baseline Surface Water and Groundwater Quality

The distilled water extract results were found to be of a poor quality compared to baseline surface and groundwater quality, with exceedances noted for the following:

Surface Water:

- pH in 47% of samples (the pH in two samples was too high while the pH in seven samples was too low).
- Arsenic in 26% of samples.
- Cadmium in 11% of samples.
- Calcium in 26% of samples.
- Chromium in 16% of samples.
- Copper in 5% of samples (i.e. one sample).
- Iron in 21% of samples.
- Lead in 5% of samples (i.e. one sample).
- Manganese in 32% of samples.
- Mercury in 5% of samples (i.e. one sample).
- Nickel in 42% of samples.
- Sulfate in 32% of samples.
- Zinc in 11% of samples.

Groundwater:

- pH in 47% of samples (the pH in two samples was too high while the pH in seven samples was too low).
- EC above in 5% of samples (i.e. one sample).
- TDS in 47% of samples.
- Arsenic in 16% of samples.
- Cadmium in 11% of samples.

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- Calcium in 26% of samples.
- Chromium in 21% of samples.
- Iron in 5% of samples (i.e. one sample).
- Magnesium in 5% of samples (i.e. one sample).
- Manganese in 21% of samples.
- Nickel in 42% of samples.
- Potassium in 47% of samples.
- Sodium in 42% of samples.
- Sulfate in 58% of samples.
- Zinc in 11% of samples.

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4. IMPLICATIONS FOR WASTE ROCK MANAGEMENT

4.1 ACID FORMING POTENTIAL

Overall 76% of the samples tested can be considered to be NAF (i.e. NAF or AC) with 24% of samples classified as PAF (PAF, PAF-LC or UC). The PAF materials consisted of samples of overburden, including the basal sand / clay and lignite zone but also to a lesser extent the upper sequence of sands and clays. Therefore, although the basal zone represents a higher risk of acid generation compared to the upper overburden, there is potential for a small proportion of overburden materials to generate acid due to the presence of pyrite. The samples of sand / FPA returned varied results, with two samples found to be NAF and two found to be PAF. Therefore, based on the limited testing conducted to date, a significant proportion of material in proximity to the ore zone may be PAF. As would be expected the clayey dolomitic limestone samples were found to be strongly acid consuming.

ANC was generally absent throughout the majority of overburden samples tested and, therefore, the waste rock has limited potential to buffer any acidity produced from the oxidation of sulfides.

Based on the data available from the testing to date, it appears that pyrite may exist in discrete or discontinuous zones. If this were the case then attempting to segregate the mine waste based on acid forming potential could be problematic. However, given the limited scope of testing relative to the proposed waste volumes, it should be possible with a more comprehensive testing programme to identify and selectively handle PAF waste.

The waste rock dump/s nominated for the PAF waste would require a cover system over the outer batters and top surface which should be resistant to erosion and designed to limit oxygen ingress and rainfall infiltration. This will limit acid generation and flushing of oxidation products and dissolved metals. The cover system should be installed progressively up the face of the dump during operations.

Any limestone materials mined during operations should be selectively handled and stockpiled for subsequent use. For example, during operations, this material can be used for sheeting of haul roads (if appropriate). In addition, placing a layer of limestone material over the top surface of waste dumps (i.e. below the cover system) could be beneficial in providing ongoing alkalinity post-closure.

If it is intended to stockpile low grade ore during operations then it is likely that acid generation will start to occur. As such, the base of these stockpile areas will need to be prepared in such a way as to limit seepage, with all run-off captured and returned to the process plant for re-use, or disposal into the TSF or open pits. If the material has not

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been processed towards the end of the mine life, it should be placed centrally within a waste dump (i.e. not within 20 m of the outer face or top surface) and encapsulated within the cover system.

4.2 MULTI-ELEMENT ENRICHMENT

The results of the analysis indicate the samples to have low levels of enrichment, with phosphorous, selenium and tellurium the only elements found to be highly enriched. The four samples logged as sand / FPA had higher levels of element enrichment than the overburden samples.

The results of the multi-element analysis were compared to a set of soil quality screening guidelines, which indicated that all samples met the criteria for human health and soil remediation/intervention. However, no samples met the ecological criteria. As such, the waste dumps will require a closure cover to isolate the materials from plant uptake.

4.3 RADIOMETRICS

The results of the radiometric testing indicate that the overburden and clayey dolomitic limestone would not require any special controls in relation to radioactive risk, with these samples recording low gross alpha and beta activities, and most measured radionuclides below the limit of detection. However, the two samples logged as sand / FPA recorded Lead-210 and Radium-226 above NORM guidelines. As such, it appears that the radiation risk is limited to the ore zone which will need to be considered in ore handling and processing. It is recommended that a radiation dose assessment is carried out for the FPA to assess the risk to site personnel and develop safe operating procedures. If it is intended to stockpile low grade ore during operations, then it would be prudent to locate these stockpiles away from main infrastructure areas, high traffic zones and populated areas. These stockpiles should also be sheeted to reduce dusting, with sediment control measures such as bunding to prevent solids being transported away from the stockpile areas.

4.4 DISTILLED WATER EXTRACT

The distilled water extract testing indicated that leaching of a proportion of the waste and FPA will contain environmentally significant metals above the assessment criteria. As such, the waste dumps and ore stockpiles which contain leachable material should be designed, constructed and managed such that seepage flows and sediment can be recovered and handled appropriately to mitigate the risk to surface water and groundwater. This will likely include base preparation of soils within waste dump and stockpile footprints to limit seepage, and shaping of the ground surface to direct water

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to sediment dams to allow the water quality to be assessed and managed. This water should be recycled for use in processing or re-directed to the open pits to minimise off-site discharge. Alternatively a passive treatment solution such as a wetland system may be appropriate for improving the water quality of run-off from waste dumps and stockpiles used to store leachable materials, to a level whereby release to surface waters would be appropriate. Prior to any release, such as may be required following wet season storm events, the water quality must be assessed to verify that sufficient dilution has occurred or that the passive treatment system is operating as intended, and the water is of an appropriate quality for release. Sediment should also be removed from the sediment dams on a regular basis and placed centrally within the waste dumps.

On closure, it is recommended that seepage flows are directed to the open pit/s, provided that the pit is expected to act as a groundwater sink. With this in mind, the project layout should preferentially consider locations for waste dumps upstream of the pit to allow gravity drainage to the pit on closure. Alternatively, a passive treatment solution such as a wetland system could be constructed on closure to improve the water quality to a standard whereby release to surface waters may be appropriate. However, such a system would require detailed design including additional testing of waste rock materials.

Based on the limited scope of testing relative to the proposed waste volumes, additional testing is required prior to operations to estimate the amount of leachable waste to be mined and determine the suitability of any passive treatment systems. Operational testing may then be required to de-lineate leaching and non-leaching materials to allow segregation during mining.

The waste rock dump/s nominated for the leachable waste would require a cover system over the outer batters and top surface which should be resistant to erosion and designed to limit rainfall infiltration. This will limit flushing of dissolved metals and phosphates. The cover system should be installed progressively up the face of the dump during operations.

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5. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this geochemical study, the following conclusions and recommendations are made:

5.1 CONCLUSIONS

- A proportion of the overburden waste and ore zone will be PAF. Based on the scope of testing to date this is assessed to be of the order of 25% of the waste.
- ANC was generally absent throughout the majority of overburden samples tested and, therefore, the waste rock has limited potential to buffer any acidity produced from the oxidation of sulfides.
- The results of the analysis indicate that the overburden samples had low levels of element enrichment, with only selenium found to be highly enriched in one sample. Significant enrichments of silver, arsenic, cadmium, phosphorous and uranium were also recorded in certain overburden samples.
- The samples logged as sand / FPA also had low levels of enrichment, albeit slightly greater than the overburden samples, with phosphorous, selenium and tellurium found to be highly enriched and cadmium, sulfur, antimony and uranium significantly enriched in certain samples.
- No samples met the ecological soil screening guidelines, although all samples met the criteria for human health and soil remediation/intervention.
- The radiometric analyses indicated that the overburden samples met the NORM guidelines. However, the activity of certain radionuclides within the samples logged as sand / FPA exceed the activity guidelines set out in the NORM guidelines.
- The distilled water extract results did not meet the reference water quality criteria for surface water or groundwater.

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5.1 RECOMMENDATIONS

- The scope of testing carried out was limited to 38 samples. It should be possible with a more comprehensive testing programme to identify and selectively handle PAF waste.
- Kinetic testing should be carried out to better define the likely extent of leaching and to be able to develop source terms for the waste dumps.
- Waste dumps containing PAF and / or leachable waste, and low grade ore stockpiles should be designed, constructed and managed such that seepage flows and sediment can be recovered and handled appropriately to mitigate risks to surface waters and groundwater.

- If any stockpiled low grade ore has not been processed towards the end of the mine life, it should be placed centrally within the waste dumps (i.e. not within 20 m of the outer face or top surface).
- Waste dumps containing PAF waste will require a cover system over the outer batters and top surface which should be resistant to erosion and designed to limit oxygen ingress and rainfall infiltration.
- Waste dumps containing leachable waste will require a cover system over the outer batters and top surface which should be resistant to erosion and designed to limit rainfall infiltration.
- All waste dumps will require a cover system which prevents plant uptake of metals from the waste materials. This should be constructed progressively up the face of the dump during operations.
- Any limestone materials mined during operations should be selectively handled and stockpiled for subsequent use in providing alkalinity to pit and waste dump areas.
- It is recommended that a radiation dose assessment is carried out for the FPA to assess risk to site personnel and develop safe operating procedures.
- Additional testing of waste rock is required prior to and during operations to improve the current level of understanding associated with the geochemical risk and develop detailed waste rock management plans.

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6. REFERENCES

1. Golder Associates (2014). Provision of Geochemical Inputs into the Farim ESIA (and Future Mine Design). Technical memorandum, Ref. No. 13514950201.502/B.0, issued 7 January 2014.

2. Golder Associates (2014). Mine Component Environmental and Social Baseline Studies. Report No. 13514950200.550-1/B.0, issued 21 February 2014.

3. Knight Piésold (2015). Farim Phosphate Project – Preliminary Waste Rock Geochemical Assessment. Document Ref. PE15-00483, issued 15th May 2015.

4. Mine Environment Neutral Drainage (MEND) Program (1991). Acid Rock Drainage Prediction Manual. Mend Project 1.16.16.

5. British Columbia Ministry of Energy and Mines (August 1998). Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia.

6. Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M. (1978). Field and laboratory methods applicable to overburden and mine soils, EPA 600/2-78-054.

7. Miller, S., Robertson A., Donohue, T. (1997). Advances in acid drainage prediction using the net acid generation test. In Proceedings of the Forth International Conference on Acid Rock Drainage (Vancouver B.C.) pp 535 - 547.

8. Stewart, W., Miller, S., Smart, R., Gerson, A., Thomas, J., Skinner, W., Levay, G. and Schumann, R. (2003). Evaluation of the Net Acid Generation (NAG) Test for Assessing the Acid Generating Capacity of Sulfide Minerals. In Proceeding of the Sixth international conference on Acid Rock Drainage (Cairns, Australia) pp 617 - 625.

9. Environmental Geochemistry International (June 2008). Extended Boil and Calculated Net Acid Generation (Calculated NAG) Test Procedure for Coal Washery Wastes.

10. Australian Government, Department of Industry, Tourism and Resources (February 2007). Managing Acid and Metalliferous Drainage.

11. AMIRA International (May 2002). ARD Test Handbook.

12. The International Network for Acid Prevention (INAP) (2009). Global Acid Rock Drainage Guide (GARD Guide). http://www.gardguide.com/

DRAFT

13. Bowen, H.J.M. (1979). Environmental Chemistry of the Elements. Academic Press, New York.

14. Australian Government (2013). National Environment Protection (Assessment of Site Contamination) Amendment Measure.

15. United States Environmental Protection Agency (U.S. EPA) Ecological Soil Screening Levels (Eco-SSLs), http://www.epa.gov/ecotox/ecossl/.

16. NEPC (1999). National Environment Protection (Assessment of Site Contamination) Measure.

17. VROM (2000), Circular on Target Values and Intervention Values for Soil Remediation, Reference DBO/1999226863, Ministry of Housing, Spatial Planning and the Environment, Bilthoven, Netherlands.

18. Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM), October 2000. Prepared by the Canadian NORM Working Group of the Federal Provincial Territorial Radiation Protection Committee.

19. International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources, Safety Series No.115, International Atomic Energy Agency (IAEA), Vienna, 1996.

20. Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Minerals Processing, Radiation Protection Series Publication No.9, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2005.

21. The Radiation Safety Act, 1975. Western Australian Legislation.

22. IFC (2004). IFC Environmental, Health and Safety Guidelines for Precious Metal Mining (Draft).

23. IFC (2007) IFC Environmental, Health and Safety Guidelines for Mining.

24. ANZECC / ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

25. NHMRC, NRMMC (2011). Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

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FIGURES

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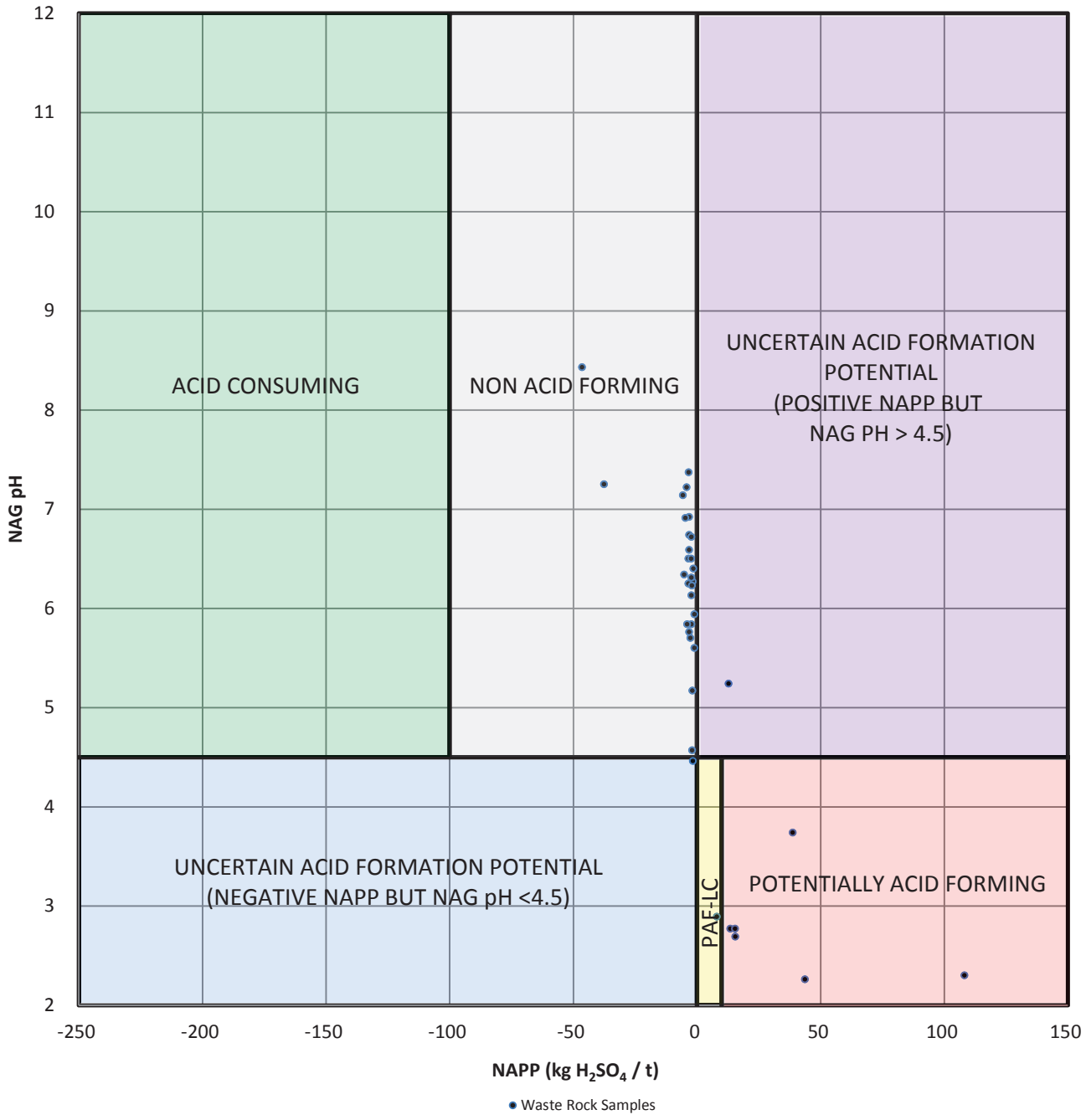
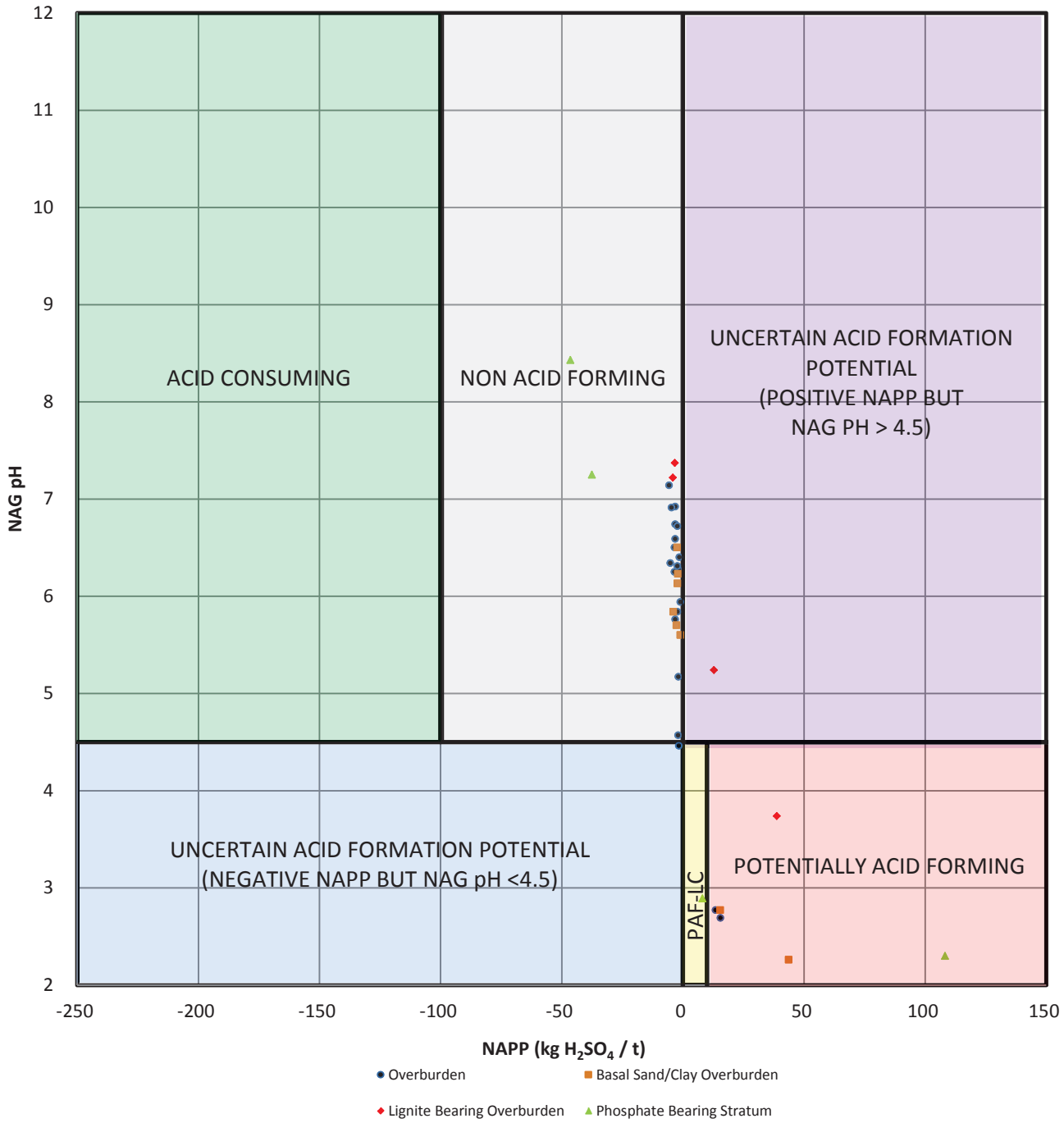
Acid Formation Potential



Note: Two acid consuming samples not shown due to NAPP values of less than -800 kg H_2SO_4/t

Acid Formation Potential	NAPP (kg H_2SO_4 / t)	NAG pH
Potential Acid Forming (PAF)	>10	<4.5
Potential Acid Forming - Low Capacity (PAF - LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than - 100	≥4.5
Uncertain	Positive	≥4.5
	Negative	<4.5

Acid Formation Potential



Note: Two acid consuming samples not shown due to NAPP values of less than -800 kg H_2SO_4/t

Acid Formation Potential	NAPP (kg H_2SO_4 / t)	NAG pH
Potential Acid Forming (PAF)	>10	<4.5
Potential Acid Forming - Low Capacity (PAF - LC)	0 to 10	<4.5
Non Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	Less than - 100	≥4.5
Uncertain	Positve	≥4.5
	Negative	<4.5

APPENDIX A

Laboratory Reports

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Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: GB MINERALS LTD.

Table 1: ABA Test Results for project FARIM PHOSPHATE

Maxxam Sample No	Sample ID	Paste pH	Paste EC	Total Carbon	Total Organic Carbon	CO2	CaCO3 Equiv.	Total S	HCl Extractable Sulphur	Sulphide Sulphur (by diff.)	Acid Generation Potential	Siderite Corr. Neutralization Potential	Fizz Rating	Net Neutralization Potential	Neutralization Potential Ratio
	Units	pH Units	uS/cm	wt%	wt%	wt%	Kg CaCO3/T	wt%	wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	Kg CaCO3/T	N/A
MY2656	1-NP-15-2, 15 M	9.11	212	0.03		0.02	<0.5	<0.02	<0.01	<0.02	<0.6	2.00	NONE	2.00	#N/A
MY2657	2-NP-15-2, 15 M	9.04	258	0.03		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	3.80	NONE	3.80	#N/A
MY2658	3-NP-15-2, 17 M	5.42	64	0.04		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	2.50	NONE	2.50	#N/A
MY2659	4-NP-15-2, 17 M	5.20	128	0.05		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	1.30	NONE	1.30	#N/A
MY2660	5-NP-15-2, 36 M	8.87	245	0.03		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	2.30	NONE	2.30	#N/A
MY2661	6-NP-15-2, 38.5 M	6.43	215	0.04		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	2.50	NONE	2.50	#N/A
MY2662	7-NP-15-2, 54.5 M	6.26	1560	4.17	0.94	11.58	263.2	2.12	0.05	2.07	64.7	25.0	SLIGHT	-39.7	0.4
MY2663	8-NP-15-2, 54.5 M	6.96	1210	3.57	1.15	8.48	192.7	2.60	0.13	2.47	77.2	64.0	SLIGHT	-13.2	0.8
MY2664	9-NP-15-2, 57.5 M	7.84	1300	10.42		36.81	836.6	0.44	0.08	0.36	11.3	825	STRONG	814	73.0
MY2665	10-NP-15-2, 57.5 M	7.87	1350	10.95		38.43	873.4	0.40	0.06	0.34	10.6	878	STRONG	867	82.8
MY2666	1-SP-15-3, 21.5 M	9.38	371	0.08		0.03	0.7	<0.02	<0.01	<0.02	<0.6	6.00	NONE	6.00	#N/A
MY2667	2-SP-15-3, 21.5 M	8.36	569	0.09		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	2.50	NONE	2.50	#N/A
MY2668	3-SP-15-3, 33 M	7.11	1040	0.04		<0.02	<0.5	0.49	0.03	0.46	14.4	0.500	NONE	-13.9	<0.1
MY2669	4-SP-15-3, 33 M	3.98	1470	0.04		<0.02	<0.5	0.58	0.07	0.51	15.9	0.0	NONE	-15.9	#N/A
MY2670	5-SP-15-3, 34.5 M	3.98	1600	0.04		<0.02	<0.5	1.54	0.08	1.46	45.6	1.00	NONE	-44.6	<0.1
MY2671	1-SP-15-1, 15 M	4.38	10	0.13		<0.02	<0.5	0.07	0.04	0.03	0.9	2.80	NONE	1.90	3.1
MY2672	2-SP-15-1, 19.5 M	4.48	929	0.07		<0.02	<0.5	0.09	0.06	0.03	0.9	2.50	NONE	1.60	2.8
MY2673	3-SP-15-1, 19.5 M	4.95	854	0.04		<0.02	<0.5	0.02	0.02	<0.02	<0.6	1.80	NONE	1.80	#N/A
MY2674	4-SP-15-1, 24.5 M	5.21	956	0.04		<0.02	<0.5	<0.02	0.01	<0.02	<0.6	1.30	NONE	1.30	#N/A
MY2675	5-SP-15-1, FPA.CO M	5.76	2240	1.80		1.15	26.1	1.19	0.07	1.12	35.0	26.8	NONE	-8.20	0.8
MY2676	6-SP-15-1, FPA.CO M	5.69	2080	1.86		2.96	67.3	5.23	0.13	5.10	159.4	48.8	SLIGHT	-111	0.3
MY2677	1-SP-15-2, 16 M	8.02	2880	0.11		<0.02	<0.5	<0.02	0.01	<0.02	<0.6	3.50	NONE	3.50	#N/A
MY2678	2-SP-15-2, 21 M	8.05	2360	0.08		0.02	<0.5	<0.02	<0.01	<0.02	<0.6	3.80	NONE	3.80	#N/A
MY2679	3-SP-15-2, 21 M	7.70	2920	0.10		0.04	0.9	<0.02	<0.01	<0.02	<0.6	3.50	NONE	3.50	#N/A
MY2680	4-SP-15-2, 26 M	8.47	3060	0.10		0.05	1.1	<0.02	<0.01	<0.02	<0.6	5.00	NONE	5.00	#N/A
MY2681	5-SP-15-2, 26 M	6.57	2530	0.06		0.05	1.1	0.07	0.05	0.02	0.6	3.80	NONE	3.20	6.3
MY2682	6-SP-15-2, 27.5 M	5.21	1580	0.06	<0.02	<0.02	<0.5	0.04	0.02	0.02	0.6	4.80	NONE	4.20	8.0
MY2683	7-SP-15-2, 27.5 M	7.88	1790	0.09	0.02	0.03	0.7	0.03	0.01	0.02	0.6	4.00	NONE	3.40	6.7
MY2684	1-NP-15-4, 15.5 M	4.95	1430	0.05		<0.02	<0.5	0.03	0.02	<0.02	<0.6	3.00	NONE	3.00	#N/A
MY2685	2-NP-15-4, 15.5 M	5.13	124	0.04		<0.02	<0.5	<0.02	0.01	<0.02	<0.6	4.50	NONE	4.50	#N/A
MY2686	3-NP-15-4, 26 M	5.76	119	0.02		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	3.50	NONE	3.50	#N/A
MY2687	4-NP-15-4, 26 M	5.45	160	0.04		<0.02	<0.5	<0.02	<0.01	<0.02	<0.6	5.50	NONE	5.50	#N/A
MY2688	5-NP-15-4, 32 M	6.93	87	0.04		<0.02	<0.5	0.04	0.02	0.02	0.6	2.00	NONE	1.40	3.3
MY2689	6-NP-15-4, 32 M	6.04	96	0.03		<0.02	<0.5	<0.02	0.01	<0.02	<0.6	2.50	NONE	2.50	#N/A
MY2690	7-NP-15-4, 33.5 M	5.95	1640	1.39		1.39	31.6	0.97	0.03	0.94	29.4	13.5	NONE	-15.9	0.5
MY2691	8-NP-15-4, 33.5 M	5.98	164	0.05		<0.02	<0.5	0.03	0.01	0.02	0.6	3.00	NONE	2.40	5.0
MY2692	9-NP-15-4, 45 M	7.71	581	5.43		16.10	365.9	0.59	0.07	0.52	16.3	54.5	SLIGHT	38.2	3.3
MY2693	10-NP-15-4, 45 M	7.77	1070	6.62		21.37	485.7	0.53	0.05	0.48	15.0	62.0	SLIGHT	47.0	4.1
Detection Limits		*N/A*	*1*	*0.02*	*0.02*	*0.02*	*0.5*	*0.02*	*0.01*	*0.02*	*0.6*	*0.1*	*N/A*	*0.1*	*N/A*
Maxxam SOP #		*Y0SOP-00*	*Y0SOP-00*	*LECO*	*LECO*	*LECO*	*BBY WI-00033*	*LECO*	*BBY0SOP-00010*	*BBY WI-00033*	*BBY WI-00033*	*BBY0SOP-00024*	*BBY0SOP-00*	*BBY WI-00033*	*BBY WI-00033*

Notes:

Lawrence, R.W. 1991. Acid Rock Drainage Prediction Manual

Skousen, J., Renton, J., Brown, H., Evans, P., Leavitt, B., Brady, K., Cohen, L. and Ziemkiewicz, P. 1997. Neutralization Potential of Overburden Samples containing Siderite, Journal of Environmental Quality, 26 (3): 673-681.

References:

Acid Generation Potential = Sulphide Sulphur (by diff.)*31.25

Fizz Rating - Reference method used is based on NP method.

Net Neutralization Potential = (Siderite Correction Neutralization Potential)-(Acid Generation Potential (S-S by diff))

Neutralization Potential Ratio = (Neutralization Potential)/(Acid Generation Potential)

Siderite Corr. Neutralization Potential - Skousen et al., Neutralization Potential of Samples With Siderite, J. Environ. Qual. 26:673-681(1997).

Paste EC - based on Field and Laboratory Methods Applicable to Overburdens and Minesoils, (EPA 600 / 2-78-054, March 1978).

Paste pH - Field and Laboratory Methods Applicable to Overburdens and Minesoils, (EPA 600 / 2-78-054, March 1978).

HCl Extractable Sulphur is based on a modified version of ASTM Method D 2492-02

Sulphide Sulphur = (Total Sulphur)-(Sulphate Sulphur)

Total sulphur, total carbon & carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

CaCO3 Equivalency = Carbonate Carbon (CO2)*(100/44)*10

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: GB MINERALS LTD.

Table 2: ABA QAQC Test Results for project FARIM PHOSPHATE

	Duplicate QC														
Maxxam Sample No	**Sample ID**	Paste pH Reported	**Paste pH Dup**	CO2 Reported	**CO2 Dup**	Total Carbon Reported	**Total Carbon Dup**	Total S Reported	**Total S Dup**	HCl Extractable Sulphur Reported	**HCl Extractable Sulphur**	Siderite Corr. Neutralization Potential Reported Reported	**Siderite Corr. Neutralization Potential Reported Dup**	Fizz Rating Reported	**Fizz Rating Dup**
	Units	pH Units	pH Units	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	N/A
MY2665 Dup	10-NP-15-2, 57.5 M	7.87	7.88							0.06	0.06	878	876	STRONG	STRONG
MY2671 Dup	1-SP-15-1, 15 M					0.13	0.14	0.07	0.07						
MY2675 Dup	5-SP-15-1, FPA.CO M	5.76	5.76							0.07	0.07	26.8	26.5	NONE	NONE
MY2685 Dup	2-NP-15-4, 15.5 M	5.13	5.06							0.01	0.01	4.50	4.00	NONE	NONE
MY2693 Dup	10-NP-15-4, 45 M	7.77	7.77			6.62	6.58	0.53	0.52	0.05	0.05	62.0	62.3	SLIGHT	SLIGHT
MY2657 Dup	2-NP-15-2, 15 M			<0.02	<0.02										
MY2670 Dup	5-SP-15-3, 34.5 M			<0.02	0.02										
MY2683 Dup	7-SP-15-2, 27.5 M			0.03	<0.02										

Reference Material QC	Paste pH	CO2	Total Carbon	Total S	HCl Extractable Sulphur
Units	pH Units	wt%	wt%	wt%	wt%
Reference Material					
ARD-Paste pH 8.29 (8017884) (8.29 pH Units)	8.24				
ARD REF MAT GS311-1 (8019137) (1.01 wt%)			1.06		
ARD REF MAT GS311-1 (8019137) (2.32 wt%)				2.34	
ARD SPIKE GS910-4 CS (8019137) (2.65 wt%)			2.77		
ARD SPIKE GS910-4 CS (8019137) (8.27 wt%)				8.23	
RS10 STD (0.06 % S)					0.05
ARD Ref Mat DBOHC (0.27 wt%)					0.26
RS10 STD (0.06 % S)					0.05
ARD Ref Mat DBOHC (0.27 wt%)					0.26
ARD Spike C02 (8022887) (1.55 wt%)		1.39			
ARD Spike C02 (8022887) (1.55 wt%)		1.45			
Blank QC					
Method Blank		<0.02			<0.01
Method Blank					<0.01
Method Blank			<0.02		
Method Blank				<0.02	

Table 3: NAG Test Results for project FARIM PHOSPHATE

Maxxam Sample No	Sample ID	Pulp Sample Weight	NAG Vol. of 15% H2O2 Used	NAG pH	NAG Volume to pH 4.5	NAG Volume to pH 7.0	NAG NaOH Conc.	NAG Acidity pH 4.5	NAG Acidity pH 7.0
	Units	g	mL	pH Units	mL	mL	N	Kg H2SO4/T	Kg H2SO4/T
MY2656	1-NP-15-2, 15 M	2.50	250.00	6.27	0	2.50	0.1	0	4.90
MY2657	2-NP-15-2, 15 M	2.50	250.00	6.25	0	2.50	0.1	0	4.90
MY2658	3-NP-15-2, 17 M	2.50	250.00	5.84	0	0.90	0.1	0	1.76
MY2659	4-NP-15-2, 17 M	2.50	250.00	5.94	0	0.70	0.1	0	1.37
MY2660	5-NP-15-2, 36 M	2.50	250.00	6.23	0	2.10	0.1	0	4.12
MY2661	6-NP-15-2, 38.5 M	2.50	250.00	6.13	0	1.40	0.1	0	2.74
MY2662	7-NP-15-2, 54.5 M	2.50	250.00	3.74	1.00	17.20	0.1	1.96	33.7
MY2663	8-NP-15-2, 54.5 M	2.50	250.00	5.24	0	9.80	0.1	0	19.2
MY2664	9-NP-15-2, 57.5 M	2.50	250.00	10.9	0	0	0.1	0	0
MY2665	10-NP-15-2, 57.5 M	2.50	250.00	11.1	0	0	0.1	0	0
MY2666	1-SP-15-3, 21.5 M	2.50	250.00	7.14	0	0	0.1	0	0
MY2667	2-SP-15-3, 21.5 M	2.50	250.00	6.31	0	1.70	0.1	0	3.33
MY2668	3-SP-15-3, 33 M	2.50	250.00	2.77	5.10	5.90	0.1	10.0	11.6
MY2669	4-SP-15-3, 33 M	2.50	250.00	2.69	4.53	7.40	0.1	8.88	14.5
MY2670	5-SP-15-3, 34.5 M	2.50	250.00	2.26	19.60	20.80	0.1	38.4	40.8
MY2671	1-SP-15-1, 15 M	2.50	250.00	4.57	0	1.20	0.1	0	2.35
MY2672	2-SP-15-1, 19.5 M	2.50	250.00	4.46	0.10	0.90	0.1	0.196	1.76
MY2673	3-SP-15-1, 19.5 M	2.50	250.00	5.17	0	1.80	0.1	0	3.53
MY2674	4-SP-15-1, 24.5 M	2.50	250.00	5.60	0	1.70	0.1	0	3.33
MY2675	5-SP-15-1, FPA.CO M	2.50	250.00	2.89	5.50	10.30	0.1	10.8	20.2
MY2676	6-SP-15-1, FPA.CO M	2.50	250.00	2.30	25.30	39.80	0.1	49.6	78.0
MY2677	1-SP-15-2, 16 M	2.50	250.00	6.74	0	0.60	0.1	0	1.18
MY2678	2-SP-15-2, 21 M	2.50	250.00	6.50	0	1.50	0.1	0	2.94
MY2679	3-SP-15-2, 21 M	2.50	250.00	6.92	0	0.20	0.1	0	0.392
MY2680	4-SP-15-2, 26 M	2.50	250.00	6.91	0	0.20	0.1	0	0.392
MY2681	5-SP-15-2, 26 M	2.50	250.00	6.59	0	0.50	0.1	0	0.980
MY2682	6-SP-15-2, 27.5 M	2.50	250.00	7.22	0	0	0.1	0	0
MY2683	7-SP-15-2, 27.5 M	2.50	250.00	7.37	0	0	0.1	0	0
MY2684	1-NP-15-4, 15.5 M	2.50	250.00	5.70	0	1.00	0.1	0	1.96
MY2685	2-NP-15-4, 15.5 M	2.50	250.00	5.84	0	0.90	0.1	0	1.76
MY2686	3-NP-15-4, 26 M	2.50	250.00	5.76	0	1.60	0.1	0	3.14
MY2687	4-NP-15-4, 26 M	2.50	250.00	6.34	0	0.20	0.1	0	0.392
MY2688	5-NP-15-4, 32 M	2.50	250.00	6.40	0	0.40	0.1	0	0.784
MY2689	6-NP-15-4, 32 M	2.50	250.00	6.72	0	0.10	0.1	0	0.196
MY2690	7-NP-15-4, 33.5 M	2.50	250.00	2.77	7.10	9.40	0.1	13.9	18.4
MY2691	8-NP-15-4, 33.5 M	2.50	250.00	6.50	0	0.20	0.1	0	0.392
MY2692	9-NP-15-4, 45 M	2.50	250.00	7.25	0	0	0.1	0	0
MY2693	10-NP-15-4, 45 M	2.50	250.00	8.43	0	0	0.1	0	0
QAQC									
Duplicates									
MY2665 Dup	10-NP-15-2, 57.5 M	2.50	250.00	11.1	0	0	0.1	0	0
MY2675 Dup	5-SP-15-1, FPA.CO M	2.50	250.00	2.92	5.30	10.00	0.1	10.4	19.6
MY2685 Dup	2-NP-15-4, 15.5 M	2.50	250.00	5.94	0	0.70	0.1	0	1.37
MY2693 Dup	10-NP-15-4, 45 M	2.50	250.00	8.51	0	0	0.1	0	0
Detection Limits		0	N/A	N/A	N/A	N/A	N/A		
Maxxam SOP #		BBY0-00007	BBY0SOP-00007	BBY0SOP-00007	BBY0SOP-00007	BBY0SOP-00007	BBY0SOP-00007	BBY WI-00033	BBY WI-00033
Method Blank			250.00000	5.49	<N/A	2.80	0.1		

Notes:

Single Addition Net Acid Generation (NAG) Test Procedure. Page 1 to 4.

References:

NAG Acidity pH 4.5 = (NAG Volume to pH 4.5) * 49 * (NaOH Conc.) / Pulp Sample Weight

NAG Acidity pH 7.0 = (NAG Volume to pH 7.0) * 49 * (NaOH Conc.) / Pulp Sample Weight

Solid:Liquid ratio used = 1:100; 2.5g Pulp Sample:250mL 15% H2O2.

Single Addition NAG - S. Miller, EGI Pty. Ltd., Net Acid Generation (NAG) Test Procedures, March 2001.

Table 4: Mercury Test Results for project FARIM PHOSPHATE

Maxxam Sample No	Sample ID Units	Hg ppm
MY2656	1-NP-15-2, 15 M	<0.01
MY2657	2-NP-15-2, 15 M	<0.01
MY2658	3-NP-15-2, 17 M	<0.01
MY2659	4-NP-15-2, 17 M	<0.01
MY2660	5-NP-15-2, 36 M	<0.01
MY2661	6-NP-15-2, 38.5 M	<0.01
MY2662	7-NP-15-2, 54.5 M	<0.01
MY2663	8-NP-15-2, 54.5 M	<0.01
MY2664	9-NP-15-2, 57.5 M	<0.01
MY2665	10-NP-15-2, 57.5 M	<0.01
MY2666	1-SP-15-3, 21.5 M	<0.01
MY2667	2-SP-15-3, 21.5 M	<0.01
MY2668	3-SP-15-3, 33 M	<0.01
MY2669	4-SP-15-3, 33 M	<0.01
MY2670	5-SP-15-3, 34.5 M	<0.01
MY2671	1-SP-15-1, 15 M	<0.01
MY2672	2-SP-15-1, 19.5 M	<0.01
MY2673	3-SP-15-1, 19.5 M	<0.01
MY2674	4-SP-15-1, 24.5 M	<0.01
MY2675	5-SP-15-1, FPA.CO M	0.02
MY2676	6-SP-15-1, FPA.CO M	0.03
MY2677	1-SP-15-2, 16 M	<0.01
MY2678	2-SP-15-2, 21 M	<0.01
MY2679	3-SP-15-2, 21 M	<0.01
MY2680	4-SP-15-2, 26 M	<0.01
MY2681	5-SP-15-2, 26 M	0.01
MY2682	6-SP-15-2, 27.5 M	0.01
MY2683	7-SP-15-2, 27.5 M	<0.01
MY2684	1-NP-15-4, 15.5 M	<0.01
MY2685	2-NP-15-4, 15.5 M	<0.01
MY2686	3-NP-15-4, 26 M	<0.01
MY2687	4-NP-15-4, 26 M	<0.01
MY2688	5-NP-15-4, 32 M	<0.01
MY2689	6-NP-15-4, 32 M	<0.01
MY2690	7-NP-15-4, 33.5 M	0.01
MY2691	8-NP-15-4, 33.5 M	<0.01
MY2692	9-NP-15-4, 45 M	0.01
MY2693	10-NP-15-4, 45 M	0.02
QAQC		
Duplicates		
MY2687 Dup	4-NP-15-4, 26 M	<0.01
MY2693 Dup	10-NP-15-4, 45 M	0.02
Blanks		
Method Blank		<0.01
Reference Material		
REF OREAS45EA PPM (8019383)		0.02
True Values REF OREAS45EA PPM		**0.34**
Percent Difference (8019383)		-94.1
Reference Material		
DS10 ppm (8019383)		0.31
True Values DS10 ppm		**0.3**
Percent Difference (8019383)		3.3
Detection Limits		0.01
Maxxam SOP #		*1DX*

Table 5: Boron on solids Test Results for project FARIM PHOSPHATE

Maxxam Sample No	Sample ID Units	B ppm
MY2656	1-NP-15-2, 15 M	16
MY2657	2-NP-15-2, 15 M	18
MY2658	3-NP-15-2, 17 M	30
MY2659	4-NP-15-2, 17 M	48
MY2660	5-NP-15-2, 36 M	26
MY2661	6-NP-15-2, 38.5 M	43
MY2662	7-NP-15-2, 54.5 M	41
MY2663	8-NP-15-2, 54.5 M	31
MY2664	9-NP-15-2, 57.5 M	10
MY2665	10-NP-15-2, 57.5 M	8
MY2666	1-SP-15-3, 21.5 M	21
MY2667	2-SP-15-3, 21.5 M	24
MY2668	3-SP-15-3, 33 M	20
MY2669	4-SP-15-3, 33 M	16
MY2670	5-SP-15-3, 34.5 M	22
MY2671	1-SP-15-1, 15 M	42
MY2672	2-SP-15-1, 19.5 M	45
MY2673	3-SP-15-1, 19.5 M	34
MY2674	4-SP-15-1, 24.5 M	26
MY2675	5-SP-15-1, FPA.CO M	61
MY2676	6-SP-15-1, FPA.CO M	29
MY2677	1-SP-15-2, 16 M	37
MY2678	2-SP-15-2, 21 M	30
MY2679	3-SP-15-2, 21 M	36
MY2680	4-SP-15-2, 26 M	33
MY2681	5-SP-15-2, 26 M	42
MY2682	6-SP-15-2, 27.5 M	47
MY2683	7-SP-15-2, 27.5 M	23
MY2684	1-NP-15-4, 15.5 M	34
MY2685	2-NP-15-4, 15.5 M	54
MY2686	3-NP-15-4, 26 M	34
MY2687	4-NP-15-4, 26 M	54
MY2688	5-NP-15-4, 32 M	46
MY2689	6-NP-15-4, 32 M	37
MY2690	7-NP-15-4, 33.5 M	60
MY2691	8-NP-15-4, 33.5 M	49
MY2692	9-NP-15-4, 45 M	38
MY2693	10-NP-15-4, 45 M	44
QAQC		
Duplicates		
MY2679 Dup	3-SP-15-2, 21 M	35
MY2692 Dup	9-NP-15-4, 45 M	38
Blanks		
Method Blank		<3
Reference Material		
STD C3		41
True Values STD C3		**42**
Percent Difference (8019383)		-2.4
Reference Material		
STD C3		43
True Values STD C3		**42**
Percent Difference (8019383)		3.3
Detection Limits		2.4
Maxxam SOP #		*PF100*

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: GB MINERALS LTD.

Table 6: 4 Acid Metals Test Results for project FARIM PHOSPHATE

Maxxam Sample No	Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	Al
	Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	%
MY2656	1-NP-15-2, 15 M	2.1	7.5	7.0	5	<0.1	5.7	1.4	62	1.77	48	1.1	4.9	15	<0.1	0.4	0.1	61	0.05	0.010	12.9	93	0.14	30	0.305	1.60
MY2657	2-NP-15-2, 15 M	1.3	6.5	4.9	5	<0.1	4.7	1.2	55	1.23	25	0.8	3.1	13	<0.1	0.2	<0.1	44	0.05	0.011	9.3	115	0.13	28	0.245	1.01
MY2658	3-NP-15-2, 17 M	1.3	11.1	24.4	20	0.2	20.4	3.4	95	3.22	22	2.8	14.8	113	<0.1	0.4	0.3	117	0.07	0.039	46.5	131	0.10	122	0.725	9.06
MY2659	4-NP-15-2, 17 M	1.4	13.0	24.6	63	<0.1	28.6	7.1	123	4.08	17	2.6	15.5	153	<0.1	0.4	0.3	139	0.14	0.041	44.6	164	0.34	154	0.683	11.0
MY2660	5-NP-15-2, 36 M	0.7	5.4	6.1	9	0.1	4.5	1.4	102	0.97	6	0.7	3.2	28	<0.1	0.2	<0.1	37	0.05	0.019	9.4	57	0.18	56	0.249	1.39
MY2661	6-NP-15-2, 38.5 M	0.6	6.5	10.5	14	<0.1	7.2	1.9	87	1.52	7	1.0	5.3	44	<0.1	0.3	0.1	55	0.05	0.023	16.3	63	0.19	80	0.342	2.84
MY2662	7-NP-15-2, 54.5 M	1.2	5.6	9.0	43	<0.1	22.2	19.7	2190	16.6	40	4.3	5.1	219	0.2	0.3	0.1	110	1.07	0.172	23.1	97	0.96	62	0.255	2.75
MY2663	8-NP-15-2, 54.5 M	1.8	10.0	6.6	52	0.1	23.5	20.1	1730	13.6	40	32.5	5.8	1540	1.7	1.1	<0.1	146	6.49	2.77	55.6	197	0.58	90	0.195	2.77
MY2664	9-NP-15-2, 57.5 M	0.8	5.8	1.8	47	0.1	17.0	1.2	186	0.94	1	11.0	2.5	912	1.7	0.7	<0.1	28	37.0	1.01	18.5	72	0.47	12	0.059	0.94
MY2665	10-NP-15-2, 57.5 M	1.1	4.0	1.3	26	<0.1	16.4	1.3	311	0.88	<1	5.4	1.8	794	1.4	0.5	<0.1	22	37.6	0.492	10.8	57	0.43	10	0.050	0.82
MY2666	1-SP-15-3, 21.5 M	0.6	4.8	5.1	6	0.3	3.7	1.2	56	0.60	3	0.8	2.6	51	<0.1	0.1	<0.1	24	0.23	0.019	12.2	50	0.15	36	0.232	0.93
MY2667	2-SP-15-3, 21.5 M	0.4	3.7	4.5	4	<0.1	4.1	1.1	51	0.44	2	0.7	3.4	26	<0.1	0.2	<0.1	21	0.04	0.009	8.3	54	0.08	24	0.275	0.80
MY2668	3-SP-15-3, 33 M	0.5	3.3	3.5	6	0.1	7.6	4.5	40	0.76	4	1.5	1.8	238	<0.1	0.2	<0.1	24	0.07	0.051	14.9	38	0.12	55	0.158	0.64
MY2669	4-SP-15-3, 33 M	0.5	3.8	4.3	52	<0.1	16.2	9.1	32	0.73	5	0.9	1.7	117	0.5	0.6	<0.1	33	0.04	0.026	14.6	66	0.05	26	0.115	0.65
MY2670	5-SP-15-3, 34.5 M	0.8	3.9	5.2	14	0.2	14.6	9.9	41	1.57	6	3.4	2.5	319	0.2	0.2	<0.1	38	0.08	0.079	18.3	79	0.09	62	0.154	1.03
MY2671	1-SP-15-1, 15 M	2.2	18.2	29.0	36	0.2	36.6	7.7	156	5.92	17	8.2	17.5	114	<0.1	0.7	0.3	104	0.05	0.075	46.1	120	0.12	111	0.851	11.1
MY2672	2-SP-15-1, 19.5 M	0.9	16.8	19.7	55	0.1	27.3	8.2	579	10.1	24	4.8	14.5	61	<0.1	0.4	0.2	113	0.04	0.035	33.8	109	0.09	78	0.628	7.83
MY2673	3-SP-15-1, 19.5 M	1.8	8.1	13.7	16	<0.1	12.3	3.1	75	5.16	38	3.4	6.8	46	<0.1	0.5	0.1	124	0.02	0.032	20.1	150	0.05	56	0.386	3.87
MY2674	4-SP-15-1, 24.5 M	1.0	6.9	11.1	12	<0.1	10.2	2.2	60	2.16	16	2.3	6.7	44	<0.1	0.3	0.1	67	0.02	0.020	17.3	60	0.05	55	0.388	3.18
MY2675	5-SP-15-1, FPA.CO M	1.7	13.3	19.0	93	0.1	29.4	18.5	937	4.74	26	9.0	10.6	146	0.4	0.6	0.3	118	1.82	0.748	36.6	130	0.37	145	0.520	6.25
MY2676	6-SP-15-1, FPA.CO M	4.2	14.1	11.8	306	0.1	28.6	24.1	1470	9.05	51	30.9	9.9	224	2.9	2.1	0.1	143	10.2	3.78	61.1	168	0.34	85	0.363	3.99
MY2677	1-SP-15-2, 16 M	1.2	7.2	7.9	11	0.6	6.6	1.7	73	1.72	14	1.2	3.9	41	<0.1	0.2	<0.1	61	0.13	0.035	16.1	74	0.25	54	0.323	1.80
MY2678	2-SP-15-2, 21 M	1.4	6.5	7.1	8	0.4	5.8	1.7	66	1.83	15	1.1	3.9	33	<0.1	0.2	<0.1	62	0.06	0.019	13.9	70	0.17	49	0.316	1.53
MY2679	3-SP-15-2, 21 M	1.7	9.6	9.5	14	1.4	8.8	2.4	83	2.51	22	1.5	5.2	48	<0.1	0.3	<0.1	82	0.07	0.024	19.2	121	0.23	60	0.386	2.12
MY2680	4-SP-15-2, 26 M	1.0	8.2	7.9	13	0.8	6.9	2.1	93	1.77	15	1.3	4.4	42	<0.1	0.1	<0.1	67	0.10	0.025	16.3	81	0.35	60	0.382	1.77
MY2681	5-SP-15-2, 26 M	1.6	9.0	14.6	38	0.3	14.2	7.0	158	6.37	56	3.7	8.4	215	<0.1	0.4	0.1	106	0.11	0.125	33.9	104	0.28	117	0.490	4.43
MY2682	6-SP-15-2, 27.5 M	1.7	6.4	23.6	69	0.1	23.9	10.6	96	2.69	10	5.5	9.4	91	<0.1	0.3	0.2	71	0.18	0.035	50.3	103	0.32	95	0.449	6.49
MY2683	7-SP-15-2, 27.5 M	1.1	4.0	9.3	19	0.3	5.9	1.9	41	1.23	3	2.0	3.4	76	<0.1	0.1	<0.1	29	0.11	0.026	22.9	58	0.25	45	0.191	1.47
MY2684	1-NP-15-4, 15.5 M	1.9	12.5	23.0	49	0.2	21.7	5.9	142	3.30	11	4.1	12.4	203	<0.1	0.6	0.3	107	0.08	0.084	36.8	109	0.22	216	0.662	8.82
MY2685	2-NP-15-4, 15.5 M	1.1	13.8	21.2	87	0.2	27.1	9.5	246	6.58	40	3.6	11.2	135	0.1	0.4	0.3	130	0.10	0.091	34.9	105	0.31	161	0.566	7.79
MY2686	3-NP-15-4, 26 M	0.5	9.7	16.4	30	<0.1	12.9	3.9	236	2.32	11	2.0	8.2	87	<0.1	0.4	0.2	80	0.05	0.031	23.8	67	0.16	121	0.476	5.48
MY2687	4-NP-15-4, 26 M	0.9	15.4	23.4	51	<0.1	22.1	6.0	214	7.10	21	3.3	12.6	118	<0.1	0.4	0.3	126	0.13	0.083	37.9	116	0.30	173	0.659	8.75
MY2688	5-NP-15-4, 32 M	0.2	6.4	8.0	17	0.1	6.1	2.0	83	1.66	6	1.0	4.0	52	<0.1	0.2	<0.1	43	0.05	0.027	12.4	39	0.08	77	0.299	1.78
MY2689	6-NP-15-4, 32 M	0.4	7.6	11.0	36	<0.1	11.4	5.0	199	4.11	20	1.2	6.0	61	<0.1	0.2	0.1	65	0.07	0.057	17.1	69	0.13	86	0.519	3.29
MY2690	7-NP-15-4, 33.5 M	0.9	11.6	19.2	79	0.1	24.0	13.8	814	4.49	16	2.5	10.2	77	<0.1	0.4	0.2	92	0.30	0.028	29.7	111	0.37	133	0.559	6.01
MY2691	8-NP-15-4, 33.5 M	0.5	7.5	11.8	28	<0.1	10.1	3.3	144	3.44	14	1.3	6.3	72	<0.1	0.3	0.2	65	0.09	0.051	19.4	64	0.14	99	0.478	3.71
MY2692	9-NP-15-4, 45 M	1.0	14.8	2.9	81	0.2	197	30.3	3440	20.1	2	71.5	6.0	150	4.6	3.1	0.1	236	15.4	>5.00	74.8	254	0.71	16	0.095	1.41
MY2693	10-NP-15-4, 45 M	0.7	14.3	3.3	101	0.2	155	21.0	4800	23.4	3	36.4	5.7	119	2.8	2.9	<0.1	176	8.98	2.66	49.7	222	1.05	16	0.107	1.99
QAQC																										
Duplicates																										
MY2674 Dup	4-SP-15-1, 24.5 M	1.4	6.8	11.2	13	<0.1	9.9	2.3	63	2.17	15	2.3	6.6	44	<0.1	0.3	<0.1	66	0.02	0.021	17.4	59	0.05	57	0.386	3.13
MY2693 Dup	10-NP-15-4, 45 M	0.9	14.5	3.3	101	0.3	155	20.3	4830	23.4	3	37.5	5.8	122	2.9	2.7	<0.1	177	8.98	2.76	48.2	224	1.06	17	0.112	1.99
Blanks																										
Method Blank										<0.01									<0.01	<0.001			<0.01		<0.001	<0.01
Method Blank		<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.2	<1		<1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<4			<0.1	<1		<1		
Reference Material																										
SPIKE OREAS 45E (%) (8019288)										24.48									0.07	0.032			0.16		0.55	6.87
True Values SPIKE OREAS 45E										**24.12**									**0.065**	**0.034**			**0.156**		**0.559**	**6.78**
Percent Difference (8019288)										1.5									7.7	-5.9			2.6		-1.6	1.3
Reference Material																										
SPIKE OREAS45E (ppm) (8019289)		2.2	769.5	19.8	48	0.4	480.9	59.5	572		17	2.6	13.6	17	<0.1	1.1	0.4	325			11.4	1035		264		
True Values SPIKE OREAS45E		**2.4**	**780**	**18.2**	**46.7**	**0.311**	**454**	**57**	**550**		**16.3**	**2.41**	**12.9**	**15.9**	**0.06**	**1**	**0.28**	**322**			**11**	**979**		**252**		
Percent Difference (8019289)		-8.3	-1.3	8.8	2.8	28.6	5.9	4.4	4.0		4.3	7.9	5.4	6.9		10.0	42.9	0.9			3.6	5.7		4.8		
Reference Material																										
OREAS25A-4% (8019288)										6.68									0.27	0.051			0.33		0.985	9.22
True Values OREAS25A-4%										**6.6**									**0.309**	**0.048**			**0.327**		**0.977**	**8.71**
Percent Difference (8019288)										1.2									-12.6	6.2			0.9		0.8	5.9
Reference Material																										
OREAS25A-4A PPM (8019289)		2.3	35.9	26.7	44	<0.1	48	8.1	499		11	2.9	15.6	49	0.1	0.7	0.4	166			21.8	123		159		
True Values OREAS25A-4A PPM		**2.55**	**33.9**	**25.2**	**44.4**	**0.1**	**45.8**	**8.2**	**470**		**12**	**2.94**	**15.8**	**48.5**		**0.67**	**0.35**	**157**			**21.8**	**115**		**147**		
Percent Difference (8019289)		-9.8	5.9	6.0	-0.9		4.8	-1.2	6.2		-8.3	-1.4	-1.3	1.0		4.5	14.3	5.7			0.0	7.0		8.2		
Detection Limits		0.1	0.1	0.1	1	0.1	0.1	0.2	1	0.01	1	0.1	0.1	1	0.1	0.1	0.1	4	0.01	0.001	0.1	1	0.01	1	0.001	0.01
Maxxam SOP #		*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*

Na	K	W	Zr	Ce	Sn	Y	Nb	Ta	Be	Sc	Li	S	Rb	Hf	In	Re	Se	Te	Tl
%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.031	0.04	0.5	60.8	23	0.7	4.4	6.7	0.3	<1	4	4.4	<0.1	1.9	1.4	<0.05	<0.005	<1	<0.5	<0.5
0.023	0.04	0.3	40.1	17	0.6	3.1	5.1	0.2	<1	3	4.4	<0.1	2.2	1.1	<0.05	<0.005	<1	<0.5	<0.5
0.022	0.33	1.6	183	87	2.9	11.9	23.6	1.4	1	15	25.5	<0.1	23.6	5.0	0.07	<0.005	<1	<0.5	<0.5
0.030	0.77	1.6	179	99	3.0	13.4	23.1	1.4	2	19	41.1	<0.1	64.2	4.7	0.06	<0.005	<1	<0.5	<0.5
0.028	0.10	0.3	51.7	19	0.6	4.5	5.3	0.3	<1	3	8.0	<0.1	8.7	1.4	<0.05	<0.005	<1	<0.5	<0.5
0.025	0.22	0.6	83.7	33	1.1	6.6	8.5	0.6	<1	5	13.1	<0.1	20.3	2.3	<0.05	<0.005	<1	<0.5	<0.5
0.035	0.21	0.5	73.3	54	0.9	24.6	7.0	0.4	1	8	30.7	2.2	17.6	1.9	0.08	<0.005	<1	<0.5	<0.5
0.043	0.09	0.3	51.7	78	0.6	133	5.2	0.3	3	7	21.5	2.4	5.9	1.3	<0.05	0.006	3	<0.5	<0.5
0.054	0.11	0.1	9.1	24	0.3	30.9	1.7	<0.1	<1	2	5.8	0.4	8.6	0.3	<0.05	<0.005	2	2.4	<0.5
0.035	0.10	0.1	7.3	14	0.2	14.9	1.6	<0.1	<1	2	5.0	0.4	7.7	0.2	<0.05	<0.005	1	2.5	<0.5
0.027	0.05	0.4	34.8	29	0.5	6.2	4.5	0.2	<1	2	10.3	<0.1	3.1	0.9	<0.05	<0.005	<1	<0.5	<0.5
0.025	0.03	0.2	39.1	18	0.6	3.8	5.1	0.3	<1	2	6.8	<0.1	2.4	1.1	<0.05	<0.005	<1	<0.5	<0.5
0.031	0.03	0.4	24.3	44	0.3	16.9	3.6	0.2	<1	2	9.1	0.5	1.9	0.7	<0.05	<0.005	<1	<0.5	<0.5
0.021	0.03	0.4	19.1	38	0.4	5.6	2.5	0.1	<1	2	9.0	0.6	1.6	0.6	<0.05	<0.005	1	<0.5	<0.5
0.029	0.06	0.8	32.6	50	0.3	33.4	3.7	0.2	<1	3	15.8	1.5	2.6	1.0	<0.05	<0.005	<1	<0.5	<0.5
0.048	0.21	2.0	195	105	4.1	17.6	33.4	2.2	2	19	55.3	<0.1	20.0	5.4	0.07	<0.005	<1	<0.5	<0.5
0.037	0.13	1.4	147	70	2.6	20.5	22.8	1.5	1	13	33.0	<0.1	12.8	4.1	<0.05	<0.005	1	<0.5	<0.5
0.029	0.09	0.7	80.3	45	1.4	8.1	11.3	0.7	<1	7	15.1	<0.1	8.6	2.2	<0.05	<0.005	<1	<0.5	<0.5
0.029	0.08	0.8	77.4	40	1.3	8.7	11.1	0.7	<1	5	14.0	<0.1	7.7	2.2	<0.05	<0.005	<1	<0.5	<0.5
0.072	0.73	1.2	160	72	2.1	31.5	15.1	1.0	3	13	73.4	1.3	49.0	4.6	0.12	<0.005	<1	<0.5	<0.5
0.068	0.40	0.8	111	81	1.1	104	10.3	0.6	2	9	43.6	5.2	33.5	3.0	<0.05	<0.005	1	<0.5	<0.5
0.117	0.08	1.1	61.7	37	0.9	5.7	7.8	0.4	<1	4	7.2	<0.1	5.9	1.7	<0.05	<0.005	<1	<0.5	<0.5
0.082	0.07	0.8	62.4	32	0.8	4.6	7.2	0.3	<1	4	6.5	<0.1	5.0	1.6	<0.05	<0.005	<1	<0.5	<0.5
0.105	0.09	2.7	74.1	45	1.5	6.4	9.7	0.6	<1	5	7.7	<0.1	7.0	2.1	<0.05	<0.005	<1	<0.5	<0.5
0.139	0.08	1.2	68.3	37	0.9	5.8	6.7	0.3	<1	4	7.9	<0.1	6.1	1.9	<0.05	<0.005	<1	<0.5	<0.5
0.098	0.30	0.8	118	87	1.4	23.6	12.5	0.8	<1	10	21.8	<0.1	26.4	3.4	0.08	<0.005	<1	<0.5	<0.5
0.071	0.31	1.2	118	102	1.7	26.7	13.6	0.9	1	15	38.8	<0.1	23.9	3.2	0.09	<0.005	<1	<0.5	<0.5
0.079	0.13	0.7	45.9	47	0.8	7.4	5.6	0.3	<1	4	10.0	<0.1	9.9	1.3	<0.05	<0.005	<1	<0.5	<0.5
0.023	0.56	1.7	176	84	2.7	25.6	20.5	1.4	2	17	37.1	<0.1	55.1	4.9	0.08	<0.005	<1	<0.5	<0.5
0.025	0.70	1.4	170	84	2.3	26.3	16.9	1.1	2	16	34.2	<0.1	70.6	4.7	0.10	<0.005	<1	<0.5	<0.5
0.018	0.43	1.0	135	53	1.7	14.2	13.5	0.9	<1	10	23.2	<0.1	42.7	3.9	<0.05	<0.005	<1	<0.5	<0.5
0.028	0.79	1.6	195	87	2.9	21.7	20.2	1.3	1	17	46.9	<0.1	75.4	5.5	0.06	<0.005	<1	<0.5	<0.5
0.013	0.22	0.5	69.3	31	0.8	5.9	7.0	0.4	<1	4	17.0	<0.1	17.9	1.8	<0.05	<0.005	<1	<0.5	<0.5
0.017	0.32	0.8	106	37	1.2	10.4	12.2	0.7	<1	7	27.7	<0.1	30.2	2.8	<0.05	<0.005	<1	<0.5	<0.5
0.026	0.69	1.3	178	68	2.1	19.0	17.3	1.2	1	11	69.5	0.9	52.3	4.8	0.08	<0.005	<1	<0.5	<0.5
0.016	0.37	0.8	112	41	1.4	10.9	12.5	0.8	<1	7	33.3	<0.1	34.4	2.9	<0.05	<0.005	<1	<0.5	<0.5
0.041	0.13	0.2	13.7	74	0.3	117	2.1	0.2	1	5	6.6	0.5	11.0	0.4	<0.05	0.007	3	<0.5	<0.5
0.031	0.20	0.3	17.0	58	0.4	69.2	3.0	0.2	1	5	7.3	0.5	16.0	0.5	<0.05	<0.005	5	<0.5	<0.5

0.028	0.08	0.6	73.0	41	1.4	8.3	11.0	0.7	<1	5	13.8	<0.1	7.7	1.9	<0.05	<0.005	<1	<0.5	<0.5
0.032	0.20	0.3	17.0	57	0.5	70.0	2.9	0.2	1	5	8.2	0.5	16.2	0.5	<0.05	<0.005	5	<0.5	<0.5

<0.001	<0.01											<0.1							
		<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<1	<1	<0.1		<0.1	<0.1	<0.05	<0.005	<1	<0.5	<0.5

0.056	0.35											<0.1							
0.059	**0.324**											**0.046**							
-5.1	8.0											-100.0							

		1.0	113.4	25	1.4	7.9	6	0.5	<1	98	7		20.5	3	0.11	<0.005	3	<0.5	<0.5
		1.07	**110**	**23.5**	**1.32**	**8.28**	**6.8**	**0.56**		**93**	**6.58**		**21.2**	**3.11**	**0.099**		**2.97**	**0.1**	**0.15**
		-6.5	3.1	6.4	6.1	-4.6	-11.8	-10.7		5.4	6.4		-3.3	-3.5	11.1		1.0		

0.146	0.52											<0.1							
0.134	**0.482**											**0.1**							
9.0	7.9																		

		1.9	152.5	47	4.1	10.4	20.1	1.4	<1	14	38.8		58.3	4.1	0.08	<0.005	3	<0.5	<0.5
		2.1		**48.9**	**4.06**	**12.3**	**22.4**	**1.6**	**1.02**	**13.7**	**36.7**		**61**	**4.53**					**0.35**
		-9.5		-3.9	1.0	-15.4	-10.3	-12.5		2.2	5.7		-4.4	-9.5					
0.001	0.01	0.1	0.1	1	0.1	0.1	0.1	0.1	1	1	0.1	0.1	0.1	0.1	0.05	0.005	1	0.5	0.5
1EX	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*	*1EX*

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 7: MEND SFE Test Results for project FARIM PHOSPHATE

Maxxam Sample No	Sample ID	Sample Weight	Volume Used	pH	EC	SO4	Total Phosphorus	Orthophosphate	Hardness CaCO3	Dissolved Aluminum (Al)	Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Bismuth (Bi)	Dissolved Boron (B)	Dissolved Cesium (Cs)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)
	Units	g	ml	pH Units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MY2656	1-NP-15-2, 15 M	250	750	9.58	147.0	4.9	3.54	0.060	0.88	1.29	0.000084	0.0589	0.00123	0.000010	<0.0000050	<0.050	<0.000050	<0.0000050	0.131	0.00295	0.0000670	0.000827
MY2658	3-NP-15-2, 17 M	250	750	6.29	14.3	0.7	0.026	0.015	<0.50	0.0143	<0.000020	0.000248	0.000476	<0.000010	<0.0000050	<0.050	<0.000050	<0.0000050	0.160	<0.00010	0.0000330	0.000129
MY2661	6-NP-15-2, 38.5 M	250	750	7.43	71.4	9.3	2.28	0.033	1.09	0.332	0.000020	0.000273	0.00167	<0.000010	<0.0000050	<0.050	0.000051	<0.0000050	0.254	0.00081	0.0000200	0.000275
MY2662	7-NP-15-2, 54.5 M	250	750	6.35	650.0	230	0.118	< 0.005	231	0.0453	<0.000020	0.000297	0.0106	<0.000010	<0.0000050	<0.050	<0.000050	0.0000330	67.1	<0.00010	0.0216	0.000155
MY2664	9-NP-15-2, 57.5 M	250	750	7.89	548.0	198	0.540	<0.005	245	0.00663	0.000283	0.000077	0.0130	<0.000010	<0.0000050	<0.050	<0.000050	0.0000150	87.7	0.00015	0.000143	0.000259
MY2666	1-SP-15-3, 21.5 M	250	750	9.72	224.0	9.7	4.36	0.093	3.47	1.11	0.000091	0.00785	0.00296	0.000020	<0.0000050	<0.050	0.000074	<0.0000050	1.01	0.00306	0.000132	0.00217
MY2668	3-SP-15-3, 33 M	250	750	7.07	496.0	145	0.151	<0.005	98.2	0.0229	0.000102	0.000345	0.0119	<0.000010	<0.0000050	<0.050	<0.000050	0.0000990	27.3	<0.00010	0.0111	0.000066
MY2670	5-SP-15-3, 34.5 M	250	750	3.36	1040.0	357	0.127	0.005	201	2.45	0.000094	0.00371	0.00659	0.0168	<0.0000050	<0.050	0.000100	0.00724	55.9	0.0155	1.04	0.00540
MY2672	2-SP-15-1, 19.5 M	250	750	4.25	366.0	34.3	0.006	<0.005	33.0	0.0237	<0.000020	<0.000020	0.00309	0.000198	<0.0000050	<0.050	0.000672	0.0000080	4.21	<0.00010	0.00135	0.000574
MY2674	4-SP-15-1, 24.5 M	250	750	5.73	368.0	41.1	0.023	<0.005	48.3	0.00393	<0.000020	0.000661	0.00305	0.000018	<0.0000050	<0.050	0.000418	0.0000150	6.70	<0.00010	0.000506	0.000159
MY2676	6-SP-15-1, FPA.CO M	250	750	5.68	994.0	394	7.59	0.025	351	0.0323	0.000212	0.00177	0.0144	0.000089	<0.0000050	<0.050	0.000070	0.00210	107	<0.00010	0.128	0.000436
MY2678	2-SP-15-2, 21 M	250	750	8.30	1175.0	37.4	0.100	<0.005	41.9	0.146	0.000032	0.000897	0.00570	<0.000010	<0.0000050	0.062	0.000068	<0.0000050	6.61	0.00016	0.0000710	0.00105
MY2680	4-SP-15-2, 26 M	250	750	8.67	1770.0	54.1	0.036	<0.005	63.5	0.0694	0.000037	0.00124	0.0159	<0.000010	<0.0000050	0.075	0.000071	0.0000070	10.1	0.00013	0.0000990	0.00103
MY2682	6-SP-15-2, 27.5 M	250	750	6.32	632.0	25.2	0.047	<0.005	66.8	0.0187	<0.000020	0.000304	0.00501	<0.000010	<0.0000050	<0.050	0.000172	0.0000300	17.3	<0.00010	0.00546	0.000096
MY2684	1-NP-15-4, 15.5 M	250	750	5.96	16.2	0.6	0.075	0.047	2.37	0.0258	<0.000020	0.000163	0.00154	0.000040	<0.0000050	<0.050	<0.000050	<0.0000050	0.449	0.00044	0.000999	0.000208
MY2686	3-NP-15-4, 26 M	250	750	5.55	23.4	1.0	0.015	0.008	2.66	0.0212	<0.000020	0.000090	0.00181	0.000022	<0.0000050	<0.050	<0.000050	<0.0000050	0.581	0.00083	0.000639	0.000115
MY2688	5-NP-15-4, 32 M	250	750	7.21	17.7	3.9	0.932	0.016	0.84	0.752	<0.000020	0.000191	0.00145	<0.000010	<0.0000050	<0.050	0.000070	<0.0000050	0.245	0.00118	0.0000690	0.000496
MY2690	7-NP-15-4, 33.5 M	250	750	5.73	484.0	188	0.024	<0.005	212	0.0642	<0.000020	0.000446	0.0104	0.000016	<0.0000050	<0.050	0.000058	0.0000090	69.1	0.00010	0.0205	0.000074
MY2692	9-NP-15-4, 45 M	250	750	7.61	241.0	72.6	9.36	<0.005	96.6	0.00387	0.000531	0.000026	0.00461	<0.000010	<0.0000050	<0.050	<0.000050	0.0000680	32.1	0.00074	0.00165	0.000397
QAQC																						
Duplicates																						
MY2688 Dup	5-NP-15-4, 32 M						0.931															
MY2684 Dup	1-NP-15-4, 15.5 M							0.047														
MY2678 Dup	2-SP-15-2, 21 M						0.101															
MY2658 Dup	3-NP-15-2, 17 M							0.015														
MY2661 Dup	6-NP-15-2, 38.5 M					9.2																
MY2664 Dup	9-NP-15-2, 57.5 M					198																
MY6339	6-NP-15-2, 38.5 M SFE DUP	250	750	7.45	80.7	8.1	<0.005	<0.005	1.42	1.03	0.000020	0.000333	0.00245	<0.000010	<0.0000050	<0.050	0.000138	<0.0000050	0.289	0.00194	0.0000610	0.000374
MY2686 Dup	3-NP-15-4, 26 M					0.9																
MY6339 Dup	6-NP-15-2, 38.5 M SFE DUP									1.03	0.000020	0.000321	0.00239	<0.000010	<0.0000050	<0.050	0.000132	<0.0000050	0.287	0.00196	0.0000640	0.000386
Blanks																						
Method Blank		0	750							<0.00050	<0.000020	<0.000020	<0.000020	<0.000010	<0.0000050	<0.050	<0.000050	<0.0000050	<0.050	<0.00010	<0.0000050	<0.000050
Method Blank						<0.5																
Method Blank						<0.5																
Method Blank						<0.5																
Reference Material																						
CRC ICPMS H2O (8017947) % recovery										109.01500	102.10000	100.12000	104.76000	101.80000	103.80000		101.30000	101.56000		103.45000	106.20000	104.14000
True Values CRC ICPMS H2O										**100**	**1**	**10**	**10**	**10**	**1**		**1**	**10**		**10**	**10**	**10**
Reference Material																						
Sulphate W K-Van (8018430) % recovery						98.74000																
Sulphate W K-Van (8018450) % recovery						101.27500																
Sulphate W K-Van (8019979) % recovery						97.795																
True Values Sulphate W K-Van						**20**																
Maxxam SOP #		BBY0SOP-000	BY0SOP-000	BY0SOP-000	BBY0SOP-00006	BY6SOP-00017		BBY WI-00033		BY7SOP-0000	BY7SOP-0000	BY7SOP-000	BY7SOP-0000	BY7SOP-0000	BY7SOP-000	BY7SOP-000	BY7SOP-0000	BBY7SOP-00002	BY7SOP-0000	BBY7SOP-00002	BBY7SOP-00002	BY7SOP-0000

References:
Hardness = (Calcium*2.497) + (Magnesium*4.118)

Dissolved Lanthanum (La)	Dissolved Iron (Fe)	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Phosphorus (P)	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Potassium (K)	Dissolved Rubidium (Rb)	Dissolved Selenium (Se)	Dissolved Silicon (Si)	Dissolved Silver (Ag)	Dissolved Sodium (Na)	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	Dissolved Tellurium (Te)	Dissolved Thallium (Tl)	Dissolved Thorium (Th)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Tungsten (W)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)	Dissolved Zirconium (Zr)	Dissolved Mercury (Hg)
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0.000982	0.344	0.000305	0.00050	0.133	0.000784	0.0579	0.0138	0.000661	0.141	0.000267	0.000563	3.59	<0.0000050	26.1	0.000884	<10	<0.000020	0.0000020	0.000175	<0.00020	0.0434	0.00111	0.000165	0.0355	0.00307	0.00182	<0.000050
<0.000050	0.0032	<0.0000050	0.00053	<0.050	0.000974	0.0129	<0.000050	0.000202	0.130	0.000674	<0.000040	1.57	<0.0000050	2.72	0.000247	<10	<0.000020	<0.0000020	<0.0000050	<0.00020	<0.00050	<0.000010	0.0000040	0.00074	0.00118	<0.00010	<0.000050
0.000125	0.0865	0.0000970	0.00070	0.110	0.000610	0.0237	0.000645	0.000265	1.01	0.00197	0.000262	2.45	<0.0000050	15.8	0.00117	<10	<0.000020	0.0000050	0.0000360	<0.00020	0.0123	0.000057	0.0000120	0.00117	0.00090	0.00208	<0.000050
<0.000050	0.0121	0.0000150	0.00705	15.3	0.887	0.0043	<0.000050	0.0127	6.43	0.0160	0.000976	1.02	<0.0000050	25.2	0.120	94	<0.000020	0.0000110	0.0000050	<0.00020	0.00284	<0.000010	0.0000140	<0.00020	0.00127	<0.00010	<0.000050
<0.000050	0.0017	<0.0000050	0.00343	6.30	0.0130	0.0027	0.00125	0.00476	8.91	0.00896	0.0229	0.55	0.0000050	3.55	0.234	82	<0.000020	0.0000090	<0.0000050	<0.00020	0.00095	<0.000010	0.00117	<0.00020	0.00021	<0.00010	<0.000050
0.000969	0.210	0.000297	0.00224	0.231	0.00103	0.105	0.00928	0.000839	1.53	0.000949	0.00112	4.78	0.0000080	41.0	0.00584	<10	<0.000020	0.0000040	0.000153	<0.00020	0.0413	0.00266	0.000618	0.0583	0.00411	0.00160	<0.000050
0.000060	0.0047	<0.0000050	0.00696	7.27	0.0404	0.0048	0.000308	0.0311	1.73	0.00220	0.00814	1.42	0.0000080	57.3	0.114	55	<0.000020	0.000146	<0.0000050	<0.00020	0.00097	0.000046	0.000115	<0.00020	0.00043	<0.00010	<0.000050
0.00505	33.1	0.000113	0.0271	14.9	0.459	0.0020	<0.000050	0.947	1.01	0.00605	0.00515	2.42	0.0000070	45.1	0.219	116	<0.000020	0.000495	0.000639	<0.00020	<0.00050	0.000010	0.0987	0.00063	0.636	0.00017	0.000152
0.000096	0.0505	0.0000180	0.00426	5.47	0.0236	0.0026	<0.000050	0.00165	2.13	0.00906	0.000267	1.90	<0.0000050	49.2	0.0270	13	<0.000020	0.0000890	<0.0000050	<0.00020	<0.00050	<0.000010	0.00108	<0.00020	0.00406	<0.00010	<0.000050
<0.000050	0.0042	<0.0000050	0.00118	7.67	0.0557	<0.0020	<0.000050	0.00127	3.08	0.00726	0.000149	1.13	<0.0000050	46.6	0.0344	14	<0.000020	0.0000470	<0.0000050	<0.00020	<0.00050	<0.000010	0.0000550	<0.00020	0.00416	<0.00010	<0.000050
<0.000050	0.0523	0.0000110	0.0339	20.6	2.26	0.0300	0.000201	0.103	10.9	0.0292	0.0211	2.25	<0.0000050	62.6	0.215	150	<0.000020	0.000369	<0.0000050	<0.00020	0.00171	<0.000010	0.0000410	0.00254	0.0729	<0.00010	<0.000050
<0.000050	0.0152	0.0000130	<0.00050	6.16	0.000255	0.0063	0.00856	0.000396	5.32	0.00183	0.000300	1.03	<0.0000050	205	0.0489	15	<0.000020	0.0000220	0.0000090	<0.00020	0.00589	0.000613	0.0000440	0.00226	<0.00010	0.00015	<0.000050
<0.000050	0.0066	<0.0000050	0.00094	9.33	0.000332	0.0063	0.00776	0.000377	6.46	0.00220	0.000360	1.25	<0.0000050	314	0.0927	21	<0.000020	0.0000160	<0.0000050	<0.00020	0.00214	0.00214	0.0000980	0.00321	<0.00010	<0.00010	<0.000050
0.000065	0.0188	0.0000060	0.0113	5.73	0.193	0.0065	<0.000050	0.00420	5.42	0.0117	0.000499	2.90	<0.0000050	86.0	0.0161	<10	<0.000020	0.0000240	<0.0000050	<0.00020	<0.00050	<0.000010	0.0000320	<0.00020	0.00421	<0.00010	<0.000050
<0.000050	0.0030	<0.0000050	0.00327	0.304	0.0190	0.0505	<0.000050	0.00137	0.841	0.00361	<0.000040	2.23	<0.0000050	2.26	0.000966	<10	<0.000020	0.0000060	<0.0000050	<0.00020	<0.00050	<0.000010	0.0000060	0.00023	0.00313	<0.00010	<0.000050
<0.000050	0.0039	<0.0000050	0.00252	0.294	0.0133	0.0082	<0.000050	0.00119	1.17	0.00510	0.000071	1.62	<0.0000050	3.21	0.00122	<10	<0.000020	0.0000080	<0.0000050	<0.00020	<0.00050	<0.000010	0.0000050	<0.00020	0.00228	<0.00010	<0.000050
0.000381	0.253	0.000202	0.00165	0.055	0.00110	0.0128	0.000353	0.000310	0.898	0.00178	0.000213	2.35	<0.0000050	2.04	0.00188	<10	<0.000020	0.0000040	0.0000890	<0.00020	0.0305	0.000017	0.0000220	0.00146	0.00081	0.00096	<0.000050
0.000077	0.0155	0.0000290	0.0103	9.59	2.17	0.0023	<0.000050	0.0123	13.2	0.0329	0.00683	1.62	<0.0000050	2.91	0.103	78	<0.000020	0.0000160	0.0000100	<0.00020	0.00468	<0.000010	0.0000040	<0.00020	0.00459	0.00012	<0.000050
<0.000050	<0.0010	<0.0000050	0.00362	4.01	0.0114	0.0033	0.00128	0.0225	6.47	0.00701	0.0716	0.39	0.0000100	3.59	0.0972	28	<0.000020	0.000118	<0.0000050	<0.00020	<0.00050	<0.000010	0.000230	0.00025	0.00017	<0.00010	<0.000050
0.000459	0.250	0.000241	0.00076	0.169	0.00109	0.0444	0.000611	0.000582	1.03	0.00247	0.000207	3.12	<0.0000050	13.1	0.00208	<10	<0.000020	0.0000130	0.000110	<0.00020	0.0382	0.000094	0.0000230	0.00183	0.00154	0.00155	<0.000050
0.000421	0.242	0.000254	0.00088	0.172	0.00106	0.0438	0.000592	0.000548	1.04	0.00257	0.000210	3.21	<0.0000050	13.4	0.00206	<10	<0.000020	0.0000090	0.000115	<0.00020	0.0380	0.000087	0.0000240	0.00187	0.00163	0.00154	<0.000050
<0.000050	<0.0010	<0.0000050	<0.00050	<0.050	<0.000050	<0.0020	<0.000050	<0.000020	<0.050	<0.000050	<0.000040	<0.10	<0.0000050	<0.050	<0.000050	<10	<0.000020	<0.0000020	<0.0000050	<0.00020	<0.00050	<0.000010	<0.0000020	<0.00020	<0.00010	<0.00010	<0.000050
106.50000	106.54400	105.09000	107.43000		100.18000		100.00000	102.43000			98.75000		85.00000		98.27000		101.10000	104.00000		95.10000	101.40000		102.13000	101.06000	103.58000		108.20000
1	**100**	**10**	**10**		**10**		**1**	**10**			**10**		**1**		**10**		**1**	**1**		**1**	**10**		**10**	**10**	**10**		**1**
BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BBY7SOP-00002

Table 10: Sample List for project FARIM PHOSPHATE

Maxxam Sample ID	Client Sample ID	Sample Form	Dry Weight Received (kg)
MY2656	1-NP-15-2, 15 M	Sandy clay	1.458
MY2657	2-NP-15-2, 15 M	Sandy clay	1.461
MY2658	3-NP-15-2, 17 M	Fine Sand	1.479
MY2659	4-NP-15-2, 17 M	Fine Sand	1.503
MY2660	5-NP-15-2, 36 M	Plastic clay	1.421
MY2661	6-NP-15-2, 38.5 M	Plastic clay	1.418
MY2662	7-NP-15-2, 54.5 M	Sand with lignite	1.128
MY2663	8-NP-15-2, 54.5 M	Sand with lignite	1.550
MY2664	9-NP-15-2, 57.5 M	Grey phosphate clay	1.424
MY2665	10-NP-15-2, 57.5 M	Grey phosphate clay	1.438
MY2666	1-SP-15-3, 21.5 M	Clay	1.764
MY2667	2-SP-15-3, 21.5 M	Clay	1.219
MY2668	3-SP-15-3, 33 M	Fine Sand	1.699
MY2669	4-SP-15-3, 33 M	Fine Sand	1.675
MY2670	5-SP-15-3, 34.5 M	Clayey sand	1.566
MY2671	1-SP-15-1, 15 M	Sandy clay/plastic clay	1.416
MY2672	2-SP-15-1, 19.5 M	Sandy clay/plastic clay	1.722
MY2673	3-SP-15-1, 19.5 M	Sandy clay/plastic clay	1.566
MY2674	4-SP-15-1, 24.5 M	Sandy clay/plastic clay	1.724
MY2675	5-SP-15-1, FPA.CO M	Sand/FPA	1.410
MY2676	6-SP-15-1, FPA.CO M	Sand/FPA	1.477
MY2677	1-SP-15-2, 16 M	Clay sandy	1.459
MY2678	2-SP-15-2, 21 M	Clay sandy	1.439
MY2679	3-SP-15-2, 21 M	Clay sandy	1.443
MY2680	4-SP-15-2, 26 M	Clay sandy	1.650
MY2681	5-SP-15-2, 26 M	Clay sandy	1.507
MY2682	6-SP-15-2, 27.5 M	Sand with lignite	1.625
MY2683	7-SP-15-2, 27.5 M	Sand with lignite	1.331
MY2684	1-NP-15-4, 15.5 M	Clay	1.656
MY2685	2-NP-15-4, 15.5 M	Clay	1.575
MY2686	3-NP-15-4, 26 M	Fine sand, sandy clay	1.615
MY2687	4-NP-15-4, 26 M	Fine sand, sandy clay	1.617
MY2688	5-NP-15-4, 32 M	Plastic clay	1.585
MY2689	6-NP-15-4, 32 M	Plastic clay	1.616
MY2690	7-NP-15-4, 33.5 M	Fine sand, plastic clay	1.646
MY2691	8-NP-15-4, 33.5 M	Fine sand, plastic clay	1.599
MY2692	9-NP-15-4, 45 M	Fine sand	1.577
MY2693	10-NP-15-4, 45 M	Fine sand	1.585
		Total Weight	58.04
		Total Samples Received	38

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 11: Sample Summary for project FARIM PHOSPHATE

GB MINERALS LTD., FARIM PHOSPHATE

Date Samples Rec'd by Maxxam:	38 sample were rec'd on 20-Aug-2015.
Sample Prep Conducted by Maxxam:	YES
Date of Analysis:	August 2015

Client:	GB MINERALS LTD.
Client Project Name:	FARIM PHOSPHATE
Client Project No:	PE301-00520/04
ARD Project #:	
Maxxam Job No:	B572323
Contact Person:	Tamilyn Gilmore
E-mail Address:	tgilmore@gbminerals.com

Data Validated by:	Ashley Leow
Position:	Burnaby ARD Laboratory Supervisor

Sample Storage

Sample rejects (and selected test residues where applicable) have been archived
Standard archive protocol is archiving for samples for 3 months after testing is complete.
If archiving is required past 3 months a fee will be required.

QUANTITATIVE PHASE ANALYSIS OF TWELVE POWDER SAMPLES USING THE RIETVELD METHOD AND X-RAY POWDER DIFFRACTION DATA.

Project: KP Australia – Farim B572323

Ashley Leow
Maxxam Analytics Inc.
4606 Canada Way
Burnaby, BC V5G 1K5

Mati Raudsepp, Ph.D.
Elisabetta Pani, Ph.D.
Edith Czech, M.Sc.
Jenny Lai, B.Sc.
Lan Kato, B.A.

Dept. of Earth, Ocean & Atmospheric Sciences
The University of British Columbia
6339 Stores Road
Vancouver, BC V6T 1Z4

August 28, 2015

EXPERIMENTAL METHOD

The twelve samples of **Project KP Australia – Farim** were reduced to the optimum grain-size range for quantitative X-ray analysis (<10 μm) by grinding under ethanol in a vibratory McCrone Micronizing Mill for 10 minutes. Continuous-scan X-ray powder-diffraction data were collected over a range 3-80°2θ with CoKα radiation on a Bruker D8 Advance Bragg-Brentano diffractometer equipped with an Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye-XE detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

RESULTS

The X-ray diffractograms were analyzed using the International Centre for Diffraction Database PDF-4 and Search-Match software by Bruker. X-ray powder-diffraction data of the samples were refined with Rietveld program Topas 4.2 (Bruker AXS). The results of quantitative phase analysis by Rietveld refinements are given in Table 1 (separate file, ***Maxxam Analytics Results August 28 2015 - Project KP Australia - Farim B572323 - 12 samples.xlsx***). These amounts represent the relative amounts of crystalline phases normalized to 100%. Ideal formulae for the minerals are given in Table 2. The Rietveld refinement plots are shown in Figures 1 – 12.

Samples (UBC numbers) 1-4, 7 and 11 contain a few percent of unanalyzed likely interstratified illite-smectite clay. Samples (UBC numbers) 5, 10 and 12 contain a few percent of unanalyzed likely smectite clay. Diffraction peaks from these clays are marked by vertical blue lines on Figures 1 – 12). As the kaolinite is structurally disordered, consider the results semi-quantitative.

Table 2. Ideal formulae of phases present.

Mineral	**Ideal Formula**
Alunite	$K_2Al_6(SO_4)_4(OH)_{12}$
Anatase	TiO_2
Calcite	$CaCO_3$
Fluorapatite, carbonate rich	$Ca_5(PO_4,CO_3)_3(F,O)$
Gypsum	$CaSO_4{\cdot}2H_2O$
Hematite	Fe_2O_3
Kaolinite	$Al_2Si_2O_5(OH)_4$
Orthoclase (K-feldspar)	$KAlSi_3O_8$
Pyrite	FeS_2
Quartz	SiO_2
Siderite	$Fe^{2+}CO_3$
Siderite, calcian	$(Fe^{2+},Ca)^{+}CO_3$
Topaz	$Al_2SiO_4(OH,F)_2$

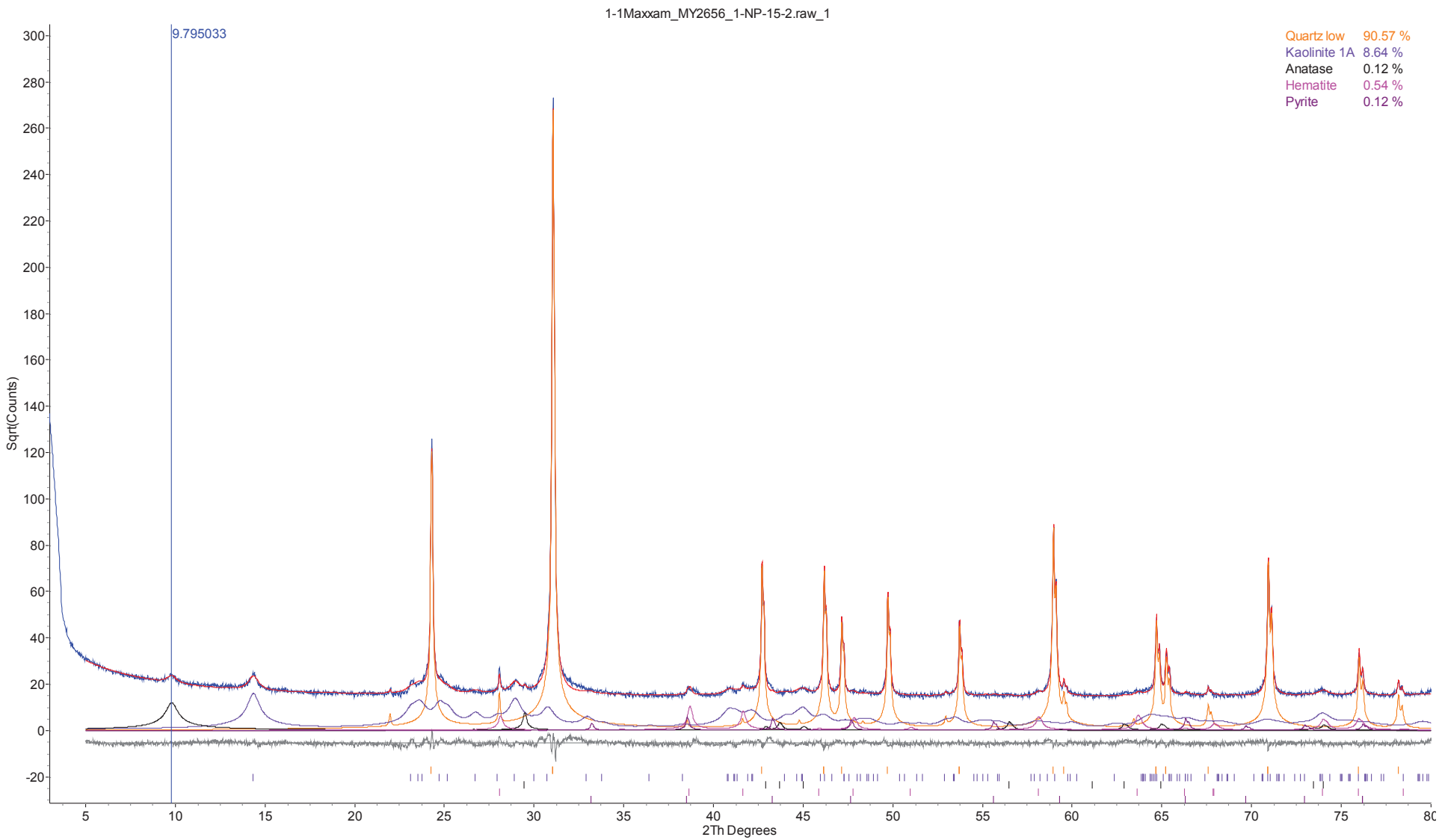

Figure 1. Rietveld refinement plot of sample **Maxxam "#1: MY2656 1-NP-15-2, 15 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

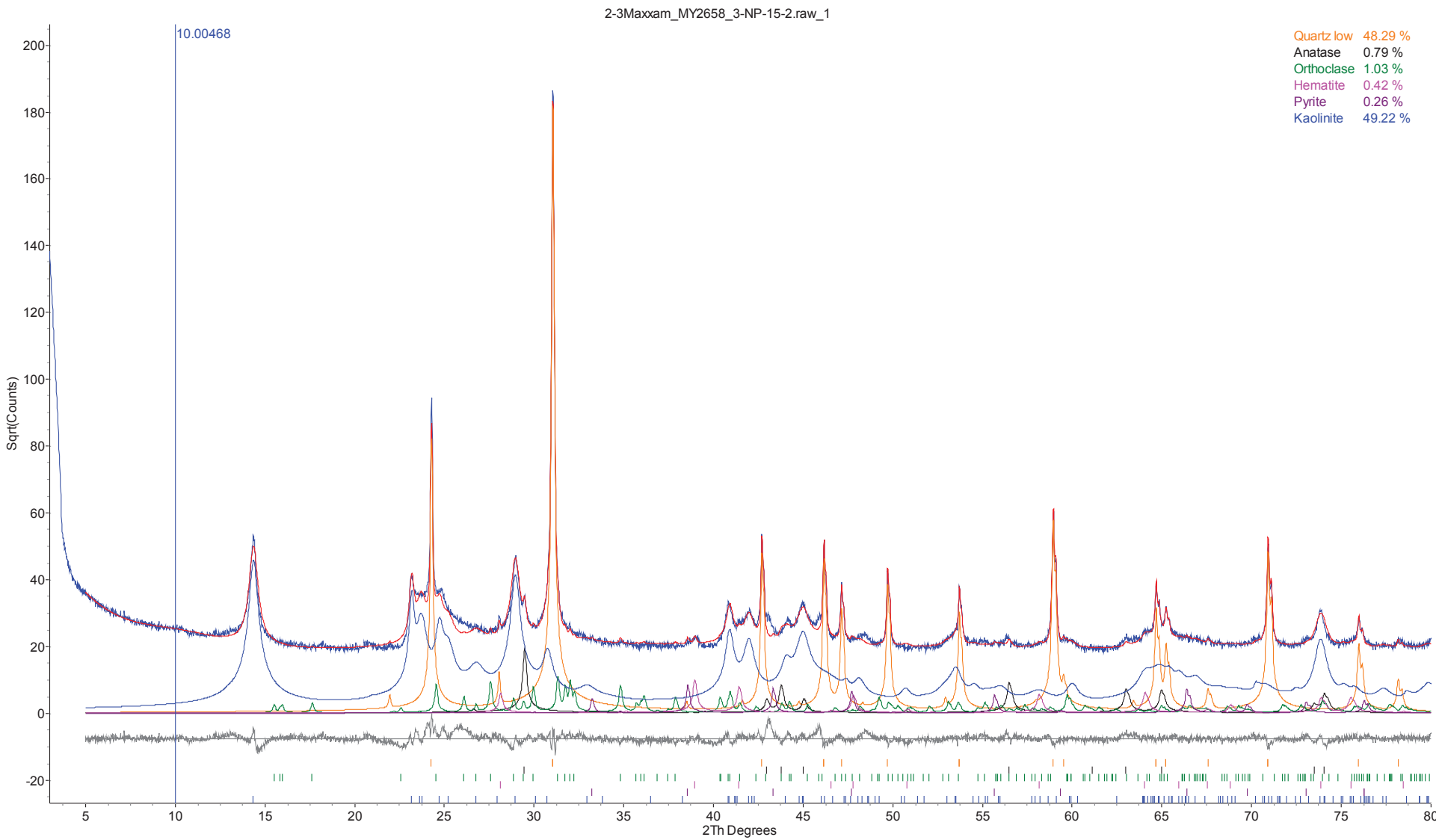

Figure 2. Rietveld refinement plot of sample **Maxxam "#3: MY2658 3-NP-15-2, 17 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

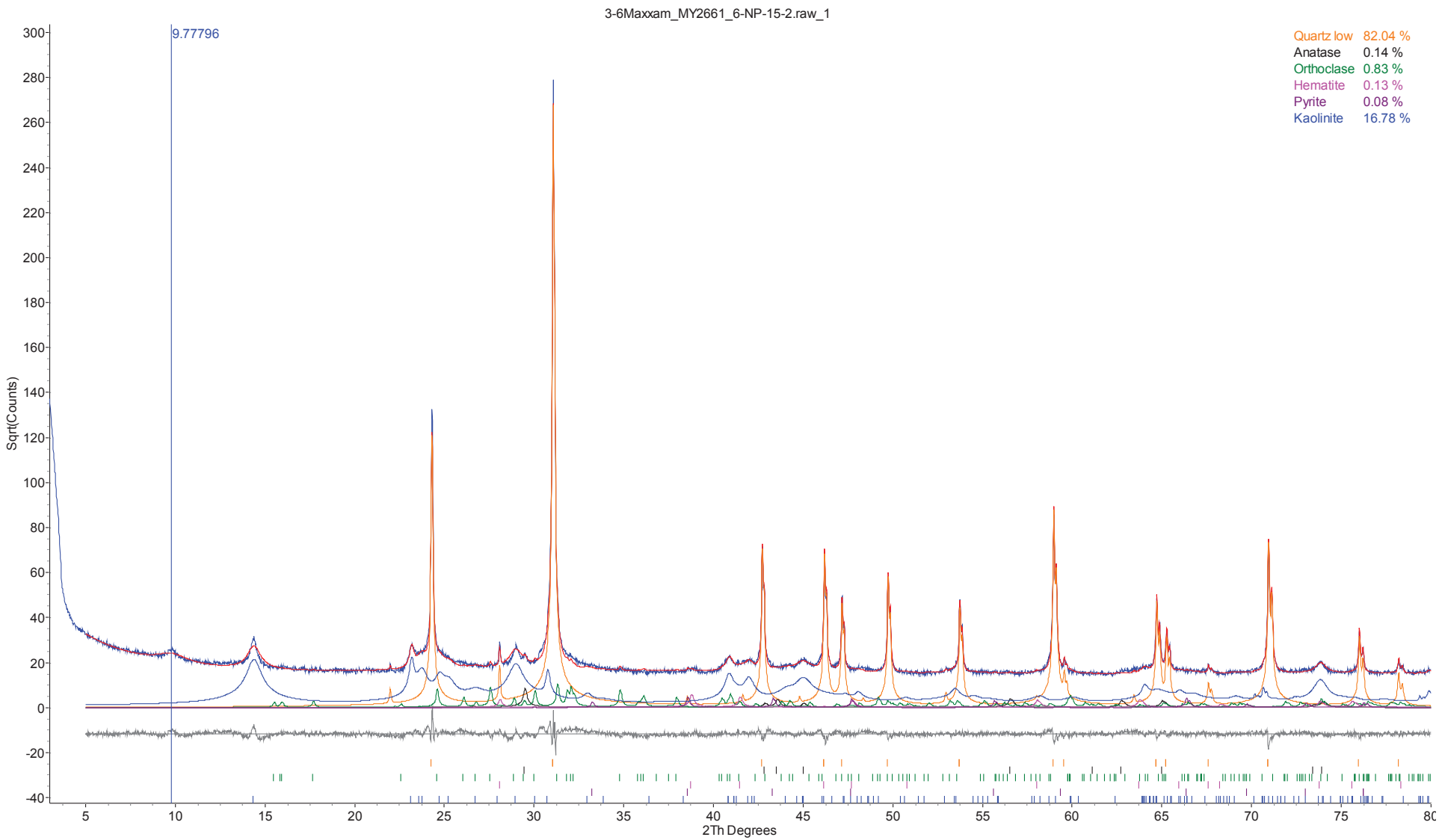

Figure 3. Rietveld refinement plot of sample **Maxxam "#6: MY2661 6-NP-15-2, 38.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

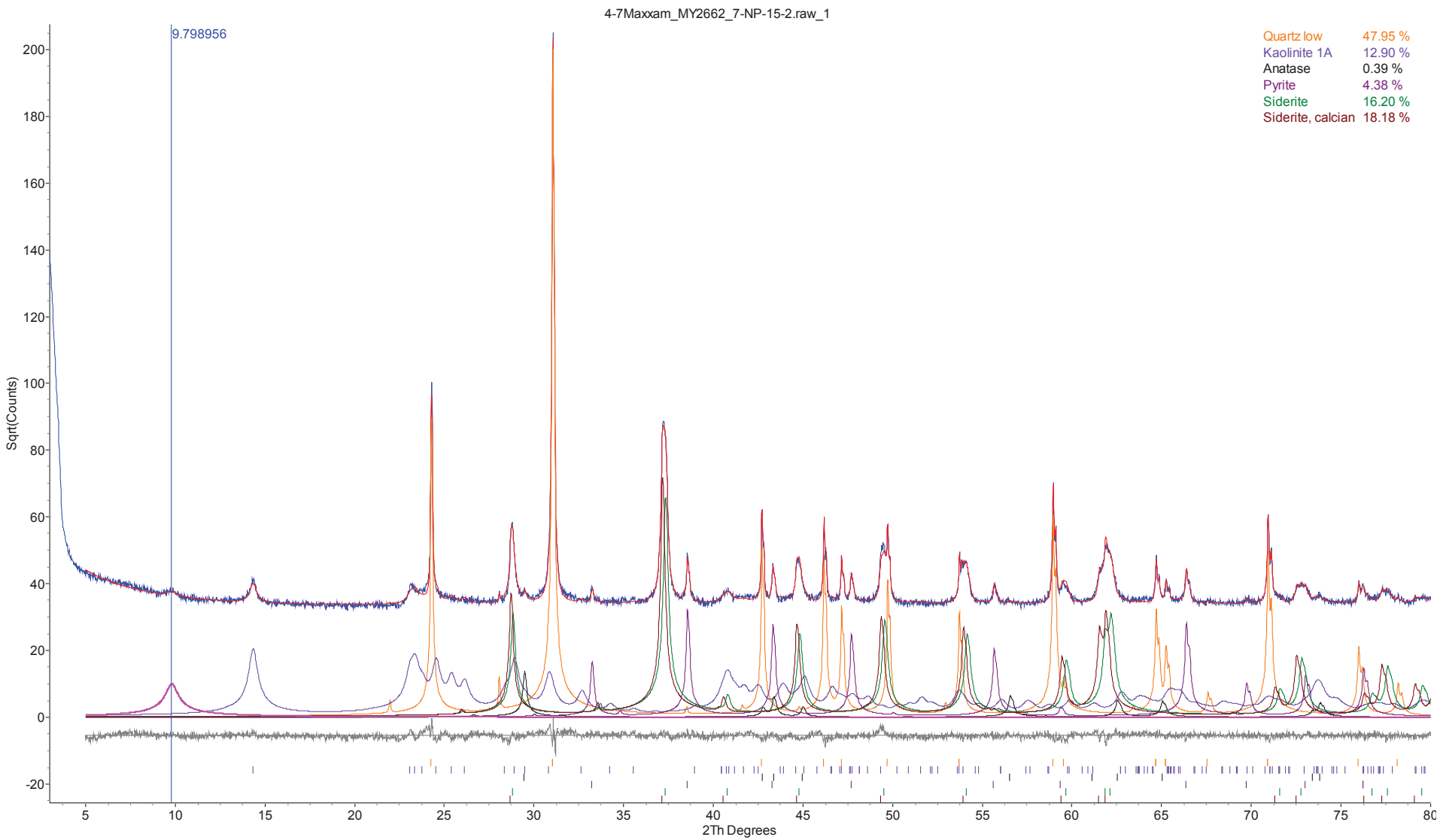

Figure 4. Rietveld refinement plot of sample **Maxxam "#7: MY2662 7-NP-15-2, 54.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

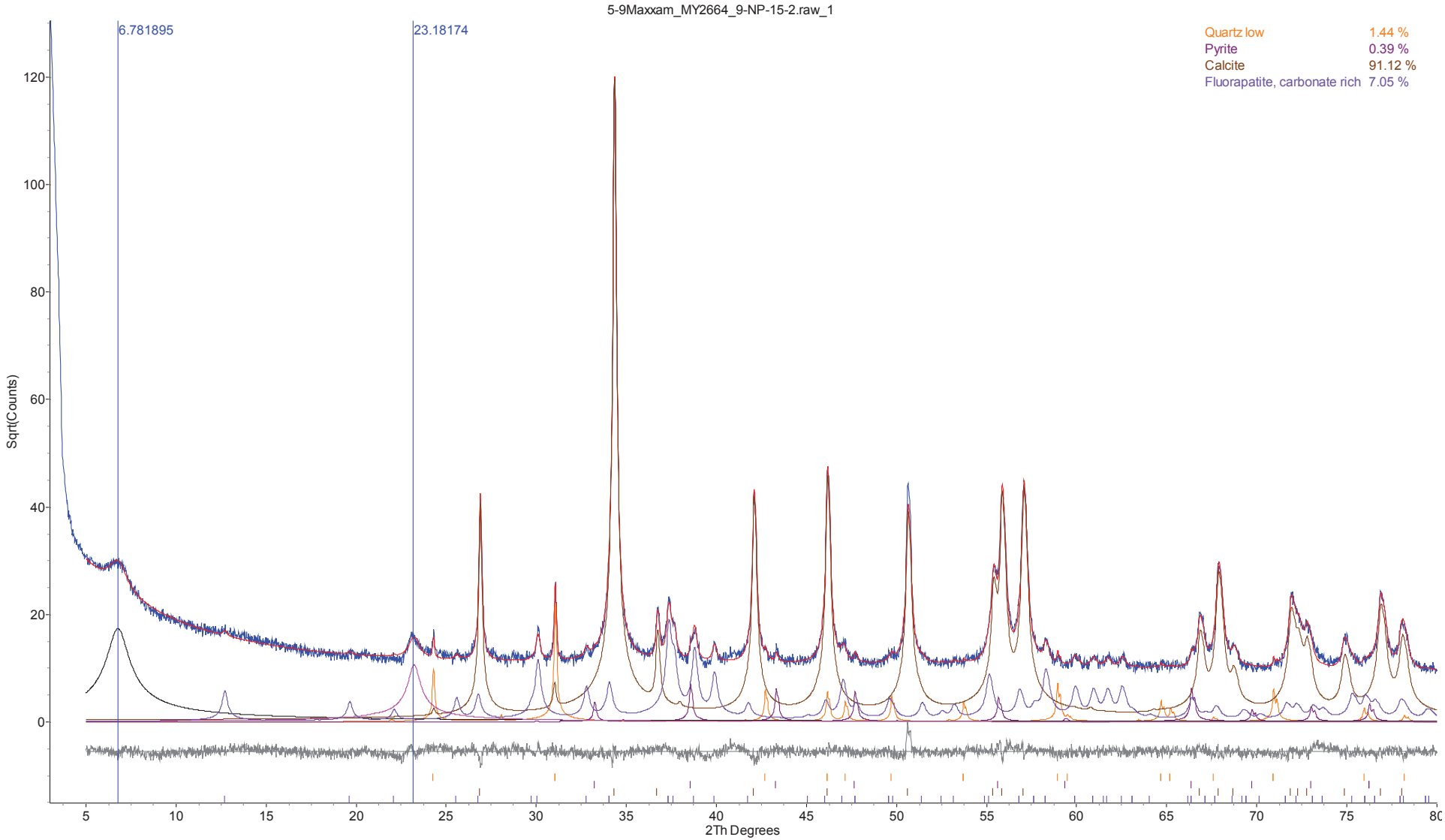

Figure 5. Rietveld refinement plot of sample **Maxxam "#9: MY2664 9-NP-15-2, 57.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

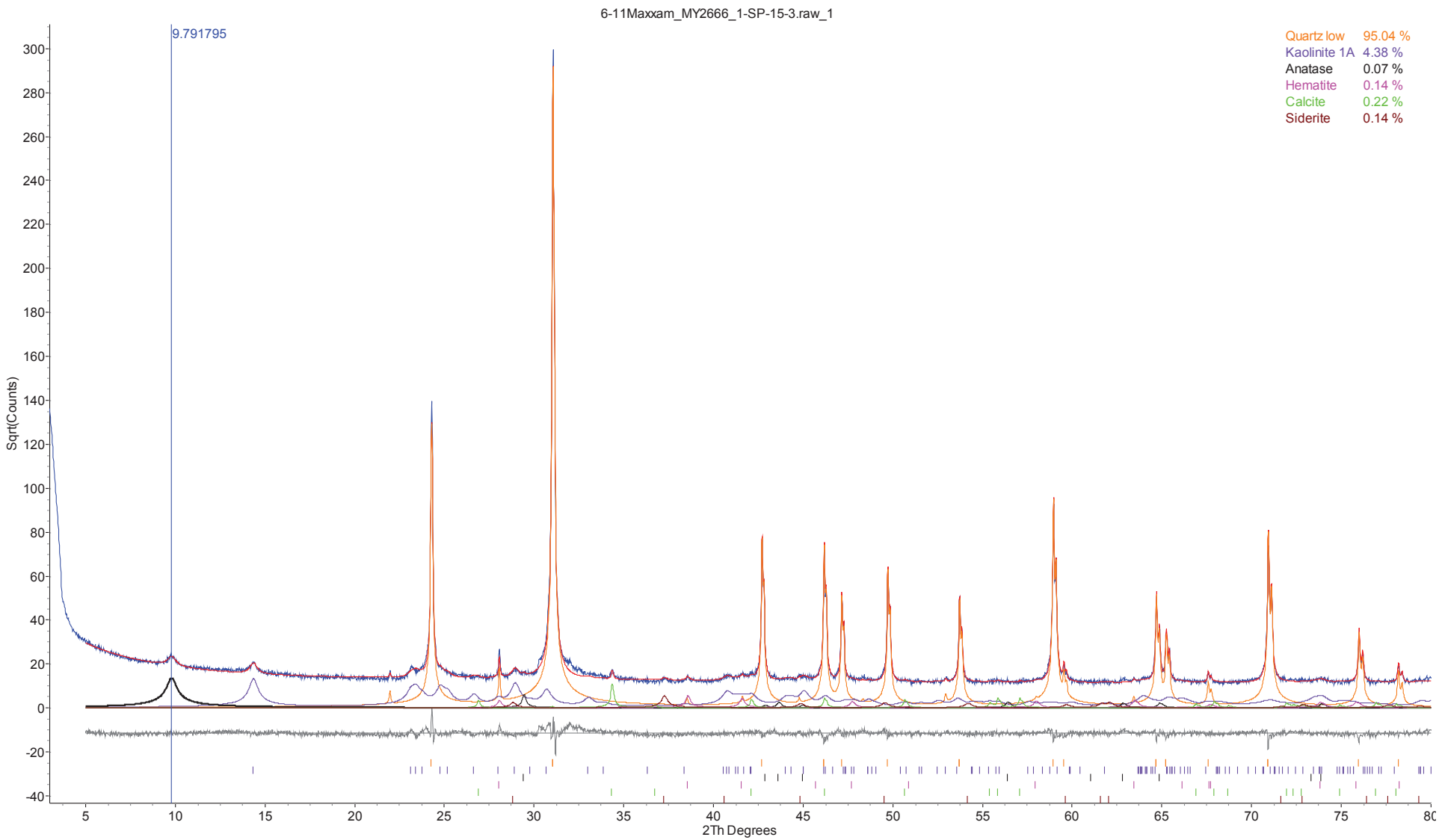

Figure 6. Rietveld refinement plot of sample **Maxxam "#11: MY2666 1-SP-15-3, 21.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

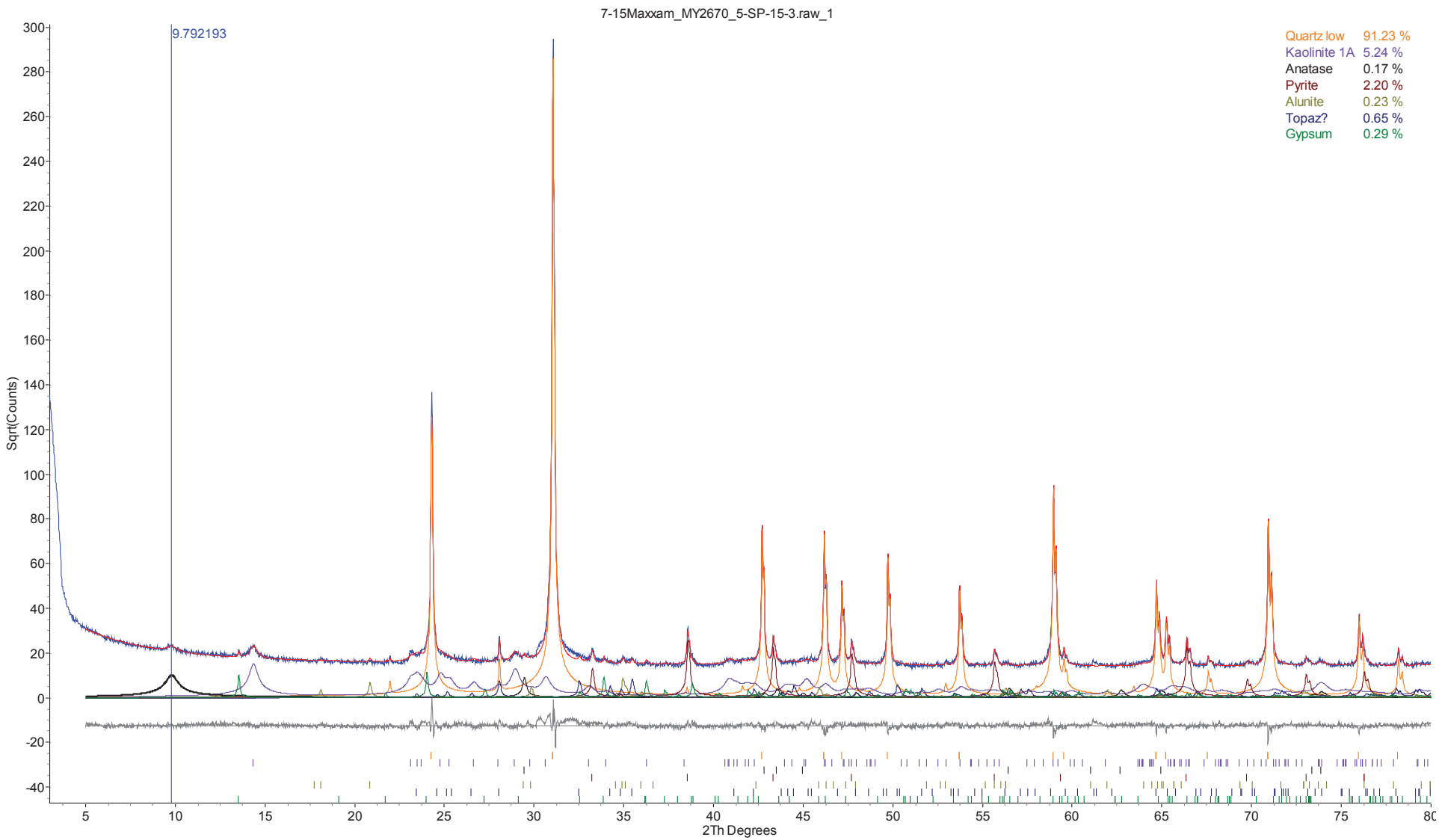

Figure 7. Rietveld refinement plot of sample **Maxxam "#15: MY2670 5-SP-15-3, 34.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

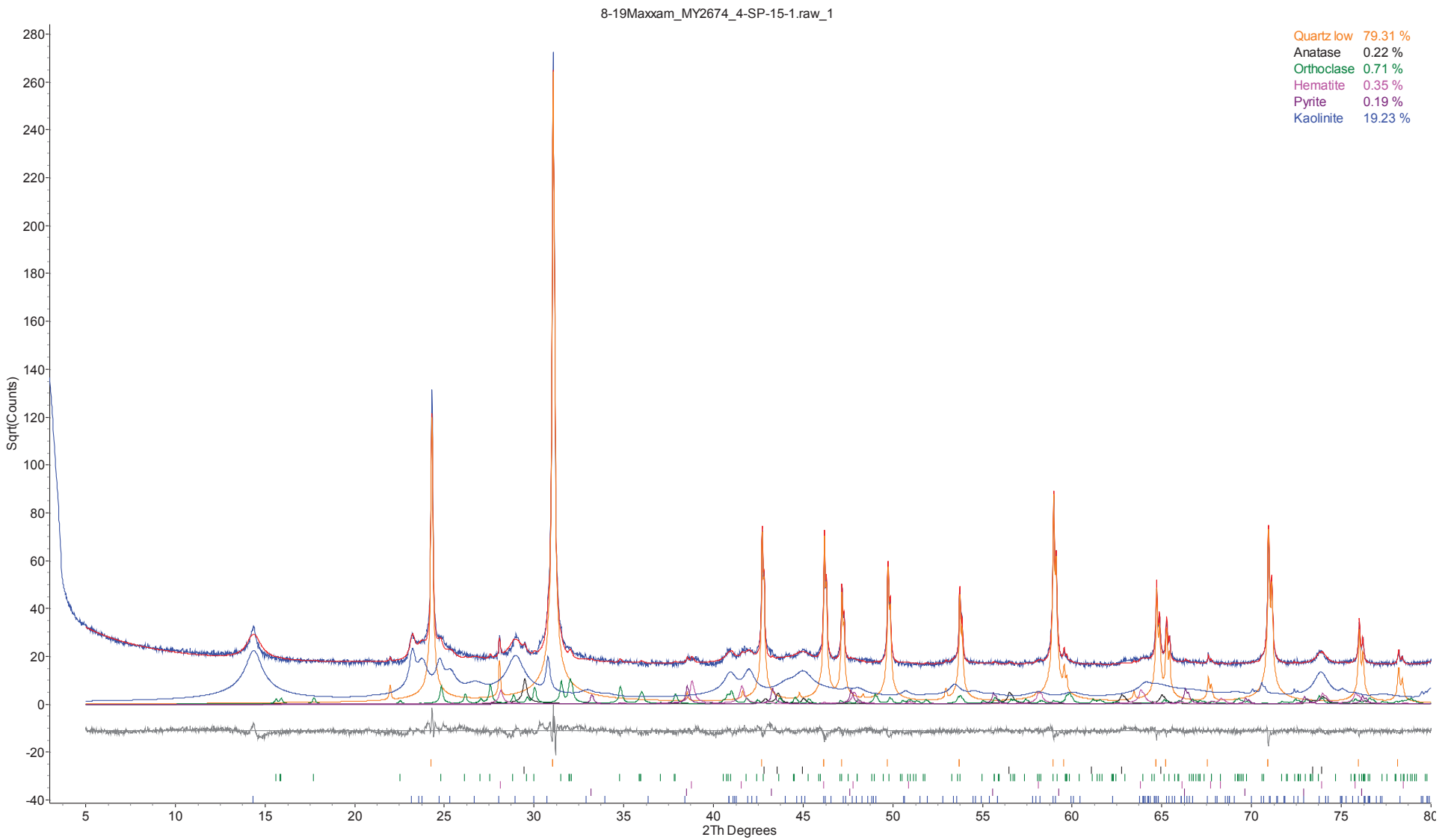

Figure 8. Rietveld refinement plot of sample **Maxxam "#19: MY2674 4-SP-15-1, 24.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

Figure 9. Rietveld refinement plot of sample **Maxxam "#21: MY2676 6-SP-15-1, FPA.CO m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

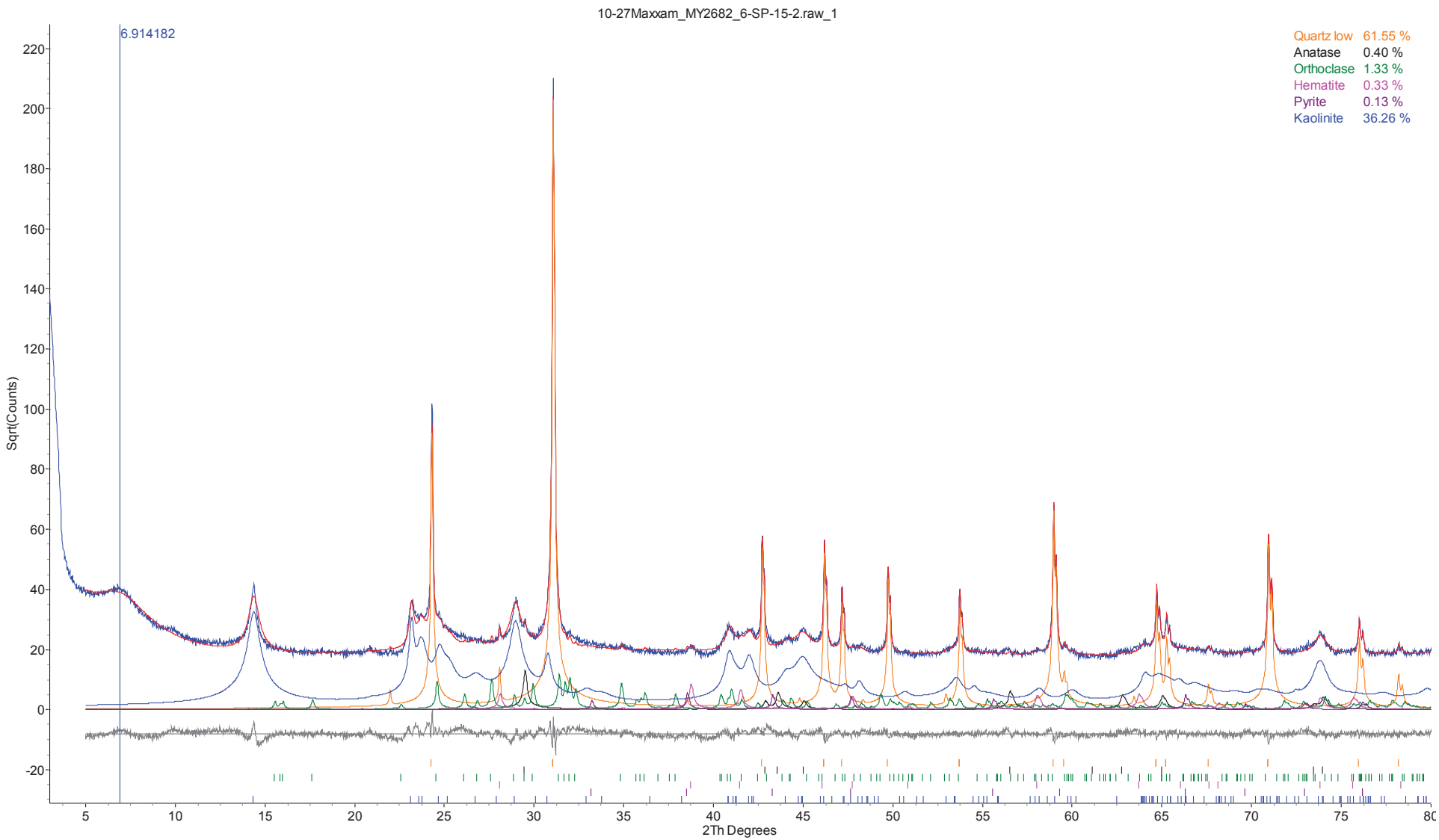

Figure 10. Rietveld refinement plot of sample **Maxxam "#27: MY2682 6-SP-15-2, 27.5 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

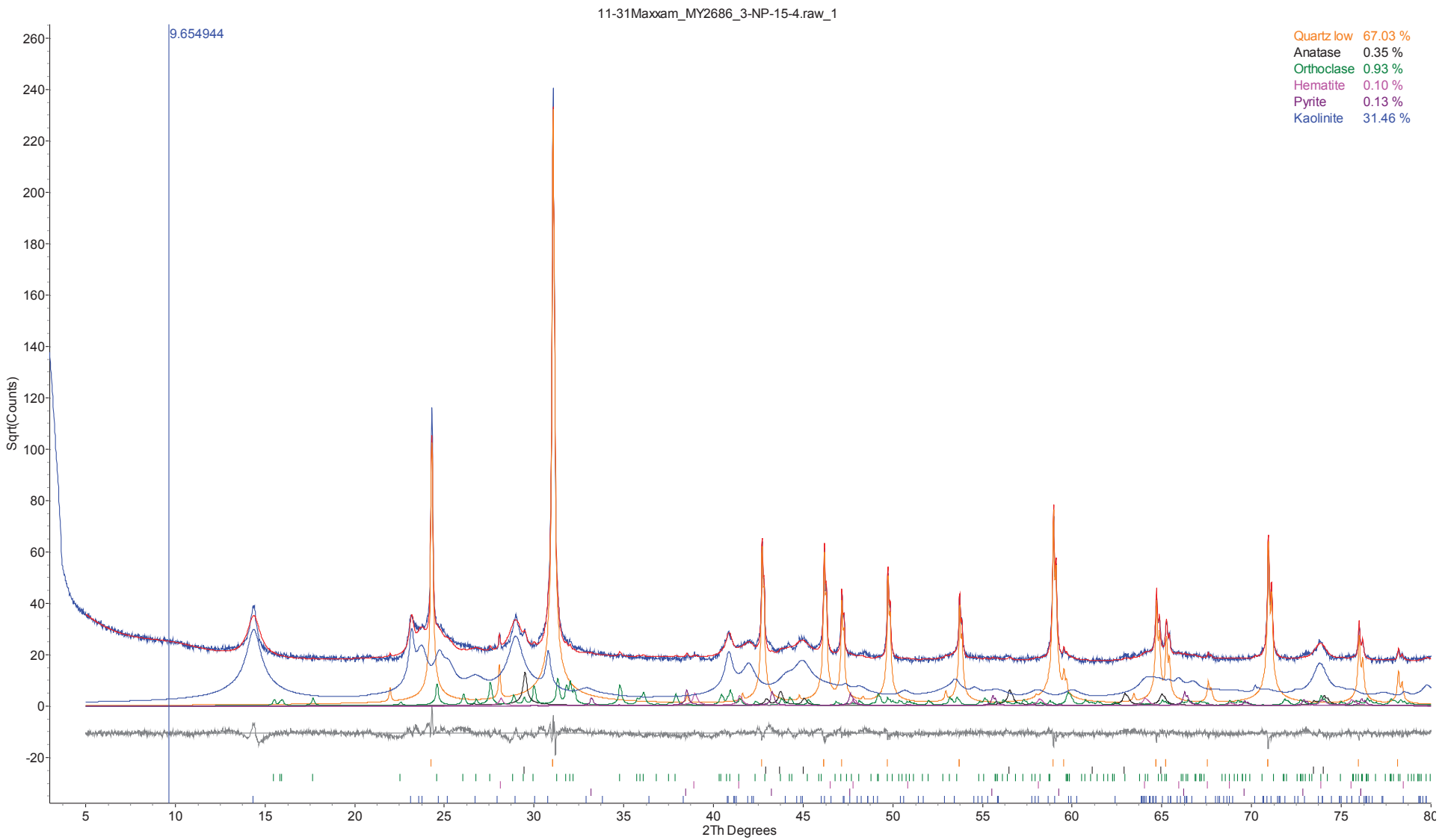

Figure 11. Rietveld refinement plot of sample **Maxxam "#31: MY2686 3-NP-15-4, 26 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

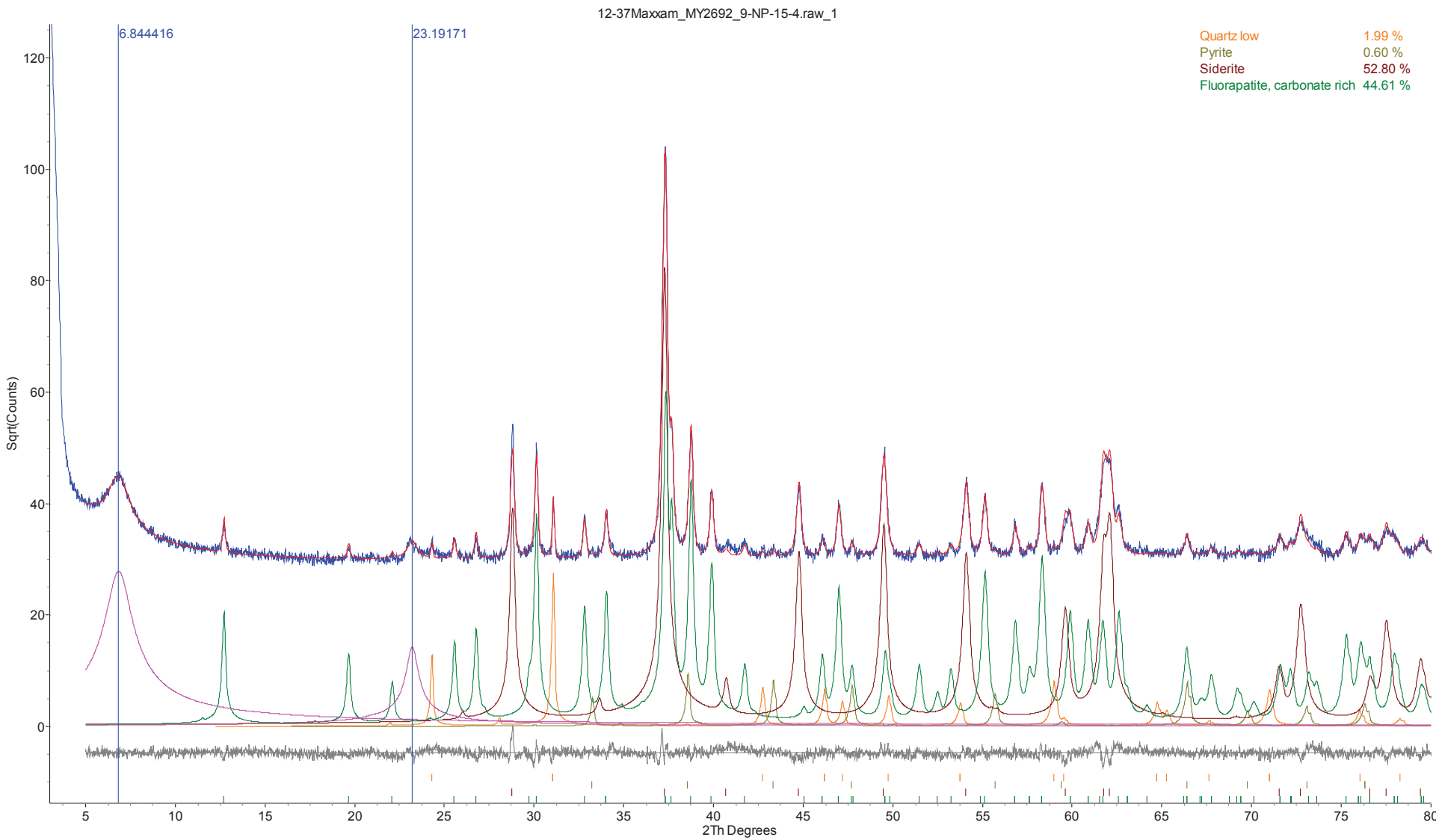

Figure 12. Rietveld refinement plot of sample **Maxxam "#37: MY2692 9-NP-15-4, 45 m"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

Table 1. Results of quantitative phase analysis (wt.%) XRD-Rietveld - Project: KP Australia – Farim B572323

UBC #		**#1**		**#2**		**#3**		**#4**		**#5**		**#6**
S. No.		**1**		**3**		**6**		**7**		**9**		**11**
Maxxam Sample ID		**MY2656**		**MY2658**		**MY2661**		**MY2662**		**MY2664**		**MY2666**
SWS Sample ID		**1-NP-15-2, 15 m**		**3-NP-15-2, 17 m**		**6-NP-15-2, 38.5 m**		**7-NP-15-2, 54.5 m**		**9-NP-15-2, 57.5 m**		**1-SP-15-3, 21.5**
	Anatase	0.1	Anatase	0.8	Anatase	0.1	Anatase	0.4	Calcite	91.1	Anatase	0.1
	Hematite	0.5	Hematite	0.4	Hematite	0.1	Kaolinite 1A	12.9	Fluorapatite, carbonate	7.1	Calcite	0.2
	Kaolinite 1A	8.6	Kaolinite	49.2	Kaolinite	16.8	Pyrite	4.4	Pyrite	0.4	Hematite	0.1
	Pyrite	0.1	Orthoclase	1.0	Orthoclase	0.8	Quartz low	47.9	Quartz low	1.4	Kaolinite 1A	4.4
	Quartz low	90.6	Pyrite	0.3	Pyrite	0.1	Siderite	16.2			Quartz low	95.0
			Quartz low	48.3	Quartz low	82.0	Siderite, calcian	18.2			Siderite	0.1
		100.0		100.0		100.0		100.0		100.0		100.0
illite-smectite		**x**		**x**		**x**		**x**				
smectite										**x**		

UBC #		**#7**		**#8**		**#9**		**#10**		**#11**		**#12**
S. No.		**15**		**19**		**21**		**27**		**31**		**37**
Maxxam Sample ID		**MY2670**		**MY2674**		**MY2676**		**MY2682**		**MY2686**		**MY2692**
SWS Sample ID		**5-SP-15-3, 34.5 m**		**4-SP-15-1, 24.5 m**		**6-SP-15-1, FPA.CO m**		**6-SP-15-2, 27.5 m**		**3-NP-15-4, 26 m**		**9-NP-15-4, 45 r**
	Alunite	0.2	Anatase	0.2	Anatase	0.4	Anatase	0.4	Anatase	0.3	Fluorapatite, carbonate	44.6
	Anatase	0.2	Hematite	0.4	Fluorapatite	29.0	Hematite	0.3	Hematite	0.1	Pyrite	0.6
	Gypsum	0.3	Kaolinite	19.2	Kaolinite 1A	20.4	Kaolinite	36.3	Kaolinite	31.5	Quartz low	2.0
	Kaolinite 1A	5.2	Orthoclase	0.7	Pyrite	9.7	Orthoclase	1.3	Orthoclase	0.9	Siderite	52.8
	Pyrite	2.2	Pyrite	0.2	Quartz low	33.4	Pyrite	0.1	Pyrite	0.1		
	Quartz low	91.2	Quartz low	79.3	Siderite	7.0	Quartz low	61.6	Quartz low	67.0		
	Topaz?	0.7										
		100.0		100.0		100.0		100.0		100.0		100.0
illite-smectite		**x**								**x**		
smectite								**x**				**x**

Maxxam
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Success Through Science®

Your Project #: B572323

Attention:Gavin Dowson

Maxxam Analytics Burnaby
4606 Canada Way
Burnaby, BC
Canada V5G 1K5

Report Date: 2015/09/04
Report #: R3651792
Version: 1 - Partial

CERTIFICATE OF ANALYSIS – PARTIAL RESULTS

MAXXAM JOB #: B5H1319
Received: 2015/08/25, 14:44

Sample Matrix: SOLID
Samples Received: 14

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Gross Alpha and Gross Beta	14	N/A	2015/09/03	BQL SOP-00008	GPFC
NORM Group Analysis	2	N/A	2015/08/28	BQL SOP-00007	Gamma Spectrometry
NORM Group Analysis	6	N/A	2015/08/29	BQL SOP-00007	Gamma Spectrometry
NORM Group Analysis	6	N/A	2015/08/30	BQL SOP-00007	Gamma Spectrometry

Remarks:

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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Simona Vatamanescu,
Email: SVatamanescu@maxxam.ca
Phone# (905)826-3080
==========
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics - Partner in Results

Maxxam Analytics International Corporation o/a Maxxam Analytics 6790 Kitimat Rd, Unit 4, Mississauga, ON L5N 5L9 Phone: (905) 826-3080 Fax: (905) 826-4151 Toll Free: 1 877-726-3080 www.maxxam.ca

Maxxam Job #: B5H1319
Report Date: 2015/09/04

Maxxam Analytics Burnaby
Client Project #: B572323

RESULTS OF ANALYSES OF SOLID

Maxxam ID		AWI740	AWI763	AWI764	AWI765	AWI766		
Sampling Date								
	UNITS	**1-NP-15-2, 15 M**	**3-NP-15-2, 17 M**	**6-NP-15-2, 38.5 M**	**7-NP-15-2, 54.5 M**	**9-NP-15-2, 57.5 M**	**RDL**	**QC Batch**
RADIONUCLIDE								
Gross Alpha	Bq/g	<0.1	0.7	0.1	0.6	0.9	0.1	4172676
Gross Beta	Bq/g	<0.1	0.6	0.3	0.4	0.7	0.1	4172676
Lead-210	Bq/g	<0.10	<0.10	<0.10	<0.10	0.10	0.10	4169420
Potassium-40	Bq/g	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	4169420
Radium-226	Bq/g	<0.10	<0.10	<0.10	<0.10	0.11	0.10	4169420
Radium-228	Bq/g	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	4169420
Thorium-228	Bq/g	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	4169420
Thorium-230	Bq/g	<0.80	<0.80	<0.80	<0.80	<0.80	0.80	4169420
Thorium-234	Bq/g	<0.050	0.060	<0.050	<0.050	0.110	0.050	4169420
Uranium-235	Bq/g	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	4169420

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam ID		AWI767	AWI768	AWI769	AWI770		
Sampling Date							
	UNITS	**1-SP-15-3, 21.5 M**	**5-SP-15-3, 34.5 M**	**4-SP-15-1, 24.5 M**	**6-SP-15-1, FPA.CO M**	**RDL**	**QC Batch**
RADIONUCLIDE							
Gross Alpha	Bq/g	<0.1	0.4	0.3	2.8	0.1	4172676
Gross Beta	Bq/g	<0.1	0.3	0.2	2.3	0.1	4172676
Lead-210	Bq/g	<0.10	<0.10	<0.10	0.34	0.10	4169420
Potassium-40	Bq/g	<1.0	<1.0	<1.0	<1.0	1.0	4169420
Radium-226	Bq/g	<0.10	<0.10	<0.10	0.33	0.10	4169420
Radium-228	Bq/g	<0.10	<0.10	<0.10	<0.10	0.10	4169420
Thorium-228	Bq/g	<0.10	<0.10	<0.10	<0.10	0.10	4169420
Thorium-230	Bq/g	<0.80	<0.80	<0.80	<0.80	0.80	4169420
Thorium-234	Bq/g	<0.050	<0.050	<0.050	0.340	0.050	4169420
Uranium-235	Bq/g	<0.10	<0.10	<0.10	<0.10	0.10	4169420

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Maxxam Job #: B5H1319
Report Date: 2015/09/04

Maxxam Analytics Burnaby
Client Project #: B572323

RESULTS OF ANALYSES OF SOLID

Maxxam ID		AWI771	AWI772	AWI773	AWI774	AWI775		
Sampling Date								
	UNITS	**2-SP-15-2, 21 M**	**6-SP-15-2, 27.5 M**	**1-NP-15-4, 15.5 M**	**5-NP-15-4, 32 M**	**9-NP-15-4, 45 M**	**RDL**	**QC Batch**
RADIONUCLIDE								
Gross Alpha	Bq/g	0.2	1.2	0.6	<0.1	7.4	0.1	4172676
Gross Beta	Bq/g	0.2	0.8	0.6	0.3	4.6	0.1	4172676
Lead-210	Bq/g	<0.10	0.12	<0.10	<0.10	0.64	0.10	4169420
Potassium-40	Bq/g	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	4169420
Radium-226	Bq/g	<0.10	0.11	<0.10	<0.10	0.84	0.10	4169420
Radium-228	Bq/g	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	4169420
Thorium-228	Bq/g	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	4169420
Thorium-230	Bq/g	<0.80	<0.80	<0.80	<0.80	<0.80	0.80	4169420
Thorium-234	Bq/g	<0.050	0.080	0.060	<0.050	0.680	0.050	4169420
Uranium-235	Bq/g	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	4169420

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Analytics - Partnering for Results

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Maxxam Job #: B5H1319
Report Date: 2015/09/04

Maxxam Analytics Burnaby
Client Project #: B572323

GENERAL COMMENTS

Results relate only to the items tested.

Maxxam Analytics - Partnering in Results

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Maxxam Job #: B5H1319
Report Date: 2015/09/04

Maxxam Analytics Burnaby
Client Project #: B572323

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
4169420	DS2	QC Standard	Lead-210	2015/08/31		90	%	74 - 126
			Potassium-40	2015/08/31		105	%	74 - 126
			Radium-226	2015/08/31		100	%	74 - 126
			Radium-228	2015/08/31		107	%	74 - 126
			Thorium-228	2015/08/31		105	%	74 - 126
			Thorium-230	2015/08/31		95	%	74 - 126
			Thorium-234	2015/08/31		95	%	74 - 126
			Uranium-235	2015/08/31		90	%	74 - 126
4169420	DS2	Method Blank	Lead-210	2015/08/31	<0.10		Bq/g	
			Potassium-40	2015/08/31	<1.0		Bq/g	
			Radium-226	2015/08/31	<0.10		Bq/g	
			Radium-228	2015/08/31	<0.10		Bq/g	
			Thorium-228	2015/08/31	<0.10		Bq/g	
			Thorium-230	2015/08/31	<0.80		Bq/g	
			Thorium-234	2015/08/31	<0.050		Bq/g	
			Uranium-235	2015/08/31	<0.10		Bq/g	
4169420	DS2	RPD [AWI773-01]	Lead-210	2015/08/31	NC		%	N/A
			Potassium-40	2015/08/31	NC		%	N/A
			Radium-226	2015/08/31	NC		%	N/A
			Radium-228	2015/08/31	NC		%	N/A
			Thorium-228	2015/08/31	NC		%	N/A
			Thorium-230	2015/08/31	NC		%	N/A
			Thorium-234	2015/08/31	NC		%	N/A
			Uranium-235	2015/08/31	NC		%	N/A
4172676	JK2	QC Standard	Gross Alpha	2015/09/03		100	%	N/A
			Gross Beta	2015/09/03		96	%	N/A
4172676	JK2	Method Blank	Gross Alpha	2015/09/03	<0.1		Bq/g	
			Gross Beta	2015/09/03	<0.1		Bq/g	
4172676	JK2	RPD [AWI770-01]	Gross Alpha	2015/09/03	0.70		%	N/A
			Gross Beta	2015/09/03	0.43		%	N/A

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

Maxxam Analytics - Partnering for Results

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Report Date: 2015/09/04

Maxxam Analytics Burnaby
Client Project #: B572323

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Donald Burgess, Senior Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics - Partnership Research

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APPENDIX B

Global Abundance Indices

Knight Piésold
CONSULTING

APPENDIX B - MULTI-ELEMENT RESULTS AND GLOBAL ABUNDANCE INDICES

Knight Piésold CONSULTING

Maxxam Sample No	Sample ID	Lithology	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Fe	Hf	Hg	In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P
	Units		ppm	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%
MY2656	1-NP-15-2, 15 M	Sandy clay	0.1	1.6	48	16	30	1	0.1	0.05	0.1	23	1.4	93	7.5	1.77	1.4	0.01	0.05	0.04	12.9	4.4	0.14	62	2.1	0.031	6.7	5.7	0.01
MY2657	2-NP-15-2, 15 M	Sandy clay	0.1	1.01	25	18	28	1	0.1	0.05	0.1	17	1.2	115	6.5	1.23	1.1	0.01	0.05	0.04	9.3	4.4	0.13	55	1.3	0.023	5.1	4.7	0.011
MY2658	3-NP-15-2, 17 M	Fine Sand	0.2	9.06	22	30	122	1	0.3	0.07	0.1	87	3.4	131	11.1	3.22	5	0.01	0.07	0.33	46.5	25.5	0.1	95	1.3	0.022	23.6	20.4	0.039
MY2659	4-NP-15-2, 17 M	Fine Sand	0.1	11	17	48	154	2	0.3	0.14	0.1	99	7.1	164	13	4.08	4.7	0.01	0.06	0.77	44.6	41.1	0.34	123	1.4	0.03	23.1	28.6	0.041
MY2660	5-NP-15-2, 36 M	Plastic clay	0.1	1.39	6	26	56	1	0.1	0.05	0.1	19	1.4	57	5.4	0.97	1.4	0.01	0.05	0.1	9.4	8	0.18	102	0.7	0.028	5.3	4.5	0.019
MY2661	6-NP-15-2, 38.5 M	Plastic clay	0.1	2.84	7	43	80	1	0.1	0.05	0.1	33	1.9	63	6.5	1.52	2.3	0.01	0.05	0.22	16.3	13.1	0.19	87	0.6	0.025	8.5	7.2	0.023
MY2662	7-NP-15-2, 54.5 M	Sand with lignite	0.1	2.75	40	41	62	1	0.1	1.07	0.2	54	19.7	97	5.6	16.6	1.9	0.01	0.08	0.21	23.1	30.7	0.96	2190	1.2	0.035	7	22.2	0.172
MY2663	8-NP-15-2, 54.5 M	Sand with lignite	0.1	2.77	40	31	90	3	0.1	6.49	1.7	78	20.1	197	10	13.6	1.3	0.01	0.05	0.09	55.6	21.5	0.58	1730	1.8	0.043	5.2	23.5	2.77
MY2664	9-NP-15-2, 57.5 M	Grey phosphate clay	0.1	0.94	1	10	12	1	0.1	37	1.7	24	1.2	72	5.8	0.94	0.3	0.01	0.05	0.11	18.5	5.8	0.47	186	0.8	0.054	1.7	17	1.01
MY2665	10-NP-15-2, 57.5 M	Grey phosphate clay	0.1	0.82	1	8	10	1	0.1	37.6	1.4	14	1.3	57	4	0.88	0.2	0.01	0.05	0.1	10.8	5	0.43	311	1.1	0.035	1.6	16.4	0.492
MY2666	1-SP-15-3, 21.5 M	Clay	0.3	0.93	3	21	36	1	0.1	0.23	0.1	29	1.2	50	4.8	0.6	0.9	0.01	0.05	0.05	12.2	10.3	0.15	56	0.6	0.027	4.5	3.7	0.019
MY2667	2-SP-15-3, 21.5 M	Clay	0.1	0.8	2	24	24	1	0.1	0.04	0.1	18	1.1	54	3.7	0.44	1.1	0.01	0.05	0.03	8.3	6.8	0.08	51	0.4	0.025	5.1	4.1	0.009
MY2668	3-SP-15-3, 33 M	Fine Sand	0.1	0.64	4	20	55	1	0.1	0.07	0.1	44	4.5	38	3.3	0.76	0.7	0.01	0.05	0.03	14.9	9.1	0.12	40	0.5	0.031	3.6	7.6	0.051
MY2669	4-SP-15-3, 33 M	Fine Sand	0.1	0.65	5	16	26	1	0.1	0.04	0.5	38	9.1	66	3.8	0.73	0.6	0.01	0.05	0.03	14.6	9	0.05	32	0.5	0.021	2.5	16.2	0.026
MY2670	5-SP-15-3, 34.5 M	Clayey sand	0.2	1.03	6	22	62	1	0.1	0.08	0.2	50	9.9	79	3.9	1.57	1	0.01	0.05	0.06	18.3	15.8	0.09	41	0.8	0.029	3.7	14.6	0.079
MY2671	1-SP-15-1, 15 M	Sandy clay/plastic clay	0.2	11.1	17	42	111	2	0.3	0.05	0.1	105	7.7	120	18.2	5.92	5.4	0.01	0.07	0.21	46.1	55.3	0.12	156	2.2	0.048	33.4	36.6	0.075
MY2672	2-SP-15-1, 19.5 M	Sandy clay/plastic clay	0.1	7.83	24	45	78	1	0.2	0.04	0.1	70	8.2	109	16.8	10.1	4.1	0.01	0.05	0.13	33.8	33	0.09	579	0.9	0.037	22.8	27.3	0.035
MY2673	3-SP-15-1, 19.5 M	Sandy clay/plastic clay	0.1	3.87	38	34	56	1	0.1	0.02	0.1	45	3.1	150	8.1	5.16	2.2	0.01	0.05	0.09	20.1	15.1	0.05	75	1.8	0.029	11.3	12.3	0.032
MY2674	4-SP-15-1, 24.5 M	Sandy clay/plastic clay	0.1	3.155	15.5	30.5	56	1	0.1	0.02	0.1	40.5	2.25	59.5	6.85	2.165	2.05	0.01	0.05	0.08	17.35	13.9	0.05	61.5	1.2	0.0285	11.05	10.05	0.0205
MY2675	5-SP-15-1, FPA.CO M	Sand/FPA	0.1	6.25	26	61	145	3	0.3	1.82	0.4	72	18.5	130	13.3	4.74	4.6	0.02	0.12	0.73	36.6	73.4	0.37	937	1.7	0.072	15.1	29.4	0.748
MY2676	6-SP-15-1, FPA.CO M	Sand/FPA	0.1	3.99	51	29	85	2	0.1	10.2	2.9	81	24.1	168	14.1	9.05	3	0.03	0.05	0.4	61.1	43.6	0.34	1470	4.2	0.068	10.3	28.6	3.78
MY2677	1-SP-15-2, 16 M	Clay sandy	0.6	1.8	14	37	54	1	0.1	0.13	0.1	37	1.7	74	7.2	1.72	1.7	0.01	0.05	0.08	16.1	7.2	0.25	73	1.2	0.117	7.8	6.6	0.035
MY2678	2-SP-15-2, 21 M	Clay sandy	0.4	1.53	15	30	49	1	0.1	0.06	0.1	32	1.7	70	6.5	1.83	1.6	0.01	0.05	0.07	13.9	6.5	0.17	66	1.4	0.082	7.2	5.8	0.019
MY2679	3-SP-15-2, 21 M	Clay sandy	1.4	2.12	22	36	60	1	0.1	0.07	0.1	45	2.4	121	9.6	2.51	2.1	0.01	0.05	0.09	19.2	7.7	0.23	83	1.7	0.105	9.7	8.8	0.024
MY2680	4-SP-15-2, 26 M	Clay sandy	0.8	1.77	15	33	60	1	0.1	0.1	0.1	37	2.1	81	8.2	1.77	1.9	0.01	0.05	0.08	16.3	7.9	0.35	93	1	0.139	6.7	6.9	0.025
MY2681	5-SP-15-2, 26 M	Clay sandy	0.3	4.43	56	42	117	1	0.1	0.11	0.1	87	7	104	9	6.37	3.4	0.01	0.08	0.3	33.9	21.8	0.28	158	1.6	0.098	12.5	14.2	0.125
MY2682	6-SP-15-2, 27.5 M	Sand with lignite	0.1	6.49	10	47	95	1	0.2	0.18	0.1	102	10.6	103	6.4	2.69	3.2	0.01	0.09	0.31	50.3	38.8	0.32	96	1.7	0.071	13.6	23.9	0.035
MY2683	7-SP-15-2, 27.5 M	Sand with lignite	0.3	1.47	3	23	45	1	0.1	0.11	0.1	47	1.9	58	4	1.23	1.3	0.01	0.05	0.13	22.9	10	0.25	41	1.1	0.079	5.6	5.9	0.026
MY2684	1-NP-15-4, 15.5 M	Clay	0.2	8.82	11	34	216	2	0.3	0.08	0.1	84	5.9	109	12.5	3.3	4.9	0.01	0.08	0.56	36.8	37.1	0.22	142	1.9	0.023	20.5	21.7	0.084
MY2685	2-NP-15-4, 15.5 M	Clay	0.2	7.79	40	54	161	2	0.3	0.1	0.1	84	9.5	105	13.8	6.58	4.7	0.01	0.1	0.7	34.9	34.2	0.31	246	1.1	0.025	16.9	27.1	0.091
MY2686	3-NP-15-4, 26 M	Fine sand, sandy clay	0.1	5.48	11	34	121	1	0.2	0.05	0.1	53	3.9	67	9.7	2.32	3.9	0.01	0.05	0.43	23.8	23.2	0.16	236	0.5	0.018	13.5	12.9	0.031
MY2687	4-NP-15-4, 26 M	Fine sand, sandy clay	0.1	8.75	21	54	173	1	0.3	0.13	0.1	87	6	116	15.4	7.1	5.5	0.01	0.06	0.79	37.9	46.9	0.3	214	0.9	0.028	20.2	22.1	0.083
MY2688	5-NP-15-4, 32 M	Plastic clay	0.1	1.78	6	46	77	1	0.1	0.05	0.1	31	2	39	6.4	1.66	1.8	0.01	0.05	0.22	12.4	17	0.08	83	0.2	0.013	7	6.1	0.027
MY2689	6-NP-15-4, 32 M	Plastic clay	0.1	3.29	20	37	86	1	0.1	0.07	0.1	37	5	69	7.6	4.11	2.8	0.01	0.05	0.32	17.1	27.7	0.13	199	0.4	0.017	12.2	11.4	0.057
MY2690	7-NP-15-4, 33.5 M	Fine sand, plastic clay	0.1	6.01	16	60	133	1	0.2	0.3	0.1	68	13.8	111	11.6	4.49	4.8	0.01	0.08	0.69	29.7	69.5	0.37	814	0.9	0.026	17.3	24	0.028
MY2691	8-NP-15-4, 33.5 M	Fine sand, plastic clay	0.1	3.71	14	49	99	1	0.2	0.09	0.1	41	3.3	64	7.5	3.44	2.9	0.01	0.05	0.37	19.4	33.3	0.14	144	0.5	0.016	12.5	10.1	0.051
MY2692	9-NP-15-4, 45 M	Fine sand	0.2	1.41	2	38	16	1	0.1	15.4	4.6	74	30.3	254	14.8	20.1	0.4	0.01	0.05	0.13	74.8	6.6	0.71	3440	1	0.041	2.1	197	5
MY2693	10-NP-15-4, 45 M	Fine sand	0.25	1.99	3	41	16.5	1	0.1	8.98	2.85	57.5	20.65	223	14.4	23.4	0.5	0.02	0.05	0.2	48.95	7.75	1.055	4815	0.8	0.0315	2.95	155	2.71

			Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Fe	Hf	Hg	In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P
	Average Crustal Abundance		0.07	82000	1.5	10	500	2.6	0.048	4.1	0.11	68	20	100	50	41	5.3	0.05	0.049	21	32	20	23	950	1.5	23	20	80	0.1
MY2656	1-NP-15-2, 15 M	Sandy clay	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2657	2-NP-15-2, 15 M	Sandy clay	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2658	3-NP-15-2, 17 M	Fine Sand	0	0	3	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2659	4-NP-15-2, 17 M	Fine Sand	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2660	5-NP-15-2, 36 M	Plastic clay	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2661	6-NP-15-2, 38.5 M	Plastic clay	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2662	7-NP-15-2, 54.5 M	Sand with lignite	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2663	8-NP-15-2, 54.5 M	Sand with lignite	0	0	4	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
MY2664	9-NP-15-2, 57.5 M	Grey phosphate clay	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
MY2665	10-NP-15-2, 57.5 M	Grey phosphate clay	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
MY2666	1-SP-15-3, 21.5 M	Clay	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2667	2-SP-15-3, 21.5 M	Clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2668	3-SP-15-3, 33 M	Fine Sand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2669	4-SP-15-3, 33 M	Fine Sand	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2670	5-SP-15-3, 34.5 M	Clayey sand	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2671	1-SP-15-1, 15 M	Sandy clay/plastic clay	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2672	2-SP-15-1, 19.5 M	Sandy clay/plastic clay	0	0	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2673	3-SP-15-1, 19.5 M	Sandy clay/plastic clay	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2674	4-SP-15-1, 24.5 M	Sandy clay/plastic clay	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2675	5-SP-15-1, FPA.CO M	Sand/FPA	0	0	3	2	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
MY2676	6-SP-15-1, FPA.CO M	Sand/FPA	0	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
MY2677	1-SP-15-2, 16 M	Clay sandy	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2678	2-SP-15-2, 21 M	Clay sandy	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2679	3-SP-15-2, 21 M	Clay sandy	3	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2680	4-SP-15-2, 26 M	Clay sandy	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2681	5-SP-15-2, 26 M	Clay sandy	1	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2682	6-SP-15-2, 27.5 M	Sand with lignite	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2683	7-SP-15-2, 27.5 M	Sand with lignite	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2684	1-NP-15-4, 15.5 M	Clay	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2685	2-NP-15-4, 15.5 M	Clay	0	0	4	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2686	3-NP-15-4, 26 M	Fine sand, sandy clay	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2687	4-NP-15-4, 26 M	Fine sand, sandy clay	0	0	3	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2688	5-NP-15-4, 32 M	Plastic clay	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2689	6-NP-15-4, 32 M	Plastic clay	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2690	7-NP-15-4, 33.5 M	Fine sand, plastic clay	0	0	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
MY2691	8-NP-15-4, 33.5 M	Fine sand, plastic clay	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MY2692	9-NP-15-4, 45 M	Fine sand	0	0	0	1	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5
MY2693	10-NP-15-4, 45 M	Fine sand	1	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4

APPENDIX B - MULTI-ELEMENT RESULTS AND GLOBAL ABUNDANCE INDICES

Knight Piésold CONSULTING

Maxxam Sample No	Sample ID	Lithology	Pb	Rb	Re	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	Units		ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
MY2656	1-NP-15-2, 15 M	Sandy clay	7	1.9	0.005	0.1	0.4	4	1	0.7	15	0.3	0.5	4.9	0.305	0.5	1.1	61	0.5	4.4	5	60.8
MY2657	2-NP-15-2, 15 M	Sandy clay	4.9	2.2	0.005	0.1	0.2	3	1	0.6	13	0.2	0.5	3.1	0.245	0.5	0.8	44	0.3	3.1	5	40.1
MY2658	3-NP-15-2, 17 M	Fine Sand	24.4	23.6	0.005	0.1	0.4	15	1	2.9	113	1.4	0.5	14.8	0.725	0.5	2.8	117	1.6	11.9	20	183
MY2659	4-NP-15-2, 17 M	Fine Sand	24.6	64.2	0.005	0.1	0.4	19	1	3	153	1.4	0.5	15.5	0.683	0.5	2.6	139	1.6	13.4	63	179
MY2660	5-NP-15-2, 36 M	Plastic clay	6.1	8.7	0.005	0.1	0.2	3	1	0.6	28	0.3	0.5	3.2	0.249	0.5	0.7	37	0.3	4.5	9	51.7
MY2661	6-NP-15-2, 38.5 M	Plastic clay	10.5	20.3	0.005	0.1	0.3	5	1	1.1	44	0.6	0.5	5.3	0.342	0.5	1	55	0.6	6.6	14	83.7
MY2662	7-NP-15-2, 54.5 M	Sand with lignite	9	17.6	0.005	2.2	0.3	8	1	0.9	219	0.4	0.5	5.1	0.255	0.5	4.3	110	0.5	24.6	43	73.3
MY2663	8-NP-15-2, 54.5 M	Sand with lignite	6.6	5.9	0.005	2.4	1.1	7	3	0.6	1540	0.3	0.5	5.8	0.195	0.5	32.5	146	0.3	133	52	51.7
MY2664	9-NP-15-2, 57.5 M	Grey phosphate clay	1.8	8.6	0.005	0.4	0.7	2	2	0.3	912	0.1	2.4	2.5	0.059	0.5	11	28	0.1	30.9	47	9.1
MY2665	10-NP-15-2, 57.5 M	Grey phosphate clay	1.3	7.7	0.005	0.4	0.5	2	1	0.2	794	0.1	2.5	1.8	0.05	0.5	5.4	22	0.1	14.9	26	7.3
MY2666	1-SP-15-3, 21.5 M	Clay	5.1	3.1	0.005	0.1	0.1	2	1	0.5	51	0.2	0.5	2.6	0.232	0.5	0.8	24	0.4	6.2	6	34.8
MY2667	2-SP-15-3, 21.5 M	Clay	4.5	2.4	0.005	0.1	0.2	2	1	0.6	26	0.3	0.5	3.4	0.275	0.5	0.7	21	0.2	3.8	4	39.1
MY2668	3-SP-15-3, 33 M	Fine Sand	3.5	1.9	0.005	0.5	0.2	2	1	0.3	238	0.2	0.5	1.8	0.158	0.5	1.5	24	0.4	16.9	6	24.3
MY2669	4-SP-15-3, 33 M	Fine Sand	4.3	1.6	0.005	0.6	0.6	2	1	0.4	117	0.1	0.5	1.7	0.115	0.5	0.9	33	0.4	5.6	52	19.1
MY2670	5-SP-15-3, 34.5 M	Clayey sand	5.2	2.6	0.005	1.5	0.2	3	1	0.3	319	0.2	0.5	2.5	0.154	0.5	3.4	38	0.8	33.4	14	32.6
MY2671	1-SP-15-1, 15 M	Sandy clay/plastic clay	29	20	0.005	0.1	0.7	19	1	4.1	114	2.2	0.5	17.5	0.851	0.5	8.2	104	2	17.6	36	195
MY2672	2-SP-15-1, 19.5 M	Sandy clay/plastic clay	19.7	12.8	0.005	0.1	0.4	13	1	2.6	61	1.5	0.5	14.5	0.628	0.5	4.8	113	1.4	20.5	55	147
MY2673	3-SP-15-1, 19.5 M	Sandy clay/plastic clay	13.7	8.6	0.005	0.1	0.5	7	1	1.4	46	0.7	0.5	6.8	0.386	0.5	3.4	124	0.7	8.1	16	80.3
MY2674	4-SP-15-1, 24.5 M	Sandy clay/plastic clay	11.15	7.7	0.005	0.1	0.3	5	1	1.35	44	0.7	0.5	6.65	0.387	0.5	2.3	66.5	0.7	8.5	12.5	75.2
MY2675	5-SP-15-1, FPA.CO M	Sand/FPA	19	49	0.005	1.3	0.6	13	1	2.1	146	1	0.5	10.6	0.52	0.5	9	118	1.2	31.5	93	160
MY2676	6-SP-15-1, FPA.CO M	Sand/FPA	11.8	33.5	0.005	5.2	2.1	9	1	1.1	224	0.6	0.5	9.9	0.363	0.5	30.9	143	0.8	104	306	111
MY2677	1-SP-15-2, 16 M	Clay sandy	7.9	5.9	0.005	0.1	0.2	4	1	0.9	41	0.4	0.5	3.9	0.323	0.5	1.2	61	1.1	5.7	11	61.7
MY2678	2-SP-15-2, 21 M	Clay sandy	7.1	5	0.005	0.1	0.2	4	1	0.8	33	0.3	0.5	3.9	0.316	0.5	1.1	62	0.8	4.6	8	62.4
MY2679	3-SP-15-2, 21 M	Clay sandy	9.5	7	0.005	0.1	0.3	5	1	1.5	48	0.6	0.5	5.2	0.386	0.5	1.5	82	2.7	6.4	14	74.1
MY2680	4-SP-15-2, 26 M	Clay sandy	7.9	6.1	0.005	0.1	0.1	4	1	0.9	42	0.3	0.5	4.4	0.382	0.5	1.3	67	1.2	5.8	13	68.3
MY2681	5-SP-15-2, 26 M	Clay sandy	14.6	26.4	0.005	0.1	0.4	10	1	1.4	215	0.8	0.5	8.4	0.49	0.5	3.7	106	0.8	23.6	38	118
MY2682	6-SP-15-2, 27.5 M	Sand with lignite	23.6	23.9	0.005	0.1	0.3	15	1	1.7	91	0.9	0.5	9.4	0.449	0.5	5.5	71	1.2	26.7	69	118
MY2683	7-SP-15-2, 27.5 M	Sand with lignite	9.3	9.9	0.005	0.1	0.1	4	1	0.8	76	0.3	0.5	3.4	0.191	0.5	2	29	0.7	7.4	19	45.9
MY2684	1-NP-15-4, 15.5 M	Clay	23	55.1	0.005	0.1	0.6	17	1	2.7	203	1.4	0.5	12.4	0.662	0.5	4.1	107	1.7	25.6	49	176
MY2685	2-NP-15-4, 15.5 M	Clay	21.2	70.6	0.005	0.1	0.4	16	1	2.3	135	1.1	0.5	11.2	0.566	0.5	3.6	130	1.4	26.3	87	170
MY2686	3-NP-15-4, 26 M	Fine sand, sandy clay	16.4	42.7	0.005	0.1	0.4	10	1	1.7	87	0.9	0.5	8.2	0.476	0.5	2	80	1	14.2	30	135
MY2687	4-NP-15-4, 26 M	Fine sand, sandy clay	23.4	75.4	0.005	0.1	0.4	17	1	2.9	118	1.3	0.5	12.6	0.659	0.5	3.3	126	1.6	21.7	51	195
MY2688	5-NP-15-4, 32 M	Plastic clay	8	17.9	0.005	0.1	0.2	4	1	0.8	52	0.4	0.5	4	0.299	0.5	1	43	0.5	5.9	17	69.3
MY2689	6-NP-15-4, 32 M	Plastic clay	11	30.2	0.005	0.1	0.2	7	1	1.2	61	0.7	0.5	6	0.519	0.5	1.2	65	0.8	10.4	36	106
MY2690	7-NP-15-4, 33.5 M	Fine sand, plastic clay	19.2	52.3	0.005	0.9	0.4	11	1	2.1	77	1.2	0.5	10.2	0.559	0.5	2.5	92	1.3	19	79	178
MY2691	8-NP-15-4, 33.5 M	Fine sand, plastic clay	11.8	34.4	0.005	0.1	0.3	7	1	1.4	72	0.8	0.5	6.3	0.478	0.5	1.3	65	0.8	10.9	28	112
MY2692	9-NP-15-4, 45 M	Fine sand	2.9	11	0.007	0.5	3.1	5	3	0.3	150	0.2	0.5	6	0.095	0.5	71.5	236	0.2	117	81	13.7
MY2693	10-NP-15-4, 45 M	Fine sand	3.3	16.1	0.005	0.5	2.8	5	5	0.45	120.5	0.2	0.5	5.75	0.1095	0.5	36.95	176.5	0.3	69.6	101	17

	Pb	Rb	Re	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
Average Crustal Abundance	14	90	0.0004	0.26	0.2	16	0.05	2.2	370	2	0.005	12	0.56	0.6	2.4	160	1	30	75	190

MY2656	1-NP-15-2, 15 M	Sandy clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2657	2-NP-15-2, 15 M	Sandy clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2658	3-NP-15-2, 17 M	Fine Sand	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2659	4-NP-15-2, 17 M	Fine Sand	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2660	5-NP-15-2, 36 M	Plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2661	6-NP-15-2, 38.5 M	Plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2662	7-NP-15-2, 54.5 M	Sand with lignite	0	0	DL	2	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2663	8-NP-15-2, 54.5 M	Sand with lignite	0	0	DL	2	1	0	5	0	1	0	DL	0	0	0	3	0	0	1	0	0
MY2664	9-NP-15-2, 57.5 M	Grey phosphate clay	0	0	DL	0	1	0	4	0	0	0	6	0	0	0	1	0	0	0	0	0
MY2665	10-NP-15-2, 57.5 M	Grey phosphate clay	0	0	DL	0	0	0	DL	0	0	0	6	0	0	0	0	0	0	0	0	0
MY2666	1-SP-15-3, 21.5 M	Clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2667	2-SP-15-3, 21.5 M	Clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2668	3-SP-15-3, 33 M	Fine Sand	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2669	4-SP-15-3, 33 M	Fine Sand	0	0	DL	0	1	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2670	5-SP-15-3, 34.5 M	Clayey sand	0	0	DL	1	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2671	1-SP-15-1, 15 M	Sandy clay/plastic clay	0	0	DL	0	1	0	DL	0	0	0	DL	0	0	0	1	0	0	0	0	0
MY2672	2-SP-15-1, 19.5 M	Sandy clay/plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2673	3-SP-15-1, 19.5 M	Sandy clay/plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2674	4-SP-15-1, 24.5 M	Sandy clay/plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2675	5-SP-15-1, FPA.CO M	Sand/FPA	0	0	DL	1	1	0	DL	0	0	0	DL	0	0	0	1	0	0	0	0	0
MY2676	6-SP-15-1, FPA.CO M	Sand/FPA	0	0	DL	3	2	0	DL	0	0	0	DL	0	0	0	3	0	0	1	1	0
MY2677	1-SP-15-2, 16 M	Clay sandy	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2678	2-SP-15-2, 21 M	Clay sandy	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2679	3-SP-15-2, 21 M	Clay sandy	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2680	4-SP-15-2, 26 M	Clay sandy	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2681	5-SP-15-2, 26 M	Clay sandy	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2682	6-SP-15-2, 27.5 M	Sand with lignite	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2683	7-SP-15-2, 27.5 M	Sand with lignite	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2684	1-NP-15-4, 15.5 M	Clay	0	0	DL	0	1	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2685	2-NP-15-4, 15.5 M	Clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2686	3-NP-15-4, 26 M	Fine sand, sandy clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2687	4-NP-15-4, 26 M	Fine sand, sandy clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2688	5-NP-15-4, 32 M	Plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2689	6-NP-15-4, 32 M	Plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2690	7-NP-15-4, 33.5 M	Fine sand, plastic clay	0	0	DL	1	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2691	8-NP-15-4, 33.5 M	Fine sand, plastic clay	0	0	DL	0	0	0	DL	0	0	0	DL	0	0	0	0	0	0	0	0	0
MY2692	9-NP-15-4, 45 M	Fine sand	0	0	3	0	3	0	5	0	0	0	DL	0	0	0	4	0	0	1	0	0
MY2693	10-NP-15-4, 45 M	Fine sand	0	0	DL	0	3	0	6	0	0	0	DL	0	0	0	3	0	0	0	0	0

APPENDIX C

Soil Quality Screening Tables

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APPENDIX C - SOIL QUALITY SCREENING TABLES

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Element	Human Health-Based Investigation Levels [1]	1-NP-15-2, 15 M	2-NP-15-2, 15 M	3-NP-15-2, 17 M	4-NP-15-2, 17 M	5-NP-15-2, 36 M	6-NP-15-2, 38.5 M	7-NP-15-2, 54.5 M	8-NP-15-2, 54.5 M	9-NP-15-2, 57.5 M	10-NP-15-2, 57.5 M	1-SP-15-3, 21.5 M	2-SP-15-3, 21.5 M	3-SP-15-3, 33 M	4-SP-15-3, 33 M	5-SP-15-3, 34.5 M	1-SP-15-1, 15 M	2-SP-15-1, 19.5 M	3-SP-15-1, 19.5 M	4-SP-15-1, 24.5 M	5-SP-15-1, FPA.CO M
	(ppm)	MY2656	MY2657	MY2658	MY2659	MY2660	MY2661	MY2662	MY2663	MY2664	MY2665	MY2666	MY2667	MY2668	MY2669	MY2670	MY2671	MY2672	MY2673	MY2674	MY2675
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	N/G	0.4	0.2	0.4	0.4	0.2	0.3	0.3	1.1	0.7	0.5	0.1	0.2	0.2	0.6	0.2	0.7	0.4	0.5	0.3	0.6
Arsenic	300	48	25	22	17	6	7	40	40	1	1	3	2	4	5	6	17	24	38	15.5	26
Barium	N/G	30	28	122	154	56	80	62	90	12	10	36	24	55	26	62	111	78	56	56	145
Beryllium	90	1	1	1	2	1	1	1	3	1	1	1	1	1	1	1	2	1	1	1	3
Boron	20000	16	18	30	48	26	43	41	31	10	8	21	24	20	16	22	42	45	34	30.5	61
Cadmium	90	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.7	1.7	1.4	0.1	0.1	0.1	0.5	0.2	0.1	0.1	0.1	0.1	0.4
Chromium	N/G	93	115	131	164	57	63	97	197	72	57	50	54	38	66	79	120	109	150	59.5	130
Cobalt	300	1.4	1.2	3.4	7.1	1.4	1.9	19.7	20.1	1.2	1.3	1.2	1.1	4.5	9.1	9.9	7.7	8.2	3.1	2.25	18.5
Copper	17000	7.5	6.5	11.1	13	5.4	6.5	5.6	10	5.8	4	4.8	3.7	3.3	3.8	3.9	18.2	16.8	8.1	6.85	13.3
Lead	600	7	4.9	24.4	24.6	6.1	10.5	9	6.6	1.8	1.3	5.1	4.5	3.5	4.3	5.2	29	19.7	13.7	11.15	19
Manganese	19000	62	55	95	123	102	87	2190	1730	186	311	56	51	40	32	41	156	579	75	61.5	937
Mercury	80	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Molybdenum	N/G	2.1	1.3	1.3	1.4	0.7	0.6	1.2	1.8	0.8	1.1	0.6	0.4	0.5	0.5	0.8	2.2	0.9	1.8	1.2	1.7
Nickel	1200	5.7	4.7	20.4	28.6	4.5	7.2	22.2	23.5	17	16.4	3.7	4.1	7.6	16.2	14.6	36.6	27.3	12.3	10.05	29.4
Phosphorus	N/G	100	110	390	410	190	230	1720	27700	10100	4920	190	90	510	260	790	750	350	320	205	7480
Selenium	700	1	1	1	1	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	1
Silver	N/G	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1
Sulfur	N/G	1000	1000	1000	1000	1000	1000	22000	24000	4000	4000	1000	1000	5000	6000	15000	1000	1000	1000	1000	13000
Tin	N/G	0.7	0.6	2.9	3	0.6	1.1	0.9	0.6	0.3	0.2	0.5	0.6	0.3	0.4	0.3	4.1	2.6	1.4	1.35	2.1
Vanadium	N/G	61	44	117	139	37	55	110	146	28	22	24	21	24	33	38	104	113	124	66.5	118
Zinc	30000	5	5	20	63	9	14	43	52	47	26	6	4	6	52	14	36	55	16	12.5	93

Element	Ecological Soil Screening Levels [2]	1-NP-15-2, 15 M	2-NP-15-2, 15 M	3-NP-15-2, 17 M	4-NP-15-2, 17 M	5-NP-15-2, 36 M	6-NP-15-2, 38.5 M	7-NP-15-2, 54.5 M	8-NP-15-2, 54.5 M	9-NP-15-2, 57.5 M	10-NP-15-2, 57.5 M	1-SP-15-3, 21.5 M	2-SP-15-3, 21.5 M	3-SP-15-3, 33 M	4-SP-15-3, 33 M	5-SP-15-3, 34.5 M	1-SP-15-1, 15 M	2-SP-15-1, 19.5 M	3-SP-15-1, 19.5 M	4-SP-15-1, 24.5 M	5-SP-15-1, FPA.CO M
	(ppm)	MY2656	MY2657	MY2658	MY2659	MY2660	MY2661	MY2662	MY2663	MY2664	MY2665	MY2666	MY2667	MY2668	MY2669	MY2670	MY2671	MY2672	MY2673	MY2674	MY2675
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	0.27	0.4	0.2	0.4	0.4	0.2	0.3	0.3	1.1	0.7	0.5	0.1	0.2	0.2	0.6	0.2	0.7	0.4	0.5	0.3	0.6
Arsenic	46	48	25	22	17	6	7	40	40	1	1	3	2	4	5	6	17	24	38	15.5	26
Barium	2000	30	28	122	154	56	80	62	90	12	10	36	24	55	26	62	111	78	56	56	145
Beryllium	21	1	1	1	2	1	1	1	3	1	1	1	1	1	1	1	2	1	1	1	3
Boron	N/G	16	18	30	48	26	43	41	31	10	8	21	24	20	16	22	42	45	34	30.5	61
Cadmium	0.36	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.7	1.7	1.4	0.1	0.1	0.1	0.5	0.2	0.1	0.1	0.1	0.1	0.4
Chromium	34	93	115	131	164	57	63	97	197	72	57	50	54	38	66	79	120	109	150	59.5	130
Cobalt	230	1.4	1.2	3.4	7.1	1.4	1.9	19.7	20.1	1.2	1.3	1.2	1.1	4.5	9.1	9.9	7.7	8.2	3.1	2.25	18.5
Copper	49	7.5	6.5	11.1	13	5.4	6.5	5.6	10	5.8	4	4.8	3.7	3.3	3.8	3.9	18.2	16.8	8.1	6.85	13.3
Lead	56	7	4.9	24.4	24.6	6.1	10.5	9	6.6	1.8	1.3	5.1	4.5	3.5	4.3	5.2	29	19.7	13.7	11.15	19
Manganese	4000	62	55	95	123	102	87	2190	1730	186	311	56	51	40	32	41	156	579	75	61.5	937
Mercury	N/G	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Molybdenum	N/G	2.1	1.3	1.3	1.4	0.7	0.6	1.2	1.8	0.8	1.1	0.6	0.4	0.5	0.5	0.8	2.2	0.9	1.8	1.2	1.7
Nickel	130	5.7	4.7	20.4	28.6	4.5	7.2	22.2	23.5	17	16.4	3.7	4.1	7.6	16.2	14.6	36.6	27.3	12.3	10.05	29.4
Phosphorus	2000	100	110	390	410	190	230	1720	27700	10100	4920	190	90	510	260	790	750	350	320	205	7480
Selenium	0.63	1	1	1	1	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	1
Silver	14	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1
Sulfur	600	1000	1000	1000	1000	1000	1000	22000	24000	4000	4000	1000	1000	5000	6000	15000	1000	1000	1000	1000	13000
Tin	N/G	0.7	0.6	2.9	3	0.6	1.1	0.9	0.6	0.3	0.2	0.5	0.6	0.3	0.4	0.3	4.1	2.6	1.4	1.35	2.1
Vanadium	280	61	44	117	139	37	55	110	146	28	22	24	21	24	33	38	104	113	124	66.5	118
Zinc	79	5	5	20	63	9	14	43	52	47	26	6	4	6	52	14	36	55	16	12.5	93

Element	Soil Remediation Intervention Values [3]	1-NP-15-2, 15 M	2-NP-15-2, 15 M	3-NP-15-2, 17 M	4-NP-15-2, 17 M	5-NP-15-2, 36 M	6-NP-15-2, 38.5 M	7-NP-15-2, 54.5 M	8-NP-15-2, 54.5 M	9-NP-15-2, 57.5 M	10-NP-15-2, 57.5 M	1-SP-15-3, 21.5 M	2-SP-15-3, 21.5 M	3-SP-15-3, 33 M	4-SP-15-3, 33 M	5-SP-15-3, 34.5 M	1-SP-15-1, 15 M	2-SP-15-1, 19.5 M	3-SP-15-1, 19.5 M	4-SP-15-1, 24.5 M	5-SP-15-1, FPA.CO M
	(ppm)	MY2656	MY2657	MY2658	MY2659	MY2660	MY2661	MY2662	MY2663	MY2664	MY2665	MY2666	MY2667	MY2668	MY2669	MY2670	MY2671	MY2672	MY2673	MY2674	MY2675
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	15	0.4	0.2	0.4	0.4	0.2	0.3	0.3	1.1	0.7	0.5	0.1	0.2	0.2	0.6	0.2	0.7	0.4	0.5	0.3	0.6
Arsenic	55	48	25	22	17	6	7	40	40	1	1	3	2	4	5	6	17	24	38	15.5	26
Barium	625	30	28	122	154	56	80	62	90	12	10	36	24	55	26	62	111	78	56	56	145
Beryllium	30	1	1	1	2	1	1	1	3	1	1	1	1	1	1	1	2	1	1	1	3
Boron	N/G	16	18	30	48	26	43	41	31	10	8	21	24	20	16	22	42	45	34	30.5	61
Cadmium	12	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.7	1.7	1.4	0.1	0.1	0.1	0.5	0.2	0.1	0.1	0.1	0.1	0.4
Chromium	380	93	115	131	164	57	63	97	197	72	57	50	54	38	66	79	120	109	150	59.5	130
Cobalt	240	1.4	1.2	3.4	7.1	1.4	1.9	19.7	20.1	1.2	1.3	1.2	1.1	4.5	9.1	9.9	7.7	8.2	3.1	2.25	18.5
Copper	190	7.5	6.5	11.1	13	5.4	6.5	5.6	10	5.8	4	4.8	3.7	3.3	3.8	3.9	18.2	16.8	8.1	6.85	13.3
Lead	530	7	4.9	24.4	24.6	6.1	10.5	9	6.6	1.8	1.3	5.1	4.5	3.5	4.3	5.2	29	19.7	13.7	11.15	19
Manganese	N/G	62	55	95	123	102	87	2190	1730	186	311	56	51	40	32	41	156	579	75	61.5	937
Mercury	10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Molybdenum	200	2.1	1.3	1.3	1.4	0.7	0.6	1.2	1.8	0.8	1.1	0.6	0.4	0.5	0.5	0.8	2.2	0.9	1.8	1.2	1.7
Nickel	210	5.7	4.7	20.4	28.6	4.5	7.2	22.2	23.5	17	16.4	3.7	4.1	7.6	16.2	14.6	36.6	27.3	12.3	10.05	29.4
Phosphorus	N/G	100	110	390	410	190	230	1720	27700	10100	4920	190	90	510	260	790	750	350	320	205	7480
Selenium	100	1	1	1	1	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	1
Silver	15	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1
Sulfur	N/G	1000	1000	1000	1000	1000	1000	22000	24000	4000	4000	1000	1000	5000	6000	15000	1000	1000	1000	1000	13000
Tin	900	0.7	0.6	2.9	3	0.6	1.1	0.9	0.6	0.3	0.2	0.5	0.6	0.3	0.4	0.3	4.1	2.6	1.4	1.35	2.1
Vanadium	250	61	44	117	139	37	55	110	146	28	22	24	21	24	33	38	104	113	124	66.5	118
Zinc	720	5	5	20	63	9	14	43	52	47	26	6	4	6	52	14	36	55	16	12.5	93

[1] National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1). Health Investigation Levels for Soil Contaminants, Generic Land Use HIL C – Recreational.
[2] United States Environmental Protection Agency (U.S. EPA) Ecological Soil Screening Levels (Eco-SSLs), http://www.epa.gov/ecotox/ecossl/ (mammalian wildlife).
[3] VROM 2000, Circular on Target Values and Intervention Values for Soil Remediation, Reference DBO/1999226863, Ministry of Housing, Spatial Planning and the Environment, Bilthoven, Netherlands. Soil remediation intervention values and indicative levels for serious soil contamination. Applies to Be, Se, Ag, Sn and Va.
[4] National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999). Former Australian ecological investigation levels for urban areas included for reference purposes in the absence of other more applicable ecological assessment criteria. Applies to P and S

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Element	Human Health-Based Investigation Levels [1]	6-SP-15-1, FPA.CO M	1-SP-15-2, 16 M	2-SP-15-2, 21 M	3-SP-15-2, 21 M	4-SP-15-2, 26 M	5-SP-15-2, 26 M	6-SP-15-2, 27.5 M	7-SP-15-2, 27.5 M	1-NP-15-4, 15.5 M	2-NP-15-4, 15.5 M	3-NP-15-4, 26 M	4-NP-15-4, 26 M	5-NP-15-4, 32 M	6-NP-15-4, 32 M	7-NP-15-4, 33.5 M	8-NP-15-4, 33.5 M	9-NP-15-4, 45 M	10-NP-15-4, 45 M
		MY2676	MY2677	MY2678	MY2679	MY2680	MY2681	MY2682	MY2683	MY2684	MY2685	MY2686	MY2687	MY2688	MY2689	MY2690	MY2691	MY2692	MY2693
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	N/G	2.1	0.2	0.2	0.3	0.1	0.4	0.3	0.1	0.6	0.4	0.4	0.4	0.2	0.2	0.4	0.3	3.1	2.8
Arsenic	300	51	14	15	22	15	56	10	3	11	40	11	21	6	20	16	14	2	3
Barium	N/G	85	54	49	60	60	117	95	45	216	161	121	173	77	86	133	99	16	16.5
Beryllium	90	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1
Boron	20000	29	37	30	36	33	42	47	23	34	54	34	54	46	37	60	49	38	41
Cadmium	90	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.6	2.85
Chromium	N/G	168	74	70	121	81	104	103	58	109	105	67	116	39	69	111	64	254	223
Cobalt	300	24.1	1.7	1.7	2.4	2.1	7	10.6	1.9	5.9	9.5	3.9	6	2	5	13.8	3.3	30.3	20.65
Copper	17000	14.1	7.2	6.5	9.6	8.2	9	6.4	4	12.5	13.8	9.7	15.4	6.4	7.6	11.6	7.5	14.8	14.4
Lead	600	11.8	7.9	7.1	9.5	7.9	14.6	23.6	9.3	23	21.2	16.4	23.4	8	11	19.2	11.8	2.9	3.3
Manganese	19000	1470	73	66	83	93	158	96	41	142	246	236	214	83	199	814	144	3440	4815
Mercury	80	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Molybdenum	N/G	4.2	1.2	1.4	1.7	1	1.6	1.7	1.1	1.9	1.1	0.5	0.9	0.2	0.4	0.9	0.5	1	0.8
Nickel	1200	28.6	6.6	5.8	8.8	6.9	14.2	23.9	5.9	21.7	27.1	12.9	22.1	6.1	11.4	24	10.1	197	155
Phosphorus	N/G	37800	350	190	240	250	1250	350	260	840	910	310	830	270	570	280	510	50000	27100
Selenium	700	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5
Silver	N/G	0.1	0.6	0.4	1.4	0.8	0.3	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.25
Sulfur	N/G	52000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	9000	1000	5000	5000
Tin	N/G	1.1	0.9	0.8	1.5	0.9	1.4	1.7	0.8	2.7	2.3	1.7	2.9	0.8	1.2	2.1	1.4	0.3	0.45
Vanadium	N/G	143	61	62	82	67	106	71	29	107	130	80	126	43	65	92	65	236	176.5
Zinc	30000	306	11	8	14	13	38	69	19	49	87	30	51	17	36	79	28	81	101

Element	Ecological Soil Screening Levels [2]	6-SP-15-1, FPA.CO M	1-SP-15-2, 16 M	2-SP-15-2, 21 M	3-SP-15-2, 21 M	4-SP-15-2, 26 M	5-SP-15-2, 26 M	6-SP-15-2, 27.5 M	7-SP-15-2, 27.5 M	1-NP-15-4, 15.5 M	2-NP-15-4, 15.5 M	3-NP-15-4, 26 M	4-NP-15-4, 26 M	5-NP-15-4, 32 M	6-NP-15-4, 32 M	7-NP-15-4, 33.5 M	8-NP-15-4, 33.5 M	9-NP-15-4, 45 M	10-NP-15-4, 45 M
		MY2676	MY2677	MY2678	MY2679	MY2680	MY2681	MY2682	MY2683	MY2684	MY2685	MY2686	MY2687	MY2688	MY2689	MY2690	MY2691	MY2692	MY2693
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	0.27	2.1	0.2	0.2	0.3	0.1	0.4	0.3	0.1	0.6	0.4	0.4	0.4	0.2	0.2	0.4	0.3	3.1	2.8
Arsenic	46	51	14	15	22	15	56	10	3	11	40	11	21	6	20	16	14	2	3
Barium	2000	85	54	49	60	60	117	95	45	216	161	121	173	77	86	133	99	16	16.5
Beryllium	21	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1
Boron	N/G	29	37	30	36	33	42	47	23	34	54	34	54	46	37	60	49	38	41
Cadmium	0.36	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.6	2.85
Chromium	34	168	74	70	121	81	104	103	58	109	105	67	116	39	69	111	64	254	223
Cobalt	230	24.1	1.7	1.7	2.4	2.1	7	10.6	1.9	5.9	9.5	3.9	6	2	5	13.8	3.3	30.3	20.65
Copper	49	14.1	7.2	6.5	9.6	8.2	9	6.4	4	12.5	13.8	9.7	15.4	6.4	7.6	11.6	7.5	14.8	14.4
Lead	56	11.8	7.9	7.1	9.5	7.9	14.6	23.6	9.3	23	21.2	16.4	23.4	8	11	19.2	11.8	2.9	3.3
Manganese	4000	1470	73	66	83	93	158	96	41	142	246	236	214	83	199	814	144	3440	4815
Mercury	N/G	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Molybdenum	N/G	4.2	1.2	1.4	1.7	1	1.6	1.7	1.1	1.9	1.1	0.5	0.9	0.2	0.4	0.9	0.5	1	0.8
Nickel	130	28.6	6.6	5.8	8.8	6.9	14.2	23.9	5.9	21.7	27.1	12.9	22.1	6.1	11.4	24	10.1	197	155
Phosphorus	2000	37800	350	190	240	250	1250	350	260	840	910	310	830	270	570	280	510	50000	27100
Selenium	0.63	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5
Silver	14	0.1	0.6	0.4	1.4	0.8	0.3	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.25
Sulfur	600	52000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	9000	1000	5000	5000
Tin	N/G	1.1	0.9	0.8	1.5	0.9	1.4	1.7	0.8	2.7	2.3	1.7	2.9	0.8	1.2	2.1	1.4	0.3	0.45
Vanadium	280	143	61	62	82	67	106	71	29	107	130	80	126	43	65	92	65	236	176.5
Zinc	79	306	11	8	14	13	38	69	19	49	87	30	51	17	36	79	28	81	101

Element	Soil Remediation Intervention Values [3]	6-SP-15-1, FPA.CO M	1-SP-15-2, 16 M	2-SP-15-2, 21 M	3-SP-15-2, 21 M	4-SP-15-2, 26 M	5-SP-15-2, 26 M	6-SP-15-2, 27.5 M	7-SP-15-2, 27.5 M	1-NP-15-4, 15.5 M	2-NP-15-4, 15.5 M	3-NP-15-4, 26 M	4-NP-15-4, 26 M	5-NP-15-4, 32 M	6-NP-15-4, 32 M	7-NP-15-4, 33.5 M	8-NP-15-4, 33.5 M	9-NP-15-4, 45 M	10-NP-15-4, 45 M
		MY2676	MY2677	MY2678	MY2679	MY2680	MY2681	MY2682	MY2683	MY2684	MY2685	MY2686	MY2687	MY2688	MY2689	MY2690	MY2691	MY2692	MY2693
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	15	2.1	0.2	0.2	0.3	0.1	0.4	0.3	0.1	0.6	0.4	0.4	0.4	0.2	0.2	0.4	0.3	3.1	2.8
Arsenic	55	51	14	15	22	15	56	10	3	11	40	11	21	6	20	16	14	2	3
Barium	625	85	54	49	60	60	117	95	45	216	161	121	173	77	86	133	99	16	16.5
Beryllium	30	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1
Boron	N/G	29	37	30	36	33	42	47	23	34	54	34	54	46	37	60	49	38	41
Cadmium	12	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.6	2.85
Chromium	380	168	74	70	121	81	104	103	58	109	105	67	116	39	69	111	64	254	223
Cobalt	240	24.1	1.7	1.7	2.4	2.1	7	10.6	1.9	5.9	9.5	3.9	6	2	5	13.8	3.3	30.3	20.65
Copper	190	14.1	7.2	6.5	9.6	8.2	9	6.4	4	12.5	13.8	9.7	15.4	6.4	7.6	11.6	7.5	14.8	14.4
Lead	530	11.8	7.9	7.1	9.5	7.9	14.6	23.6	9.3	23	21.2	16.4	23.4	8	11	19.2	11.8	2.9	3.3
Manganese	N/G	1470	73	66	83	93	158	96	41	142	246	236	214	83	199	814	144	3440	4815
Mercury	10	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Molybdenum	200	4.2	1.2	1.4	1.7	1	1.6	1.7	1.1	1.9	1.1	0.5	0.9	0.2	0.4	0.9	0.5	1	0.8
Nickel	210	28.6	6.6	5.8	8.8	6.9	14.2	23.9	5.9	21.7	27.1	12.9	22.1	6.1	11.4	24	10.1	197	155
Phosphorus	N/G	37800	350	190	240	250	1250	350	260	840	910	310	830	270	570	280	510	50000	27100
Selenium	100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5
Silver	15	0.1	0.6	0.4	1.4	0.8	0.3	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.25
Sulfur	N/G	52000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	9000	1000	5000	5000
Tin	900	1.1	0.9	0.8	1.5	0.9	1.4	1.7	0.8	2.7	2.3	1.7	2.9	0.8	1.2	2.1	1.4	0.3	0.45
Vanadium	250	143	61	62	82	67	106	71	29	107	130	80	126	43	65	92	65	236	176.5
Zinc	720	306	11	8	14	13	38	69	19	49	87	30	51	17	36	79	28	81	101

APPENDIX D

Distilled Water Extract Tables

Knight Piésold
CONSULTING

APPENDIX D - DISTILLED WATER EXTRACT TABLES

Knight Piésold CONSULTING

Maxxam Sample No	Sample ID	Sample Weight	Volume Used	pH	EC	TDS (Estimate)	Hardness CaCO3	Dissolved Aluminum (Al)	Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Bismuth (Bi)	Dissolved Boron (B)	Dissolved Cesium (Cs)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)	Dissolved Lanthanum (La)	Dissolved Iron (Fe)	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Mercury (Hg)	Dissolved Phosphorus (P)
	Units	g	ml	pH Units	uS/cm	ppm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Release Guidelines			6 - 9	N/G	2000	N/G	5	N/G	0.1	N/G	N/G	N/G	5	N/G	0.01	1000	1	1	0.3	N/G	2	0.1	N/G	2000	N/G	0.002	N/G
MY2656	1-NP-15-2, 15 M	250	750	9.58	147.0	108.05	0.88	1.29	0.000084	0.0589	0.00123	0.000010	0.0000050	0.050	0.000050	0.0000050	0.131	0.00295	0.0000670	0.000827	0.000982	0.344	0.000305	0.00050	0.133	0.000784	0.000050	0.0579
MY2658	3-NP-15-2, 17 M	250	750	6.29	14.3	10.51	0.50	0.0143	0.000020	0.000248	0.000476	0.000010	0.0000050	0.050	0.000050	0.0000050	0.160	0.00010	0.0000330	0.000129	0.000050	0.0032	0.0000050	0.00053	0.050	0.000974	0.000050	0.0129
MY2661	6-NP-15-2, 38.5 M	250	750	7.43	71.4	52.48	1.09	0.332	0.000020	0.000273	0.00167	0.000010	0.0000050	0.050	0.000051	0.0000050	0.254	0.00081	0.0000200	0.000275	0.000125	0.0865	0.0000970	0.00070	0.110	0.000610	0.000050	0.0237
MY2662	7-NP-15-2, 54.5 M	250	750	6.35	650.0	477.75	231	0.0453	0.000020	0.000297	0.0106	0.000010	0.0000050	0.050	0.000050	0.0000330	67.1	0.00010	0.0216	0.000155	0.000050	0.0121	0.0000150	0.00705	15.3	0.887	0.000050	0.0043
MY2664	9-NP-15-2, 57.5 M	250	750	7.89	548.0	402.78	245	0.00663	0.000283	0.000077	0.0130	0.000010	0.0000050	0.050	0.000050	0.0000150	87.7	0.00015	0.000143	0.000259	0.000050	0.0017	0.0000050	0.00343	6.30	0.0130	0.000050	0.0027
MY2666	1-SP-15-3, 21.5 M	250	750	9.72	224.0	164.64	3.47	1.11	0.000091	0.00785	0.00296	0.000020	0.0000050	0.050	0.000074	0.0000050	1.01	0.00306	0.000132	0.00217	0.000969	0.210	0.000297	0.00224	0.231	0.00103	0.000050	0.105
MY2668	3-SP-15-3, 33 M	250	750	7.07	496.0	364.56	98.2	0.0229	0.000102	0.000345	0.0119	0.000010	0.0000050	0.050	0.000050	0.0000990	27.3	0.00010	0.0111	0.000066	0.000060	0.0047	0.0000050	0.00696	7.27	0.0404	0.000050	0.0048
MY2670	5-SP-15-3, 34.5 M	250	750	3.36	1040.0	764.40	201	2.45	0.000094	0.00371	0.00659	0.0168	0.0000050	0.050	0.000100	0.00724	55.9	0.0155	1.04	0.00540	0.00505	33.1	0.000113	0.0271	14.9	0.459	0.000152	0.0020
MY2672	2-SP-15-1, 19.5 M	250	750	4.25	366.0	269.01	33.0	0.0237	0.000020	0.000020	0.00309	0.000198	0.0000050	0.050	0.000672	0.0000080	4.21	0.00010	0.00135	0.000574	0.000096	0.0505	0.0000180	0.00426	5.47	0.0236	0.000050	0.0026
MY2674	4-SP-15-1, 24.5 M	250	750	5.73	368.0	270.48	48.3	0.00393	0.000020	0.000661	0.00305	0.000018	0.0000050	0.050	0.000418	0.0000150	6.70	0.00010	0.000506	0.000159	0.000050	0.0042	0.0000050	0.00118	7.67	0.0557	0.000050	0.0020
MY2676	6-SP-15-1, FPA.CO M	250	750	5.68	994.0	730.59	351	0.0323	0.000212	0.00177	0.0144	0.000089	0.0000050	0.050	0.000070	0.00210	107	0.00010	0.128	0.000436	0.000050	0.0523	0.0000110	0.0339	20.6	2.26	0.000050	0.0300
MY2678	2-SP-15-2, 21 M	250	750	8.30	1175.0	863.63	41.9	0.146	0.000032	0.000897	0.00570	0.000010	0.0000050	0.062	0.000068	0.0000050	6.61	0.00016	0.0000710	0.00105	0.000050	0.0152	0.0000130	0.00050	6.16	0.000255	0.000050	0.0063
MY2680	4-SP-15-2, 26 M	250	750	8.67	1770.0	1300.95	63.5	0.0694	0.000037	0.00124	0.0159	0.000010	0.0000050	0.075	0.000071	0.0000070	10.1	0.00013	0.0000990	0.00103	0.000050	0.0066	0.0000050	0.00094	9.33	0.000332	0.000050	0.0063
MY2682	6-SP-15-2, 27.5 M	250	750	6.32	632.0	464.52	66.8	0.0187	0.000020	0.000304	0.00501	0.000010	0.0000050	0.050	0.000172	0.0000300	17.3	0.00010	0.00546	0.000096	0.000065	0.0188	0.0000060	0.0113	5.73	0.193	0.000050	0.0065
MY2684	1-NP-15-4, 15.5 M	250	750	5.96	16.2	11.91	2.37	0.0258	0.000020	0.000163	0.00154	0.000040	0.0000050	0.050	0.000050	0.0000050	0.449	0.00044	0.000999	0.000208	0.000050	0.0030	0.0000050	0.00327	0.304	0.0190	0.000050	0.0505
MY2686	3-NP-15-4, 26 M	250	750	5.55	23.4	17.20	2.66	0.0212	0.000020	0.000090	0.00181	0.000022	0.0000050	0.050	0.000050	0.0000050	0.581	0.00083	0.000639	0.000115	0.000050	0.0039	0.0000050	0.00252	0.294	0.0133	0.000050	0.0082
MY2688	5-NP-15-4, 32 M	250	750	7.21	17.7	13.01	0.84	0.752	0.000020	0.000191	0.00145	0.000010	0.0000050	0.050	0.000070	0.0000050	0.245	0.00118	0.0000690	0.000496	0.000381	0.253	0.000202	0.00165	0.055	0.00110	0.000050	0.0128
MY2690	7-NP-15-4, 33.5 M	250	750	5.73	484.0	355.74	212	0.0642	0.000020	0.000446	0.0104	0.000016	0.0000050	0.050	0.000058	0.0000090	69.1	0.00010	0.0205	0.000074	0.000077	0.0155	0.0000290	0.0103	9.59	2.17	0.000050	0.0023
MY2692	9-NP-15-4, 45 M	250	750	7.61	241.0	177.14	96.6	0.00387	0.000531	0.000026	0.00461	0.000010	0.0000050	0.050	0.000050	0.0000680	32.1	0.00074	0.00165	0.000397	0.000050	0.0010	0.0000050	0.00362	4.01	0.0114	0.000050	0.0033

Maxxam Sample No	Sample ID	Sample Weight	Volume Used	pH	EC	TDS (Estimate)	Hardness CaCO3	Dissolved Aluminum (Al)	Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Bismuth (Bi)	Dissolved Boron (B)	Dissolved Cesium (Cs)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)	Dissolved Lanthanum (La)	Dissolved Iron (Fe)	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Mercury (Hg)	Dissolved Phosphorus (P)
	Units	g	ml	pH Units	uS/cm	ppm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Drinking Water Guidelines			6.5 - 8.5	N/G	600	N/G	0.2	0.003	0.01	2	N/G	N/G	4	N/G	0.002	N/G	N/G	N/G	1	N/G	0.3	0.01	N/G	N/G	0.1	0.001	N/G
MY2656	1-NP-15-2, 15 M	250	750	9.58	147.0	108.05	0.88	1.29	0.000084	0.0589	0.00123	0.000010	0.0000050	0.050	0.000050	0.0000050	0.131	0.00295	0.0000670	0.000827	0.000982	0.344	0.000305	0.00050	0.133	0.000784	0.000050	0.0579
MY2658	3-NP-15-2, 17 M	250	750	6.29	14.3	10.51	0.50	0.0143	0.000020	0.000248	0.000476	0.000010	0.0000050	0.050	0.000050	0.0000050	0.160	0.00010	0.0000330	0.000129	0.000050	0.0032	0.0000050	0.00053	0.050	0.000974	0.000050	0.0129
MY2661	6-NP-15-2, 38.5 M	250	750	7.43	71.4	52.48	1.09	0.332	0.000020	0.000273	0.00167	0.000010	0.0000050	0.050	0.000051	0.0000050	0.254	0.00081	0.0000200	0.000275	0.000125	0.0865	0.0000970	0.00070	0.110	0.000610	0.000050	0.0237
MY2662	7-NP-15-2, 54.5 M	250	750	6.35	650.0	477.75	231	0.0453	0.000020	0.000297	0.0106	0.000010	0.0000050	0.050	0.000050	0.0000330	67.1	0.00010	0.0216	0.000155	0.000050	0.0121	0.0000150	0.00705	15.3	0.887	0.000050	0.0043
MY2664	9-NP-15-2, 57.5 M	250	750	7.89	548.0	402.78	245	0.00663	0.000283	0.000077	0.0130	0.000010	0.0000050	0.050	0.000050	0.0000150	87.7	0.00015	0.000143	0.000259	0.000050	0.0017	0.0000050	0.00343	6.30	0.0130	0.000050	0.0027
MY2666	1-SP-15-3, 21.5 M	250	750	9.72	224.0	164.64	3.47	1.11	0.000091	0.00785	0.00296	0.000020	0.0000050	0.050	0.000074	0.0000050	1.01	0.00306	0.000132	0.00217	0.000969	0.210	0.000297	0.00224	0.231	0.00103	0.000050	0.105
MY2668	3-SP-15-3, 33 M	250	750	7.07	496.0	364.56	98.2	0.0229	0.000102	0.000345	0.0119	0.000010	0.0000050	0.050	0.000050	0.0000990	27.3	0.00010	0.0111	0.000066	0.000060	0.0047	0.0000050	0.00696	7.27	0.0404	0.000050	0.0048
MY2670	5-SP-15-3, 34.5 M	250	750	3.36	1040.0	764.40	201	2.45	0.000094	0.00371	0.00659	0.0168	0.0000050	0.050	0.000100	0.00724	55.9	0.0155	1.04	0.00540	0.00505	33.1	0.000113	0.0271	14.9	0.459	0.000152	0.0020
MY2672	2-SP-15-1, 19.5 M	250	750	4.25	366.0	269.01	33.0	0.0237	0.000020	0.000020	0.00309	0.000198	0.0000050	0.050	0.000672	0.0000080	4.21	0.00010	0.00135	0.000574	0.000096	0.0505	0.0000180	0.00426	5.47	0.0236	0.000050	0.0026
MY2674	4-SP-15-1, 24.5 M	250	750	5.73	368.0	270.48	48.3	0.00393	0.000020	0.000661	0.00305	0.000018	0.0000050	0.050	0.000418	0.0000150	6.70	0.00010	0.000506	0.000159	0.000050	0.0042	0.0000050	0.00118	7.67	0.0557	0.000050	0.0020
MY2676	6-SP-15-1, FPA.CO M	250	750	5.68	994.0	730.59	351	0.0323	0.000212	0.00177	0.0144	0.000089	0.0000050	0.050	0.000070	0.00210	107	0.00010	0.128	0.000436	0.000050	0.0523	0.0000110	0.0339	20.6	2.26	0.000050	0.0300
MY2678	2-SP-15-2, 21 M	250	750	8.30	1175.0	863.63	41.9	0.146	0.000032	0.000897	0.00570	0.000010	0.0000050	0.062	0.000068	0.0000050	6.61	0.00016	0.0000710	0.00105	0.000050	0.0152	0.0000130	0.00050	6.16	0.000255	0.000050	0.0063
MY2680	4-SP-15-2, 26 M	250	750	8.67	1770.0	1300.95	63.5	0.0694	0.000037	0.00124	0.0159	0.000010	0.0000050	0.075	0.000071	0.0000070	10.1	0.00013	0.0000990	0.00103	0.000050	0.0066	0.0000050	0.00094	9.33	0.000332	0.000050	0.0063
MY2682	6-SP-15-2, 27.5 M	250	750	6.32	632.0	464.52	66.8	0.0187	0.000020	0.000304	0.00501	0.000010	0.0000050	0.050	0.000172	0.0000300	17.3	0.00010	0.00546	0.000096	0.000065	0.0188	0.0000060	0.0113	5.73	0.193	0.000050	0.0065
MY2684	1-NP-15-4, 15.5 M	250	750	5.96	16.2	11.91	2.37	0.0258	0.000020	0.000163	0.00154	0.000040	0.0000050	0.050	0.000050	0.0000050	0.449	0.00044	0.000999	0.000208	0.000050	0.0030	0.0000050	0.00327	0.304	0.0190	0.000050	0.0505
MY2686	3-NP-15-4, 26 M	250	750	5.55	23.4	17.20	2.66	0.0212	0.000020	0.000090	0.00181	0.000022	0.0000050	0.050	0.000050	0.0000050	0.581	0.00083	0.000639	0.000115	0.000050	0.0039	0.0000050	0.00252	0.294	0.0133	0.000050	0.0082
MY2688	5-NP-15-4, 32 M	250	750	7.21	17.7	13.01	0.84	0.752	0.000020	0.000191	0.00145	0.000010	0.0000050	0.050	0.000070	0.0000050	0.245	0.00118	0.0000690	0.000496	0.000381	0.253	0.000202	0.00165	0.055	0.00110	0.000050	0.0128
MY2690	7-NP-15-4, 33.5 M	250	750	5.73	484.0	355.74	212	0.0642	0.000020	0.000446	0.0104	0.000016	0.0000050	0.050	0.000058	0.0000090	69.1	0.00010	0.0205	0.000074	0.000077	0.0155	0.0000290	0.0103	9.59	2.17	0.000050	0.0023
MY2692	9-NP-15-4, 45 M	250	750	7.61	241.0	177.14	96.6	0.00387	0.000531	0.000026	0.00461	0.000010	0.0000050	0.050	0.000050	0.0000680	32.1	0.00074	0.00165	0.000397	0.000050	0.0010	0.0000050	0.00362	4.01	0.0114	0.000050	0.0033

Maxxam Sample No	Sample ID	Sample Weight	Volume Used	pH	EC	TDS (Estimate)	Hardness CaCO3	Dissolved Aluminum (Al)	Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Bismuth (Bi)	Dissolved Boron (B)	Dissolved Cesium (Cs)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)	Dissolved Lanthanum (La)	Dissolved Iron (Fe)	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Mercury (Hg)	Dissolved Phosphorus (P)
	Units	g	ml	pH Units	uS/cm	ppm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Baseline Surface Water			7.10	3905	2527	N/G	N/G	N/G	0.0009	N/G	N/G	N/G	N/G	N/G	0.0001	40.8	0.002	N/G	0.005	N/G	0.20	0.0003	N/G	77.50	0.05	0.00002	N/G
	Baseline Groundwater			6.40	1334	293	N/G	N/G	N/G	0.0018	N/G	N/G	N/G	N/G	N/G	0.0002	45.3	0.001	N/G	0.015	N/G	1.30	0.0010	N/G	15.90	0.34	N/M	N/G
MY2656	1-NP-15-2, 15 M	250	750	9.58	147.0	108.05	0.88	1.29	0.000084	0.0589	0.00123	0.000010	0.0000050	0.050	0.000050	0.0000050	0.131	0.00295	0.0000670	0.000827	0.000982	0.344	0.000305	0.00050	0.133	0.000784	0.000050	0.0579
MY2658	3-NP-15-2, 17 M	250	750	6.29	14.3	10.51	0.50	0.0143	0.000020	0.000248	0.000476	0.000010	0.0000050	0.050	0.000050	0.0000050	0.160	0.00010	0.0000330	0.000129	0.000050	0.0032	0.0000050	0.00053	0.050	0.000974	0.000050	0.0129
MY2661	6-NP-15-2, 38.5 M	250	750	7.43	71.4	52.48	1.09	0.332	0.000020	0.000273	0.00167	0.000010	0.0000050	0.050	0.000051	0.0000050	0.254	0.00081	0.0000200	0.000275	0.000125	0.0865	0.0000970	0.00070	0.110	0.000610	0.000050	0.0237
MY2662	7-NP-15-2, 54.5 M	250	750	6.35	650.0	477.75	231	0.0453	0.000020	0.000297	0.0106	0.000010	0.0000050	0.050	0.000050	0.0000330	67.1	0.00010	0.0216	0.000155	0.000050	0.0121	0.0000150	0.00705	15.3	0.887	0.000050	0.0043
MY2664	9-NP-15-2, 57.5 M	250	750	7.89	548.0	402.78	245	0.00663	0.000283	0.000077	0.0130	0.000010	0.0000050	0.050	0.000050	0.0000150	87.7	0.00015	0.000143	0.000259	0.000050	0.0017	0.0000050	0.00343	6.30	0.0130	0.000050	0.0027
MY2666	1-SP-15-3, 21.5 M	250	750	9.72	224.0	164.64	3.47	1.11	0.000091	0.00785	0.00296	0.000020	0.0000050	0.050	0.000074	0.0000050	1.01	0.00306	0.000132	0.00217	0.000969	0.210	0.000297	0.00224	0.231	0.00103	0.000050	0.105
MY2668	3-SP-15-3, 33 M	250	750	7.07	496.0	364.56	98.2	0.0229	0.000102	0.000345	0.0119	0.000010	0.0000050	0.050	0.000050	0.0000990	27.3	0.00010	0.0111	0.000066	0.000060	0.0047	0.0000050	0.00696	7.27	0.0404	0.000050	0.0048
MY2670	5-SP-15-3, 34.5 M	250	750	3.36	1040.0	764.40	201	2.45	0.000094	0.00371	0.00659	0.0168	0.0000050	0.050	0.000100	0.00724	55.9	0.0155	1.04	0.00540	0.00505	33.1	0.000113	0.0271	14.9	0.459	0.000152	0.0020
MY2672	2-SP-15-1, 19.5 M	250	750	4.25	366.0	269.01	33.0	0.0237	0.000020	0.000020	0.00309	0.000198	0.0000050	0.050	0.000672	0.0000080	4.21	0.00010	0.00135	0.000574	0.000096	0.0505	0.0000180	0.00426	5.47	0.0236	0.000050	0.0026
MY2674	4-SP-15-1, 24.5 M	250	750	5.73	368.0	270.48	48.3	0.00393	0.000020	0.000661	0.00305	0.000018	0.0000050	0.050	0.000418	0.0000150	6.70	0.00010	0.000506	0.000159	0.000050	0.0042	0.0000050	0.00118	7.67	0.0557	0.000050	0.0020
MY2676	6-SP-15-1, FPA.CO M	250	750	5.68	994.0	730.59	351	0.0323	0.000212	0.00177	0.0144	0.000089	0.0000050	0.050	0.000070	0.00210	107	0.00010	0.128	0.000436	0.000050	0.0523	0.0000110	0.0339	20.6	2.26	0.000050	0.0300
MY2678	2-SP-15-2, 21 M	250	750	8.30	1175.0	863.63	41.9	0.146	0.000032	0.000897	0.00570	0.000010	0.0000050	0.062	0.000068	0.0000050	6.61	0.00016	0.0000710	0.00105	0.000050	0.0152	0.0000130	0.00050	6.16	0.000255	0.000050	0.0063
MY2680	4-SP-15-2, 26 M	250	750	8.67	1770.0	1300.95	63.5	0.0694	0.000037	0.00124	0.0159	0.000010	0.0000050	0.075	0.000071	0.0000070	10.1	0.00013	0.0000990	0.00103	0.000050	0.0066	0.0000050	0.00094	9.33	0.000332	0.000050	0.0063
MY2682	6-SP-15-2, 27.5 M	250	750	6.32	632.0	464.52	66.8	0.0187	0.000020	0.000304	0.00501	0.000010	0.0000050	0.050	0.000172	0.0000300	17.3	0.00010	0.00546	0.000096	0.000065	0.0188	0.0000060	0.0113	5.73	0.193	0.000050	0.0065
MY2684	1-NP-15-4, 15.5 M	250	750	5.96	16.2	11.91	2.37	0.0258	0.000020	0.000163	0.00154	0.000040	0.0000050	0.050	0.000050	0.0000050	0.449	0.00044	0.000999	0.000208	0.000050	0.0030	0.0000050	0.00327	0.304	0.0190	0.000050	0.0505
MY2686	3-NP-15-4, 26 M	250	750	5.55	23.4	17.20	2.66	0.0212	0.000020	0.000090	0.00181	0.000022	0.0000050	0.050	0.000050	0.0000050	0.581	0.00083	0.000639	0.000115	0.000050	0.0039	0.0000050	0.00252	0.294	0.0133	0.000050	0.0082
MY2688	5-NP-15-4, 32 M	250	750	7.21	17.7	13.01	0.84	0.752	0.000020	0.000191	0.00145	0.000010	0.0000050	0.050	0.000070	0.0000050	0.245	0.00118	0.0000690	0.000496	0.000381	0.253	0.000202	0.00165	0.055	0.00110	0.000050	0.0128
MY2690	7-NP-15-4, 33.5 M	250	750	5.73	484.0	355.74	212	0.0642	0.000020	0.000446	0.0104	0.000016	0.0000050	0.050	0.000058	0.0000090	69.1	0.00010	0.0205	0.000074	0.000077	0.0155	0.0000290	0.0103	9.59	2.17	0.000050	0.0023
MY2692	9-NP-15-4, 45 M	250	750	7.61	241.0	177.14	96.6	0.00387	0.000531	0.000026	0.00461	0.000010	0.0000050	0.050	0.000050	0.0000680	32.1	0.00074	0.00165	0.000397	0.000050	0.0010	0.0000050	0.00362	4.01	0.0114	0.000050	0.0033

APPENDIX D - DISTILLED WATER EXTRACT TABLES

Knight Piésold CONSULTING

Maxxam Sample No	Sample ID	Total Phosphorus	Ortho-phosphate	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Potassium (K)	Dissolved Rubidium (Rb)	Dissolved Selenium (Se)	Dissolved Silicon (Si)	Dissolved Silver (Ag)	Dissolved Sodium (Na)	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	SO4	Dissolved Tellurium (Te)	Dissolved Thallium (Tl)	Dissolved Thorium (Th)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Tungsten (W)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)	Dissolved Zirconium (Zr)
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Release Guidelines	0.01	0.004	0.15	0.5	N/G	N/G	0.02	N/G	0.5	N/G	N/G	N/G	1000	N/G	N/G	N/G	N/G	N/G	N/G	0.2	N/G	0.5	N/G
MY2656	1-NP-15-2, 15 M	3.54	0.060	0.0138	0.000661	0.141	0.000267	0.000563	3.59	0.0000050	26.1	0.000884	10	4.9	0.000020	0.0000020	0.000175	0.00020	0.0434	0.00111	0.000165	0.0355	0.00307	0.00182
MY2658	3-NP-15-2, 17 M	0.026	0.015	0.000050	0.000202	0.130	0.000674	0.000040	1.57	0.0000050	2.72	0.000247	10	0.7	0.000020	0.0000020	0.0000050	0.00020	0.00050	0.000010	0.0000040	0.00074	0.00118	0.00010
MY2661	6-NP-15-2, 38.5 M	2.28	0.033	0.000645	0.000265	1.01	0.00197	0.000262	2.45	0.0000050	15.8	0.00117	10	9.3	0.000020	0.0000050	0.0000360	0.00020	0.0123	0.000057	0.0000120	0.00117	0.00090	0.00208
MY2662	7-NP-15-2, 54.5 M	0.118	0.005	0.000050	0.0127	6.43	0.0160	0.000976	1.02	0.0000050	25.2	0.120	94	230	0.000020	0.0000110	0.0000050	0.00020	0.00284	0.000010	0.0000140	0.00020	0.00127	0.00010
MY2664	9-NP-15-2, 57.5 M	0.540	0.005	0.00125	0.00476	8.91	0.00896	0.0229	0.55	0.0000050	3.55	0.234	82	198	0.000020	0.0000090	0.0000050	0.00020	0.00095	0.000010	0.00117	0.00020	0.00021	0.00010
MY2666	1-SP-15-3, 21.5 M	4.36	0.093	0.00928	0.000839	1.53	0.000949	0.00112	4.78	0.0000080	41.0	0.00584	10	9.7	0.000020	0.0000040	0.000153	0.00020	0.0413	0.00266	0.000618	0.0583	0.00411	0.00160
MY2668	3-SP-15-3, 33 M	0.151	0.005	0.000308	0.0311	1.73	0.00220	0.00814	1.42	0.0000080	57.3	0.114	55	145	0.000020	0.000146	0.0000050	0.00020	0.00097	0.000046	0.000115	0.00020	0.00043	0.00010
MY2670	5-SP-15-3, 34.5 M	0.127	0.005	0.000050	0.947	1.01	0.00605	0.00515	2.42	0.0000070	45.1	0.219	116	357	0.000020	0.000495	0.000639	0.00020	0.00050	0.000010	0.0987	0.00063	0.636	0.00017
MY2672	2-SP-15-1, 19.5 M	0.006	0.005	0.000050	0.00165	2.13	0.00906	0.000267	1.90	0.0000050	49.2	0.0270	13	34.3	0.000020	0.0000890	0.0000050	0.00020	0.00050	0.000010	0.00108	0.00020	0.00406	0.00010
MY2674	4-SP-15-1, 24.5 M	0.023	0.005	0.000050	0.00127	3.08	0.00726	0.000149	1.13	0.0000050	46.6	0.0344	14	41.1	0.000020	0.0000470	0.0000050	0.00020	0.00050	0.000010	0.0000550	0.00020	0.00416	0.00010
MY2676	6-SP-15-1, FPA.CO M	7.590	0.025	0.000201	0.103	10.9	0.0292	0.0211	2.25	0.0000050	62.6	0.215	150	394	0.000020	0.000369	0.0000050	0.00020	0.00171	0.000010	0.0000410	0.00254	0.0729	0.00010
MY2678	2-SP-15-2, 21 M	0.101	0.005	0.00856	0.000396	5.32	0.00183	0.000300	1.03	0.0000050	205	0.0489	15	37.4	0.000020	0.0000220	0.0000090	0.00020	0.00589	0.000613	0.0000440	0.00226	0.00010	0.00015
MY2680	4-SP-15-2, 26 M	0.036	0.005	0.00776	0.000377	6.46	0.00220	0.000360	1.25	0.0000050	314	0.0927	21	54.1	0.000020	0.0000160	0.0000050	0.00020	0.00214	0.00214	0.0000980	0.00321	0.00010	0.00010
MY2682	6-SP-15-2, 27.5 M	0.047	0.005	0.000050	0.00420	5.42	0.0117	0.000499	2.90	0.0000050	86.0	0.0161	10	25.2	0.000020	0.0000240	0.0000050	0.00020	0.00050	0.000010	0.0000320	0.00020	0.00421	0.00010
MY2684	1-NP-15-4, 15.5 M	0.075	0.047	0.000050	0.00137	0.841	0.00361	0.000040	2.23	0.0000050	2.26	0.000966	10	0.6	0.000020	0.0000060	0.0000050	0.00020	0.00050	0.000010	0.0000060	0.00023	0.00313	0.00010
MY2686	3-NP-15-4, 26 M	0.015	0.008	0.000050	0.00119	1.17	0.00510	0.000071	1.62	0.0000050	3.21	0.00122	10	1.0	0.000020	0.0000080	0.0000050	0.00020	0.00050	0.000010	0.0000050	0.00020	0.00228	0.00010
MY2688	5-NP-15-4, 32 M	0.932	0.016	0.000353	0.000310	0.898	0.00178	0.000213	2.35	0.0000050	2.04	0.00188	10	3.9	0.000020	0.0000040	0.0000890	0.00020	0.0305	0.000017	0.0000220	0.00146	0.00081	0.00096
MY2690	7-NP-15-4, 33.5 M	0.024	0.005	0.000050	0.0123	13.2	0.0329	0.00683	1.62	0.0000050	2.91	0.103	78	188	0.000020	0.0000160	0.0000100	0.00020	0.00468	0.000010	0.0000040	0.00020	0.00459	0.00012
MY2692	9-NP-15-4, 45 M	9.36	0.005	0.00128	0.0225	6.47	0.00701	0.0716	0.39	0.0000100	3.59	0.0972	28	72.6	0.000020	0.000118	0.0000050	0.00020	0.00050	0.000010	0.000230	0.00025	0.00017	0.00010

Maxxam Sample No	Sample ID	Total Phosphorus	Orthophosphate	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Potassium (K)	Dissolved Rubidium (Rb)	Dissolved Selenium (Se)	Dissolved Silicon (Si)	Dissolved Silver (Ag)	Dissolved Sodium (Na)	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	SO4	Dissolved Tellurium (Te)	Dissolved Thallium (Tl)	Dissolved Thorium (Th)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Tungsten (W)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)	Dissolved Zirconium (Zr)
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Drinking Water Guidelines	N/G	N/G	0.05	0.02	N/G	N/G	0.01	N/G	0.1	180	N/G	N/G	250	N/G	N/G	N/G	N/G	N/G	N/G	0.017	N/G	3	N/G
MY2656	1-NP-15-2, 15 M	3.54	0.060	0.0138	0.000661	0.141	0.000267	0.000563	3.59	0.0000050	26.1	0.000884	10	4.9	0.000020	0.0000020	0.000175	0.00020	0.0434	0.00111	0.000165	0.0355	0.00307	0.00182
MY2658	3-NP-15-2, 17 M	0.026	0.015	0.000050	0.000202	0.130	0.000674	0.000040	1.57	0.0000050	2.72	0.000247	10	0.7	0.000020	0.0000020	0.0000050	0.00020	0.00050	0.000010	0.0000040	0.00074	0.00118	0.00010
MY2661	6-NP-15-2, 38.5 M	2.28	0.033	0.000645	0.000265	1.01	0.00197	0.000262	2.45	0.0000050	15.8	0.00117	10	9.3	0.000020	0.0000050	0.0000360	0.00020	0.0123	0.000057	0.0000120	0.00117	0.00090	0.00208
MY2662	7-NP-15-2, 54.5 M	0.118	0.005	0.000050	0.0127	6.43	0.0160	0.000976	1.02	0.0000050	25.2	0.120	94	230	0.000020	0.0000110	0.0000050	0.00020	0.00284	0.000010	0.0000140	0.00020	0.00127	0.00010
MY2664	9-NP-15-2, 57.5 M	0.540	0.005	0.00125	0.00476	8.91	0.00896	0.0229	0.55	0.0000050	3.55	0.234	82	198	0.000020	0.0000090	0.0000050	0.00020	0.00095	0.000010	0.00117	0.00020	0.00021	0.00010
MY2666	1-SP-15-3, 21.5 M	4.36	0.093	0.00928	0.000839	1.53	0.000949	0.00112	4.78	0.0000080	41.0	0.00584	10	9.7	0.000020	0.0000040	0.000153	0.00020	0.0413	0.00266	0.000618	0.0583	0.00411	0.00160
MY2668	3-SP-15-3, 33 M	0.151	0.005	0.000308	0.0311	1.73	0.00220	0.00814	1.42	0.0000080	57.3	0.114	55	145	0.000020	0.000146	0.0000050	0.00020	0.00097	0.000046	0.000115	0.00020	0.00043	0.00010
MY2670	5-SP-15-3, 34.5 M	0.127	0.005	0.000050	0.947	1.01	0.00605	0.00515	2.42	0.0000070	45.1	0.219	116	357	0.000020	0.000495	0.000639	0.00020	0.00050	0.000010	0.0987	0.00063	0.636	0.00017
MY2672	2-SP-15-1, 19.5 M	0.006	0.005	0.000050	0.00165	2.13	0.00906	0.000267	1.90	0.0000050	49.2	0.0270	13	34.3	0.000020	0.0000890	0.0000050	0.00020	0.00050	0.000010	0.00108	0.00020	0.00406	0.00010
MY2674	4-SP-15-1, 24.5 M	0.023	0.005	0.000050	0.00127	3.08	0.00726	0.000149	1.13	0.0000050	46.6	0.0344	14	41.1	0.000020	0.0000470	0.0000050	0.00020	0.00050	0.000010	0.0000550	0.00020	0.00416	0.00010
MY2676	6-SP-15-1, FPA.CO M	7.59	0.025	0.000201	0.103	10.9	0.0292	0.0211	2.25	0.0000050	62.6	0.215	150	394	0.000020	0.000369	0.0000050	0.00020	0.00171	0.000010	0.0000410	0.00254	0.0729	0.00010
MY2678	2-SP-15-2, 21 M	0.101	0.005	0.00856	0.000396	5.32	0.00183	0.000300	1.03	0.0000050	205	0.0489	15	37.4	0.000020	0.0000220	0.0000090	0.00020	0.00589	0.000613	0.0000440	0.00226	0.00010	0.00015
MY2680	4-SP-15-2, 26 M	0.036	0.005	0.00776	0.000377	6.46	0.00220	0.000360	1.25	0.0000050	314	0.0927	21	54.1	0.000020	0.0000160	0.0000050	0.00020	0.00214	0.00214	0.0000980	0.00321	0.00010	0.00010
MY2682	6-SP-15-2, 27.5 M	0.047	0.005	0.000050	0.00420	5.42	0.0117	0.000499	2.90	0.0000050	86.0	0.0161	10	25.2	0.000020	0.0000240	0.0000050	0.00020	0.00050	0.000010	0.0000320	0.00020	0.00421	0.00010
MY2684	1-NP-15-4, 15.5 M	0.075	0.047	0.000050	0.00137	0.841	0.00361	0.000040	2.23	0.0000050	2.26	0.000966	10	0.6	0.000020	0.0000060	0.0000050	0.00020	0.00050	0.000010	0.0000060	0.00023	0.00313	0.00010
MY2686	3-NP-15-4, 26 M	0.015	0.008	0.000050	0.00119	1.17	0.00510	0.000071	1.62	0.0000050	3.21	0.00122	10	1.0	0.000020	0.0000080	0.0000050	0.00020	0.00050	0.000010	0.0000050	0.00020	0.00228	0.00010
MY2688	5-NP-15-4, 32 M	0.932	0.016	0.000353	0.000310	0.898	0.00178	0.000213	2.35	0.0000050	2.04	0.00188	10	3.9	0.000020	0.0000040	0.0000890	0.00020	0.0305	0.000017	0.0000220	0.00146	0.00081	0.00096
MY2690	7-NP-15-4, 33.5 M	0.024	0.005	0.000050	0.0123	13.2	0.0329	0.00683	1.62	0.0000050	2.91	0.103	78	188	0.000020	0.0000160	0.0000100	0.00020	0.00468	0.000010	0.0000040	0.00020	0.00459	0.00012
MY2692	9-NP-15-4, 45 M	9.36	0.005	0.00128	0.0225	6.47	0.00701	0.0716	0.39	0.0000100	3.59	0.0972	28	72.6	0.000020	0.000118	0.0000050	0.00020	0.00050	0.000010	0.000230	0.00025	0.00017	0.00010

Maxxam Sample No	Sample ID	Total Phosphorus	Orthophosphate	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Potassium (K)	Dissolved Rubidium (Rb)	Dissolved Selenium (Se)	Dissolved Silicon (Si)	Dissolved Silver (Ag)	Dissolved Sodium (Na)	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	SO4	Dissolved Tellurium (Te)	Dissolved Thallium (Tl)	Dissolved Thorium (Th)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Tungsten (W)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)	Dissolved Zirconium (Zr)
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Baseline Surface Water	N/G	0.14	N/G	0.002	25.30	N/G	N/G	N/G	N/G	769	N/G	N/G	120	N/G	N/G	N/G	N/G	N/G	N/G	N/G	N/G	0.01	N/G
	Baseline Groundwater	N/G	0.15	N/G	0.002	2.80	N/G	N/G	N/G	N/G	42	N/G	N/G	28	N/G	N/G	N/G	N/G	N/G	N/G	N/G	N/G	0.06	N/G
MY2656	1-NP-15-2, 15 M	3.54	0.060	0.0138	0.000661	0.141	0.000267	0.000563	3.59	0.0000050	26.1	0.000884	10	4.9	0.000020	0.0000020	0.000175	0.00020	0.0434	0.00111	0.000165	0.0355	0.00307	0.00182
MY2658	3-NP-15-2, 17 M	0.026	0.015	0.000050	0.000202	0.130	0.000674	0.000040	1.57	0.0000050	2.72	0.000247	10	0.7	0.000020	0.0000020	0.0000050	0.00020	0.00050	0.000010	0.0000040	0.00074	0.00118	0.00010
MY2661	6-NP-15-2, 38.5 M	2.28	0.033	0.000645	0.000265	1.01	0.00197	0.000262	2.45	0.0000050	15.8	0.00117	10	9.3	0.000020	0.0000050	0.0000360	0.00020	0.0123	0.000057	0.0000120	0.00117	0.00090	0.00208
MY2662	7-NP-15-2, 54.5 M	0.118	0.005	0.000050	0.0127	6.43	0.0160	0.000976	1.02	0.0000050	25.2	0.120	94	230	0.000020	0.0000110	0.0000050	0.00020	0.00284	0.000010	0.0000140	0.00020	0.00127	0.00010
MY2664	9-NP-15-2, 57.5 M	0.540	0.005	0.00125	0.00476	8.91	0.00896	0.0229	0.55	0.0000050	3.55	0.234	82	198	0.000020	0.0000090	0.0000050	0.00020	0.00095	0.000010	0.00117	0.00020	0.00021	0.00010
MY2666	1-SP-15-3, 21.5 M	4.36	0.093	0.00928	0.000839	1.53	0.000949	0.00112	4.78	0.0000080	41.0	0.00584	10	9.7	0.000020	0.0000040	0.000153	0.00020	0.0413	0.00266	0.000618	0.0583	0.00411	0.00160
MY2668	3-SP-15-3, 33 M	0.151	0.005	0.000308	0.0311	1.73	0.00220	0.00814	1.42	0.0000080	57.3	0.114	55	145	0.000020	0.000146	0.0000050	0.00020	0.00097	0.000046	0.000115	0.00020	0.00043	0.00010
MY2670	5-SP-15-3, 34.5 M	0.127	0.005	0.000050	0.947	1.01	0.00605	0.00515	2.42	0.0000070	45.1	0.219	116	357	0.000020	0.000495	0.000639	0.00020	0.00050	0.000010	0.0987	0.00063	0.636	0.00017
MY2672	2-SP-15-1, 19.5 M	0.006	0.005	0.000050	0.00165	2.13	0.00906	0.000267	1.90	0.0000050	49.2	0.0270	13	34.3	0.000020	0.0000890	0.0000050	0.00020	0.00050	0.000010	0.00108	0.00020	0.00406	0.00010
MY2674	4-SP-15-1, 24.5 M	0.023	0.005	0.000050	0.00127	3.08	0.00726	0.000149	1.13	0.0000050	46.6	0.0344	14	41.1	0.000020	0.0000470	0.0000050	0.00020	0.00050	0.000010	0.0000550	0.00020	0.00416	0.00010
MY2676	6-SP-15-1, FPA.CO M	7.59	0.025	0.000201	0.103	10.9	0.0292	0.0211	2.25	0.0000050	62.6	0.215	150	394	0.000020	0.000369	0.0000050	0.00020	0.00171	0.000010	0.0000410	0.00254	0.0729	0.00010
MY2678	2-SP-15-2, 21 M	0.101	0.005	0.00856	0.000396	5.32	0.00183	0.000300	1.03	0.0000050	205	0.0489	15	37.4	0.000020	0.0000220	0.0000090	0.00020	0.00589	0.000613	0.0000440	0.00226	0.00010	0.00015
MY2680	4-SP-15-2, 26 M	0.036	0.005	0.00776	0.000377	6.46	0.00220	0.000360	1.25	0.0000050	314	0.0927	21	54.1	0.000020	0.0000160	0.0000050	0.00020	0.00214	0.00214	0.0000980	0.00321	0.00010	0.00010
MY2682	6-SP-15-2, 27.5 M	0.047	0.005	0.000050	0.00420	5.42	0.0117	0.000499	2.90	0.0000050	86.0	0.0161	10	25.2	0.000020	0.0000240	0.0000050	0.00020	0.00050	0.000010	0.0000320	0.00020	0.00421	0.00010
MY2684	1-NP-15-4, 15.5 M	0.075	0.047	0.000050	0.00137	0.841	0.00361	0.000040	2.23	0.0000050	2.26	0.000966	10	0.6	0.000020	0.0000060	0.0000050	0.00020	0.00050	0.000010	0.0000060	0.00023	0.00313	0.00010
MY2686	3-NP-15-4, 26 M	0.015	0.008	0.000050	0.00119	1.17	0.00510	0.000071	1.62	0.0000050	3.21	0.00122	10	1.0	0.000020	0.0000080	0.0000050	0.00020	0.00050	0.000010	0.0000050	0.00020	0.00228	0.00010
MY2688	5-NP-15-4, 32 M	0.932	0.016	0.000353	0.000310	0.898	0.00178	0.000213	2.35	0.0000050	2.04	0.00188	10	3.9	0.000020	0.0000040	0.0000890	0.00020	0.0305	0.000017	0.0000220	0.00146	0.00081	0.00096
MY2690	7-NP-15-4, 33.5 M	0.024	0.005	0.000050	0.0123	13.2	0.0329	0.00683	1.62	0.0000050	2.91	0.103	78	188	0.000020	0.0000160	0.0000100	0.00020	0.00468	0.000010	0.0000040	0.00020	0.00459	0.00012
MY2692	9-NP-15-4, 45 M	9.36	0.005	0.00128	0.0225	6.47	0.00701	0.0716	0.39	0.0000100	3.59	0.0972	28	72.6	0.000020	0.000118	0.0000050	0.00020	0.00050	0.000010	0.000230	0.00025	0.00017	0.00010

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Reg. No. 2014/268110/07

P.O. Box 19287
Noordbrug
2522
South Africa
280 Beyers Naude Ave, Potchefstroom, 2531
Tel +27 (0) 18 2945448
Mobile +27 (0)82 344 2758
http://www.hudsonecology.co.za

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REPORT ON

TERRESTRIAL ECOLOGY BASELINE STUDY FARIM PHOSPHATE PROJECT, GUINEA-BISSAU

Report Number: 2015/009/01

Submitted to:

Scherman Colloty & Associates

1 Rossini Rd
Pari Park
Port Elizabeth
6070

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EXECUTIVE SUMMARY

The Farim Phosphate Project is located in the central northern part of Guinea-Bissau, approximately 25 km south of the Senegal border, approximately 5 km west of the town of Farim and 120 km northeast of Bissau, the capital of Guinea-Bissau. The Project will include an open pit mine, processing plant, waste disposal facilitates and a proposed port facility to the east of Bissau.

A total of 341 plant species were recorded during the surveys. Floral species diversity in the area is moderate to high, but not as high as many regions of West Africa, such as the Upper Guinea Forest zone. A large proportion of the species recorded are indigenous with few exotic species occurring in the area although, in areas of higher anthropogenic disturbances, some exotic species are more prevalent.

Flora assessments were conducted in wet and dry seasons between November 2011 and May 2015 respectively. Based on physiognomy, moisture regime, rockiness, slope and soil properties, seven main communities were recognised, namely:

- *Rhizophora – Avicennia* Mangrove community (Farim and Ponta Chugue study areas);
- Natural Forest vegetation community (Farim study area only);
- Secondary Forest community (Farim study area only);
- *Elias – Cyperus* Floodplain community (Farim and Ponta Chugue study areas);
- *Oryza* Paddy vegetation community (Farim and Ponta Chuge study areas);
- *Dialium - Sterculia* coastal woodland vegetation community (Ponta Chuge study area only); and
- *Anadelphia afzeliana* seasonally wet grassland community.

The *Oryza* Paddy vegetation community occurs in areas of freshwater wetlands which are not affected by tidal ebbs and flows throughout the country, these areas of freshwater wetlands have been modified to facilitate the planting of rice, so alterations to the flow of freshwater systems create large inundated areas where rice is planted. Although tree species are sparse within these areas a few species are often associated with these areas, especially *Anthostema senegalense*, *Elaeis guineensis*, *Pterocarpus santalinoides* and *Sarcocephalus latifolius*. Closer to the permanently inundated areas there are communities in which some common species are *Eichhornia natans*, *Nymphoides indica*, *Ottelia ulvifolia*, *Rotala tenella*, *Sphenoclea zeylanica* and *Utricularia gibba*. The herbaceous layer in this vegetation community is dominated by *Oryza glaberrima, Oryza longistaminata* and *Oryza sativa*, which has been planted for food. The only species found which is known to be listed by the IUCN Red Data list is *Raphia palma-pinus,* which is found along rivers and is listed as Data Deficient. A further two Red Data species *Floscopa axillaris* and *Digitaria patagiata* may also occur in this vegetation community, but due to the fact that the studies were conducted at an inappropriate time to determine this with any certainty, it must be assumed that there is a high probability of occurrence of these species in this vegetation community. A total of 103 flora species were recorded in this vegetation community

Large sections of natural forests have been cleared in order to grow Cashew nuts and other crops. This vegetation community encompasses areas that have been cleared and that have been replanted with Cashew trees (*Anacardium occidentale*). The cashew plantations vary from areas which are dominated by Cashew trees, with some local trees such as *Albizia zygia*, *Detarium senegalense*, *Dialium guineense* and *Malacantha alnifolia* still occurring within these plantations. Other areas have been effectively devoid of natural vegetation and are completely dominated by *Anacardium occidentale.*Many of the areas that have been recently cleared are devoide of larger trees, but still contain many of the species associated with natural forests. These areas may be easily rehabilitated, but areas where a greater deal of disturbance has taken place will be far more difficult to rehabilitate. A total of 145 flora species were recorded in this vegetation community.

Another halophytic community recorded in the study area is the so-called salt water *lala*, a grassland. This vegetation community is found on Fluvisols in the floodplain areas adjacent to the larger rivers which are under tidal influence. The alinity of the water which floods these areas has resulted in the dominance of salt-tolerant species, such as *Paspalum vaginatum* as common species and the communities of *Blutaparum vermiculare , Cyperus amabilis, Cyperus crassipes, Cyperus cyperoides, Cyperus difformis, Cyperus dilatatus* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. The woody layer of these areas is poorly defined but *Hyphaene thebaica, Phoenix reclinata* and *Elias guineensis* occur in this vegetation community with few Adansonia digitata also scattered within this vegetation community. The denuded areas of these areas are widely utilised by local communities for the gathering of salt during the dry season and this vegetation community appears to be an important dry season grazing area. A total of 76 flora species were recorded in this vegetation community

The natural forest community occupies large areas of the northern part of the study area, with some variation in structure and composition. Common tree species include *Albizia zygia*, *Detarium senegalense*, *Dialium guineense, Malacantha alnifolia, Anisophyllea laurina, Dialium guineense, Hunteria umbellata, Malacantha alnifolia, Parinari excelsa* and *Strombosia pustulata.* Lianas such as *Agelaea pentagyna, Calycobolus heudelotii* and *Landolphia dulcis* are also common. The shrub layer is usually poor in these areas, but some common shrub species include *Clerodendrum sinuatum*, *Combretum micranthum* and *Psychotria peduncularis* and among the most frequent climbers are *Mezoneuron benthamianum*, *Saba senegalensis* and *Tetracera potatoria*. This vegetation community is currently under threat due mainly to slash and burn agricultural practises for the cultivation of food crops or Cashew nuts. Although only one Red Data species was recorded in this vegetation community, the likelihood of occurrence of Red Data species in this community is high. A total of 209 flora species were recorded in this vegetation community

Mangrove forests line all the larger rivers in the region. These areas are dominated by *Rhizophora* spp. (mainly *R. mangle* but also *R. racemosa* and to a lesser extent *R. harrisonii*). In the zones less frequently flooded by salt water *Avicennia germinans* is the prominent species. Other halophytic communities are the so-called salt water *lala*, a grassland found on Fluvisols with *Paspalum vaginatum* as common species and the communities of *Blutaparum vermiculare* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. No Red Data species were recorded in this vegetation community and, due to the specialisation required for plants to survive in the tidal saline conditions, it is unlikely that any of the Red Data species, known to occur in the area, will occur in this vegetation community. Species diversity is low in this vegetation community, but species occurring in the area are highly specialised and this vegetation community can be characterised as a unique vegetation community. This vegetation community is integral in the functioning of the estuarine nature of the larger rivers in the area. A total of 29 highly specialised flora species were recorded in this vegetation community.

The *Dialium* - *Sterculia* coastal woodland vegetation community occurs in the transition zone between the terrestrial and the halophytic communities in the coastal regions. According to Catarino (2004), there are three types of coastal transition vegetation, which are usually identified according to species composition of the substratum. The substrata of the transitional zone in the vicinity of Ponta Chugue, for the most part, has been severly transformed, due to cropping of mainly millet (*Pennisetum glaucum*) and peanuts (*Arachis hypogaea*). Many of the tree strata species recorded, by Catarino (2004), to occur on ferralsols (Identified by the redder colour and clayey composition), namely *Dialium guineense*, *Elaeis guineensis*, *Phoenix reclinata*, *Sterculia tragacantha* and *Ximenia Americana* are present in the transitional zone closer to the coast itself. Slightly further inland on the Arenosols (identified by the greyer colour and sandier composition) *Dialium guineense*, *Lannea acida* and *Neocarya macrophylla* are typical species. On the Fluvisols closer to the drainage lines, *Dichrostachys cinerea* subsp. *Platycarpa* var. *platycarpa*, *Phoenix reclinata* and *Vernonia colorata* are dominant.

The most extensive wetland vegetation in the country is the locally called lala, a wet grass savannah with *Anadelphia afzeliana* being the dominant species in this vegetation community. This vegetation community is prevalent on gleysols, which are fine textured soils, deep, grey-coloured, from alluvial origin, with the upper layers often rich in organic matter. Furthermore, this vegetation community prevails in the inner lowland plains flooded by rainwater during the wet season, located mostly in the

lower zones of the mainland. Noticeable in the area of Ponta Chugue, is that this vegetation community is particularly homogenous, with *Anadelphia afzeliana* being by far the most dominant species. It is likely that this is the result of human intervention through the use of fire, or harvesting of this grass species for thatching purposes.

During the surveys two Red Data floral species were recorded (*Albizia ferruginea* and *Raphia palma-pinus*). *Albizia ferruginea* were found within the natural forest areas and *Raphia palma-pinus* was recorded in the *Elias – Cyperus* floodplain and *Oryza* paddy communities. Two more species (*Floscopa axillaris* and *Digitaria patagiata)* may occur in the study areas. Both these species occur in seasonally wet freshwater systems, in the study area the seasonally wet freshwater systems are all but completely transformed into rice paddies, nevertheless both these species have historically been recorded in rice paddies in other parts of Guinea-Bissau and West Africa. All studies conducted in the area were undertaken before or after the height of the wet season when both these species flower. Species of these genera were recorded during the surveys, however without inflorescences and flowers on the plants it is impossible to tell whether the species recorded are the listed species or the unlisted species of the same genera. According to the Precautionary Principle (COMEST, 2005) (as indicated in IFC Performance Standard 6), until conclusive studies to the contrary can be conducted, it must be assumed that these species are present in the freshwater systems within the study area.

The faunal assessment was conducted in the wet and dry seasons between November 2011 and May 2015.

Non-chordate diversity within the study area was relatively high with a total of 124 arthropod species being recorded during the study. Most species recorded were common species with some specialised species being recorded in the mangrove communities. Although the mangrove species are highly specialised for this habitat type, they are locally common and not of conservation importance.Most of the species recorded are not restricted in terms of range and habitat preferences. Common species included Red Winged Dropwing (*Trithemis kirbyi*) and locust (*Locusta* sp.)

The herpetofauna of the region can be classified as having moderate diversity, of the 69 reptile species known to occur in Guinea Bissau, only 11 species recorded. This may be due to the proximity of the project area to the town of Farim and other settlements in the area. Common species occurring in the area include Ornate Monitor (*Varanus ornatus*) (Figure 14) and Tree Agama (*Agama agama*) (Figure 14).

The region can be classified as having low amphibian diversity, of the 34 amphibian species recorded in Guinea Bissau, 5 species were recorded during the 2011/12 surveys. Amphibian species do not appear to be utilized by the local community for food, although some species are said to have superstitious importance or medicinal uses. Of the 5 amphibian species recorded during the surveys, none are listed on the IUCN Red data list for the area. Amphibian species diversity was low. It must be noted that the rivers in the area are tidal and have a very high salinity. These are both characteristics to which amphibians are very sensitive. Due to the permeability of amphibian skin, saline water causes loss of fluids and dehydration in frog species (Vitt & Caldwell, 2009) or as found by Bentley and Schmidt-Nielsen (1971) due to sodium toxicity due to sodium entering through the permeable skin. During their study they found that Rana pipiens (Leopard frog) died within an hour of being placed in sea-water (Bentley & Schmidt-Nielsena, 1971). For this reason most of the rivers in the study area are uninhabitable for amphibian species, and only freshwater systems host this taxon. Five amphibian species were recorded, which included only common species such as *Ametia angolensis* and *Ametiophrynus regularis*, and none of the recorded species are listed as Red Data species or restricted in terms of range or habitat.

Avifaunal diversity in the study area was very high with a large number of upper trophic level species occurring in the area. The Hooded Vulture is currently listed as Endangered by the IUCN (2010). Seventy five species were recorded, these include Palmnut Vulture (*Gypohierax angolensis),* Long-crested eagle *(Lophaetus occipitalis),* Hooded vulture *(Necrosyrtes monachus) and* Gymnogene (*Polyboroides typus).* In general, species diversity was moderate to high throughout the study area with the rice paddies and natural forests showing the highest levels of species diversity.

Mammal species diversity was very low in the study area, probably due to severe subsistence hunting. Hunters were regularly seen or heard during the surveys often with animals ranging from

snakes to monkeys. This not only reduces the number of animals and species in the area, but also causes the remaining animals to be very shy of humans, which in turn makes accurate survey of species occurring in the area very difficult.

Of the 192 mammal species known to occur in the study area, 15 species were recorded during the 2011 to 2015 surveys. The species recorded in the study area include Striped Ground Squirrel (*Xerus erythropus),* Musk shrew *(Crocidura* sp). Lesser Spot-nosed Guenon (*Cercopithecus petaurista),* Red colobus *(Procolobus badius).* Species trapped during the surveys included *Mastomys natalensis* and *Crocidura* sp. All species recorded are common species, with the exception of *Procolobus badius,* which is listed as **Endangered** (IUCN, 2010). It must be noted that this species was recorded dead and being transported by a hunter from some distance away in the natural forests to the north .

A total of 28 Red Data fauna species may occur in the area, according to the IUCN Red Data list. Some of the animals listed are believed to be locally extinct and suitable habitat for others is not available. The Red Data species that may occur in the study area consist of 2 reptile species, 15 avian species and 11 mammal species. The habitat suitability for Red Data species ranges from low to high with 4 species for which the habitat suitability can be classified as high. Only two Red Data species were recorded during the 2011 to 2015 surveys, namely the Red Colobus and the Hooded Vulture, the Red Colobus was, however, killed by a hunter just south of the Senegal border. All indications of this study appear to show that the African slender –snouted crocodile and the West African dwarf crocodile do not occur in this area. Features of the demographics of the crocodile population in the Cacheu river system showed that the crocodile population increases exponentially with an increase in distance from the Cacheu River Mouth. Only two individuals were recorded in the Cacheu River downstream from Farim indicating the majority of individuals of this taxon occurs upstream of the mining area, thereby making it unlikely that the development will have a significant effect on crocodile populations in the river.

The fact that young crocodiles use the area close to the mine site along the river as a nursery area may be a fact which will require more study as dewatering of the mangroves and loss of this habitat may impact crocodile populations.

Although *Necrosyrtes monachus* is currently listed on the IUCN Red Data List as critically endangered (CR), it is a locally common species in the area with a total of more than 600 individuals being recorded during the surveys. This species has become highly human commensal throughout West Africa and is well adapted to anthropogenic disturbance. *Necrosyrtes monachus* appears to be unaffected by the current anthropogenic activities in the area and it is unlikely that the mining will have a significant effect on these species. A monitoring program could be put in place in order to monitor any unforeseen effects.

Due to the specialised nature of *Gypohierax angolensis*, their range is very restricted in the study area. Although a small percentage of palm trees will be lost during the mining operations it is unlikely that this will affect the *Gypohierax angolensis* populations in the area.

Guinea-Bissau has a surprisingly low number of exotic species (one of the lowest in Africa with only eight exotic invasive species occurring in the country). The invasive exotic species known to occur in Guinea Bissau are summarised below:

Lantana camara

Eichhornia crassipes (aquatic plant)

Leucaena leucocephala (tree)

Prosopis spp. (tree, shrub)

Adenanthera pavonina (tree)

Columba livia (bird)

Rattus rattus (mammal)

Mus domesticus (Mammal)

During this study only Lantana camara was recorded in the wild, although some exotic species are resent in the settlement areas. In a country like Guinea-Bissau the introduction of exotic species is of less concern than other impacts, mainly due to the fact that the salinity of the soil and water will exclude many non-indigenous species. The increase in human population may, however, cause an explosion of human commensal species such as Rattus rattus and Mus domesticus, due to the increased food supply. This impact can be mitigated by the implementation of sanitary disposal.

The ecological function of the Farim mine study area can generally be described as moderate for the majority of the study area, although this does vary from low (in the highly transformed areas due to slash and burn cropping techniques) to high in the more inaccessible areas. Areas in which prospecting and slash and burn farming has taken place, as well as areas in which settlements have been established are considered as areas where ecological function is reduced. The cashew plantations and secondary forests appear to both have moderate ecological function, particularly in areas where indigenous species have been allowed to intersperse the Cashew trees. Although areas such as the rice paddies are transformed to some extent, the fauna species composition of these areas seem to indicate that the ecological integrity can still be considered high.

At the Ponta Chugue port site, the ecological integrity of the site varies between high for the *Rhizophora – Avicennia* Mangrove community, *Elias – Cyperus* Floodplain community and the less degraded *Dialium - Sterculia* coastal woodland vegetation community, moderate for the more degraded *Dialium - Sterculia* coastal woodland vegetation community and *Anadelphia afzeliana* seasonally wet grassland community and low for the *Oryza* Paddy vegetation community. The *Oryza* Paddy vegetation community in this area are considered more degraded than those at the Farim mine site due to the fact that there is a monoculture of *Oryza spp*. in these areas, whereas the *Oryza* Paddy vegetation community near the Farim mine site show far greater species diversity, with a large number of indigenous species resent in these areas.

The Farim mine study area falls within the dry tropical forest biome of the Guinean Forest zone and due to the high species diversity and intrinsic conservation value of the area it is classified as having high conservation importance. In order to show area of increased conservation importance due to the presence of Red Data species or other intrinsic factors the area has been divided into areas of low, moderate and high conservation importance (Figure 41). Areas that have been severely disturbed such as settlements are considered of low conservation importance. These areas are, however, quite small in relation to the overall study area (>30% of the study area). Areas that have been disturbed by farming are considered of moderate conservation importance due to the fact that rehabilitation of these areas is possible. The natural forest, floodplain and mangrove areas are considered of very high conservation importance due to the presence of Red Data species in these areas and the intrinsic importance of these areas. Finally, the rice paddies may host two of the red data plant species endemic to the region (*Floscopa axillaris* and *Digitaria patagiata*). During the May 2015 surveys an attempt was made to determine the presence/absence of these species within rice paddies, but the first rains had not yet begun and these annual species were not yet emergent. In keeping with the Precautionary Principle (COMEST, 2005), we need to assume these species are present in these areas until a conclusive study can be conducted

The conservation importance at the Ponta Chugue port site can generally be described as moderate due to the disturbance in the area. The larger population in the surrounding areas and, subsequently, the increased population pressure placed on many of the vegetation communities in the area have resulted in the suitability of these vegetation communities to host Red Data or protected species has been greatly reduced. Two vegetation communities can be considered as having a high conservation importance, these are the less degraded *Dialium - Sterculia* coastal woodland vegetation community and the *Rhizophora – Avicennia* Mangrove community. The presence or absence of listed species in these areas could not be confirmed, due to the studies being conducted during an inappropriate season and it is suggested that studies be conducted to gain more clarity on the presence or absence of listed species in this area.

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1 INTRODUCTION

Hudson Ecology Pty Ltd was commissioned by Knight Piésold Ltd., via Scherman, Colloty and Associates to conduct an ecological assessment of ecosystems associated with the Farim Phosphate Project.

The Farim Phosphate Project is located in the central northern part of Guinea-Bissau, approximately 25 km south of the Senegal border, approximately 5 km west of the town of Farim and 120 km northeast of Bissau, the capital of Guinea-Bissau. The Project will include an open pit mine, processing plant, waste disposal facilitates and a proposed port facility to the east of Bissau.

The initial biodiversity study for this project was conducted in November 2011, and since then a number of studies were conducted by Golder Associates Africa Pty Ltd and Golder Associates (UK) Ltd. The studies conducted pertaining to biodiversity were:

- 2011
  - 08/11/2011 – 17/11/2011 Terrestrial Ecology Baseline Study (Adrian Hudson, Golder Associates Africa Pty Ltd); and
  - 08/11/2011 – 17/11/2011 Aquatic Ecology Baseline Study (Warren Aken, Golder Associates Africa Pty Ltd).
- 2012
  - 05/03/2012 – 14/03/2011 Terrestrial Ecology Baseline Study (Adrian Hudson, Golder Associates Africa Pty Ltd);
  - 05/03/2012 – 14/03/2011 Aquatic Ecology Baseline Study (Warren Aken, Golder Associates Africa Pty Ltd);
  - 15/09/2012- 21/09/2012 Direct Shipping Option terrestrial assessment study (Adrian Hudson, Golder Associates Africa Pty Ltd); and
  - 15/09/2012- 21/09/2012 Direct Shipping Option marine/aquatic assessment study (Isabel Johnson, Golder Associates Africa Pty Ltd).
- 2013
  - 29/08/2013 – 12/09/2013 Species of concern study (Adrian Hudson, Golder Associates Africa Pty Ltd)

This study was conducted in order to supplement these studies, according to the gap analysis by Knight Piesold, which, with regards to the initial reports stated:

- *A survey of flowering plant species of conservation concern was not conducted;and*
- *The issue of invasive plants was not discussed or assessed.*

2 AIMS AND OBJECTIVES

The aim of this study was to update the existing studies with regards to species of concern, with specific reference to flowering plant species, and update the report. The time in the field was also used to update delineations of vegetation communities and assess possible impacts of exotic species.

The objectives in this study can be summarised as follows:

The key aims and objectives of this study included:

- Augment and update the description of the ecological setting in which the project is located;
- Augment data identifying species likely to be impacted by the project with special reference to Red Data fauna and flora species;
- Re-delineate habitats likely to be impacted by the project;
- Assess possible impacts of exotic species;
- Update the terrestrial baseline information to be used in the ESIA; and
- Update the Ecological Impact Assessment according to the recommendations made in the Knight Piesold Gap analysis.

- The terrestrial ecology impact assessment has been prepared separately and integrated into the overall ESIA being prepared by Knight Piésold

3 SCOPE OF WORK

The scope of work for this project includes:

- Review of existing literature on biodiversity of the area;
- Review of previous work conducted for the project;
- A site visit (conducted from the 1st to the 10th of May 2015)
- Rewrite the previous baseline report and impact assessment, using previous and new data, according to the recommendations made in the Knight Piesold gap analysis.

4 METHODOLOGY

In addition to utilising data collected during the initial five site visits, the site was visited between the 1th and 10th of May 2015 to conduct the wet season study of the proposed mine and port areas.

4.1 Desktop review of relevant documentation

The following documents were reviewed in order to obtain secondary data on the terrestrial ecology environment, and also to gain an understanding of the scope and context of the proposed project:

- White, F. (1983). The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa3 plates, Northwestern Africa, Northeastern Africa, and Southern Africa, 1:5,000,000. Paris: UNESCO;

- Bakarr, M.I., G.A.B. da Fonseca, R.A. Mittermeier, A.B. Rylands and K. Walker Painemilla (eds.). 2001. Hunting and Bushmeat Utilization in the African Rain Forest: Perspectives toward a Blueprint for Conservation Action. Advances in Applied Biodiversity Science 2. Center for Applied Biodiversity Science, Conservation International. Washington, DC.

- Barnes, R.F.W. 1999. Is there a future for elephants in West Africa? Mammal Review 29: 175–199.

- Barrie, A. 2002. Post conflict conservation status of large mammals in the Western Area Forest Reserve (WAFR), Sierra Leone. Unpublished M. Sc. thesis. Freetown, Sierra Leone: Njala University College.

- Barrie, A. and O.I. Aalangdong. 2005. Rapid assessment of large mammals at Draw River, Boi-Tano and Krokosua Hills. *In*: McCullough, J., J. Decher, and D. Guba Kpelle (eds.). A Biological Assessment of the Terrestrial Ecosystems of the Draw River, Boi-Tano, Tano Nimiri and Krokosua Hills Forest Reserves, Southwestern Ghana. RAP Bulletin of Biological Assessment 36. Conservation International. Washington, DC. Pp. 67–72, 153.

- Barrie, A. and S. Kante. 2004. A rapid survey of the large mammals of the Forêt Classée du Pic de Fon, Guinea. *In:* McCullough, J. (ed.). A Rapid Biological Assessment of the Forêt Classée du Pic de Fon, Simandou Range, South-eastern Republic of Guinea. RAP Bulletin of Biological Assessment 35. Conservation International. Washington, DC. Pp. 84–90.

- Chapman, C.A., M.J. Lawes and H.A.C. Eeley. 2006. What hope for African primate diversity? African Journal of Ecology 44:116 –133.

- Davies, A.G. 1987. Conservation of primates in the Gola Forest reserves, Sierra Leone. Primate Conservation 8: 151–153.

- Davies, G. and M. Hoffmann (eds.). 2002. African Forest Biodiversity. A Field Survey Manual for Vertebrates. Earthwatch Europe. UK.

- Grubb, P., T.S. Jones, A.G. Davies, E. Edberg, E.D. Starin and J.E. Hill. 1998. Mammals of Ghana, Sierra Leone and The Gambia. The Tendrine Press. Zennor, St Ives.
- Kingdon, J. 1997. The Kingdon Field Guide to African Mammals. Academic Press. San Diego.
- Kormos, R. and C. Boesch. 2003. Regional Action Plan for the Conservation of Chimpanzees in West Africa IUCN/SSC Action Plan. Conservation International. Washington, DC.
- Lee, P.C., J. Thornback and E.L. Bennett. 1988. Threatened Primates of Africa. The IUCN Red Data Book. IUCN. Gland, Switzerland and Cambridge, UK.
- Mittermeier, R.A., P. Robles Gil, M. Hoffmann, J. Pilgrom, T. Brooks, C.G. Mittermeier, J. Lamoreux and G.A.B. da Fonseca (eds.). 2004. Hotspots Revisited. Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. CEMEX/Agrupación Sierra Madre, Mexico City.
- Oates, J.F. 1986. Action Plan for African Primate Conservation 1986 –1990. IUCN/SSC Primate Specialist Group. New York.
- Oates, J.F. 1999. Myth and Reality in the Rainforest: How Conservation Strategies are Failing in Africa. University of California Press. Berkeley.
- Oates, J.F., M. Abedi-Lartey, S. McGraw, T.T. Struhsacker and G.H. Whitesides. 2000. Extinction of a West African red colobus monkey. Conservation Biology 14: 1526–1532.
- Sanderson, J. and M. Trolle. 2005. Monitoring elusive mammals. Unattended camera reveals secrets of some of the world's wildest places. American Scientist 93: 148–155.
- Sayer, J.A., C.S. Harcourt and N.M. Collins (eds.). 1992. The Conservation Atlas of Tropical Forests. Africa. Simon and Schuster. New York.
- Waitkuwait, W.E. and J. Suter. (eds) 2001. Report on the establishment of a community-based bio-monitoring programme in and around Sapo National Park, Sinoe County, Liberia. Unpublished report Flora and Fauna International. Cambridge, UK.
- Waitkuwait, W.E. and Suter, J. ed., 2003. Report on the First Year of Operation of a Community-Based Biomonitoring Programme in and around Sapo National Park, Sinoe County, Liberia. FFI, Cambridge, UK.
- Whitesides, G.H., J.F. Oates, S.M. Green and R.P. Kluberdanz. 1988. Estimating primate densities from transects in a West African rain forest: a comparison of techniques J. Anim. Ecol. 57: 345–367.
- Wilkie, D.S., J.G. Sidle and G.C. Boundzanga. 1992. Mechanised logging, market hunting, and a bank loan in Congo. Conservation Biology 6: 570–580.

4.2 Study area

The regional study area is given in Figure 1, while the local study area is shown in Figure 2 for Farim and Figure 3 for Ponta Chugue. Once on site, the ecology team identified and visited sites associated with the Farim Phosphate Project. The team visited and assessed all vegetation communities and surveyed relevant sites.

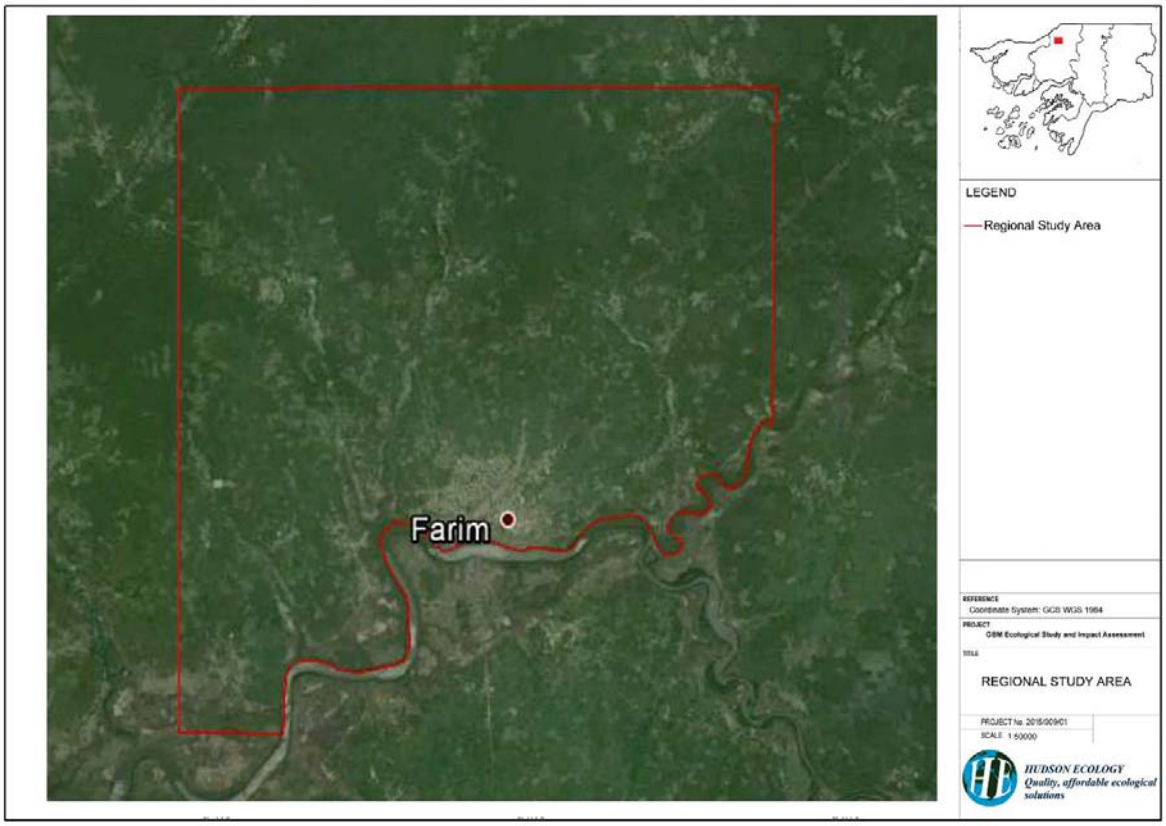

Figure 1: Regional study area

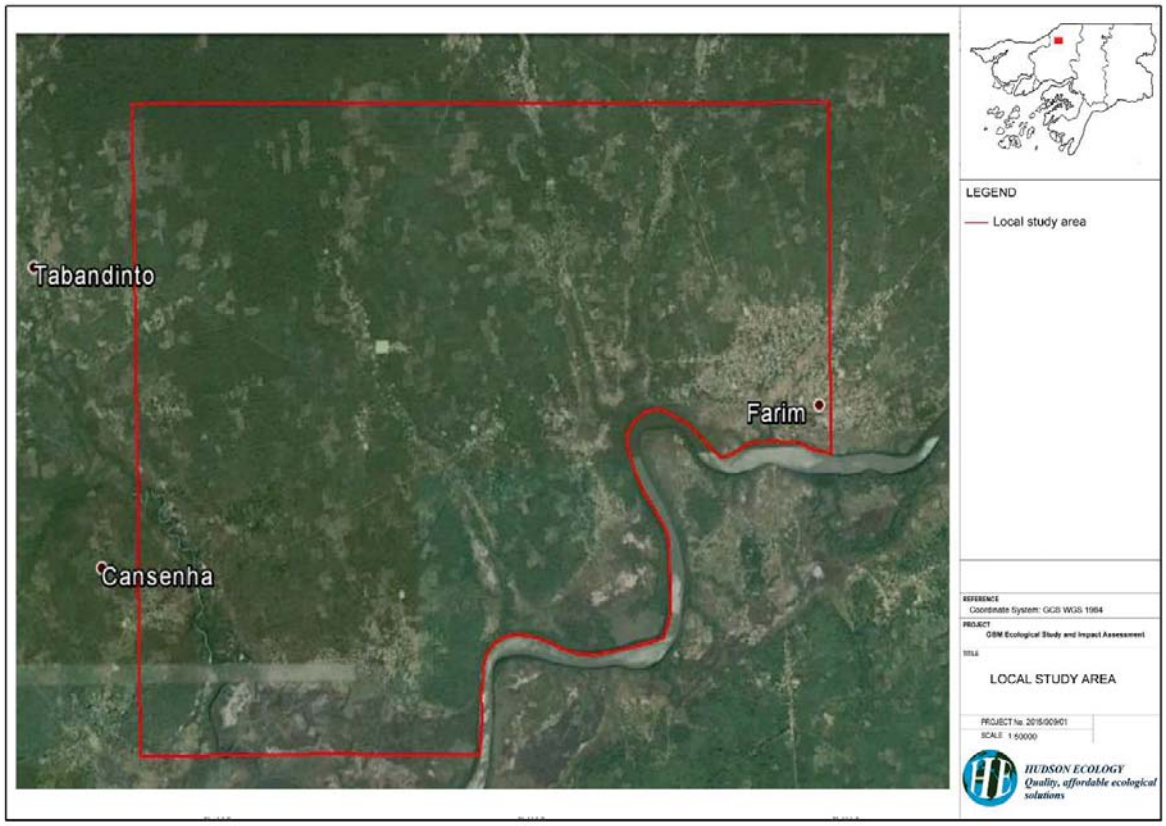

Figure 2: Farim local study area

Figure 3: Ponta Chugue study area

4.3 Methodologies

Twenty study sites were randomly selected within the regional study area (Figure 4). In order to enable a characterization of the environment, as well as floral and faunal species that may be impacted by the proposed mining activities, faunal and floral groups were investigated. These species were then used in order to determine the possible magnitude of the impact of the proposed activities. The groups of species investigated were:

- Vegetation;
- Arthropoda;
- Avifauna;
- Mammals;
- Herpetofauna (Reptiles); and
- Amphibia

All methods implemented during this investigation are based on accepted scientific investigative techniques and principles, and were performed to accepted standards and norms, whilst taking the limitations of this investigation into consideration. The Precautionary Principle was applied throughout the assessments.

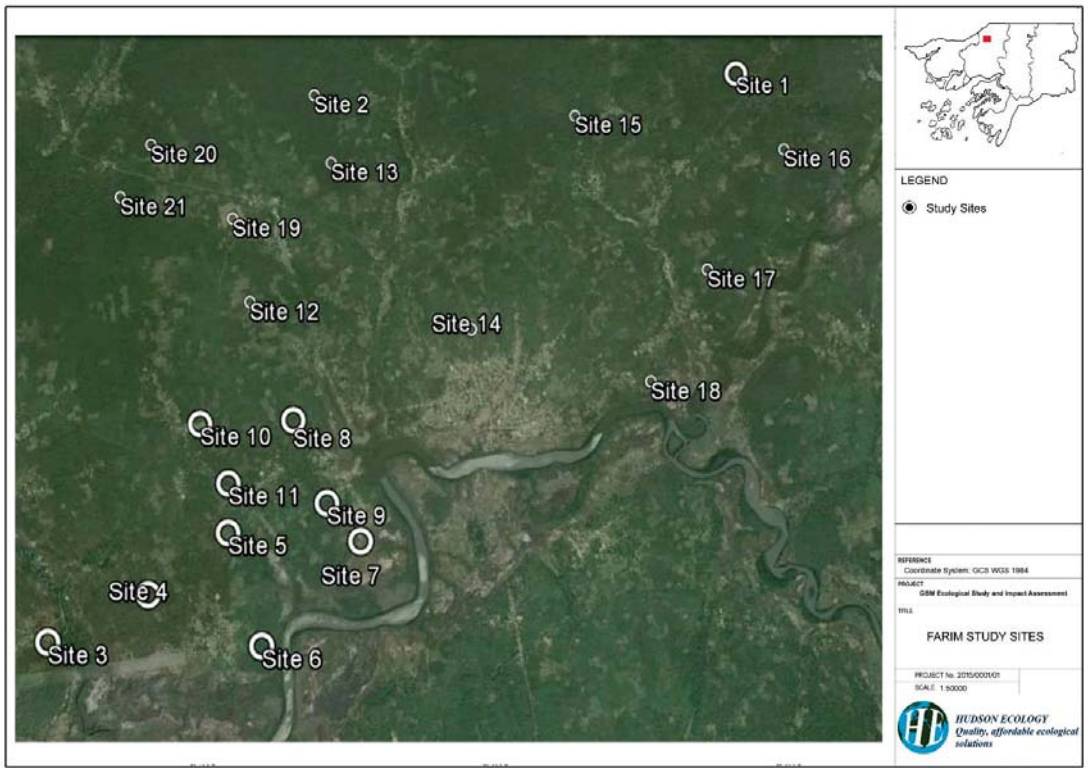

Figure 4: Farim terrestrial ecology study sites

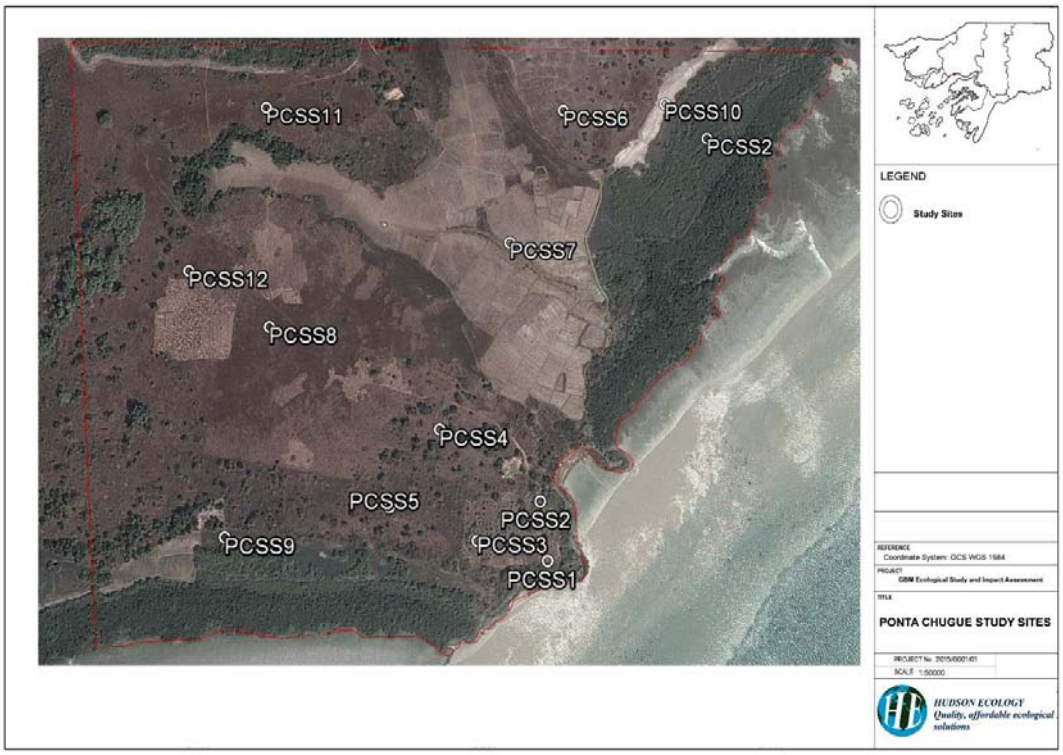

Figure 5: Ponta Chugue terrestrial ecology study sites

4.3.1 General Floristic Attributes

The vegetation assessment was based on a variation of the Braun-Blanquet method whereby vegetation is stratified, by means of aerial or satellite imagery with physiognomic characteristics as a first approximation. Stratification was further augmented by sites being selected to represent each of the areas that will be impacted by the current development footprint. Representative areas within these stratifications are then surveyed by means of line-point transects for grasses, sedges and forbs, as well as belt transects for shrubs and trees. Data obtained from these surveys are then subject to analysis to establish differences or similarities between observed units. Results and species lists provided should be interpreted with the above mentioned survey limitations in mind.

During the floral surveys conducted during a wet season survey in 2011 and a dry season survey in 2012, cognisance was taken of the following environmental attributes and general information:

- Biophysical environment (geology, topography, aspect, slope etc.);
- Regional vegetation;
- Current status of habitats;
- Red Data habitat suitability;
- Digital photographs; and
- GPS reference points.

Phytosociological data accumulated include the following:

- Plant species and growth forms;
- Dominant plant species;
- Cover abundance values; and
- Samples or digital images of unidentified plant species.

The desktop analysis of data was used to establish differences or similarities between vegetation communities, which were then described in terms of floristic species composition as well as driving environmental parameters. Results and species lists provided should be interpreted with the abovementioned survey limitations in mind.

4.3.2 Red Data Floral Assessment

- Compare data collected during the surveys and the IUCN Red Data plant species list to compile a list of Red Data plant species that may potentially occur within the study area.
- A survey of this kind (instantaneous sampling bout or “snapshot” investigations) poses severe limitations to the identification of Red Data plant species. Therefore, emphasis was placed on the identification of habitat that would be suitable for sustaining Red Data plant species, by associating available habitat to known habitat requirements of Red Data plant species.

4.3.3 Floristic Sensitivity Analysis

Floristic sensitivity analysis was determined by taking two factors into account namely ecological function and conservation importance. This sensitivity was quantified by subjectively assessing the ecological function and conservation importance of the vegetation. These were defined as follows:

Ecological Function:

- High ecological function: Sensitive ecosystems with either low inherent resistance or resilience towards disturbance factors or highly dynamic systems considered to be stable and important for the maintenance of ecosystems integrity (e.g. pristine grasslands, pristine wetlands and pristine ridges);

- Medium ecological function: Relatively important ecosystems at gradients of intermediate disturbances. An area may be considered of medium ecological function if it is directly adjacent to sensitive/pristine ecosystem; and

- Low ecological function: Degraded and highly disturbed systems with little or no ecological function.

Conservation Importance:

- High conservation importance: Ecosystems with high species richness and usually provide suitable habitat for a number of threatened species. Usually termed 'no-go' areas and unsuitable for development, and should be protected;

- Medium conservation importance: Ecosystems with intermediate levels of species diversity without any threatened species. Low-density development may be allowed, provided the current species diversity is conserved; and

- Low conservation importance: Areas with little or no conservation potential and usually species poor (most species are usually exotic).

The Precautionary Principle was applied throughout this investigation (COMEST, 2005).

4.3.4 General Faunal Attributes

4.3.4.1 Arthropoda

Arthropods were surveyed by means of setting out of pitfall traps, in selected areas within the various vegetation communities, and intensive transects making use of visual identification. Furthermore capture of species on the wing was also undertaken in order to aid identification, this was done by means of sweep-netting. Identification of species was done to the lowest possible taxonomic level using *inter alia* Picker et al (2002).

Suitable habitat was identified for scorpions, spiders and butterflies in order to select areas in which to sample by means of pitfall traps and visual identification, as well as to determine the possibility of the occurrences of Red Data or protected species of these taxa.

4.3.4.2 Reptilia

Suitable areas were identified and sampled using active search and capture methods, searches were concentrated in rocky areas and disused ant hills were investigated for the presence of snakes. Snakes and other reptiles are identified visually and only captured if visual identification is hampered by swift-moving snakes or if the snake is obscured from view. Branch (1996) and Broadley (1971) were used as identification guides, where necessary.

4.3.4.3 Amphibia

Suitable areas for frogs were sampled by means of active search and capture and acoustic identification methods, especially at night when highest amphibian activity is expected. Areas were also netted for tadpoles and amphibian species identified by means of tadpoles. Du Preez and Carruthers (2009) was used to confirm identification where necessary.

4.3.4.4 Aves

Avifauna were surveyed by means of transects and point counts (Bibby, et al., 1993) and visual identification and the calls of bird species were used to identify species. Wherever possible, visual identification was used to confirm call identifications. Bird ranges were confirmed using Harrison *et al* (1997). Other guides were also utilised (Hockey, et al., 2005) (International, 2000) (Sinclair & Ryan, 2003)

4.3.4.5 Mammalia

Visual sightings and ecological indications were used to identify the small mammal inhabitants of the study area. Scats were also collected and used for identification of nocturnal small mammals. A number of reference sources *inter alia* Stuart and Stuart (2007) and Smithers (1983) were used for identification purposes.

4.3.5 Red Data Faunal Assessment

The following parameters were used to assess the Probability of Occurrence of each Red Data species:

- Habitat requirements (HR) – Most Red Data animals have very specific habitat requirements and the presence of these habitat characteristics in the study area was evaluated;
- Habitat status (HS) – The status or ecological condition of available habitat in the area is assessed. Often a high level of habitat degradation prevalent in a specific habitat will negate the potential presence of Red Data species (this is especially evident in wetland habitats); and
- Habitat linkage (HL) – Movement between areas for breeding and feeding forms an essential part of the existence of many species. Connectivity of the study area to surrounding habitat and the adequacy of these linkages are evaluated for the ecological functioning of Red Data species within the study area.

Probability of occurrence is presented in four categories, namely:

- Low;
- Medium;
- High; and
- Recorded.

In order to assess the status of Red Data fauna species in the study area, the following sources were used:

- IUCN Red List Categories and Criteria (IUCN, 2001); and
- IUCN Red List of Threatened Species (IUCN, 2011).

5 ASSUMPTIONS AND LIMITATIONS

- Accuracy of the maps, ecosystems, routes and desktop assessments were made using Google earth and converting the .kml files to .shp files and are subject to the accuracy of Google Earth imagery with some loss of accuracy during the conversion process;
- GPS co-ordinates are accurate to within 10m and lines drawn on maps can only be assumed to be accurate to within a distance of 100m;
- Data obtained from published articles, reference books, field guides, official databases or any other official published or electronic sources are assumed to be correct and no review of such data was undertaken by Hudson Ecology Pty Ltd;
- Satellite imagery obtained was limited to imagery on Google Earth, thus the ability to accurately map vegetation communities was limited;
- Time and budget constraints do not allow for an intensive survey of the entire study area, and as with any survey of this kind, rare and cryptic species may be overlooked during the study;

- Every possible precaution was taken to reduce the effect of the above-mentioned limitations on the data collected for this study.

- The fact that a species or Red Data species is not recorded during a survey cannot support the assumption that the species in question does not occur in the area, it can only indicate a decreased probability of the species occurring in the area. This is particularly pertinent if the species has been recently or historically recorded in the area; and

- Ecological studies should be undertaken over a number of seasons in order to obtain long term ecological data. Studies are usually conducted in this way in order to eliminate the effects of unusual climatic conditions or other unusual conditions prevailing at the study area during the time of study. The results of this study are based on a literature review, data collected during previous studies in the area and a single field survey conducted in early May 2015.

- The wet season study conducted in early May 2015 did not represent ideal conditions for a wet season study as it was conducted before the beginning of the wet season and annual plant species were not emergent, and thus not visible or identifiable for study. Many migratory bird species were also no longer present in the area.

6 RESULTS

This section provides a detailed discussion of the terrestrial ecology baseline environment and context in which the proposed project will take place within the Farim Phosphate Project exploration area.

6.1 Physical Setting

Guinea-Bissau is located in the Northern Intertropical Zone of West Africa, between 10°59' – 12°20' north and 13°40' – 16°43' west, having a surface area of 36,125 km^2. It is bordered by the Republic of Senegal to the north, the Republic of Guinea to the east and south and by the Atlantic Ocean to the west. The country includes a continental mainland and a group of 40 islands, the Bijagós Archipelago, not far from the continent. There are also some other islands separated from the continent only by narrow sea straits, such as Bolama, Pecixe and Melo.

6.1.1 Geomorphology

The geomorphology of the Guinean territory shows a smooth relief, with most of the land below 50 m altitude. The coastal zones are mainly lowlands. With the high tide range occurring here, reaching up to 6 m, extensive areas in the coastal zones remain exposed to the daily tidal effect. Most of the inner centre and north-eastern parts of the country are occupied by scarcely raised plains, where the altitude does not surpass 100 m.

The inner south-eastern region is the hilliest region of the country but the Boé Hills, the most raised part of their territory, only reach 298 m altitude (Mota, 1954). The islands of the Bijagós Archipelago show morphology similar to the mainland, with a sinuous shoreline and low altitudes.

The hydrographic network is complex and extensive. In addition to the climate, it is conditioned by the levelling of the territory and by the marine transgression (Ribeiro, 1950). Low altitudes in a large portion of the territory allow flooding of extensive areas in the river banks and coastal plains, which can remain flooded during the rainy season and even several weeks after its end. The same occurs often in lowland inner plains with slow superficial drainage and impermeable soils.

Because water flow has a strong dependence on rainfall, the fresh watercourses show a seasonal flow regime, classified as tropical pluvious (Costa, 1946). As a consequence most of the streams and some rivers dry up by the end of the dry season. There are a few permanent fresh watercourses in the country with the Corubal, Farim and Geba being the most important rivers. Most of the locally called rivers are in fact estuaries and inlets, which penetrate deeply in the continental territory due to the plain relief.

In addition to the rivers, there are some small lakes in the country, namely in the southern and eastern regions. Temporary pools with variable sizes, locally called *vendus*, are common in the south-east (Alves, 2000).

6.1.2 Climate

Without geomorphologic features sufficiently marked to influence it, the climate in Guinea-Bissau depends mainly on its geographic position between the tropics. The climate, and particularly the rain regime, is conditioned by the seasonal migration of the Intertropical Convergence Zone (ITCZ).

In the dry season, from November to May, the ITCZ is positioned to the south of the territory, which is under the influence of continental, dry air masses coming from the north-east or north (White, 1983). When the ITCZ, in its yearly movement from south to north reaches the territory, the rainy season begins. The rains start usually in late May or early June, advance from south-west to north-east and last during the length of time in which the ITCZ is over or has moved to the north of the country. The rainy season usually ends in late October, when the ITCZ returns south. Annual rainfall is the climatic factor that shows the largest differences in the country, decreasing from 2400–2600 mm in the south-west to 1200–1400 mm in the north-east (White, 1983).

The differences in temperature between regions are small: the annual means vary from 25.9 to 27.1 °C and the mean annual temperature in the country is around 26.5 °C. There are two annual maxima and minima in the air temperature: by the end of the dry season, in April or May, there is a primary maximum and in October or November a secondary one. The mean minimum temperatures have a primary minimum in the December or January and a secondary one in August, in the rainy season. The annual thermal ranges are also low: the differences between the annual minimum and maximum averages vary from 7.0 to 14.7 °C which is greater in the eastern inner region (WWF & IUCN, 1994).

The relative humidity shows large seasonal variations related to the rain regime and the prevailing winds. Their annual means vary from 69 to 79%. Hayward & Oguntoyinbo (1987), in a classification of the climatic regions in West Africa locate the country in zone 7 West, characterized by rains from June to November, with a peak in August, annual rainfall from 1500 to 2000 mm and the higher annual temperatures occurring in April–May. According to Fosberg *et al.* (1961) only the coastal part of the country is included in the humid tropics.

6.1.3 Soils

As most tropical soils, the greater part of Guinea-Bissau soils are poor both in organic matter and ion exchange bases. The most representative soil groups in the country are Ferralsols, Plinthosols, Gleysols, Fluvisols and Arenosols. There are other substrates that cannot be considered as soils, such as lateritic cuirasses and mud deposits (WWF & IUCN, 1994).

Ferralsols – deep soils with a sandy or sandy-clayish texture, are very common all over the country. The soils of this group are quite poor in nutrients and organic matter and, according to the topographic position can have red, orange, yellow or grey colours. The natural vegetation in these soils is mainly woodland and savannah woodland, as well as forest in the south-west of the country. Most of the country's agriculture is done on this kind of soils.

Plinthosols – mineral soils that show, at small deepness, layers of lateritic materials more or less consolidated. These soils occur in a greater extent in the inner part of the country, and particularly in the south-east and are occupied mostly by woodland and savannah woodland. Even though these soils are poor and shallow, some areas are used for rain fed agriculture.

Arenosols – sandy soils, mainly quartzose, scarce in organic matter, deep and well drained. Derived from consolidated dunes, these occur in belts in the north and south coastal regions of the mainland as well as in some islands in the Bijagós archipelago and are mainly covered by savannah woodland.

Gleysols – fine textured soils, deep, grey-coloured, from alluvial origin, with the upper layers often rich in organic matter. Occurring mainly in the inner lowlands and near the upper and middle courses of rivers in the continental territory and in some islands, Gleysols are almost absent in the inner east region. As most of the Gleysols are flooded in the rainy season, the natural vegetation is mainly composed of wet grass savannah, locally called *lala*. They are often used to crop wetland rice.

Fluvisols – fine textured soils from fluvial origin occur along the coastline and in the lower courses of rivers. They are often reached by salt water and therefore rich in sodium. The natural vegetation on the Fluvisols is mainly mangrove and grass savannah, and this kind of soils is often cropped with wetland rice, after an ingenious desalinization process.

Other substrates – the lateritic cuirasses are layers of secondary rock at the surface, not covered by fine earth particles that fill only the gaps and holes. In most cases only sparse herbaceous vegetation develops on it. The coastal muds and sands are flooded on each high tide and most of them support mangrove.

6.1.4 Current Status and Land Use

Natural resources found in Guinea-Bissau include fish, timber, phosphates, bauxite, clay, granite, limestone and unexploited deposits of petroleum. 8.31% of the land is arable and 250 square kilometres is irrigated. Natural hazards include a hot, dry, dusty harmattan haze that may reduce visibility during the dry season and brush fires. Severe environmental issues include deforestation; soil erosion; overgrazing and overfishing (White, 1983).

6.1.5 Regional Overview of the Vegetation

The coastal lowlands are covered by dense forests, mostly swamp forests, while the interior is savanna covered, with gallery forests along streams. The low coasts and estuarine shores are cloaked by mangroves, indeed there is little coastline that is not so vegetated. The exceptions are a 15 km strip along Vareola Bay, south of Cape Roxo and immediately north of the Cacheu River mouth, which is sandy, and a 3 km strip south of Point Cabaciera (12°02'N/16°20'W), which is sandy/rocky. Other shores devoid of mangroves occur on the offshore islands, e.g. the north facing shores of Caravella, Carache and Bubaque Islands, and the west facing shores of Caravella, Uno and Orango Islands. The outermost islands, Unhocomo and Unhocomomozinho, are rocky (Catarino, et al., 2008) .

Upstream of the mangroves, and behind them, are swamps dominated either by palms and pandans, or by freshwater swamp forest trees. Inland the country is characterised by low hills, 30-100 m asl. There is little flat land and no important wetland. However, almost all the narrow gallery forests are subject to periods of inundation during the rainy season (Catarino, et al., 2008) .

Tidal forests (mangroves) cloak much of the coast and extend far up many streams. They reach 160 km up the Cacheu River, where after they grade into palm swamps and freshwater swamp forest. This latter vegetation once extended for another 42 km upstream to the town of Farim (12°29'N/15°13'W), but much of it has been replaced by rice fields. Towards the river mouth the mangroves reach a maximum width of 15 km on the north bank. Once there were more than 110 000 ha of mangrove forest and 13 000 ha of freshwater swamp forest on this single river system, but 10 -15 % has been cleared in recent years. Tidal forests, backed by freshwater swamp forests, used to extend for 110 km up the Mansoa River, but here too most of the upper 65 km of brackish and freshwater forests have been cleared. Mangrove forests still reach 35 km up the Tombali River, but up the Cumbija River the upper 55 km have again been cleared. On this river mangroves now occupy only the lower 15 km. By contrast, the Geba Estuary, the largest inlet in Guinea Bissau, never had extensive mangroves, being characterised by banks of high relief. Nevertheless, a major block of 9000 ha, which used to extend along the south bank upstream from the mouth for nearly 50 km, reaching widths of 3 km, has now been reduced to scattered stands. Above this, for many kilometres upstream, mangroves have always been scarce although small stands do occur in suitable sites. The estuaries of the Grande de Buba and Cacine Rivers are also lacking in extensive mangrove forests, except near their mouths. The offshore islands are partly fringed by mangroves, but this is a coast of submergence and the high islands of the Bijagos Archipelago, which represent old hilltops, rise quite steeply from the sea in places. However, all along the coast, numerous recent offshore mudbanks are largely, or even completely, covered by mangroves. There were approximately 250 000 ha of tidal forest in Guinea Bissau in 1975, but this had been reduced by 15-20% by 1986 (Catarino, et al., 2008).

The mangrove and Guinean/Soudanian freshwater swamp forest flora is as described in the regional introduction. The fauna is typical of tropical West African coastal swamps, again as detailed in the regional introduction. The coastal mudflats are important as a wintering ground for Palearctic waders, and the Bijagos Islands support many sea birds (Catarino, et al., 2008).

Mangrove timber has long been cut for fuel, and mangrove poles are used for building. There are many villages in the mangroves, and fish, crabs and prawns from the mangroves have traditionally been an important source of protein for the people. Many thousands of hectares of swamp forest have been cleared for rice cultivation, particularly on the upstream ends of estuarine swamp forests. Annual production now exceeds 45 000 tonnes, and this is to be increased. Fishing is the second most important export industry in Guinea Bissau, most of the fish being trawled offshore and exported to the USSR. These fish and prawns however, spend their juvenile stages in the mangroves, and the vast annual catches, exceeding 100 000

tonnes of fish and 2000 tonnes of prawns, will inevitably alter the balance of the estuarine food chains. Overfishing is a fact rather than a threat (Catarino, et al., 2008).

Floodplains occur on almost all rivers in Guinea Bissau above the limits of tidal influence. They extend, in semi-continuous fashion, up the Corubal for 230 km to the border with Guinea, and far up the Geba River. In general they are forested, but narrow, about 0.5-2 km wide. Many hectares of riverine floodplain have been cleared for rice paddy (Catarino, et al., 2008).

6.2 Flora Assessment

In the currently accepted phytogeographic framework of Africa (White, 1983), Guinea-Bissau is included in the Guinea-Congolia/Sudania regional transition zone, or zone XI. As a consequence of human intervention, mainly fire and shifting agriculture, the more common vegetation types in this zone are secondary formations, such as woodland and savannah woodland. On the other hand, some residual patches of closed forest types may have significant affinities to the peripheral and driest types of Guinean forest. Nevertheless, according to White (1983), even before the increase of human activity that has led to vegetation degradation in most of the area, the open formations could have been already dominant, especially where the soils are shallow. Thus, the phytogeographic zone XI can be characterized by the occurrence of transition woodland types, which are an ecotone between the Guineo-Congolian forest to the south and the woodland and savannah woodland to the north and north-east of the zone.

A number of rivers flow across the study area in a general north-south direction. These rivers flow into the Farim River (also known as the Cacheu River along its lower length), which then flows approximately 110km to the Atlantic Ocean. Most of the rivers feeding the Farim River are seasonal and flow only during the wet seasons, but the main river and larger tributaries can be classified as permanent and are tidal in nature. In this region rainfall is circa 2100 mm/yr and the floodplain areas are inundated during the wet season. The floodplains, in the area, are regularly inundated by saline water and therefore do not support plant species which are not tolerant of salinity.

A total of 341 plant species were recorded during the surveys. Floral species diversity in the area is moderate to high, but not as high as many regions of West Africa, such as the Upper Guinea Forest zone. A large proportion of the species recorded are indigenous with few exotic species occurring in the area although, in areas of higher anthropogenic disturbances, some exotic species are more prevalent.

6.2.1 Vegetation Communities

Flora assessments were conducted in wet and dry seasons between November 2011 and May 2015 respectively. Based on physiognomy, moisture regime, rockiness, slope and soil properties, seven main communities were recognised, namely:

- *Rhizophora – Avicennia* Mangrove community (Farim and Ponta Chugue study areas);
- Natural Forest vegetation community (Farim study area only);
- Secondary Forest community (Farim study area only);
- *Elias – Cyperus* Floodplain community (Farim and Ponta Chugue study areas);
- *Oryza* Paddy vegetation community (Farim and Ponta Chuge study areas);
- *Dialium - Sterculia* coastal woodland vegetation community (Ponta Chuge study area only); and
- *Anadelphia afzeliana* seasonally wet grassland community.

These vegetation communities are shown in Figure 6. A further “vegetation community” namely township vegetation community was identified within the villages and towns in the area, but due to the transformed nature of these areas, these communities were not extensively surveyed and are indicated in Figure 6 in black.

The total area of the study area was calculated to be 19566.4ha. **Error! Reference source not found.** gives he relative areas of each of the vegetation communities to the study area.

Table 1: Areas of vegetation communities at Farim

Vegetation Community	Area in ha	% of total study area
Rhizophora – Avicennia Mangrove community	1005.5	5.14%
Natural Forest vegetation community	5034.9	25.73%
Secondary Forest community	10174.2	52.00%
Elias – Cyperus Floodplain community	1254.4	6.41%
Oryza Paddy vegetation community	1325	6.77%
Townships	772.4	3.95%
Total	**19566.4**	**100.00%**

Table 2: Areas of vegetation communities at Ponta Chugue

Vegetation Community	Area in ha	% of total study area
Rhizophora – Avicennia Mangrove community	11.2	19%
Dialium - Sterculia coastal woodland vegetation community	15.5	27%
Anadelphia afzeliana seasonally wet grassland community	17	29%
Elias – Cyperus Floodplain community	2.9	5%
Oryza Paddy vegetation community	11.8	20%
Total	**58.4**	**100%**

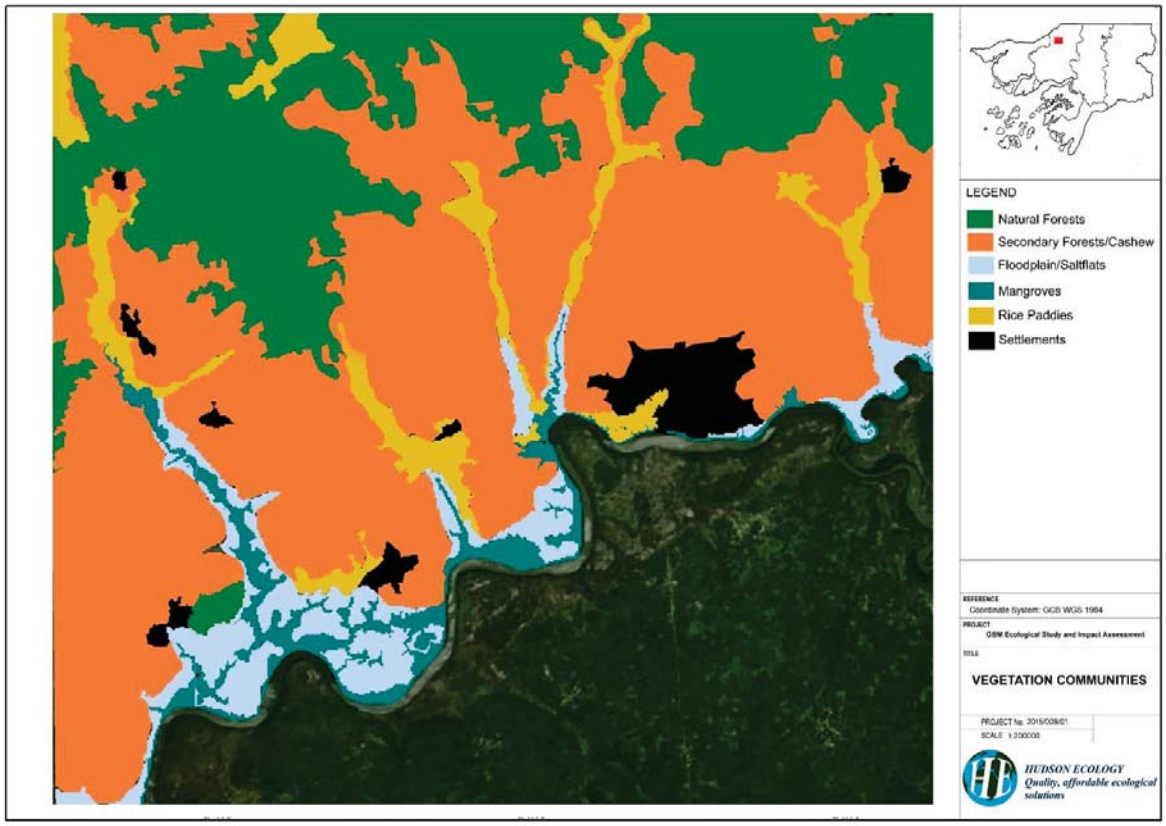

Figure 6: Farim phosphate study area showing vegetation communities

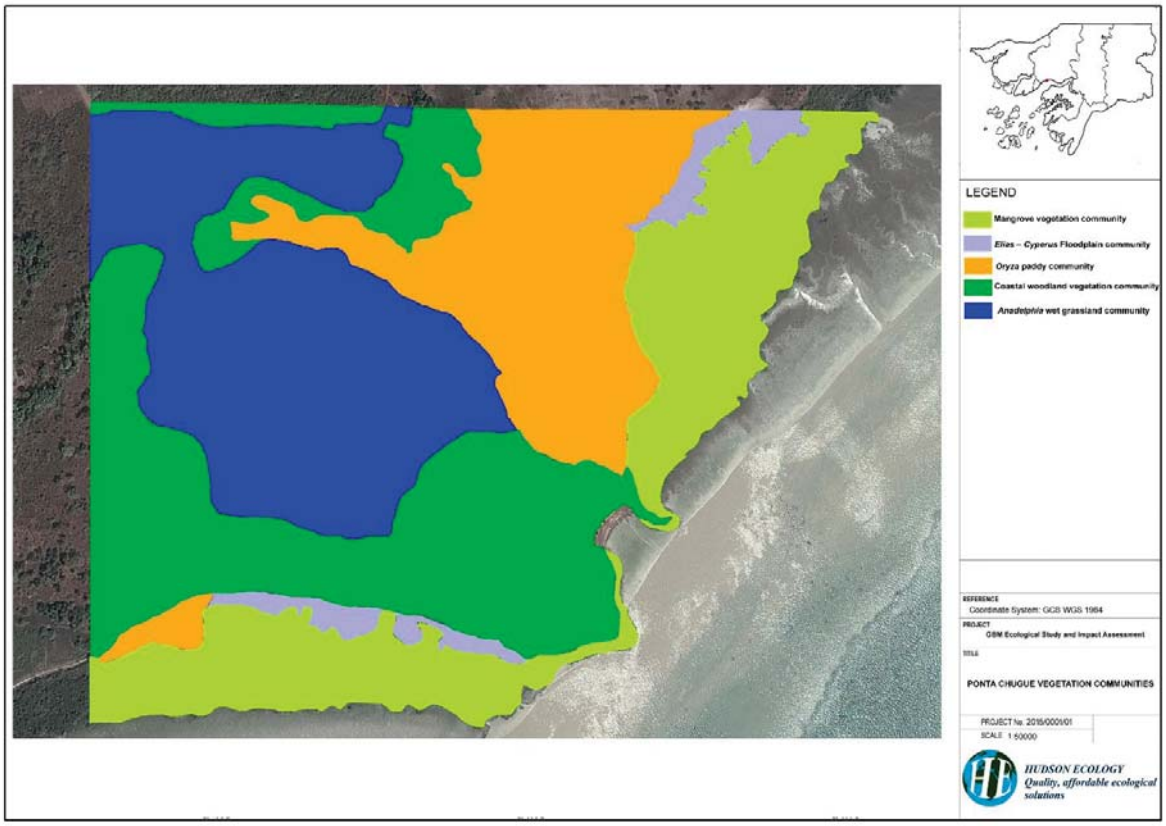

Figure 7: Ponta Chugue Vegetation Communities

6.2.1.1 Oryza paddy community

This vegetation community occurs in areas of freshwater wetlands which are not affected by tidal ebbs and flows throughout the country, these areas of freshwater wetlands have been modified to facilitate the planting of rice, so alterations to the flow of freshwater systems create large inundated areas where rice is planted. Although tree species are sparse within these areas a few species are often associated with these areas, especially *Anthostema senegalense*, *Elaeis guineensis*, *Pterocarpus santalinoides* and *Sarcocephalus latifolius*. Closer to the permanently inundated areas there are communities in which some common species are *Eichhornia natans*, *Nymphoides indica*, *Ottelia ulvifolia*, *Rotala tenella*, *Sphenoclea zeylanica* and *Utricularia gibba*. The herbaceous layer in this vegetation community is dominated by *Oryza glaberrima, Oryza longistaminata* and *Oryza sativa*, which has been planted for food. The only species found which is known to be listed by the IUCN Red Data list is *Raphia palma-pinus,* which is found along rivers and is listed as Data Deficient. A further two Red Data species *Floscopa axillaris* and *Digitaria patagiata* may also occur in this vegetation community, but due to the fact that the studies were conducted at an inappropriate time to determine this with any certainty, it must be assumed that there is a high probability of occurrence of these species in this vegetation community. A total of 103 flora species were recorded in this vegetation community and complete list of species for this vegetation community is given in APPENDIX A .

Sensitivity aspects

- This vegetation community has been moderately disturbed;
- As little vegetation clearing takes place for this agriculture, this vegetation community could be relatively easily rehabilitated to a natural state;
- Moderate species diversity;

- Floristic status of this variation is low - moderate;
- Suitability of the habitat for Red Data flora and faunal species is high;
- One floral Red Data species, *Raphia palma-pinus,* was found in this vegetation community;
- Ecological integrity of this community is Moderate; and
- The Conservation importance of this community is moderate.

6.2.1.2 Secondary Forest community

Large sections of natural forests have been cleared in order to grow Cashew nuts and other crops. This vegetation community encompasses areas that have been cleared and that have been replanted with Cashew trees (*Anacardium occidentale*). The cashew plantations vary from areas which are dominated by Cashew trees, with some local trees such as *Albizia zygia*, *Detarium senegalense*, *Dialium guineense* and *Malacantha alnifolia* still occurring within these plantations. Other areas have been effectively devoid of natural vegetation and are completely dominated by *Anacardium occidentale.*Many of the areas that have been recently cleared are devoide of larger trees, but still contain many of the species associated with natural forests. These areas may be easily rehabilitated, but areas where a greater deal of disturbance has taken place will be far more difficult to rehabilitate. A total of 145 flora species were recorded in this vegetation community and a complete list of recorded species in this vegetation community is given in APPENDIX A.

Sensitivity aspects

- This vegetation community has been moderately to severely disturbed;
- Depending on the severity of the vegetation clearing , which has taken place, rehabilitation of this vegetation community could be relatively easily conducted, but in more severely degraded areas rehabilitation will be more difficult;
- Low - moderate species diversity;
- Floristic status of this variation is low - moderate;
- Suitability of the habitat for Red Data flora and fauna species is moderate;
- No floral Red Data species were recorded in this vegetation community;
- Ecological integrity of this community is moderate; and
- The Conservation importance of this community is moderate.

6.2.1.3 Elias – Cyperus Floodplain community

Another halophytic community recorded in the study area is the so-called salt water *lala*, a grassland. This vegetation community is found on Fluvisols in the floodplain areas adjacent to the larger rivers which are under tidal influence. The alinity of the water which floods these areas has resulted in the dominance of salt-tolerant species, such as *Paspalum vaginatum* as common species and the communities of *Blutaparum vermiculare , Cyperus amabilis, Cyperus crassipes, Cyperus cyperoides, Cyperus difformis, Cyperus dilatatus* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. The woody layer of these areas is poorly defined but *Hyphaene thebaica, Phoenix reclinata* and *Elias guineensis* occur in this vegetation community with few Adansonia digitata also scattered within this vegetation community. The denuded areas of these areas are widely utilised by local communities for the gathering of salt during the dry season and this vegetation community appears to be an important dry season grazing area. A total of 76 flora species were recorded in this vegetation community and are given in APPENDIX A.

Sensitivity aspects

- This vegetation community has been very slightly disturbed in some areas, mainly due to trampling by cattle;
- Where degraded rehabilitation of this vegetation community will occur naturally;
- Low species diversity due to the effects of the saline water on this vegetation community, but many specialised species occur;
- Floristic status of this variation is low - moderate;
- Suitability of the habitat for Red Data flora and fauna species is moderate to high;
- No floral Red Data species were recorded in this vegetation community;
- Ecological integrity of this community is high; and
- The Conservation importance of this community is high.

6.2.1.4 Natural Forest community

The natural forest community occupies large areas of the northern part of the study area, with some variation in structure and composition. Common tree species include *Albizia zygia*, *Detarium senegalense*, *Dialium guineense, Malacantha alnifolia, Anisophyllea laurina, Dialium guineense, Hunteria umbellata, Malacantha alnifolia, Parinari excelsa* and *Strombosia pustulata.* Lianas such as *Agelaea pentagyna, Calycobolus heudelotii* and *Landolphia dulcis* are also common. The shrub layer is usually poor in these areas, but some common shrub species include *Clerodendrum sinuatum*, *Combretum micranthum* and *Psychotria peduncularis* and among the most frequent climbers are *Mezoneuron benthamianum*, *Saba senegalensis* and *Tetracera potatoria*. This vegetation community is currently under threat due mainly to slash and burn agricultural practises for the cultivation of food crops or Cashew nuts. Although only one Red Data species was recorded in this vegetation community, the likelihood of occurrence of Red Data species in this community is high. A total of 209 flora species were recorded in this vegetation community and are given in APPENDIX A

Sensitivity aspects

- This vegetation community has been very slightly disturbed in some areas;
- Where degraded rehabilitation of this vegetation community will occur naturally, if not further impacted;
- Moderate to high species diversity;
- Floristic status of this variation is moderate - high;
- Suitability of the habitat for Red Data flora and fauna species is high, with one Red Data species recorded;
- Ecological integrity of this community is high; and
- The Conservation importance of this community is high.

6.2.1.5 Rhizophora – Avicennia Mangrove community

Mangrove forests line all the larger rivers in the region. These areas are dominated by *Rhizophora* spp. (mainly *R. mangle* but also *R. racemosa* and to a lesser extent *R. harrisonii*). In the zones less frequently flooded by salt water *Avicennia germinans* is the prominent species. Other halophytic communities are the so-called salt water *lala*, a grassland found on Fluvisols with *Paspalum vaginatum* as common species and the communities of *Blutaparum vermiculare* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. No Red Data species were recorded in this vegetation community and, due to the

specialisation required for plants to survive in the tidal saline conditions, it is unlikely that any of the Red Data species, known to occur in the area, will occur in this vegetation community. Species diversity is low in this vegetation community, but species occurring in the area are highly specialised and this vegetation community can be characterised as a unique vegetation community. This vegetation community is integral in the functioning of the estuarine nature of the larger rivers in the area. A total of 29 highly specialised flora species were recorded in this vegetation community and are given in APPENDIX A.

Sensitivity aspects

- This vegetation community has been very slightly disturbed in some areas;
- Where degraded rehabilitation of this vegetation community will occur naturally, if not further impacted;
- Moderate to high species diversity;
- Floristic status of this variation is moderate - high;
- Suitability of the habitat for Red Data flora and fauna species is high, with one Red Data species recorded;
- Ecological integrity of this community is high; and
- The Conservation importance of this community is high.

6.2.1.6 Dialium guineense - Sterculia tragacantha coastal woodland vegetation community

This particular kind of vegetation occurs in the transition zone between the terrestrial and the halophytic communities in the coastal regions. According to Catarino (2004), there are three types of coastal transition vegetation, which are usually identified according to species composition of the substratum. The substrata of the transitional zone in the vicinity of Ponta Chugue, for the most part, has been severly transformed, due to cropping of mainly millet (*Pennisetum glaucum*) and peanuts (*Arachis hypogaea*). Many of the tree strata species recorded, by Catarino (2004), to occur on ferralsols (Identified by the redder colour and clayey composition), namely *Dialium guineense*, *Elaeis guineensis*, *Phoenix reclinata*, *Sterculia tragacantha* and *Ximenia Americana* are present in the transitional zone closer to the coast itself. Slightly further inland on the Arenosols (identified by the greyer colour and sandier composition) *Dialium guineense*, *Lannea acida* and *Neocarya macrophylla* are typical species. On the Fluvisols closer to the drainage lines, *Dichrostachys cinerea* subsp. *Platycarpa* var. *platycarpa*, *Phoenix reclinata* and *Vernonia colorata* are dominant.

Sensitivity aspects

- This vegetation community has been disturbed in some areas;
- Where degraded rehabilitation of this vegetation community will occur naturally, if not further impacted;
- Moderate to high species diversity;
- Floristic status of this variation is moderate - high;
- Suitability of the habitat for Red Data flora and fauna species is moderate;
- Ecological integrity of this community is moderate; and
- The Conservation importance of this community is moderate.

6.2.1.7 Anadelphia afzeliana wet grassland community

The most extensive wetland vegetation in the country is the locally called lala, a wet grass savannah with *Anadelphia afzeliana* being the dominant species in this vegetation community. This vegetation community is prevalent on gleysols, which are fine textured soils, deep, grey-coloured, from alluvial origin, with the upper

layers often rich in organic matter. Furthermore, this vegetation community prevails in the inner lowland plains flooded by rainwater during the wet season, located mostly in the lower zones of the mainland. Noticeable in the area of Ponta Chugue, is that this vegetation community is particularly homogenous, with *Anadelphia afzeliana* being by far the most dominant species. It is likely that this is the result of human intervention through the use of fire, or harvesting of this grass species for thatching purposes.

Sensitivity aspects

- The homogeneity of this vegetation community is indicative of it being perturbed by human intervention;
- Rehabilitation of this vegetation community will occur naturally, if not further impacted;
- Low to moderate species diversity;
- Floristic status of this variation is moderate;
- Suitability of the habitat for Red Data flora and fauna species is low, although *Floscopa axillaris* and *Digitaria patagiata* have a moderate to high probability of occurence in this vegetation community;
- Ecological integrity of this community is moderate; and
- The Conservation importance of this community is moderate.

6.2.2 Species of Importance

During the surveys two Red Data floral species were recorded (Table 3). One species were found within the natural forest areas and the other was recorded in the *Elias – Cyperus* floodplain and *Oryza* paddy communities.

Table 3 shows the Red Data floral species that may occur in the area according to the IUCN Red Data list, with the recorded species indicated.

It must be kept in mind that more Red Data species may occur in the area, but due to inaccessibility of certain areas, the presence of other Red Data species could not be verified. No Red Data species were recorded within the area to be affected by the mining during the studies conducted.

Table 3: Red Data floral species for Guinea-Bissau

Family	Scientific Name	Red List status	Probability of Occurrence	Likely host vegetation community
LEGUMINOSAE	*Afzelia africana*	VU	High	Natural forest
LEGUMINOSAE	*Albizia ferruginea*	VU	Recorded	Natural forest
GRAMINEAE	*Digitaria patagiata*	DD	High	*Oryza* Rice paddies, *Anadelphia afzeliana* wet grassland community
COMMELINACEAE	*Floscopa axillaris*	DD	High	*Oryza* Rice paddies, *Anadelphia afzeliana* wet grassland community
MELIACEAE	*Khaya senegalensis*	VU	Moderate	Natural forest
PODOSTEMACEAE	*Ledermanniella adamesii*	DD	Low	Open fresh water systems
MORACEAE	*Milicia regia*	VU	Low	Natural forest
PALMAE	*Raphia palma-pinus*	DD	Recorded	*Elias – Cyperus* floodplain, Anadelphia afzeliana wet grassland community and *Oryza* paddy communities

6.2.2.1 Floscopa axillaris

6.2.2.1.1 Description

Nearly glabrous, except the inflorescence. Appears to be an annual. Base of stem procumbent, rooting copiously from many nodes, whence spring clusters of weak stems 2–5 in. long, obliquely erect, very leafy. Leaves 1/2–1 in. long, elliptic or lanceolate, acute. Panicles terminal, and terminal on short axillary branches, pubescent. Ultimate branches of the inflorescence nearly 1 in. long, with numerous small flowers. Pedicels hardly 1/20 in. long; bracts at their base 1/16 in. long, ovate. Capsule and seeds of the genus.

Figure 8: Floscopus axillaris

6.2.2.1.2 Background

6.2.2.1.2.1 ***Justification:***

The species distribution is relatively widespread but there is a lack of information on the size and trend of the population and also on major threats. More information is needed before a full assessment can be made. It is currently listed as Data Deficient (Diop, 2010)

6.2.2.1.2.2 ***Geographic Range***

Figure 9: Distribution of Floscopa axillaris

Countries: Benin; Burkina Faso; Guinea; Guinea-Bissau; Senegal; Sierra Leone (Diop, 2010)

6.2.2.1.2.3 ***Demography***

Population: Unknown. (Diop, 2010)

Population Trend: Unknown (Diop, 2010)

6.2.2.1.2.4 ***Habitat and Ecology***

Habitat and Ecology: Marshes and swamps. Shallow water, temporary or permanent, still streams, grassy marshes and rice fields. (Diop, 2010)

Systems: Freshwater

6.2.2.1.2.5 ***Threats***

Major Threat(s): Unknown. (Diop, 2010)

6.2.2.1.2.6 ***Conservation Actions***

Conservation Actions: Research actions needed. (Diop, 2010)

6.2.2.2 Digitaria patagiata

6.2.2.2.1 Description

Culms prostrate; 5–20 cm long; rooting from lower nodes. Leaf-sheaths hirsute. Leaf-sheath auricles erect. Ligule an eciliate membrane; 1–2.5 mm long. Leaf-blades 2.5–3 cm long; 1–2 mm wide. Leaf-blade surface hirsute.Inflorescence composed of racemes. Racemes 1; single; unilateral; 1–6 cm long. Rhachis angular. Spikelet packing lax. Spikelets in pairs. Fertile spikelets pedicelled; 2 in the cluster. Pedicels unequal. Spikelets comprising 1 basal sterile florets; 1 fertile florets; without rhachilla extension. Spikelets lanceolate; dorsally compressed; 3 mm long; falling entire. Glumes two; dissimilar; reaching apex of florets; thinner than fertile lemma. Lower glume oblong; clasping; 0.25–0.33 length of spikelet; hyaline; pallid; without keels; 0 -veined. Lower glume lateral veins absent. Lower glume apex truncate. Upper glume elliptic; 1 length of spikelet; membranous; without keels; 5 -veined. Upper glume surface pilose; hairy between veins; with

verruculose hairs. Upper glume apex acute. Basal sterile florets barren; without significant palea. Lemma of lower sterile floret elliptic; 1 length of spikelet; membranous; 5 -veined; pilose; hairy between veins; with verruculose hairs; with dorsal tufts of hair (at base); 2 hair tufts in all; acute. Fertile lemma elliptic; 2.7 mm long; cartilaginous; much thinner on margins; pallid; without keel. Lemma margins flat; covering most of palea. Lemma apex acute. Palea cartilaginous.

Figure 10: Digitaria patagiata

6.2.2.2.1.1 ***Background***

A poorly known species. Further research is required on the population, range and threats. Listed as Data Deficient. (Diop & Mahamane, 2010)

6.2.2.2.1.2 ***Geographic Range***

Figure 11: Distribution of Digitaria patagiata

Limited area in western Casamance and in Guinea (Kindia and Friguiagbé) and Guinea-Bissau. The species could be further widespread, there is a record listed for Nigeria (Diop & Mahamane, 2010).

Countries: Guinea; Guinea-Bissau; Senegal (Diop & Mahamane, 2010)

6.2.2.2.1.3 ***Population***

Population: Unknown. (Diop & Mahamane, 2010)

Population Trend: Unknown (Diop & Mahamane, 2010)

6.2.2.2.1.4 ***Habitat and Ecology***

Occurs in moist soils, rice fields and temporary flooded areas. Mat forming. (Diop & Mahamane, 2010)

Systems: Terrestrial; Freshwater (Diop & Mahamane, 2010)

6.2.2.2.1.5 ***Use and Trade [top]***

This species is utilized but no specific information about its use is available. (Diop & Mahamane, 2010)

6.2.2.2.1.6 ***Threats***

Major Threat(s): Unknown. (Diop & Mahamane, 2010)

6.2.2.2.1.7 ***Conservation Actions***

Conservation Actions: In Senegal at least occurs in some protected areas. Research on the population, range and threats are required (Diop & Mahamane, 2010).

6.2.2.3 Results

Both these species occur in seasonally wet freshwater systems, in the study area the seasonally wet freshwater systems are all but completely transformed into rice paddies, nevertheless both these species have historically been recorded in rice paddies in other parts of Guinea-Bissau and West Africa. All studies conducted in the area were undertaken before or after the height of the wet season when both these species flower. Species of these genera were recorded during the surveys, however without inflorescences and flowers on the plants it is impossible to tell whether the species recorded are the listed species or the unlisted species of the same genera. According to the Precautionary Principle (COMEST, 2005) (as indicated in IFC Performance Standard 6), until conclusive studies to the contrary can be conducted, it must be assumed that these species are present in the freshwater systems within the study area.

6.3 Fauna Assessment

The faunal assessment was conducted in the wet and dry seasons between November 2011 and May 2015.

6.3.1 Recorded Faunal Species

6.3.1.1 Non-chordates

Non-chordate diversity within the study area was relatively high with a total of 124 arthropod species being recorded during the study. Most species recorded were common species with some specialised species being recorded in the mangrove communities. Although the mangrove species are highly specialised for this habitat type, they are locally common and not of conservation importance.Most of the species recorded are not restricted in terms of range and habitat preferences. Common species included Red Winged Dropwing (*Trithemis kirbyi*) (Figure 12) and locust (*Locusta* sp.)(Figure 12. The complete list of species recorded is given in APPENDIX B.

Figure 12: Trithemis kirbyi

Figure 13: Locusta sp.

6.3.1.2 Herpetofauna

The herpetofauna of the region can be classified as having moderate diversity, of the 69 reptile species known to occur in Guinea Bissau (APPENDIX C), only 11 species recorded. This may be due to the proximity of the project area to the town of Farim and other settlements in the area. Common species occurring in the area include Ornate Monitor (*Varanus ornatus*) (Figure 14) and Tree Agama (*Agama agama*) (Figure 14). The complete list of recorded species is given in

Table 4.

Figure 14: Agama agama

Figure 15: Varanus ornatus

Table 4: Reptile species recorded in the study area.

Family	Scientific Name	IUCN Status
AGAMIDAE	*Agama agama*	Not Listed
ELAPIDAE	*Bitis arietans*	Not Listed
ELAPIDAE	*Causus rhombeatus*	Not Listed
CROCODYLIDAE	*Crocodylus niloticus*	Not Listed
COLUBRIDAE	*Dasypeltis fasciata*	Not Listed
ELAPIDAE	*Naja melanoleuca*	Not Listed
ELAPIDAE	*Naja nigricollis*	Not Listed
COLUBRIDAE	*Philothamnus irregularis*	Not Listed
COLUBRIDAE	*Psammophis lineatus*	Not Listed
VARANUS	*Varanus exanthematicus*	Not Listed
VARANUS	*Varanus ornatus*	Not Listed

6.3.1.3 Amphibia

The region can be classified as having low amphibian diversity, of the 34 amphibian species recorded in Guinea Bissau (APPENDIX D), 5 species were recorded during the 2011 to 2015 surveys. Amphibian species do not appear to be utilized by the local community for food, although some species are said to have superstitious importance or medicinal uses. Of the 5 amphibian species recorded during the surveys, none are listed on the IUCN Red data list for the area. Amphibian species diversity was low. It must be noted that the rivers in the area are tidal and have a very high salinity. These are both characteristics to which amphibians are very sensitive. Due to the permeability of amphibian skin, saline water causes loss of fluids and dehydration in frog species (Vitt & Caldwell, 2009) or as found by Bentley and Schmidt-Nielsen (1971) due to sodium toxicity due to sodium entering through the permeable skin. During their study they found that Rana pipiens (Leopard frog) died within an hour of being placed in sea-water (Bentley & Schmidt-Nielsena, 1971). For this reason most of the rivers in the study area are uninhabitable for amphibian species, and only freshwater systems host this taxon. Five amphibian species were recorded (Table 5), which included only common species such as *Ametia angolensis* (Figure 16) and *Ametiophrynus regularis* (Figure 16), and none of the recorded species are listed as Red Data species or restricted in terms of range or habitat.

Figure 16: Ametia angolensis

Figure 17: Ametiophrynus regularis

Table 5: Amphibian species recorded in the study area.

Family	Genus & Species	IUCN Status
BUFONIDAE	*Amietophrynus regularis*	Not Listed
HYPEROLIIDAE	*Hyperolius occidentalis*	Not Listed
HYPEROLIIDAE	*Kassina senegalensis*	Not Listed
PHRYNOBATRACHIDAE	*Phrynobatrachus natalensis*	Not Listed
RANIDAE	*Ametia angolensis*	Not Listed

6.3.1.4 Avifauna

Avifaunal diversity in the study area was very high with a large number of upper trophic level species occurring in the area. The Hooded Vulture is currently listed as Endangered by the IUCN (2010). Seventy five species were recorded and are indicated in APPENDIX E, these include Palmnut Vulture (*Gypohierax angolensis),* Long-crested eagle *(Lophaetus occipitalis),* Hooded vulture *(Necrosyrtes monachus) and* Gymnogene (*Polyboroides typus).*

Figure 18: Long-crested Eagle (Lophaetus occipitalis)

Figure 19: Hooded Vulture (Necrosyrtes monachus)

In general, species diversity was moderate to high throughout the study area with the rice paddies and natural forests showing the highest levels of species diversity.

6.3.1.5 Mammalia

Mammal species diversity was very low in the study area, probably due to severe subsistence hunting. Hunters were regularly seen or heard during the surveys often with animals ranging from snakes to monkeys. This not only reduces the number of animals and species in the area, but also causes the remaining animals to be very shy of humans, which in turn makes accurate survey of species occurring in the area very difficult.

Of the 192 mammal species known to occur in the study area (APPENDIX F), 15 species were recorded during the 2011 to 2015 surveys. The species recorded in the study area include Striped Ground Squirrel (*Xerus erythropus),* Musk shrew *(Crocidura* sp). Lesser Spot-nosed Guenon (*Cercopithecus petaurista),* Red colobus *(Procolobus badius).* Species trapped during the surveys included *Mastomys natalensis* and *Crocidura* sp. All species recorded are common species, with the exception of *Procolobus badius,* which is listed as **Endangered** (IUCN, 2010). It must be noted that this species was recorded dead and being transported by a hunter from some distance away in the natural forests to the north . The species recorded are listed in Table 6.

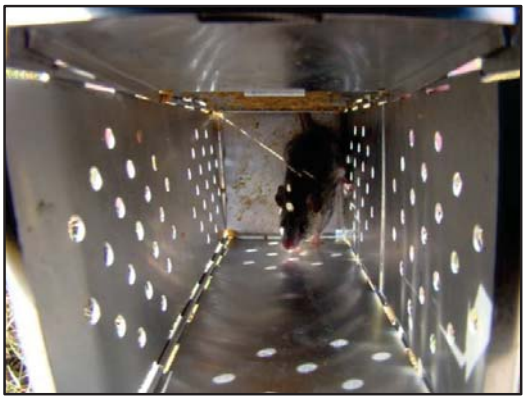

Figure 20: Mastomys natalensis

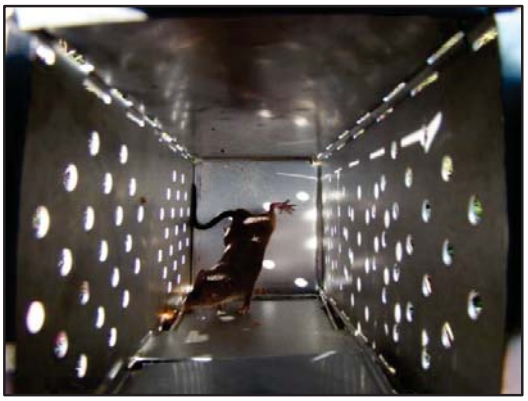

Figure 21: Crocidura poensis

Table 6: Mammal species recorded in the study area

Family	Scientific Name	IUCN Status
BOVIDAE	*Cephalophus monticola*	
CERCOPITHECIDAE	*Cercopithecus aethiops*	
CERCOPITHECIDAE	*Cercopithecus petaurista*	
CERCOPITHECOIDEA	*Procolubus badius*	EN
GALAGIDAE	*Galago senegalensis*	
HYSTRICIDAE	*Atherurus africanus*	
MURIDAE	*Lemniscomys striatus*	
MURIDAE	*Mastomys erythroleucus*	
MURIDAE	*Mastomys natalensis*	
MURIDAE	*Praomys rostratus*	
NESOMVIDAE	*Cricetomys gambianus*	
NESOMVIDAE	*Dendromus melanotis*	
NYCTERIDAE	*Nycteris gambiensis*	
SCIURIDAE	*Xerus erythropus*	
SORICIDAE	*Crocidura poensis*	
VESPERTILIONIDAE	*Pipistrellus nanulus*	

6.3.2 Red Data Faunal Species

Red Data faunal species that may occur in the area are listed in Table 7. A total of 28 Red Data fauna species may occur in the area, according to the IUCN Red Data list. Some of the animals listed are believed to be locally extinct and suitable habitat for others is not available. According to the abovementioned criteria with regard to habitat, probability of the species occurrence in the area affected by the mining project was determined and is give in Table 7.

Table 7: Red Data fauna species which may occur in the study area

FAMILY	Scientific Name	Common Name	IUCN STATUS	Probability of Occurence
GRUIDAE	*Balearica pavonina*	Black Crowned-Crane	VU	High
BUCEROTIDAE	*Ceratogymna elata*	Yellow-casqued Hornbill	NT	High
ACCIPITRIDAE	*Circaetus beaudouini*	Beaudouin's Snake-Eagle	VU	High
ACCIPITRIDAE	*Circus macrourus*	Pallid Harrier	NT	Moderate
SCOLOPACIDAE	*Gallinago media*	Great Snipe	NT	Low
ACCIPITRIDAE	*Gyps africanus*	White-backed Vulture	NT	Low
ACCIPITRIDAE	*Gyps rueppellii*	Rueppell's Griffon	NT	Low
SCOLOPACIDAE	*Limosa limosa*	Black-tailed Godwit	NT	Moderate
ACCIPITRIDAE	*Necrosyrtes monachus*	Hooded Vulture	EN	Recorded
ACCIPITRIDAE	*Neophron percnopterus*	Egyptian Vulture	EN	Low
OTIDIDAE	*Neotis denhami*	Stanley Bustard	NT	Low
SCOLOPACIDAE	*Numenius arquata*	Eurasian Curlew	NT	Moderate
PHOENICOPTERIDAE	*Phoenicopterus minor*	Lesser Flamingo	NT	Moderate
PSITTACIDAE	*Psittacus erithacus*	Gray Parrot	NT	Moderate
ACCIPITRIDAE	*Trigonoceps occipitalis*	White-headed Vulture	VU	Low
CANIDAE	*Lycaon pictus*	African Wild Dog	EN	Locally Extinct
CERCOPITHECIDAE	*Cercocebus atys*	Sooty Mangabey	VU	Low
CERCOPITHECIDAE	*Colobus polykomos*	King Colobus	VU	Low
CERCOPITHECOIDEA	*Papio papio*	Guinea Baboon	NT	Low
CERCOPITHECOIDEA	*Procolubus badius*	Red Colobus	EN	Recorded
ELEPHANTIDAE	*Loxodonta africana*	African Bush Elephant	VU	Locally Extinct
FELIDAE	*Panthera leo*	Lion	VU	Locally Extinct
FELIDAE	*Panthera pardus*	Leopard	NT	Locally Extinct
HIPPOPOTAMIDAE	*Hippopotamus amphibius*	Common Hippopotamus	VU	Locally Extinct
HOMINIDAE	*Pan troglodytes*	Common Chimpanzee	EN	Locally Extinct
PTEROPODIDAE	*Eidolon helvum*	Straw-coloured Fruit Bat	NT	High
CROCODYLIDAE	*Mecistops cataphractus*	Slender-snouted Crocodile	DD	Low
CROCODYLIDAE	*Osteolaemus tetraspis*	African Dwarf Crocodile	VU	Low

The Red Data species that may occur in the study area consist of 2 reptile species, 15 avian species and 11 mammal species. The habitat suitability for Red Data species ranges from low to high with 4 species for which the habitat suitability can be classified as high. Only two Red Data species were recorded during the

2011 to 2015 surveys, namely the Red Colobus and the Hooded Vulture (Table 7), the Red Colobus was, however, killed by a hunter just south of the Senegal border.

6.3.2.1 Crocodiles

According to the IUCN (IUCN, 2013), three species of crocodiles are known to occur in Guinea-Bissau, namely:

- The Nile crocodile (Crocodylus niloticus)
- The West African dwarf crocodile (Osteolaemus tetraspis)
- The African slender-snouted crocodile (Mecistops cataphractus)

According to the latest IUCN assessments the *Mecistops cataphractus* is thought to be extinct in Senegal, the Gambia and Guinea-Bissau. Furthermore, although reported to occur in Guinea-Bissau, by the IUCN, there is some conflicting information with regards to *Osteolaemus tetraspis's* range, with many literature sources only indicating its range as far west as Guinea.

Osteolaemus tetraspis and *Mecistops cataphractus* are also known to be strictly freshwater species and therefore do not occur in estuaries and other saline or brackish-water systems. Because the water in the Cacheu River system has very high salinity, it is highly unlikely that either of these species would occur within the study area.

Descriptions of each of the crocodile species, known to occur in the region, are given in sections 6.3.2.1.1 to 6.3.2.1.3 below.

6.3.2.1.1 The Nile crocodile (Crocodylus niloticus)

Figure 22: Crocodylus niloticus

6.3.2.1.1.1 Description

Nile crocodiles have a dark bronze colouration above, with black spots on the back and a dirty purple on the belly. The flanks, which are yellowish-green in colour, have dark patches arranged in oblique stripes and green eyes. There is some variation relative to environment; specimens from swift-flowing waters tend to be lighter in colour than those dwelling in lakes or swamps.

Like all crocodiles, the Nile crocodile is a quadruped with four short, splayed legs, a long, powerful tail, a scaly hide with rows of ossified scutes running down its back and tail, and powerful jaws. It has nictitating membranes to protect the eyes and lachrymal glands to cleanse its eyes with tears. The nostrils, eyes, and ears are situated on the top of the head, so the rest of the body can remain concealed underwater. The coloration also helps to camouflage it; juveniles are grey, multi-coloured, or brown, with dark cross-bands on the tail and body. As it matures, it becomes darker and the cross-bands fade, especially those on the body.

The Nile crocodile is the largest crocodilian in Africa and is the second-largest crocodilian after the saltwater crocodile. The male crocodile usually measure from 3.5 to 5 m long, but very old, mature ones can grow to 5.5 m or more (Somma, 2002). Mature female Nile crocodiles measure 2.4 to 3.8 m. Like all crocodiles they are sexually dimorphic, with the males up to 30% larger than the females, though the difference is less compared to some species, like the saltwater crocodile (Somma, 2002).

Typical Nile crocodile weight is from 225 to 550 kg, though exceptionally large males can range up to 900 kg or more, in weight (Somma, 2002).

Evidence exists of Nile crocodiles from cooler climates like the southern tip of Africa being smaller, and may reach lengths of only 4 m. Dwarf Nile crocodiles also exist in Mali and in the Sahara Desert, which reach only 2 to 3 m in length. Their reduced size is probably the result of the less than ideal environmental conditions, not genetics (Somma, 2002).

6.3.2.1.1.2 *Geographic Range*

Range Description

The Nile crocodile is the most common crocodilian found in Africa today. They are common throughout the continent (Figure 23). Their historic range however, was even wider. They were found as north as the Mediterranean coast in the Nile delta. Today they are common in Somalia, Ethiopia, Uganda, Kenya, Egypt, Central African Republic, Republic of the Congo, Democratic Republic of the Congo, Burkina Faso, Equatorial Guinea, Nigeria, Tanzania, Rwanda, Burundi, Zambia, Zimbabwe, Gabon, Angola, South Africa, Malawi, Mozambique, Sudan, South Sudan, Botswana, and Cameroon. Isolated populations also exist in Madagascar and in Senegal. They are recorded by Herodotus to have inhabited Lake Moeris. They are thought to have become extinct in the Seychelles in the early 19th century. They are known from fossil remains to have once inhabited Lake Edward (Guggisberg, 1972). The Nile crocodile's current range of distribution extends from the Senegal River, Lake Chad, Wadai and the Sudan to the Cunene and the Okavango Delta. In Madagascar, crocodiles occur in the western and southern parts from Sembirano to Port Dauphin. They have occasionally been spotted in Zanzibar and the Comoros (Guggisberg, 1972). Until recently, many permanent waters in the Sahara still housed relict populations (Hekkala, et al., 2011).

Countries

According to the Crocodile Specialist Group (1996a) , *C. niloticus* occurs in Angola (Angola), Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Congo, The Democratic Republic of the, Côte d'Ivoire, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, United Republic of, Togo, Uganda, Zambia and Zimbabwe.

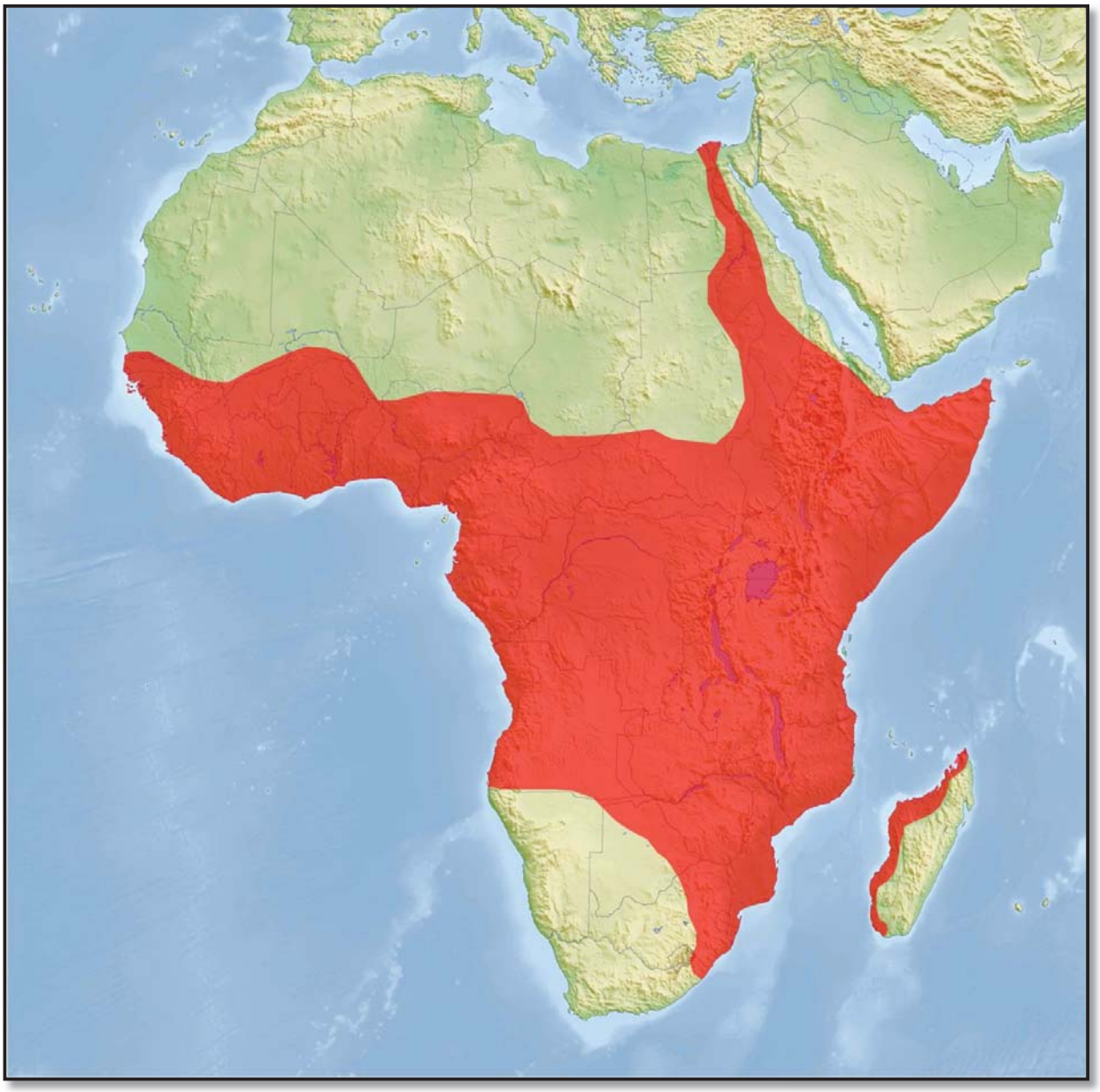

Figure 23: Geographic distribution range of Crocodylus niloticus

6.3.2.1.1.3 *Population*

Population

From the 1940s to the 1960s, the Nile crocodile was hunted, primarily for high-quality leather, though also for meat with its purported curative properties. The population was severely depleted, and the species faced extinction. National laws, and international trade regulations have resulted in resurgence in many areas, and the species as a whole is no longer threatened with extinction. Crocodile 'protection programs' are artificial environments where crocodiles exist safely and without the threat of extermination from hunters (Crocodile Specialist Group, 1996a).

An estimated 250,000 to 500,000 individuals occur in the wild. The Nile crocodile is also widely distributed, with strong, documented populations in many countries in eastern and southern Africa, including Somalia, Ethiopia, Kenya, Zambia and Zimbabwe. Successful sustainable-yield programs focused on ranching crocodiles for their skins have been successfully implemented in this area, and even countries with quotas are moving toward ranching. In 1993, 80,000 Nile crocodile skins were produced, the majority from ranches in Zimbabwe and South Africa (Crocodile Specialist Group, 1996a).

The situation is grimmer in central and west Africa, which makes up about two-thirds of the Nile crocodile's habitat. The crocodile population in this area is much sparser, and has not been adequately surveyed (Crocodile Specialist Group, 1996a).

The IUCN Red List assesses the Nile crocodile as "Least Concern (LR/lc)". [1] The CITES lists the Nile crocodile under Appendix I (threatened with extinction) in most of its range; and under Appendix II (not threatened, but trade must be controlled) in the remainder, which either allows ranching or sets an annual quota of skins taken from the wild. This species is farmed for its meat and leather in some parts of Africa (Crocodile Specialist Group, 1996a).

Population Trend

Decreasing (Crocodile Specialist Group, 1996a).

6.3.2.1.1.4 *Habitat and Ecology*

Habitats

In East Africa, they are found mostly in rivers, lakes, marshes, and dams. They have been known to enter the sea in some areas, with one specimen having been seen 11 kilometres (6.8 mi) off St Lucia Bay in 1917. In Madagascar, they have adapted to living in caves (Guggisberg, 1972).

Reproduction

For males, the onset of sexual maturity occurs when they are about 3 metres long, while for females, it occurs when they reach 2 to 2.5 metres in length. This takes about 10 years for either sex, under normal conditions. During the mating season, males attract females by bellowing, slapping their snouts in the water, blowing water out of their noses, and making a variety of other noises. The larger males of a population tend to be more successful. Once a female has been attracted, the pair warbles and rubs the undersides of their jaws together. Females lay their eggs about two months after mating (Crocodile Specialist Group, 1996a).

Nesting is in November or December, which is the dry season in the north of Africa, and the rainy season in the south. Preferred nesting locations are sandy shores, dry stream beds, or riverbanks. The female then digs a hole a few metres from the bank and up to 500 mm (20 in) deep, and lays between 25 and 80 eggs. The number of eggs varies, but averages around 50. Multiple females may nest close together (Crocodile Specialist Group, 1996a).

Unlike most other crocodilians, female Nile crocodiles bury their eggs in sand rather than incubate them in rotting vegetation (Guggisberg, 1972). After burying the eggs, the female then guards them for the three-month incubation period. The sire will often stay nearby, and both parents will fiercely attack anything approaching their eggs. The female will only leave the nest if she needs to cool off (thermoregulation) by taking a quick dip or seeking out a patch of shade. Despite the attentive care of both parents, the nests are often raided by humans and monitor lizards or other animals while she is temporarily absent (Crocodile Specialist Group, 1996a).

The hatchlings start to make a high-pitched chirping noise before hatching, which is the signal for the mother to rip open the nest. The parents may pick up the eggs in their mouths, and roll them between their tongue and the upper palate to help crack the shell and release their offspring. Once the eggs hatch, the female may

lead the hatchlings to water, or even carry them there in her mouth, as female American alligators have been observed doing (Crocodile Specialist Group, 1996a).

Nile crocodiles have temperature-dependent sex determination (TSD), which means the sex of their hatchlings is determined not by genetics, but by the average temperature during the middle third of their incubation period. If the temperature inside the nest is below 31.7°C (89.1°F), or above 34.5°C (94.1°F), the offspring will be female. Males can only be born if the temperature is within that narrow range (Crocodile Specialist Group, 1996a).

Hatchlings are about 300 mm (12 in) long at birth, and grow that much each year. The new mother will protect her offspring for up to two years, and if there are multiple nests in the same area, the mothers may form a crèche. During this time, the mothers may pick up their offspring either in their mouths or gular fold (throat pouch), to keep the babies safe. The mother will sometimes carry her young on her back to avoid their being eaten by turtles or water snakes. At the end of the two years, the hatchlings will be about 1.2 m long, and will naturally depart the nest area, avoiding the territories of older and larger crocodiles (Crocodile Specialist Group, 1996a).

Systems

Freshwater and terrestrial (Crocodile Specialist Group, 1996a).

6.3.2.1.1.5 ***Threats***

While the natural population in these areas may be lower due to a less-than-ideal environment and competition with sympatric slender-snouted and dwarf crocodiles, extirpation may be a serious threat in some of these areas. Additional factors are a loss of wetland habitats, and hunting in the 1970s. Additional ecological surveys and establishing management programs are necessary to resolve this (Crocodile Specialist Group, 1996a).

The Nile crocodile is the top predator in its environment, and is responsible for checking the population of species such as the barbel catfish, a predator that can over eat fish populations on which other species, like birds, depend. The Nile crocodile also consumes dead animals that would otherwise pollute the waters. The main threats to them, in turn, are pollution, loss of habitat, hunting, and human activities such as accidental entanglement in fishing nets (Crocodile Specialist Group, 1996a).

Much of the hunting stems from their reputation as a man-eater, which is not entirely unjustified. Unlike other "man-eating" crocodiles, such as the saltwater crocodile, the Nile crocodile lives in close proximity to human populations, so contact is more frequent. Although most attacks do not get reported, the Nile crocodile is estimated to kill hundreds (possibly thousands) of people each year, which is more than all other crocodilian species combined. One study posited the number of attacks by Nile crocodiles per year as 275 to 745, of which 63% are fatal, as opposed to an estimated 30 attacks per year by saltwater crocodiles, of which 50% are fatal. In both species, the mean size of crocodiles involved in nonfatal attacks was about 3 m as opposed to a reported range of 2.5–5 m or larger for crocodiles responsible for fatal attacks. The average estimated size of crocodiles involved in fatal attacks is 3.5 m. Since a majority of fatal attacks are believed to be predatory in nature, the Nile crocodile can be considered the most prolific predator of humans among wild animals (Crocodile Specialist Group, 1996a).

6.3.2.1.1.6 ***Conservation Actions***

Crocodylus niloticus is listed on CITES Appendix I [except the populations of Botswana, Egypt (subject to a zero quota for wild specimens traded for commercial purposes), Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, South Africa, Uganda, the United Republic of Tanzania (subject to an annual export quota of no more than 1,600 wild specimens including hunting trophies, in addition to ranched specimens), Zambia and Zimbabwe, which are included in Appendix II] (Crocodile Specialist Group, 1996a).

6.3.2.1.1.7 ***Regionally relevant knowledge***

Few studies have been conducted on *C. niloticus* in Guinea-Bissau; therefore regionally relevant knowledge on this species is negligible.

6.3.2.1.2 The West African Dwarf Crocodile (Osteolaemus tetraspis)

Figure 24: Osteolaemus tetraspis

6.3.2.1.2.1 ***Description***

As its name suggests, the dwarf crocodile is a diminutive species, with individuals rarely reaching lengths of 1.6 m (Crocodile Specialist Group, 1996b). It is a heavily armoured crocodile, which is dark in colour on the back and sides with a yellowish belly featuring many black patches (Crocodile Specialist Group, 1996b). Juveniles have light brown banding on the body and tail and yellowish patterns on the head. In all individuals, the snout is short and rather blunt (Crocodile Specialist Group, 1996b). The Congo dwarf crocodile subspecies (*O. t. osborni*) is poorly known. It is generally lighter in colour (Crocodile Specialist Group, 1996b) and has a flatter and more slender snout. It may yet prove to be a separate species

6.3.2.1.2.2 ***Geographic Range***

Range Description

Osteolaemus tetraspis ranges across tropical lowland regions of sub-Saharan West Africa and West Central Africa (Figure 25). Such a distribution greatly overlaps with that of the slender-snouted crocodile, encompassing countries as far West as Senegal, reaching the Central African Republic in the East, and ranging as southerly as Angola. The subspecies O. t. tetraspis is found mainly in the westerly reaches of this range while *O. t. osborni* is restricted to the Democratic Republic of Congo's rain forest (Crocodile Specialist Group, 1996b).

Countries

According to the Crocodile Specialist Group (1996b), *Osteolaemus tetraspis* occurs in Angola (Angola); Benin; Burkina Faso; Cameroon; Central African Republic; Congo; Congo, The Democratic Republic of the; Côte d'Ivoire; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Liberia; Nigeria; Senegal; Sierra Leone; Togo

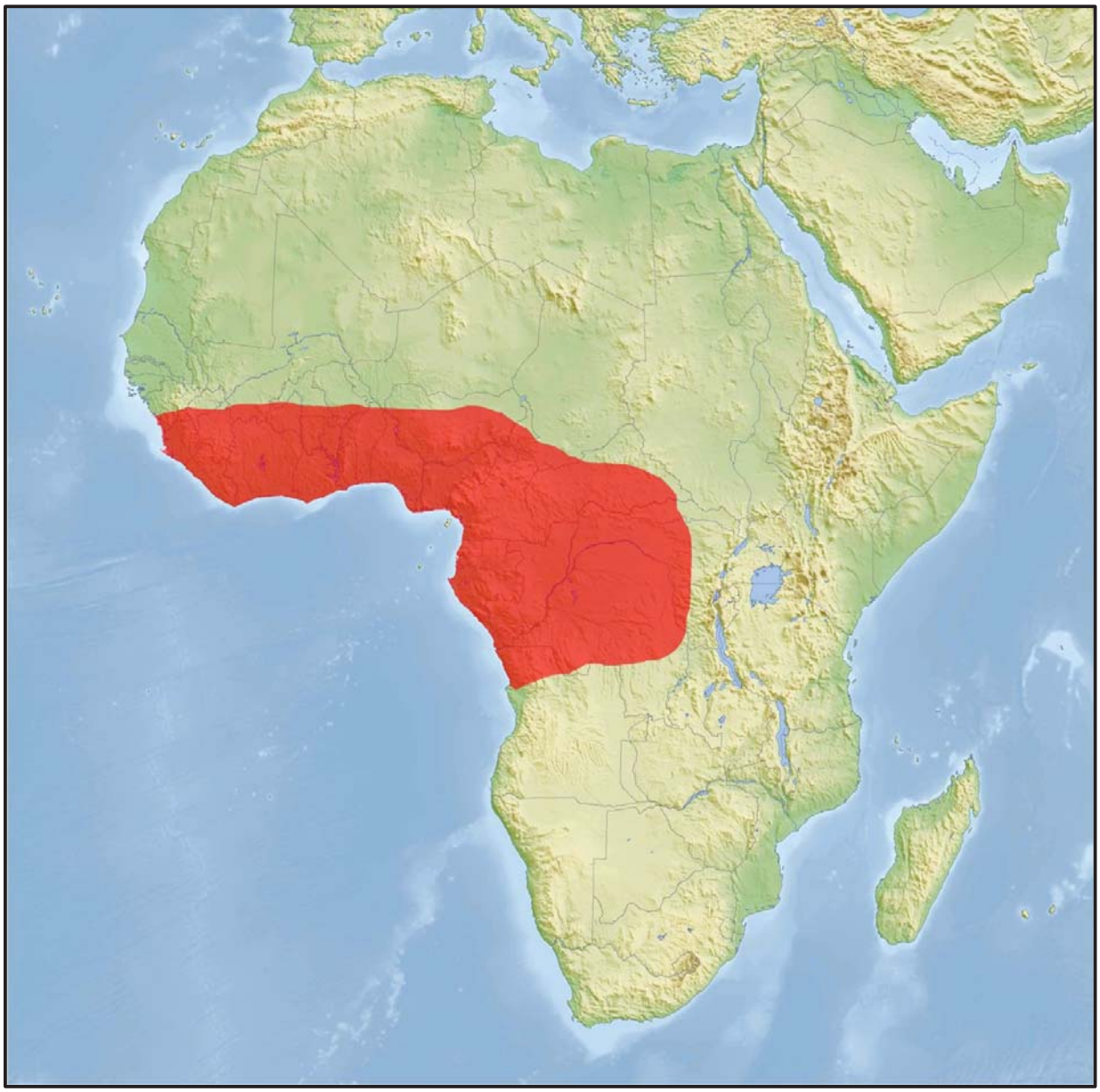

Figure 25: Geographic distribution range of Osteolaemus tetraspis

6.3.2.1.2.3 *Population*

Population

Dwarf crocodiles are a little-known species so, unlike their more studied relatives, conservationists aren't as aware of how their populations are faring under the growing human pressure over the ecosystems where they abide. Where survey data is available, it shows some degree of decline, either by hunting for bush meat or habitat loss due to deforestation. However, it is a widely spread, and presumably numerous, species so is not as endangered as other forest denizens (Crocodile Specialist Group, 1996b).

Population Trend

Decreasing

6.3.2.1.2.4 *Habitat and Ecology*

Habitats

This crocodile is found mainly in swamps and swamp forests, with a preference for slow-moving bodies of water (Crocodile Specialist Group, 1996b). Occasionally, this species may occur in pools in savannah habitats, where they are reported to spend the dry season in burrows or hidden beneath extensive tree root structures (Crocodile Specialist Group, 1996b; Thorbjarnarson & Eaton, 2003). They also utilise isolated pools in forests (Crocodile Specialist Group, 1996b).

Reproduction

Interacting closely only in breeding season, female dwarf crocodiles build their nest mounds at the beginning of the wet season, which spans May and June. The nest, situated near the water, is a mound of wet, decaying vegetation that incubates the eggs due to the heat generated by the decomposition of the plant material (Crocodile Specialist Group, 1996b). A small number of eggs are laid, numbering about 10, though in extreme cases it can go up to 20 eggs, and they incubate in 85 to 105 days. Hatchlings measure 28 cm when emerging from the eggs. The female guards the nest during the incubation period and after the eggs hatch it watches over the young for an unknown period of time as young can be eaten by a great range of predators (birds, fish, mammals and reptiles, including other crocodiles) (Crocodile Specialist Group, 1996b).

Systems

Terrestrial and freshwater

6.3.2.1.2.5 *Threats*

The main threats facing this species include habitat destruction and hunting for meat for local consumption. Data collected from Congo show that tens of thousands of dwarf crocodiles are sold for food on local markets each year (Crocodile Specialist Group, 1996b). The small size and non-aggressive nature of the dwarf crocodile makes its capture and transport relatively easy, and so it is the most heavily hunted crocodile in the area. They are either bound and transported alive to markets or killed and stored on ice (Thorbjarnarson & Eaton, 2003). The hide of this species is of a relatively poor quality and so commercial hunting for this reason has not been a serious problem (Crocodile Specialist Group, 1996b). In some countries, including Gambia and Liberia, the population of this crocodile is severely depleted, and it may soon become extinct in these areas (Thorbjarnarson & Eaton, 2003). At present there is a lack of reliable survey data on this crocodile, and so the overall status of the species is unclear

6.3.2.1.2.6 *Conservation Actions*

This species is listed under Appendix I of the Convention on International Trade in Endangered Species (CITES) and so international trade in this species is controlled (Crocodile Specialist Group, 1996b). Plans are presently under discussion to set up captive breeding programmes for the dwarf crocodile. However, the most pressing requirement is for an extensive survey and monitoring scheme to establish the status of the species, with priority given to the countries where the species seems to be most at risk (Thorbjarnarson & Eaton, 2003). Preliminary surveys were carried out in 2003 by the Wildlife Conservation Society in Congo and Gabon to examine the potential for a research programme into the ecology of the three African species of crocodile and the impact of the bush meat trade on their populations

6.3.2.1.2.7 *Regionally relevant knowledge*

It is very likely that this species does not occur in Guinea–Bissau, and that the entry in the IUCN database is in error, but no conclusive studies have been conducted to determine this.

6.3.2.1.3 The African Slender-snouted Crocodile (Mecistops cataphractus)

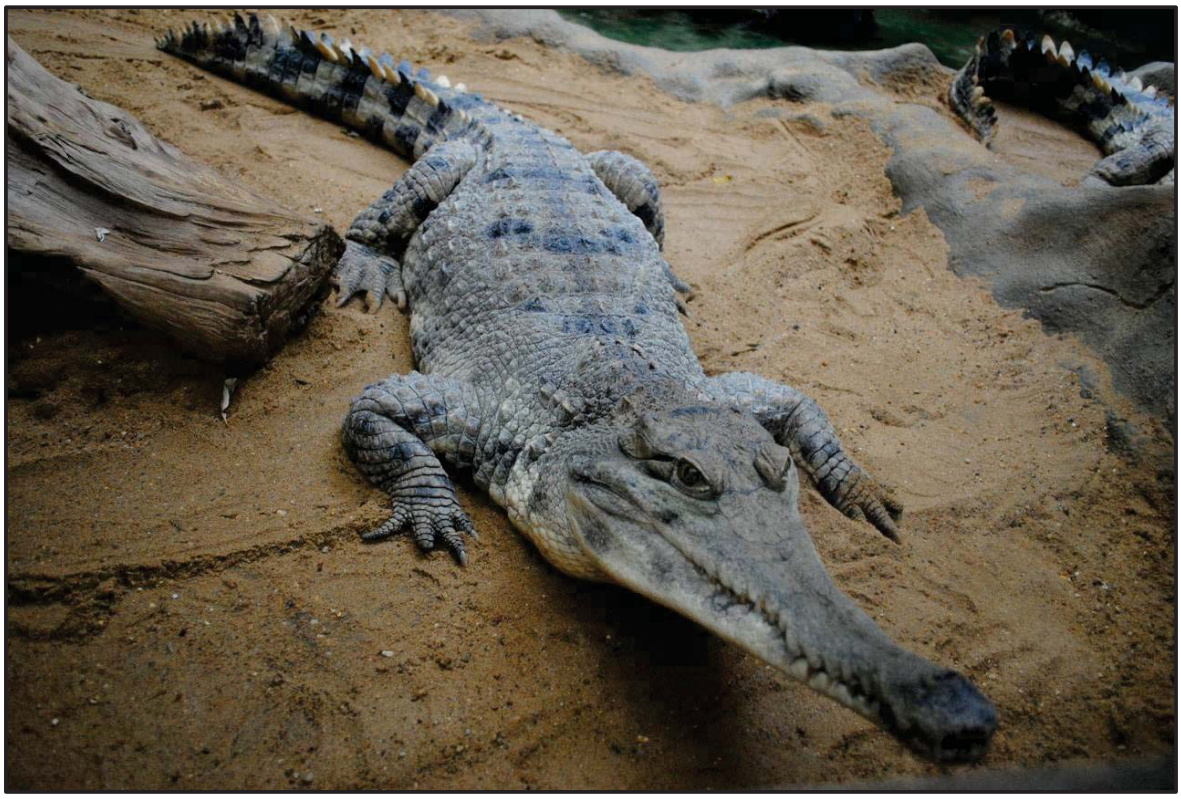

Figure 26: Mecistops cataphractus

6.3.2.1.3.1 ***Description***

The African slender-snouted crocodile (Mecistops cataphractus) is a species of crocodile. Recent studies in DNA and morphology suggest that it may belong in its own genus, *Mecistops.*

The African slender-snouted crocodile is among the least known of the world's crocodilians (Crocodile Specialist Group, 1996c). Its defining feature is its extremely slender snout, devoid of any bony ridges (Crocodile Specialist Group, 1996c). The leathery skin of the adult is brownish-yellow with large black spots, and the olive coloured head is spotted with brown. Young crocodiles are greenish-grey to greenish-yellow in colour with black blotches and markings (Crocodile Specialist Group, 1996c). Six or so rows of tough scales run down the crocodile's back, leading to the species name cataphractus, meaning 'clad in armour' in Greek

6.3.2.1.3.2 ***Geographic Range***

Range Description

Occurs in the equatorial rainforest belt of Central and West Africa; from southern Mauritania, east to the Central African Republic and south to Angola and Tanzania (Figure 27) (Crocodile Specialist Group, 1996c)

Countries

Angola (Angola); Benin; Burkina Faso; Cameroon; Central African Republic; Chad; Congo; Congo, The Democratic Republic of the; Côte d'Ivoire; Equatorial Guinea; Gabon; Ghana; Guinea; Liberia; Mali; Mauritania; Nigeria; Sierra Leone; Tanzania, United Republic of; Togo; Zambia (Crocodile Specialist Group, 1996c).

Possibly extinct:

Gambia; Guinea-Bissau; Senegal (Crocodile Specialist Group, 1996c).

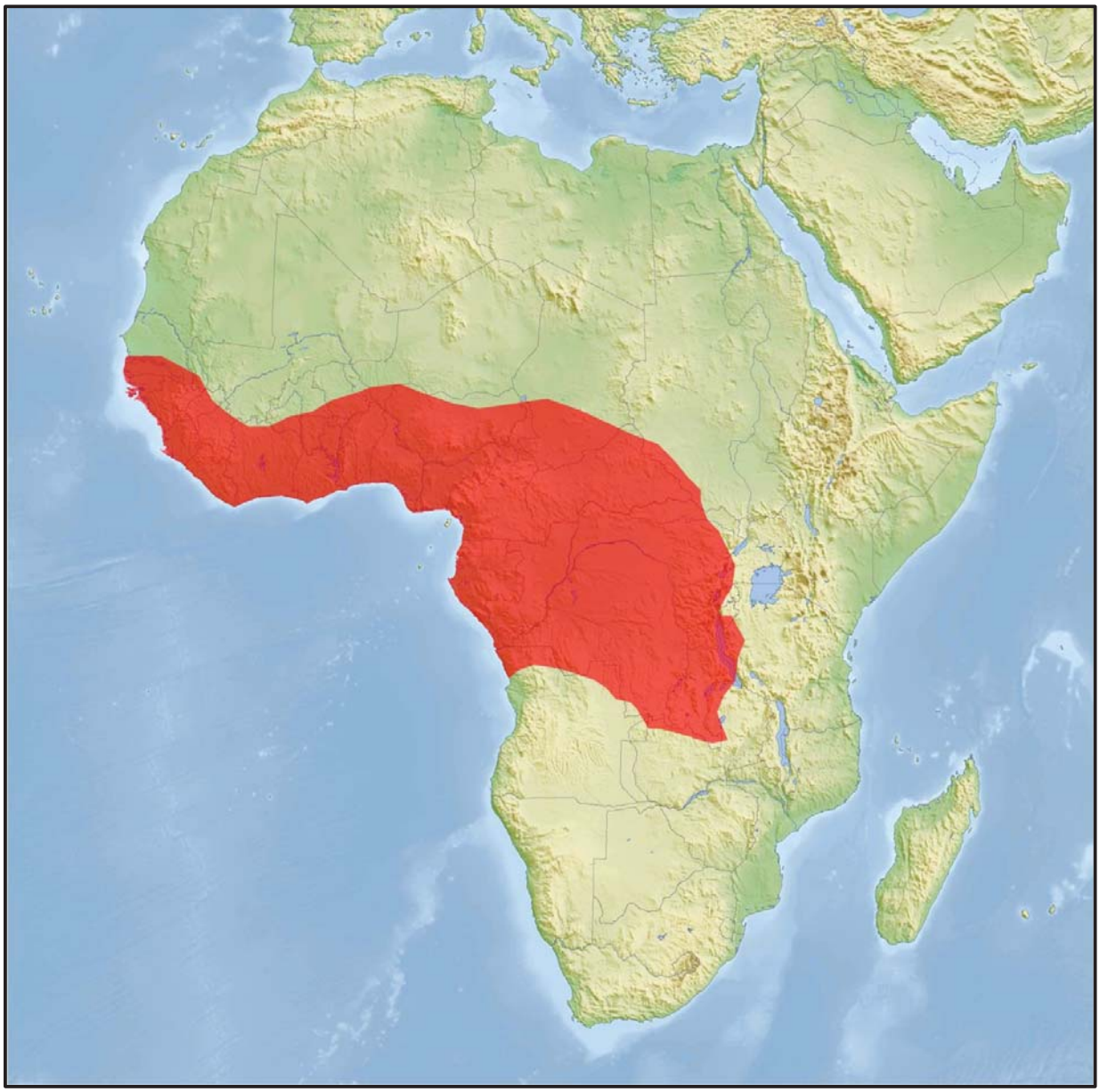

Figure 27: Geographic distribution range of Mecistops cataphractus

6.3.2.1.3.3 *Population*

Population

The fact this species is very poorly studied has led to little data being available, and therefore the global population of this species is currently unknown (Crocodile Specialist Group, 1996c).

Population Trend

Decreasing (Crocodile Specialist Group, 1996c)

6.3.2.1.3.4 *Habitat and Ecology*

Habitats

The African slender-snouted crocodile inhabits rivers, marshes, lakes and pools within rainforests (Crocodile Specialist Group, 1996c). While habitat data are not exhaustive, the slender-snouted crocodile is apparently confined to freshwater and typically prefers larger, swift-flowing streams (Crocodile Specialist Group, 1996c).

Reproduction

Depending on the region and its climatological patterns, mating is reported to begin in February; and from March the female constructs a nest by scraping vegetation together with her hind feet (Crocodile Specialist Group, 1996c). These large mounds, up to 80 centimetres high and two metres wide, are situated in a shady spot a few metres from small rainforest streams (Crocodile Specialist Group, 1996c). The female lays between 12 and 30 large, hard-shelled eggs in two layers in the mound, where a temperature of 27.4 to 34 degrees Celsius is maintained (Crocodile Specialist Group, 1996c). At the beginning of the rainy season, after 90 to 100 days of incubation, young crocodiles start to emerge from the elliptical eggs (Crocodile Specialist Group, 1996c). Their characteristic chirping instigates the mother to break open the nest and assist with the hatching process, causing the hatchlings to scatter over the flooded rainforest floor (Crocodile Specialist Group, 1996c). Slender-snouted crocodiles display some degree of parental care of hatchlings, with females aggressively defending their young when they emit distress calls. It is unknown for how many months this maternal care is given

Systems

Terrestrial and freshwater (Crocodile Specialist Group, 1996c).

6.3.2.1.3.5 *Threats*

The sparse information on the African slender-snouted crocodile makes it difficult to determine its conservation status, and thus the World Conservation Union (IUCN) has declared it Data Deficient (Crocodile Specialist Group, 1996c). However, the little survey data that is available suggests that many populations may be depleted, and possibly even extirpated in The Gambia, Senegal and Guinea-Bissau (Crocodile Specialist Group, 1996c). These declines are likely to be the result of hunting, for its hide and for food (Crocodile Specialist Group, 1996c), and the disruption of vital riverside vegetation (Crocodile Specialist Group, 1996c). Slender-snouted crocodiles are extremely vulnerable to being caught and drowned in fishing nets when attempting to eat fish struggling in the nets. Very few significant populations of this species exist in Central or West Africa, and additional data and protection is urgently required.

6.3.2.1.3.6 *Conservation Actions*

The African slender-snouted crocodile is legally protected in many of its range countries, although this is poorly enforced. The sparse information available indicates that populations of this rare ‘armour-clad’ crocodile are declining, so better enforcement of laws, changes in legal status, and firmer hunting regulations are clearly needed. However, the lack of definitive information on this species’ ecology, population dynamics and status makes such actions hard to develop, and the inaccessibility and political instability throughout much of its range hinders most efforts for further research or action (Crocodile Specialist Group, 1996c).

6.3.2.1.3.7 *Regionally relevant knowledge*

This species is thought to be extinct in Guinea-Bissau, Senegal and the Gambia (Crocodile Specialist Group, 1996c).

6.3.2.1.4 Objectives

The objectives of the crocodilian study were to determine the abundance and diversity of crocodilian within the Cacheau River.

6.3.2.1.5 Methodology

Due to their aquatic, cryptic nature and the wide range of habitats crocodiles frequent, total counts are often prohibitively expensive (Bayliss, et al., 1986). The ability to see crocodiles varies temporally and therefore

total population counts are rarely, if ever, achieved in the wild (Games, et al., 1992; Nichols, 1992). In addition, total counts are unrealistic in large areas such as the Okavango Delta where much of the habitat is inaccessible (Hutton & Woolhouse, 1989). However, this method has successfully been used in small rivers and lakes (Hutton, 1992). Sample counts involve dividing and total sample area up into more manageable subdivisions, surveying them and then extrapolating for the whole region (Games, et al., 1992). Individuals in crocodilian populations are almost never randomly spaced (Combrink, 2004). Rather, crocodiles concentrate in favourable habitats or areas where resources are abundant. Reasons for the spatial distribution of crocodiles may include seemingly insignificant factors such as avoidance of prevailing winds and subsequent wave action (Combrink, 2004). For this reason stratified sampling, which is defined as sampling over a range of habitats within which the population density is fairly uniform (Caughley, 1977) is commonly used when surveying crocodilian populations (Combrink, 2004).

The Cacheu River was surveyed from the mouth to the 180km inland point. Based on the above findings by other studies, the methodology used to survey crocodiles was to divide the Cacheu River into 20km sections, these sections were then surveyed by boat with a crew of 4 actively searching for crocodiles in the river or on the banks. Equal survey effort was applied in all areas of the river. Approximate size, species and age group were recorded for each of the crocodiles spotted.

The survey was conducted from the 1st of September 2013 until the 4th of September 2013.

Figure 28: Area investigated for crocodile activity

6.3.2.1.6 Results

Only Nile crocodile (*C. niloticus*) were recorded during the study, this was expected as *Mecistops cataphractus* are expected to be extinct in Guinea-Bissau and *Osteolaemus tetraspis* is unlikely to occur in the habitat available, if it does, in fact, occur in Guinea-Bissau (a fact which is in some doubt).

A total of 25 crocodiles were recorded along the length of the 180 km stretch of the Cacheu River surveyed (Table 8, Figure 29). The survey data, therefore, demonstrate a very low total number of crocodiles, although there is a good distribution of crocodiles over the size classes (Table 8), compared to that expected to be present in healthy populations (Combrink, 2004).

Although the number of crocodiles per kilometer of river amounts to only 0.14 crocodiles/km this is a slightly skewed, due to the stretch of river where no crocodiles were recorded.

Table 8: Crocodile survey data

Distance from Cacheu River Mouth	Number of *Crocodylus niloticus*	**Crocodile size class**			
		3-4m	2-3m	1-2m	<1m
0-20km	0	0	0	0	0
20-40km	0	0	0	0	0
40-60km	0	0	0	0	0
60-80km	0	0	0	0	0
80-100km	1	0	1	0	0
100-120km	0	0	0	0	0
120-140km	1	0	0	0	0
140-160km	4	0	2	1	1
160-180km	19	4	6	6	3

The distribution of crocodiles recorded in the Cacheu River show that the density of crocodiles increases, exponentially, with distance from the Cacheu River mouth. When looking at the crocodile densities in the 20km reaches of river from the mouth to where the surveys ended the first 4-20km reaches showed 0 crocodiles/km average density, the following 20km showed only a 0.05 crocodile/km average density. The 100-120km reach showed and average density of 0 crocodiles/km, after which the densities started to climb rapidly, with the mean density of the 120-140km, 140-160km and 160-180km stretches being 0.05 crocodiles/km, 0.2 crocodiles/km and 0.95 crocodiles/km, respectively. The surveys found that 76% of crocodiles recorded were found in the uppermost 20km reach of the Cacheu River surveyed (160-180km from the Cacheu River mouth), with no crocodiles recorded in the first 80km stretch of the Cacheu River surveyed (0-80km from the Cacheu River mouth).

It must be noted that these surveys cannot be assumed to be a total count of crocodiles with the Farim River and is more of an indication of the distribution of crocodiles in the Cacheu River.

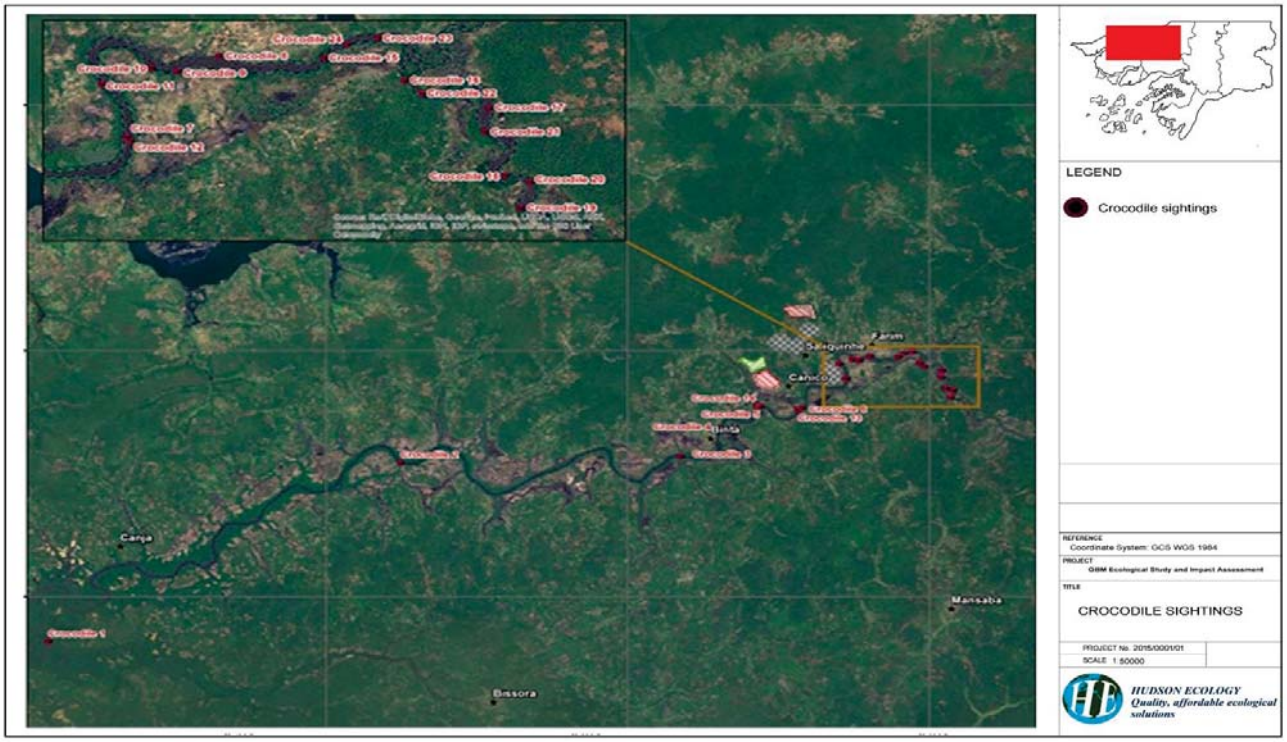

Figure 29: Recorded crocodile sightings

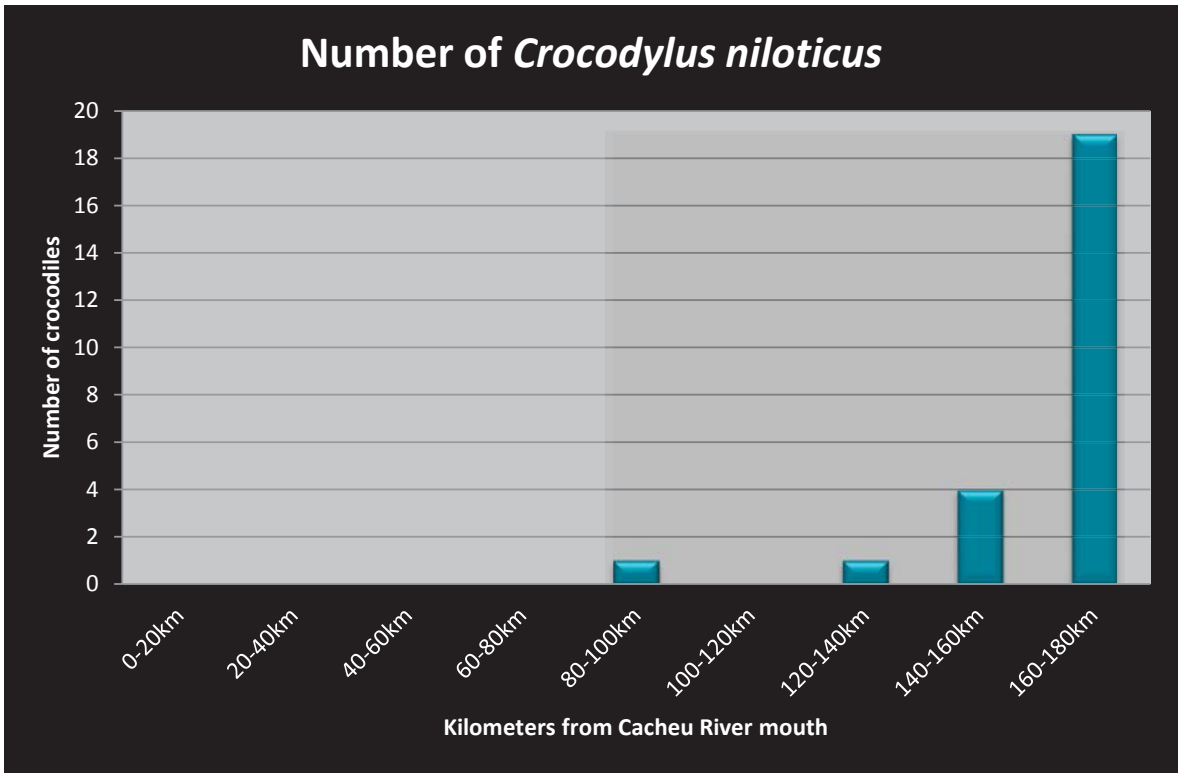

Figure 30: Graphical depiction of the crocodile numbers recorded, along the surveyed reach of the Cacheu River

6.3.2.1.7 Discussion

Crocodilian populations have been studied worldwide, as most wild populations today are under serious threat due to habitat loss, degradation and pollution (Pooley, 1969; Ross, 1998). Although these large predators are perceived by many as non-essential members of healthy aquatic ecosystems, they are actually keystone and sentinel species that can provide information on the long-term health of an ecosystem. The data reported here clearly indicate that the Nile crocodile population in the Cacheu River is healthy and probably still fulfils an integral role in the system.

Features of the demographics of the crocodile population in the Cacheu river system showed that the crocodile population increases exponentially with an increase in distance from the Cacheu River Mouth. Nile crocodiles are a freshwater species, and although they possess a salt gland, they are not able to excrete salt as efficiently as their saltwater counterparts (Guggisberg, 1972). The more saline the water becomes, the less suitable the habitat will become for the Nile crocodile, and as shown by the study by Combrink (2004), crocodile density is not randomly distributed, but dependant on habitat suitability. This study therefore concurs with the findings of Combrink (2004), showing that the crocodiles in the Cacheu River are dependent on habitat suitability and increase in density with an increase in habitat suitability.

The mean population density of the current crocodile population in the Cacheu River equates to 0.14 crocodiles/km of river. However, the entire shoreline is not good habitat for basking, nesting and other behaviours.

An interesting finding of this study was that the area of the river from just west of Farim, eastwards was well utilised as a nursery area with young crocodiles using the exposed mangrove mud flats to hunt for mudskippers and fiddler crabs. This is not an activity that has been studied extensively in the past and could warrant further study, as this area may therefore be an important area for the propagation of this species in the Cacheu River.

6.3.2.2 Vultures

6.3.2.2.1 Introduction

Two vulture species of concern were investigated for the purposes of this study, namely: the Palm-nut Vulture (*Gypohierax angolensis*) and the Hooded Vulture (*Necrosyrtes monachus*). The reasons for selecting these species are that the Hooded Vulture is currently classified by the IUCN as a critically endangered species (IUCN, 2013) and the Palm-nut Vulture is considered by the WWF as one of the vulturine charismatic mega fauna.

6.3.2.2.2 Palm-nut Vulture (Gypohierax angolensis)

Figure 31: Gypohierax angolensis

6.3.2.2.2.1 Description

With its extensive white plumage, and black wing and tail feathers, the adult palm-nut vulture can be crudely mistaken for both the African fish eagle and the Egyptian vulture, but clearly lacks the chestnut body of the former and the white tail of the latter (Sinclair & Ryan, 2003; Sinclair, et al., 2002). While the head, throat and neck is well feathered, reddish bare skin, conspicuous around the face and eyes, is distinctly vulturine (Sinclair & Ryan, 2003; Sinclair, et al., 2002). The sexes are almost identical in appearance, with the female being only slightly larger than the male. Juveniles on the other hand are predominately brown with partially black wings and take a lengthy three to four years to make the transition into the adult plumage

6.3.2.2.2.2 Geographic Range

Range Description

The palm-nut vulture has a widespread and locally abundant distribution in Africa, from the Gambia across to Kenya, and south as far as north-east South Africa (BirdLife International , 2013)

Countries

According to BirdLife International (2013), *Gypohierax angolensis* occurs in Angola; Benin; Botswana; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; Congo; Congo, The Democratic Republic of the; Côte d'Ivoire; Equatorial Guinea; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Liberia; Malawi; Mali; Mozambique; Namibia; Niger; Nigeria; Rwanda; Senegal; Sierra Leone; South Africa; South Sudan; Sudan; Tanzania, United Republic of; Togo; Uganda; Zambia; Zimbabwe Vagrant: Lesotho

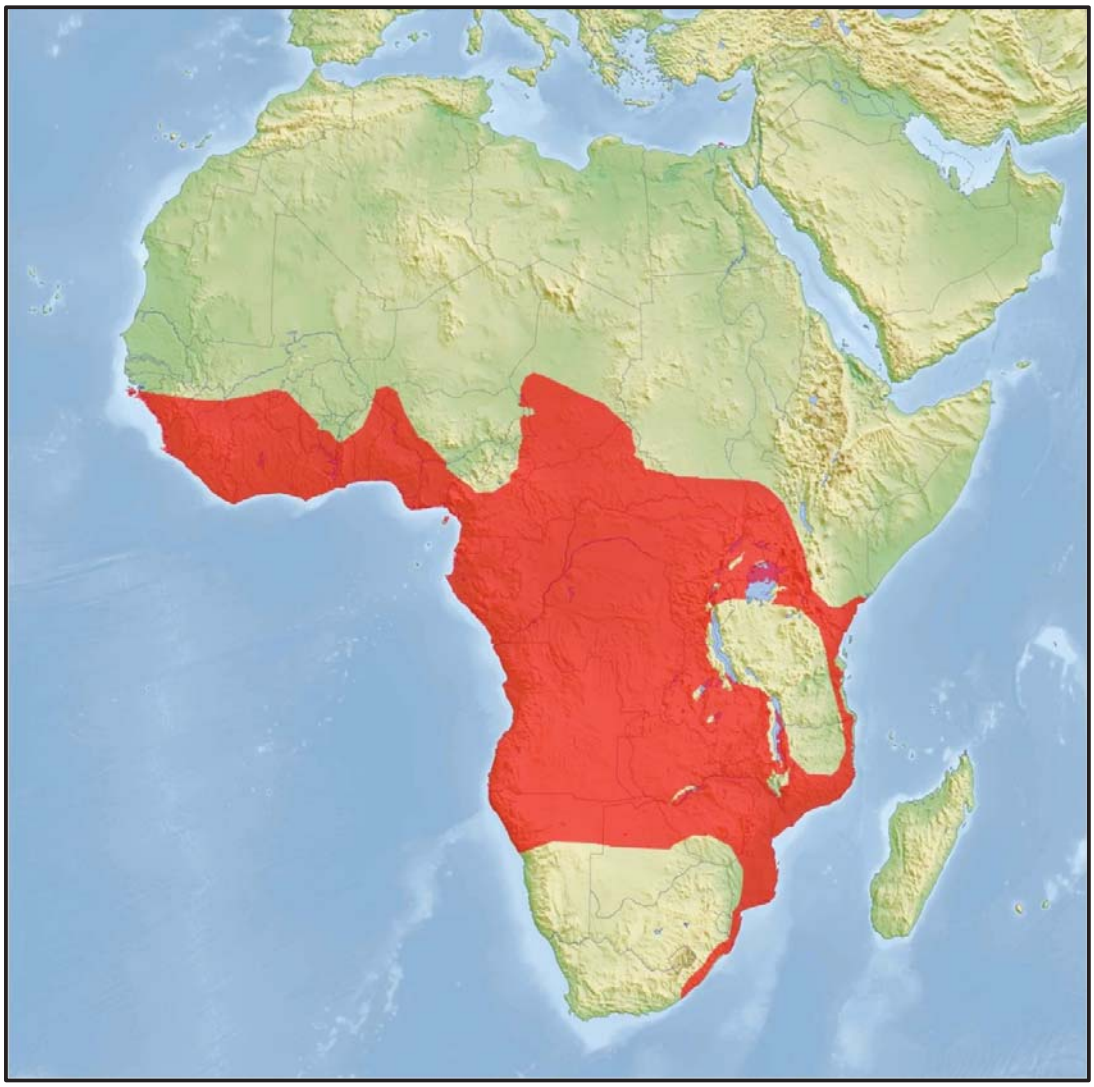

Figure 32: Geographic distribution range of Gypohierax angolensis

6.3.2.2.2.3 ***Population***

Population

The population of palm-nut vultures appears to be stable with estimates in 2001 of approximately 240,000 individuals in Africa (BirdLife International , 2013).

Population Trend

Stable (BirdLife International , 2013)

6.3.2.2.2.4 ***Habitat and Ecology***

Habitats

As the name suggests, the distribution of the palm-nut vulture closely tracks that of oil (*Elaeis* sp.) or raffia (*Raphia* sp.) palms (Thomson & Moreau, 1957). Consequently, it is most common in coastal forests and mangrove swamps below 1,500 metres, but also occurs in wet savannahs (BirdLife International , 2013).

Reproduction

Breeding pairs construct large stick nests high up in tall trees and will often exhibit a strong attachment to the nest site, staying within its vicinity year round. At the beginning of the breeding season, pairs soar together in an aerial display of rolling and diving, much more acrobatic than most vultures (Ferguson-Lees & Christie, 2001; Virani, et al., 2011; Sinclair, et al., 2002). During each breeding cycle, a single, white and chocolate-

brown egg is laid, which is incubated by both sexes, over a period of four to six weeks (Ferguson-Lees & Christie, 2001; Virani, et al., 2011; Sinclair, et al., 2002). Normally around 85 to 90 days after hatching, the young brown chicks will fledge

Systems

Terrestrial and Freshwater (BirdLife International , 2013)

6.3.2.2.2.5 ***Threats***

In West Africa this species is at risk from habitat destruction, in other areas its range is expanding in unison with spreading oil palm plantations (BirdLife International , 2013).

6.3.2.2.2.6 ***Conservation Actions***

There are no known conservation measures in place for the palm-nut vulture (BirdLife International , 2013).

6.3.2.2.2.7 ***Regionally relevant knowledge***

In the region *Gypohierax angolensis* is a locally common species, it feeds mainly on palm trees growing in wetland areas and rice paddies but is often seen fishing on larger rivers such as the Cacheu River.

6.3.2.2.3 Hooded Vulture (Necrosyrtes monachus)

Figure 33: Hooded Vulture (Necrosyrtes monachus)

6.3.2.2.3.1 ***Description***

This species is a small (67-70 cm), scruffy-looking, mostly brown vulture, with long thin bill, bare crown, face and foreneck, conspicuous ear-holes, and downy nape and hindneck (Sinclair & Ryan, 2003). Perches hunched with wings drooping. Sexes are alike, while juveniles usually have a pale face blue and hood of short down dark brown rather than beige (Sinclair & Ryan, 2003).

6.3.2.2.3.2 *Geographic Range*

Range Description

Necrosyrtes monachus is widespread in sub-Saharan Africa; from Senegal and southern Mauritania east through southern Niger and Chad, to southern Sudan, South Sudan, Ethiopia and western Somalia, southwards to northern Namibia and Botswana, and through Zimbabwe to southern Mozambique and north-eastern South Africa (Ferguson-Lees & Christie, 2001). The species is generally sedentary, with some dispersal by non-breeders and immature birds, and movements in response to rainfall in the Sahel of West Africa (Ferguson-Lees & Christie, 2001). Data and observations of varying coverage and quality from various parts of its range suggest that the species is undergoing a very rapid decline in its global population (Ogada & Buij, 2011).

Countries

According to Birdlife international (BirdLife International , 2013), *Necrosyrtes monachus* occurs in: Angola; Benin; Botswana; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; Congo, The Democratic Republic of the; Côte d'Ivoire; Djibouti; Eritrea; Ethiopia; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Liberia; Malawi; Mali; Mauritania; Mozambique; Namibia; Niger; Nigeria; Rwanda; Senegal; Sierra Leone; Somalia; South Africa; South Sudan; Sudan; Swaziland; Tanzania, United Republic of; Togo; Uganda; Zambia and Zimbabwe. This species also occurs as a vagrant in Morocco (BirdLife International , 2012).

6.3.2.2.3.3 *Population*

Population

Given evidence of recent declines in various parts of its range, this species' population is estimated to number a maximum of 197,000 individuals (Ferguson-Lees & Christie, 2001; BirdLife International , 2012).

Population Trend

Declining (BirdLife International , 2012)

6.3.2.2.3.4 *Habitat and Ecology*

Habitats

The species is often associated with human settlements, but is also found in open grassland, forest edge, wooded savanna, desert and along coasts (Ferguson-Lees & Christie, 2001). It occurs up to 4,000 m, but is most numerous below 1,800 m. It feeds mainly on carrion, but also takes insects.

6.3.2.2.3.5 *Reproduction*

In West Africa and Kenya it breeds throughout the year, but especially from November to July. Breeding in north-east Africa occurs mainly in October-June, with birds in southern Africa tending to breed in May-December (Ogada & Buij, 2011). It is an arboreal nester and lays a clutch of one egg. Its incubation period lasts 46-54 days, followed by a fledging period of 80-130 days. Young are dependent on their parents for a further 3-4 months after fledging (Ferguson-Lees & Christie, 2001).

Systems

Terrestrial (BirdLife International , 2012)

6.3.2.2.3.6 *Threats*

Major threats to this species include non-target poisoning, capture for traditional medicine and bush meat, and direct persecution (Ogada & Buij, 2011). Hooded Vulture meat is reportedly sold as chicken in some places. Intentional poisoning of vultures may be carried out in some areas by poachers in order to hide the locations of their kills. Secondary poisoning with carbofuran pesticides at livestock baits being used to poison mammalian predators is also an issue in East Africa (Otieno, et al., 2010). Declines have also been attributed to land conversion through development and improvements to abattoir hygiene and rubbish disposal in some areas (Ogada & Buij, 2011). The species may also be threatened by avian influenza (H5N1), from which it appears to suffer some mortality and which it probably acquires from feeding on discarded dead poultry (Ducatez et al. 2007).

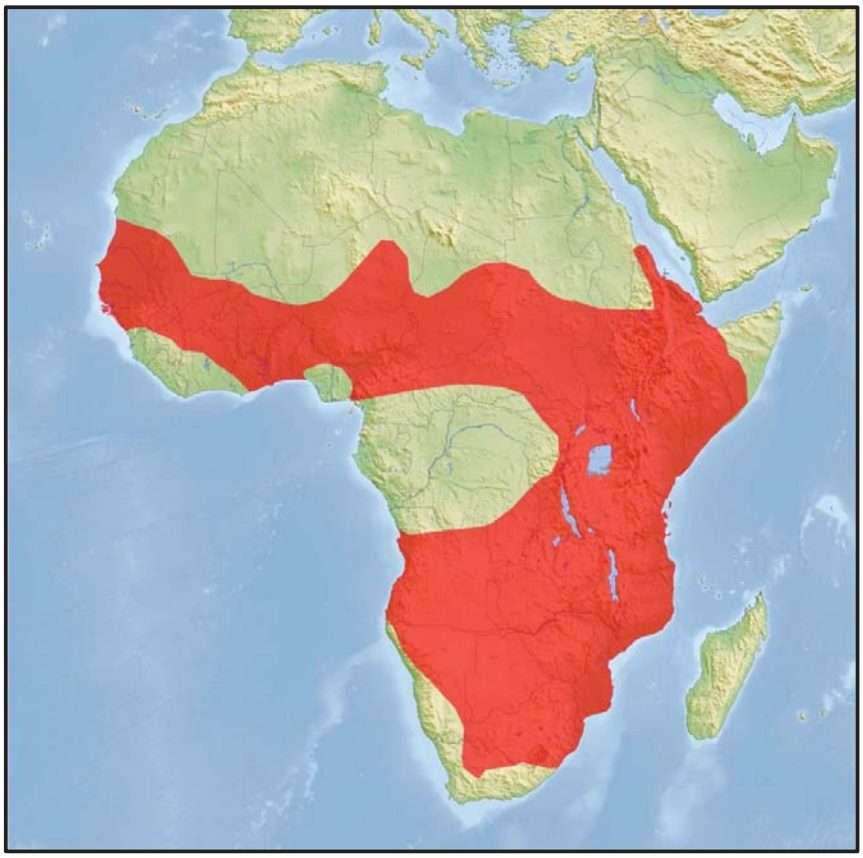

Figure 34: Geographic distribution range of Necrosyrtes monachus

6.3.2.2.3.7 ***Conservation Actions***

No targeted actions are known. This widespread species occurs in a large number of protected areas. Carry out systematic surveys throughout the species' range to acquire a more accurate population estimate and monitor trends. Raise awareness of the species' plight and the impact of hunting and persecution. Monitor rates of land-use change across its range. Monitor effects of poisoning on the species and its use in muti trade and for meat (Otieno, et al., 2010).

6.3.2.2.3.8 ***Regionally relevant knowledge***

Necrosyrtes monachus is a locally common species in many countries in West Africa. It often occurs in large numbers in cities and large towns.

6.3.2.2.4 Objectives

The objectives of the vulture study were to determine the abundance and diversity of *Necrosyrtes monachus* and *Gypohierax angolensis* vulture species within vicinity of the mine and adjacent areas.

6.3.2.2.5 Methodology

6.3.2.2.5.1 ***Field methodology***

For the purposes of the vulture study, 40 sites were randomly selected in the area of influence (AoI) and adjacent areas

Figure 35). At these sites, the presence or absence, of vultures, was investigated but means of a 10 minute point count and three 300m transects, as described in Bibby et al. (1993). The sites were also investigated for environmental factors. These factors were predetermined and were investigated as follows:

- The level of urbanisation at the site (0 being very low and 5 being very high);
- The number of palm trees occurring on site and proximity to large numbers of palm trees (0 being very low and 5 being very high);

- The amount of natural vegetation on site and proximity to natural vegetation (0 being very low and 5 being very high);
- The amount of livestock in the vicinity of the site or proximity to areas with large numbers of livestock (0 being very low and 5 being very high); and
- The level of agricultural activity in the areas and proximity to areas of agricultural activity (0 being very low and 5 being very high).

The environmental factor studies conducted, were used to produce a high level index for each environmental investigated at each site, these indices were:

- An Urbanisation index;
- A Palm Tree Index;
- A Natural Vegetation Index;
- A Livestock index; and
- An Agricultural index.

A number of 0 – 5 were given to each of these sites as shown in Table 9.

Table 9: Index scores assigned for each of the selected indices

Index score	Description
0	Very low
1	Low
2	Low - moderate
3	Moderate
4	High
5	Very High

The vulture study took place from the 5th of September 2013 until the 10th of September 2013. The sampling took place by means of a single sampling bout at each of the sites. The dates, on which each of the sites was investigated, is given in

Table 10.

Surveys which were carried out at each site were conducted throughout the day, and not only in the early mornings when bird activity is at its most (Bibby, et al., 1993). This did not affect the counts, as vultures are active throughout the day and are a very visually conspicuous taxon. As described by Bibby et al (1993), transects were carried out on foot at a steady walking speed of *circa* 3kmlh. All target species, as well as the numbers of individuals of each species, were recorded with a Trimble Juno GPS enabled PDA. During the surveys environmental indices were also recorded according to the methods described above.

Table 10: Vulture sampling sites and dates they were sampled

Locations	Taxa investigated	Completion Date
VS 1 - VS16	Vultures	5 September 2013
VS 17 - VS20	Vultures	6 September 2013
VS 21 - VS24	Vultures	7 September 2013
VS 25 – VS30	Vultures	8 September 2013
VS 31 – VS35	Vultures	9 September 2013
VS 36 - VS40	Vultures	10 September 2013

Correlations and Non-metric multidimensional scaling (PC-Ord) (McCune & Grace, 2002) were used in order to determine whether there was a correlation between the vulture data and any of the environmental factors.

6.3.2.2.6 Background

Birds, like all other living organisms, need certain resources and conditions to survive and propagate. The needs of birds, as well as the availability of resources and conditions to fulfil these needs, determine the distribution of these birds. The fact that humans alter the environment for a variety of needs causes changes in the factors determining birds ability to utilize those areas, and can (and usually does) cause a change in bird species composition in those areas (Hockey, 2003).

Effects of human intervention can have a negative effect on species diversity and numbers, deforestation, land degradation, invasion of exotics and other habitat destruction, caused by human activities, may cause areas to become unsuitable for species. Destruction of forest habitats will cause a decline or total disappearance of forest specialists in the same way draining wetlands to build residential areas will make the area unsuitable for wetland birds (e.g. aquatic birds and waders) and make the area more suitable for generalist species (e.g. starlings) and human commensals such as sparrows (Hockey, 2003).

Human intervention in the environment does not always have a negative impact on bird species. Human movement westwards in southern Africa has caused an increase in man-made structures that form suitable breeding places for birds such as the South African Cliff Swallow (*Hirundo spilodera*) and human commensals such as the Southern Grey-headed Sparrow (*Passer diffuses*). Furthermore, the Southern Grey-headed Sparrow's (*Passer diffuses*) movements appear to be closely tracked by its nest parasite, the Lesser Honeyguide (Hockey, 2003). The construction of dams and mini wetlands by humans, for irrigation and stock watering, has also increased the ranges of water-dependent bird species such as the Burchell's Sandgrouse (*Pterocles burchelli*) and Sclater's Lark (*Spizocorys sclateri*) (Hockey, 2003).

Although factors influencing bird diversity are well documented, there is still an ongoing debate as to which of the factors influencing bird diversity are more important in determining the presence or absence of bird species in a specific area. In a USGS paper (DeGraaf, et al., 1991) on forest and rangeland birds, food, water and shelter were named as most important factors with nest sites, song posts and perch sites as secondary considerations. The paper does go on to mention that proximate factors such as vegetation structure give indications of ultimate factors such as food availability. Lack (1933) suggested that birds are "programmed" to select habitats by identifying features and patterns that are not immediately required for survival. Lack (1933) also proposed that different species are limited in their ranges by one of three factors more than the other two. The factors taken into consideration during the study were: suitable climatic conditions, sufficient food supply and a safe nesting place. Lack (1933) suggested that birds do not adapt to a specific area, but choose the area because of their ability to recognise potentially satisfactory ultimate factors by means of the visible proximate factors.

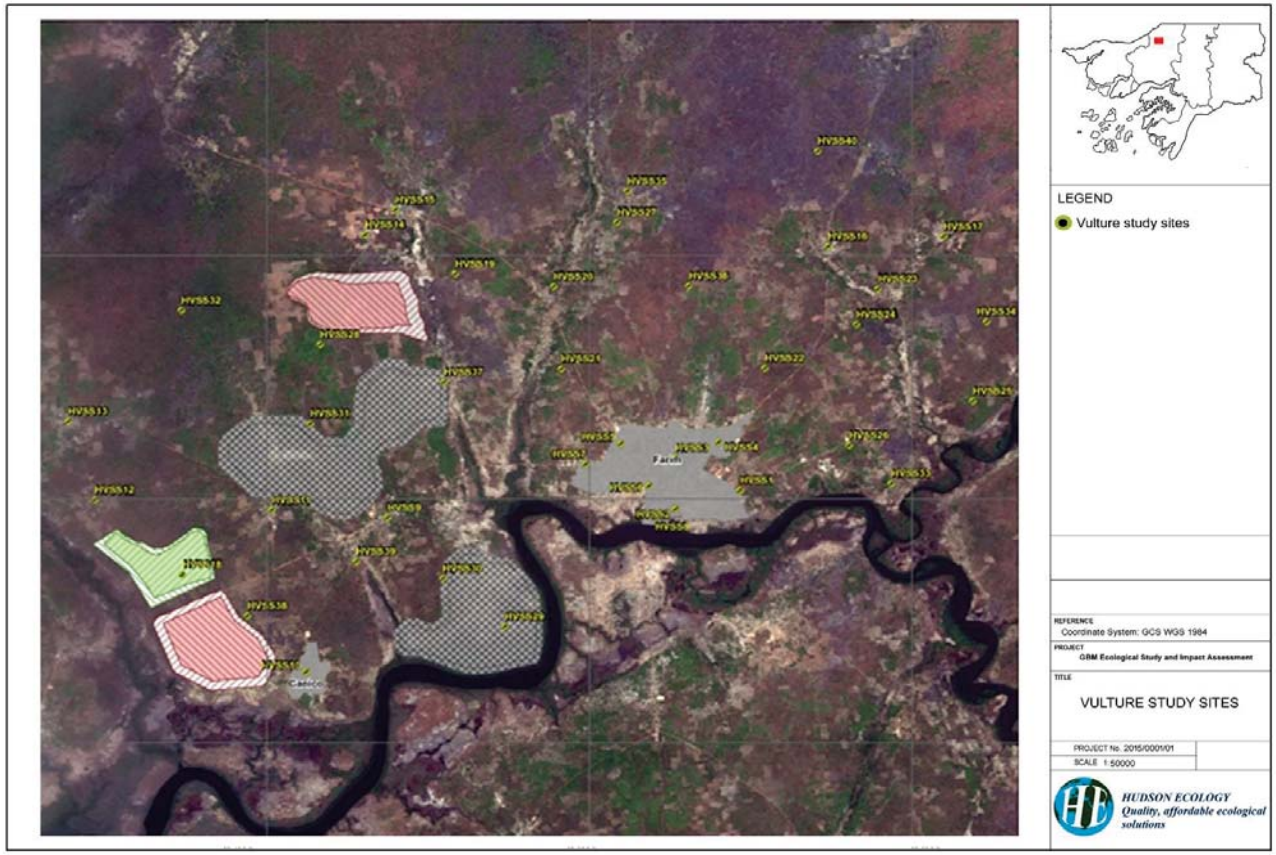

Figure 35: Vulture study sites

6.3.2.2.6.1 *Food*

Studies have been done to examine the possibility that food availability influences the distribution of birds. A study by Johnson & Sherry (Johnson & Sherry, 2001) indicated that food availability does influence the distribution of birds; this study did, however, not take vegetation structure into account during the site selection process. If food availability is not a limiting factor, or if birds are unable to track variations in food availability between habitats, then food availability will not be a determining factor in the distribution of avian species.

Dewalt et al. (2003)did show a correlation between frugivorous birds and the availability of food in tropical forest areas. Insectivore distributions may also be affected by food availability, although the effect may not be as profound, due to the wide distributions of insects. In the same way food availability may not be definitive indicator of distribution of granivorous birds in savanna or grasslands, due to the abundance of seed-bearing grasses in these areas (De Walt, et al., 2003).

Large and small raptor species are, to a much greater extent, restricted in their distribution by food availability (Casey & Hein, 1994) and tend to be greater specialists than birds of other guilds. Raptors also need perches from which to hunt, as well as open areas in which to hunt (Casey & Hein, 1994) although some owl species, as well as eagle species such as the Crowned Eagle (*Stephanoaetus coronatus*) do hunt in forest areas.

6.3.2.2.6.2 *Water availability*

Birds vary in their needs for water. Granivorous birds and birds such as Sclater's Lark (*Spizocorys sclateri*] and the sandgrouse species are also restricted in their distribution by their dependency on a daily supply of water (Hockey, 2003). Many of the birds occurring in the drier area of southern Africa are, however, not dependent on a regular supply of water (Maclean, 1993).

6.3.2.2.6.3 *Nesting sites*

Bird species, particularly specialist species, require specific nesting sites. Some birds, for example Pinkbilled Lark (*Spizocorys conirostris*), Larklike Bunting (*Emberiza impetuans*] and Kori Bustard (*Ardeotis kori*) are ground nesting (Maclean, 1993). Others, for instance Jackal Buzzards (*Buteo rufofuscus*), Peregrine Falcons (Falco peregrinus) and Cliff Swallows (*Hirundo spilodera*), require cliffs, rocky ledges or sometimes man-made structures in areas where cliffs do not occur. Species that only nest in trees also exist, for instance Fork-tailed Drongo (*Dicrurus adsirnilis*), Pied Babblers (*Turdoides bicolor*) and Bateleurs (Terathopius ecaudatus) (Maclean, 1993). Many species like the Pririt Batis (*Batis pririt*), Longbilled Crombec (*Sylvietta rufescens*) and Yellow-bellied Eremomelas (*Eremomela icteropygialis*) nest only in the habitat shrub layer (Maclean, 1993). The last section of birds that can be grouped according to breeding habits are birds such as the Desert Cisticola (*Cisticola aridulus*), White-winged Widowbird (*Euplectes albonotatus*) and Kalahari Robin (*Cercotrichas paena*) that nest in grass just above the ground (Maclean, 1993).

The importance of nesting sites cannot be marginalised; Ricklefs (1969) found that nest predation is the major cause of reproductive failure in birds.

6.3.2.2.6.4 *Competition*

Competition is the process by which species or individuals within species compete for resources. Subsequently, certain species or individuals become deprived of those resources due to the inability to compete with more efficient or aggressive competitors (Begon, et al., 1996).

Competition can be direct, whereby individuals actually interact in order to gain access to a resource (birds jostling for song perches), or indirect, whereby an individual's use of a resource leads to the inability of other individuals to utilize that resource (effective predatory birds hunting out prey so that there is less prey for less effective predatory birds) (Begon, et al., 1996).

Interspecific competition can be defined as competition between different species (Begon et a/, 1996). In the case of birds this can be competition for food, nesting sites, song perches and hunting perches. The result of interspecific competition is the reduction in fecundity, survivorship and growth as a result of the interference by individuals of another species (Begon, et al., 1996). Interspecific competition is most pronounced in bird species that belong to the same guild or that in some way or another utilizes the same resources, be it for feeding breeding or nesting. This competition leads to the regulation of the numbers of individuals of species occurring in a system. In areas where resources competed over are in limited supply, competition is more pronounced and can ultimately lead to the complete exclusion of one or more of the weaker competing species.

Intraspecific competition is defined in Begon et al (1996) as competition between individuals of the same species. Competition between birds of the same species does not lead to the exclusion of the species from an area, but does have a profound effect on the numbers of individuals of the species in a system (Begon, et al., 1996).

In the case of birds, competition has a much more profound effect on specialist species when compared with generalist species. Generalists are more resilient to environmental pressures due to the fact that they are more adaptable than specialists who, as their name would indicate, are much specialised in their choice of food type, methods of feeding, nesting areas or breeding (Maesetas, et al., 2003).

6.3.2.2.6.5 ***Predation***

Predation is defined as the killing and consumption of one organism (prey) by another organism (predator) (Begon, et al., 1996). Besides the obvious effects of predation namely: reduction of prey population size, "weeding out of older and weaker individuals and reducing intraspecific competition within the prey population, predation can have other effects on a prey populations, depending on the conditions under which the predation takes place. In theory, prey populations will not be totally depleted by predators due to reduction in predator numbers when prey populations are decreased in number (Begon, et al., 1996).

However, due to human interference in system processes, prey populations can decrease below the critical level required by that population to regenerate itself; this can lead to local extinctions of those species. Human factors that can increase the intensity or effect of predation are: fragmentation of habitat (Keyser, 2002), introduction of predators, domestic or wild, (Maesetas, et al., 2003) and (in birds) destruction of suitable nesting habitat (Maesetas, et al., 2003).

6.3.2.2.6.6 ***Vegetation structure***

De Walt et al. (2003) states that, although the roles of vegetation structure in shaping faunal communities is not clear, vegetation can provide important resources for nesting, foraging and protection for a variety of taxa. MacArthur & MacArthur (1961) showed a definite positive correlation between vertical height diversity of vegetation and number of bird species in North American forest areas.

Furthermore, studies in forest areas (Willson, 1974) and desert scrub (Tomoff, 1974) showed no positive correlation between foliage height diversity and bird species diversity. Dean (2000) also indicated that an increase in taller, woody vegetation shows an increase in avian species richness, when compared to the surrounding shrubland in the Karoo semi-desert areas of South Africa.

Willson (1974) also found no positive correlation between spatial heterogeneity and bird species diversity. These findings appear to indicate that bird species diversity is either more dependent on other factors than spatial heterogeneity or that the findings of these studies were affected by variables that were not taken into account by the researchers.

Flather et al. (1992) found that vertical habitat structure alone could not account for species diversity, and concluded that in order to predict avian species diversity effectively, spatial heterogeneity needed to be taken into account.

Whitford (Whitford, 1997) indicates that bird species diversity actually increased with an increasing degree of desertification (desertification usually indicates less floral species diversity).

A study of avian demography in afforested grasslands in Illinois, USA showed that the planting of trees in grasslands caused a rapid decline in not only grassland species, but in the total number of species in the afforested area (Naddra & Nyberg, 2001). This appears to oppose the school of thought that avian diversity is enhanced by vertical structural diversity.

6.3.2.2.7 Results

6.3.2.2.7.1 ***Palm-nut Vulture (Gypohierax angolensis)***

A total of 51 Palm-nut Vultures were recorded during the surveys. The palm-tree index for the sites showed that 26 of the sites had a palm-tree index of 0, 0 sites had a palm-tree index of 1, 2 sites had a palm-tree index of 2, 5 sites had a palm-tree index of 3, 3 sites had a palm-tree index of 4 and 4 sites had a palm-tree index of 5. The vast majority of *Gypohierax angolensis* recorded (47 individuals) occurred at the study sites with a palm-tree index of 3 or higher, of which 24 occurred at study sites with a palm-tree index of 5.

When represented graphically, the data show that *Gypohierax angolensis* populations (average number of individuals per site) within the study area show a linear correlation (P=0.035) (Figure 36) when compared to the palm tree index of the various sites. When compared with the other indices determined during the study

Gypohierax angolensis populations within the study area showed absolutely no correlation at all (P>>0.05). *Gypohierax angolensis* were also found to be numerous along rivers and noted to be catching fish in these areas. None of these areas formed part of the study sites, but this was recorded and rivers were noted as an area of high *Gypohierax angolensis* activity.

6.3.2.2.7.2 ***Hooded Vulture (Necrosyrtes monachus)***

A total of 659 Hooded Vultures were recorded during the surveys. The urbanisation index for the sites showed that 17 of the sites had an urbanisation index of 0, 4 sites had an urbanisation index of 1, 2 sites had an urbanisation index of 2, 5 sites had an urbanisation index of 3, 4 sites had an urbanisation index of 4 and 8 sites had an urbanisation index of 5. The vast majority of *Necrosyrtes monachus* recorded (616 individuals) occurred at the study sites with a urbanisation index of 3 or higher, of which 396 occurred at study sites with a palm-tree index of 5.

The livestock index for the sites showed that 5 of the sites had a livestock index of 0, 8 sites had a livestock index of 1, 4 sites had a livestock index of 2, 7 sites had a livestock index of 3, 6 sites had a livestock index of4 and 10 sites had a livestock index of 5. The vast majority of *Necrosyrtes monachus* recorded (648 individuals) occurred at the study sites with a palm-tree index of 3 or higher, of which 463 occurred at study sites with an urbanisation index of 5.

When represented graphically, the data show that *Necrosyrtes monachus* populations (average number of individuals per site) within the study area show a linear correlation (P=0.02) (

Figure 37) when compared to the urbanisation index of the various sites. When compared with the livestock index determined during the study *Necrosyrtes monachus* populations within the study area showed an exponential correlation (

Figure 38). *Necrosyrtes monachus* populations showed no correlation when plotted against the Palm Tree Index or Agricultural index. Contrary to initial expectations, *Necrosyrtes monachus* populations showed a weak negative linear correlation to the Natural Vegetation Index.

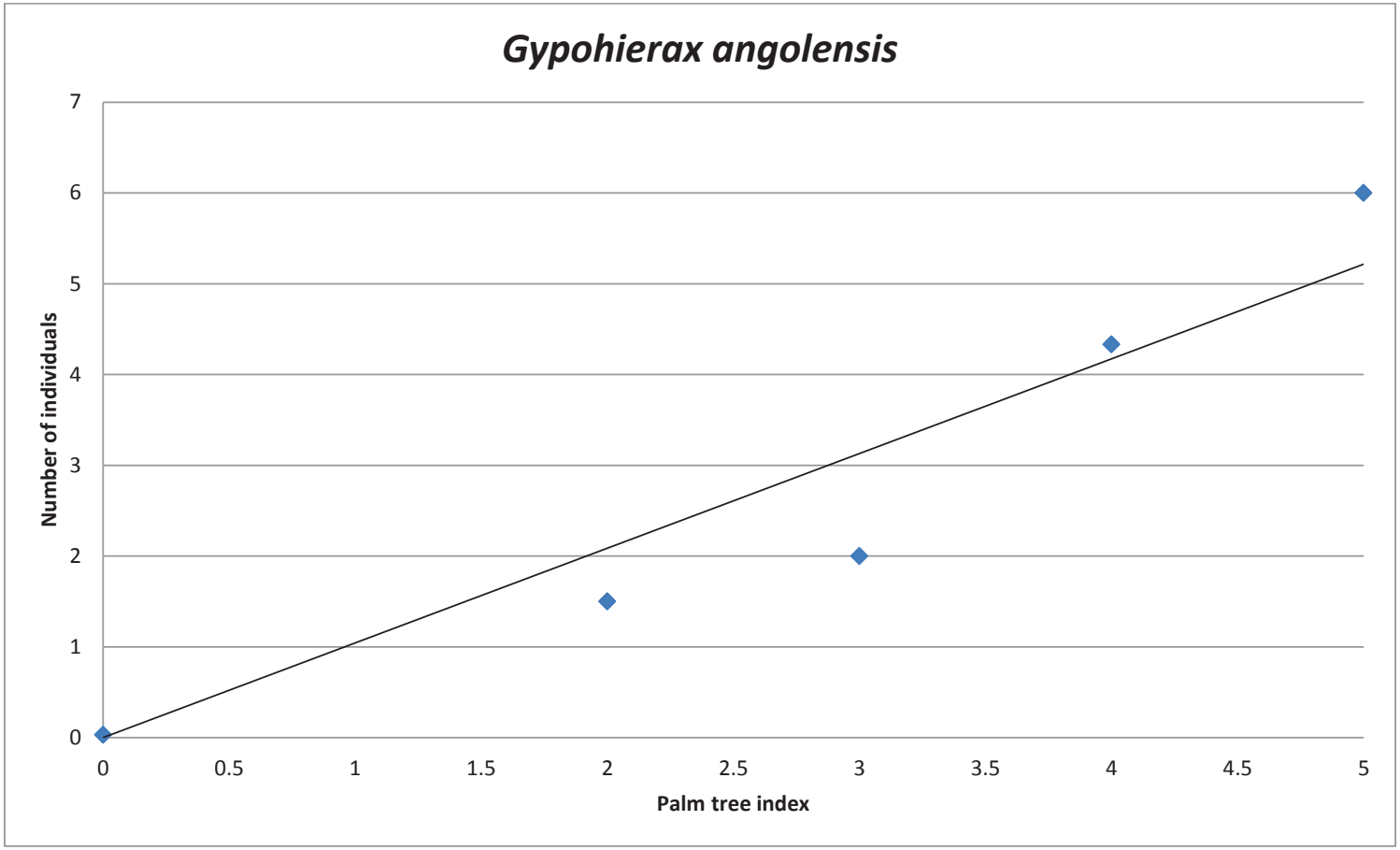

Figure 36: Correlation between average number of individuals and palm tree index

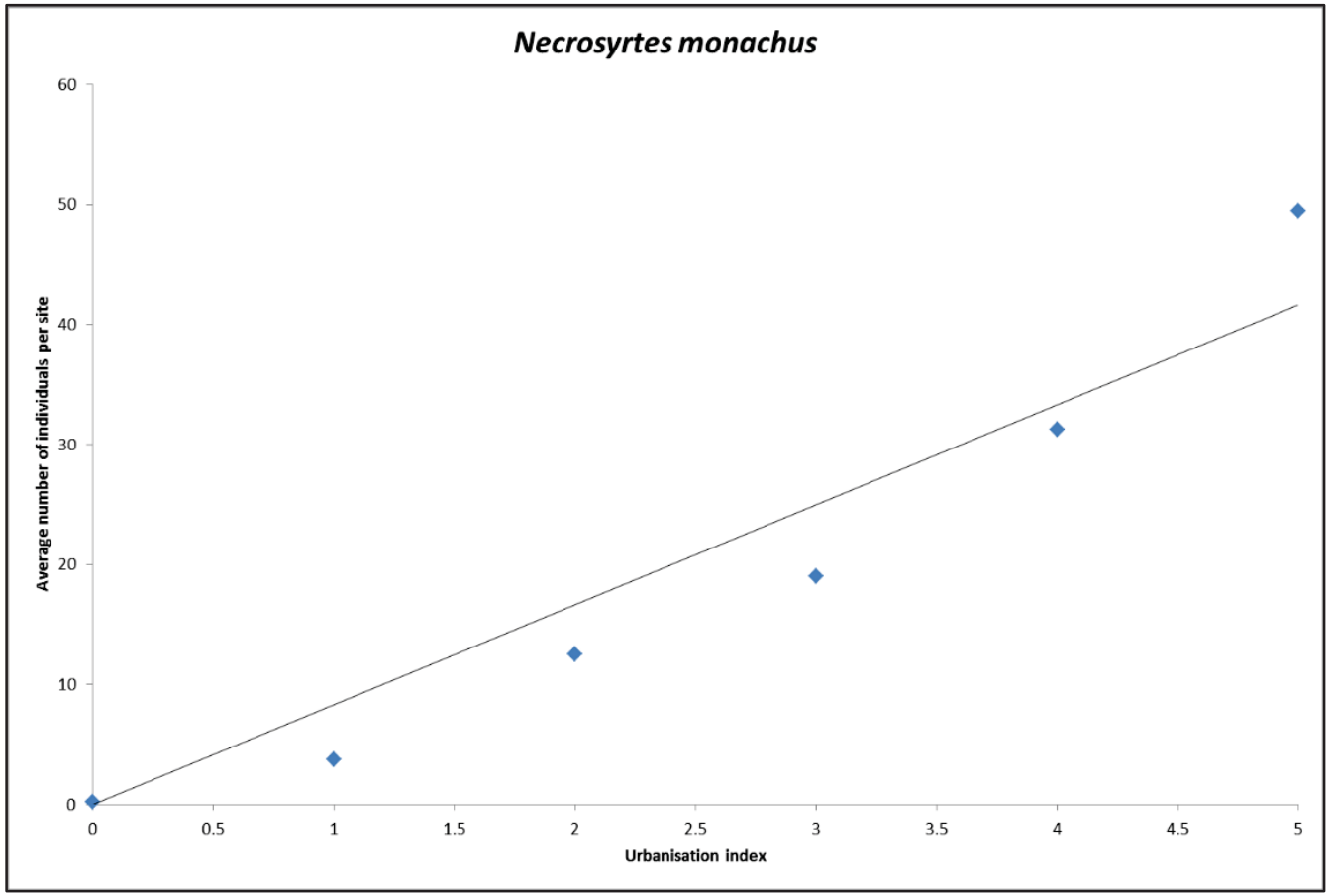

Figure 37: Correlation between average number of Necroyrtes monachus individuals per site and the urbanisation index of the sites

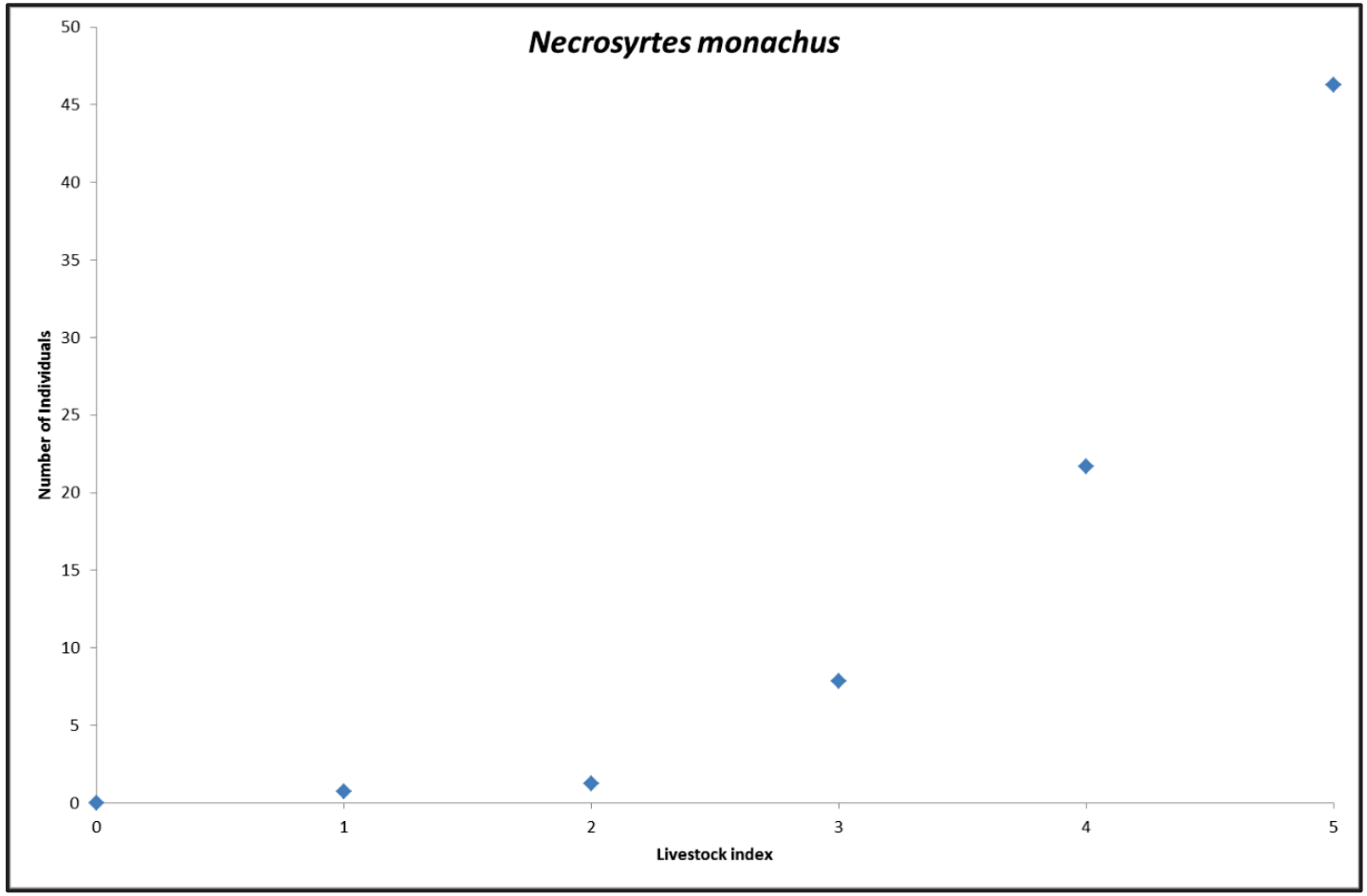

Figure 38: Correlation between average number of Necroyrtes monachus individuals per site and the livestock index of the sites

6.3.2.2.8 Discussion

From the above review we can see that birds are usually restricted, to varying degrees, in their ranges by the following factors (Hudson & Bouwman, 2007):

- Food;
- Water availability;
- Nesting sites;
- Competition;
- Predation; and
- Vegetation structure.

Furthermore, it is apparent that human impacts can affect these factors, causing not only the exclusion of birds from an area, because of the destruction of natural habitats necessary to provide these factors (Hudson & Bouwman, 2008), but also cause an influx of certain species to areas because, of an increase in one of these factors, or an extension of a species range, due to the availability of these factors where there were none previously (Hudson & Bouwman, 2007).

6.3.2.2.9 Palm-nut Vulture (Gypohierax angolensis)

The Palm-nut Vulture (*Gypohierax angolensis*), is not considered endangered or critically endangered by the IUCN, Although impacts on this species will not trigger further investigations according to IFC Performance Standard 6, it was included in this study due to its status as “charismatic megafauna” listed by the WWF.

Gypohierax angolensis appears to be restricted in its range mainly by food sources. This study showed that this species is limited in its distribution to areas which have either a presence of palm-trees, which are the producers of palm nuts (the main diet of *Gypohierax angolensis*), or fish which are a secondary diet of this species (hence its alternative common name, the vulturine fish eagle).

Water availability is not a limiting factor to any species (including *Gypohierax angolensis*) in this region due to the high rainfall during the wet season and perennial water bodies being scattered throughout the study area. Suitable vegetation for nesting sites for *Gypohierax angolensis* occur throughout the study area and this was not seen as a limiting factor in the distribution of this species within the study area.

Because of the specialised nature of *Gypohierax angolensis*, there are no real competitors for this species with regards to food sources, with the possible exception of human populations in the area. That being said, these species will often pre-empt the harvesting of palm nuts by humans and therefore reduce the effect of this competition. Few species prey on vultures of any kind and no known predators of *Gypohierax angolensis* occur in the study area. There may be the isolated incidence of old or sick members of this species being attacked and killed by domestic or feral dogs, but such incidences are very unlikely.

Vegetation structure is thought unlikely to play a role in the distribution of this species as vegetation throughout the study area is highly impacted by anthropogenic disturbances. Furthermore, the areas in which this species was found, were already impacted due to agriculture by means of rice paddies. Vegetation structure of the rice paddies is also very different to that of the mature mangroves lining the river, which is the other vegetation community in which this species was recorded.

This species is absent in areas of urbanisation, although they do occur in rice paddies and near small villages, where palm trees are present indicating some sensitivity to urbanisation.

6.3.2.2.10 Hooded Vulture (Necrosyrtes monachus)

Based on the findings of this study it would appear that the vast majority of medium to large mammal species, which would usually be the preferable food source of the hooded vultures in the area, have become almost extinct, due to overutilization by the human population. This has caused vulture populations to leave the natural areas, which they would have inhabited historically, and this species

has moved to areas inhabited by humans in order to utilise the resources available there (livestock, dogs and other animals dying of disease or other causes).

It would appear as though, over many years, this species has adapted to a symbiotic relationship with humans and become a human commensal species. This species has adapted to factors, which would have previously been a deterrent, such as anthropogenic noise, and now inhabits the same areas inhabited by people. This is clearly visible by the strong correlation between *Necrosyrtes monachus* and urbanisation in the area, while there is no correlation between *Necrosyrtes monachus* and factors such as natural vegetation.

Water availability is not a limiting factor to any species (including *Necrosyrtes monachus*) in this region due to the high rainfall during the wet season and perennial water bodies being scattered throughout the study area. Suitable vegetation for nesting sites for *Necrosyrtes monachus* occur throughout the study area and this was not seen as a limiting factor in the distribution of this species within the study area.

Because of the specialised nature of *Necrosyrtes monachus*, there are no real competitors for this species with regards to food sources, with the possible exception of human populations in the area. That being said, these species will often pre-empt the harvesting of palm nuts by humans and therefore reduce the effect of this competition. Few species prey on vultures of any kind and no known predators of *Necrosyrtes monachus* occur in the study area. There may be the isolated incidence of old or sick members of this species being attacked and killed by domestic or feral dogs, but such incidences are very unlikely.

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6.3.2.3 Conclusions and Recommendations

6.3.2.3.1 Crocodiles

All indications of this study appear to show that the African slender –snouted crocodile and the West African dwarf crocodile do not occur in this area. Features of the demographics of the crocodile population in the Cacheu river system showed that the crocodile population increases exponentially with an increase in distance from the Cacheu River Mouth. Only two individuals were recorded in the Cacheu River downstream from Farim indicating the majority of individuals of this taxon occurs upstream of the mining area, thereby making it unlikely that the development will have a significant effect on crocodile populations in the river.

The fact that young crocodiles use the area close to the mine site along the river as a nursery area may be a fact which will require more study as dewatering of the mangroves and loss of this habitat may impact crocodile populations.

6.3.2.3.2 Vultures

Although *Necrosyrtes monachus* is currently listed on the IUCN Red Data List as critically endangered (CR), it is a locally common species in the area with a total of more than 600 individuals being recorded during the surveys. This species has become highly human commensal throughout West Africa and is well adapted to anthropogenic disturbance. *Necrosyrtes monachus* appears to be unaffected by the current anthropogenic activities in the area and it is unlikely that the mining will have a significant effect on these species. A monitoring program could be put in place in order to monitor any unforeseen effects.

Due to the specialised nature of *Gypohierax angolensis*, their range is very restricted in the study area. Although a small percentage of palm trees will be lost during the mining operations it is unlikely that this will affect the *Gypohierax angolensis* populations in the area.

6.3.3 Exotic Species

Guinea-Bissau has a surprisingly low number of exotic species (one of the lowest in Africa with only eight exotic invasive species occurring in the country). The invasive exotic species known to occur in Guinea Bissau are summarised below:

Lantana camara

Originally from Malaysia

A spreading shrub or untidy scrambler growing up to 2m or higher. Stems usually covered with short, stiff hairs and recurved thorns. Dark green, rough, hairy leaves which are paler below and smell strongly when crushed. Pink, red, crimson, orange, yellow or white flowers in compact, flat-topped heads, often with several colours in one head, appear from September to April. Glossy green fruits which turn purplish-black. Poisonous. Competes with and replaces indigenous species. Allelopathic suppression of indigenous species interrupts regeneration processes and reduces biodiversity of natural ecosystems. Dense stands in plantations obstruct access and utilization. Poisonous to humans and animals and responsible for livestock mortalities. Reduces the grazing potential of the land.

Eichhornia crassipes (aquatic plant)

Originally from South America, *Eichhornia crassipes* is one of the worst aquatic weeds in the world. Its beautiful, large purple and violet flowers make it a popular ornamental plant for ponds. It is now found in more than 50 countries on five continents. Water hyacinth is a very fast growing plant, with populations known to double in as little as 12 days. Infestations of this weed block waterways, limiting boat traffic, swimming and fishing. Water hyacinth also prevents sunlight and oxygen from reaching the water column and submerged plants. Its shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems.

Leucaena leucocephala (tree)

The fast-growing, nitrogen-fixing tree/shrub Leucaena leucocephala, is cultivated as a fodder plant, for green manure, as a windbreak, for reforestation, as a biofuel crop etc. Leucaena has been widely introduced due to its beneficial qualities; it has become an aggressive invader in disturbed areas in many tropical and sub-tropical locations and is listed as one of the '100 of the World's Worst Invasive Alien Species'. This thornless tree can form dense monospecific thickets and is difficult to eradicate once established. It renders extensive areas unusable and inaccessible and threatens native plants.

Prosopis spp. (tree, shrub)

Members of the genus *Prosopis* spp., which are commonly known as mesquite or algarrobo, include at least 44 defined species and many hybrids. This leads to problems with identification. For this reason, information about different species in the *Prosopis* genus is presented in this genus-level profile. Native to the Americas, *Prosopis* species are fast growing, nitrogen fixing and very salt and drought tolerant shrubs or trees. Most are thorny, although thornless types are known. Animals eat the pods and may spread seeds widely. Trees develop a shrubby growth form if cut or grazed. The four main species that have presented problems as weeds world-wide are *P. glandulosa* and *P. velutina* in more subtropical regions and *P. juliflora* and *P. pallida* in the truly tropical zone.

Adenanthera pavonina (tree)

A medium-sized tree up to 15m high, *Adenanthera pavonina* is native to India and Malaysia. It has been planted extensively throughout the tropics as an ornamental and has become naturalised in many countries. It invades intact, undisturbed hardwood forests as well as disturbed sites and can quickly form large colonies.

Columba livia (bird)

Columba livia is native to Europe and has been introduced worldwide as a food source, or for game. These pigeons prefer to live near human habitation, such as farmland and buildings. They cause considerable damage to buildings and monuments because of their corrosive droppings. They also pose a health hazard, since they are capable of transmitting a variety of diseases to humans and to domestic poultry and wildlife.

Rattus rattus (mammal)

The black rat (Rattus rattus, also known as the ship rat, roof rat, house rat, Alexandrine rat, old English rat, and other names) is a common long-tailed rodent of the genus Rattus (rats) in the subfamily Murinae (murine rodents). The species originated in tropical Asia and spread through the Near East in Roman times before reaching Europe by the 1st century and spreading with Europeans

across the world. Black rats are generalist omnivores. They are serious pests to farmers as they eat a wide range of agricultural crops.

Mus domesticus (Mammal)

The house mouse (Mus musculus) is a small mammal of the order Rodentia, characteristically having a pointed snout, small rounded ears, and a long naked or almost hairless tail. It is one of the most numerous species of the genus Mus. Although a wild animal, the house mouse mainly lives in association with humans.

During this study only *Lantana camara* was recorded in the wild, although some exotic species are resent in the settlement areas. In a country like Guinea-Bissau the introduction of exotic species is of less concern than other impacts, mainly due to the fact that the salinity of the soil and water will exclude many non-indigenous species. The increase in human population may, however, cause an explosion of human commensal species such as *Rattus rattus* and *Mus domesticus*, due to the increased food supply. This impact can be mitigated by the implementation of sanitary disposal.

6.4 Ecological Integrity

The ecological function of the Farim mine study area can generally be described as moderate for the majority of the study area, although this does vary from low (in the highly transformed areas due to slash and burn cropping techniques) to high in the more inaccessible areas. Areas in which prospecting and slash and burn farming has taken place, as well as areas in which settlements have been established are considered as areas where ecological function is reduced. The cashew plantations and secondary forests appear to both have moderate ecological function, particularly in areas where indigenous species have been allowed to intersperse the Cashew trees. Although areas such as the rice paddies are transformed to some extent, the fauna species composition of these areas seem to indicate that the ecological integrity can still be considered high. The ecological function of the study area is indicated in Figure 39.

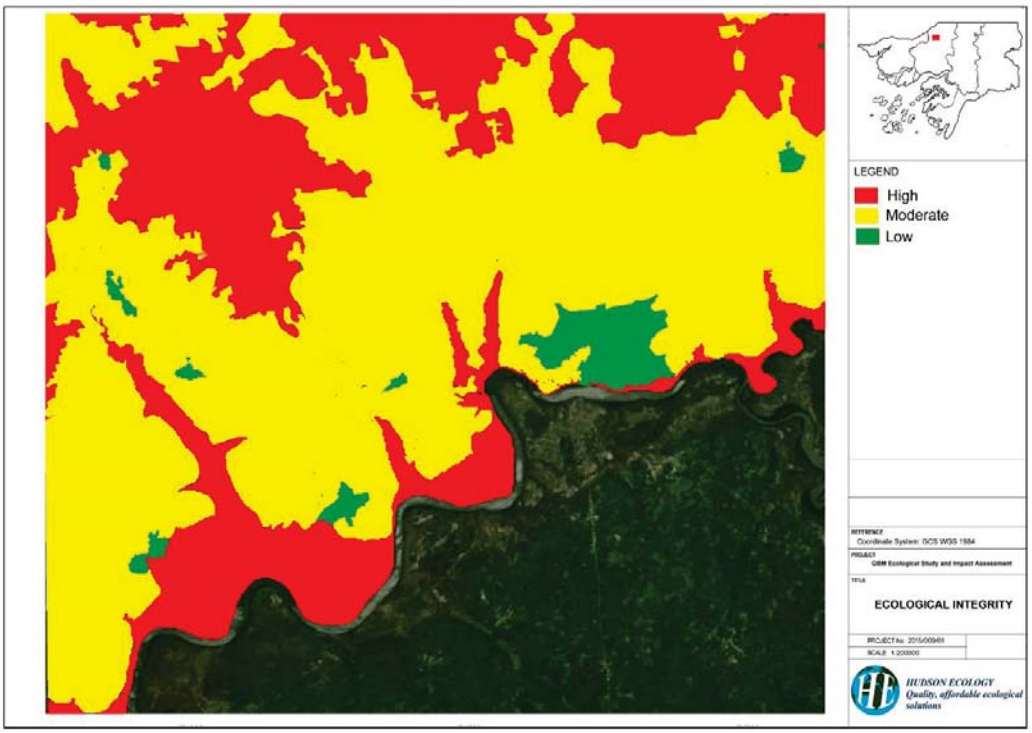

Figure 39: Ecological integrity within the study area

At the Ponta Chugue port site, the ecological integrity of the site varies between high for the *Rhizophora – Avicennia* Mangrove community, *Elias – Cyperus* Floodplain community and the less degraded *Dialium - Sterculia* coastal woodland vegetation community, moderate for the more degraded *Dialium - Sterculia* coastal woodland vegetation community and *Anadelphia afzeliana* seasonally wet grassland community and low for the *Oryza* Paddy vegetation community. The *Oryza* Paddy vegetation community in this area are considered more degraded than those at the Farim mine site due to the fact that there is a monoculture of *Oryza* spp. in these areas, whereas the *Oryza* Paddy vegetation community near the Farim mine site show far greater species diversity, with a large number of indigenous species resent in these areas. Ecological integrity of the vegetation communities in the Ponta Chugue study area is shown Figure 40.

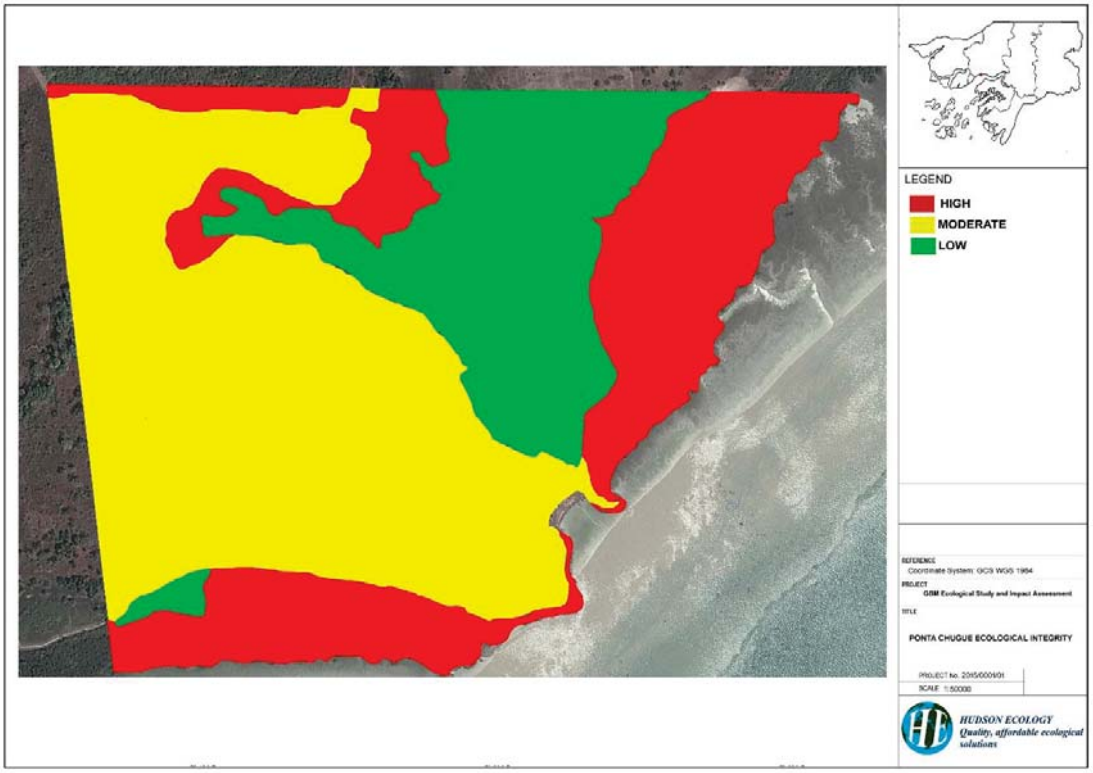

Figure 40: Ponta Chugue Ecological Integrity

6.5 Conservation Importance

The Farim mine study area falls within the dry tropical forest biome of the Guinean Forest zone and due to the high species diversity and intrinsic conservation value of the area it is classified as having high conservation importance. In order to show area of increased conservation importance due to the presence of Red Data species or other intrinsic factors the area has been divided into areas of low, moderate and high conservation importance (Figure 41). Areas that have been severely disturbed such as settlements are considered of low conservation importance. These areas are, however, quite small in relation to the overall study area (>30% of the study area). Areas that have been disturbed by farming are considered of moderate conservation importance due to the fact that rehabilitation of these areas is possible. The natural forest, floodplain and mangrove areas are considered of very high conservation importance due to the presence of Red Data species in these areas and the intrinsic importance of these areas. Finally, the rice paddies may host two of the red data plant species endemic to the region (*Floscopa axillaris* and *Digitaria patagiata*). During the May 2015 surveys an attempt was made to determine the presence/absence of these species within rice

paddies, but the first rains had not yet begun and these annual species were not yet emergent. In keeping with the Precautionary Principle (COMEST, 2005), we need to assume these species are present in these areas until a conclusive study can be conducted.

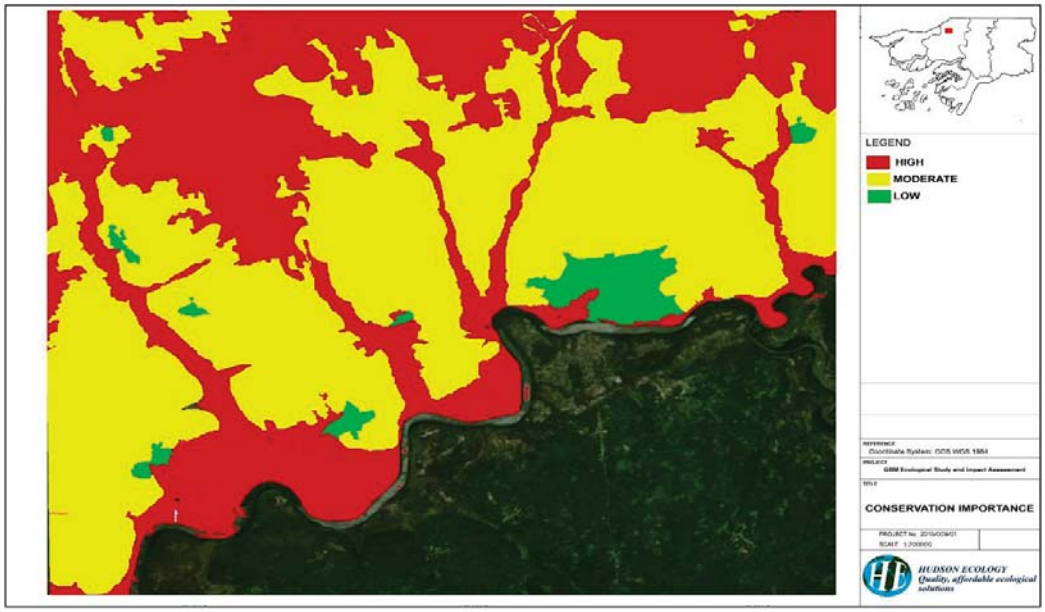

Figure 41: Conservation importance within the study area

The conservation importance at the Ponta Chugue port site can generally be described as moderate due to the disturbance in the area. The larger population in the surrounding areas and, subsequently, the increased population pressure placed on many of the vegetation communities in the area have resulted in the suitability of these vegetation communities to host Red Data or protected species has been greatly reduced. Two vegetation communities can be considered as having a high conservation importance, these are the less degraded *Dialium* - *Sterculia* coastal woodland vegetation community and the *Rhizophora* – *Avicennia* Mangrove community. The presence or absence of listed species in these areas could not be confirmed, due to the studies being conducted during an inappropriate season and it is suggested that studies be conducted to gain more clarity on the presence or absence of listed species in this area.

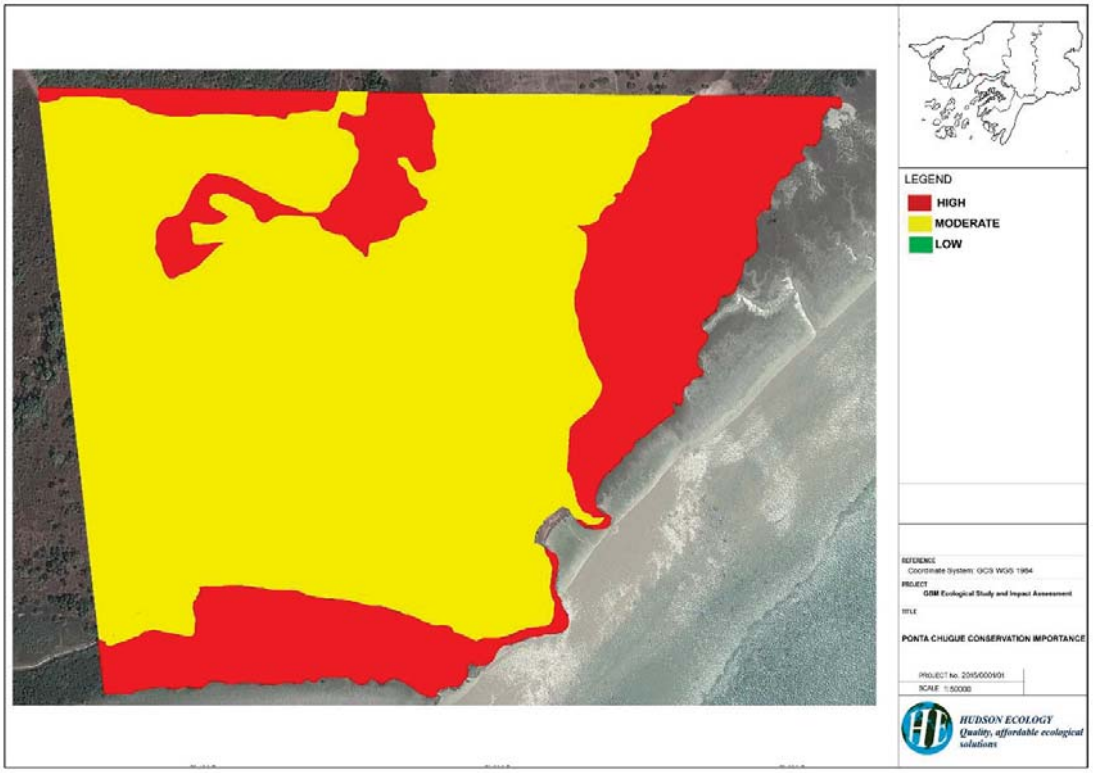

Figure 42: Ponta Chugue Conservation Importance

7 DISCUSSION AND CONCLUSIONS

The Farim Phosphate Project is located in the central northern part of Guinea-Bissau, approximately 25 km south of the Senegal border, approximately 5 km west of the town of Farim and 120 km northeast of Bissau, the capital of Guinea-Bissau. The Project will include an open pit mine, processing plant, waste disposal facilitates and a proposed port facility to the east of Bissau.

A total of 341 plant species were recorded during the surveys. Floral species diversity in the area is moderate to high, but not as high as many regions of West Africa, such as the Upper Guinea Forest zone. A large proportion of the species recorded are indigenous with few exotic species occurring in the area although, in areas of higher anthropogenic disturbances, some exotic species are more prevalent.

Flora assessments were conducted in wet and dry seasons between November 2011 and May 2015 respectively. Based on physiognomy, moisture regime, rockiness, slope and soil properties, seven main communities were recognised, namely:

- *Rhizophora – Avicennia* Mangrove community (Farim and Ponta Chugue study areas);
- Natural Forest vegetation community (Farim study area only);
- Secondary Forest community (Farim study area only);
- *Elias – Cyperus* Floodplain community (Farim and Ponta Chugue study areas);

- *Oryza* Paddy vegetation community (Farim and Ponta Chuge study areas);
- *Dialium - Sterculia* coastal woodland vegetation community (Ponta Chuge study area only); and
- *Anadelphia afzeliana* seasonally wet grassland community.

The *Oryza* Paddy vegetation community occurs in areas of freshwater wetlands which are not affected by tidal ebbs and flows throughout the country, these areas of freshwater wetlands have been modified to facilitate the planting of rice, so alterations to the flow of freshwater systems create large inundated areas where rice is planted. Although tree species are sparse within these areas a few species are often associated with these areas, especially *Anthostema senegalense*, *Elaeis guineensis*, *Pterocarpus santalinoides* and *Sarcocephalus latifolius*. Closer to the permanently inundated areas there are communities in which some common species are *Eichhornia natans*, *Nymphoides indica*, *Ottelia ulvifolia*, *Rotala tenella*, *Sphenoclea zeylanica* and *Utricularia gibba*. The herbaceous layer in this vegetation community is dominated by *Oryza glaberrima, Oryza longistaminata* and *Oryza sativa*, which has been planted for food. The only species found which is known to be listed by the IUCN Red Data list is *Raphia palma-pinus,* which is found along rivers and is listed as Data Deficient. A further two Red Data species *Floscopa axillaris* and *Digitaria patagiata* may also occur in this vegetation community, but due to the fact that the studies were conducted at an inappropriate time to determine this with any certainty, it must be assumed that there is a high probability of occurrence of these species in this vegetation community. A total of 103 flora species were recorded in this vegetation community

Large sections of natural forests have been cleared in order to grow Cashew nuts and other crops. This vegetation community encompasses areas that have been cleared and that have been replanted with Cashew trees (*Anacardium occidentale*). The cashew plantations vary from areas which are dominated by Cashew trees, with some local trees such as *Albizia zygia*, *Detarium senegalense*, *Dialium guineense* and *Malacantha alnifolia* still occurring within these plantations. Other areas have been effectively devoid of natural vegetation and are completely dominated by *Anacardium occidentale.*Many of the areas that have been recently cleared are devoide of larger trees, but still contain many of the species associated with natural forests. These areas may be easily rehabilitated, but areas where a greater deal of disturbance has taken place will be far more difficult to rehabilitate. A total of 145 flora species were recorded in this vegetation community.

Another halophytic community recorded in the study area is the so-called salt water *lala*, a grassland. This vegetation community is found on Fluvisols in the floodplain areas adjacent to the larger rivers which are under tidal influence. The alinity of the water which floods these areas has resulted in the dominance of salt-tolerant species, such as *Paspalum vaginatum* as common species and the communities of *Blutaparum vermiculare , Cyperus amabilis, Cyperus crassipes, Cyperus cyperoides, Cyperus difformis, Cyperus dilatatus* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. The woody layer of these areas is poorly defined but *Hyphaene thebaica, Phoenix reclinata* and *Elias guineensis* occur in this vegetation community with few Adansonia digitata also scattered within this vegetation community. The denuded areas of these areas are widely utilised by local communities for the gathering of salt during the dry season and this vegetation community appears to be an important dry season grazing area. A total of 76 flora species were recorded in this vegetation community

The natural forest community occupies large areas of the northern part of the study area, with some variation in structure and composition. Common tree species include *Albizia zygia*, *Detarium senegalense*, *Dialium guineense, Malacantha alnifolia, Anisophyllea laurina, Dialium guineense, Hunteria umbellata, Malacantha alnifolia, Parinari excelsa* and *Strombosia pustulata.* Lianas such as *Agelaea pentagyna, Calycobolus heudelotii* and *Landolphia dulcis* are also common. The shrub layer is usually poor in these areas, but some common shrub species include *Clerodendrum sinuatum*, *Combretum micranthum* and *Psychotria peduncularis* and among the most frequent climbers are *Mezoneuron benthamianum*, *Saba senegalensis* and *Tetracera potatoria*. This vegetation community is currently under threat due mainly to slash and burn agricultural practises for the cultivation of food crops or Cashew nuts. Although only one Red Data species was recorded in this vegetation community, the likelihood of occurrence of Red Data species in this community is high. A total of 209 flora species were recorded in this vegetation community

Mangrove forests line all the larger rivers in the region. These areas are dominated by *Rhizophora* spp. (mainly *R. mangle* but also *R. racemosa* and to a lesser extent *R. harrisonii*). In the zones less frequently flooded by salt water *Avicennia germinans* is the prominent species. Other halophytic communities are the so-called salt water *lala*, a grassland found on Fluvisols with *Paspalum vaginatum* as common species and the communities of *Blutaparum vermiculare* and *Sesuvium portulacastrum* which are found in small patches along the shoreline. No Red Data species were recorded in this vegetation community and, due to the specialisation required for plants to survive in the tidal saline conditions, it is unlikely that any of the Red Data species, known to occur in the area, will occur in this vegetation community. Species diversity is low in this vegetation community, but species occurring in the area are highly specialised and this vegetation community can be characterised as a unique vegetation community. This vegetation community is integral in the functioning of the estuarine nature of the larger rivers in the area. A total of 29 highly specialised flora species were recorded in this vegetation community.

The *Dialium* - *Sterculia* coastal woodland vegetation community occurs in the transition zone between the terrestrial and the halophytic communities in the coastal regions. According to Catarino (2004), there are three types of coastal transition vegetation, which are usually identified according to species composition of the substratum. The substrata of the transitional zone in the vicinity of Ponta Chugue, for the most part, has been severly transformed, due to cropping of mainly millet (*Pennisetum glaucum*) and peanuts (*Arachis hypogaea*). Many of the tree strata species recorded, by Catarino (2004), to occur on ferralsols (Identified by the redder colour and clayey composition), namely *Dialium guineense*, *Elaeis guineensis*, *Phoenix reclinata*, *Sterculia tragacantha* and *Ximenia Americana* are present in the transitional zone closer to the coast itself. Slightly further inland on the Arenosols (identified by the greyer colour and sandier composition) *Dialium guineense*, *Lannea acida* and *Neocarya macrophylla* are typical species. On the Fluvisols closer to the drainage lines, *Dichrostachys cinerea* subsp. *Platycarpa* var. *platycarpa*, *Phoenix reclinata* and *Vernonia colorata* are dominant.

The most extensive wetland vegetation in the country is the locally called lala, a wet grass savannah with *Anadelphia afzeliana* being the dominant species in this vegetation community. This vegetation community is prevalent on gleysols, which are fine textured soils, deep, grey-coloured, from alluvial origin, with the upper layers often rich in organic matter. Furthermore, this vegetation community prevails in the inner lowland plains flooded by rainwater during the wet season, located mostly in the lower zones of the mainland. Noticeable in the area of Ponta Chugue, is that this vegetation community is particularly homogenous, with *Anadelphia afzeliana* being by far the most dominant species. It is likely that this is the result of human intervention through the use of fire, or harvesting of this grass species for thatching purposes.

During the surveys two Red Data floral species were recorded (*Albizia ferruginea* and *Raphia palma-pinus*). *Albizia ferruginea* were found within the natural forest areas and *Raphia palma-pinus* was recorded in the *Elias – Cyperus* floodplain and *Oryza* paddy communities. Two more species (*Floscopa axillaris* and *Digitaria patagiata)* may occur in the study areas. Both these species occur in seasonally wet freshwater systems, in the study area the seasonally wet freshwater systems are all but completely transformed into rice paddies, nevertheless both these species have historically been recorded in rice paddies in other parts of Guinea-Bissau and West Africa. All studies conducted in the area were undertaken before or after the height of the wet season when both these species flower. Species of these genera were recorded during the surveys, however without inflorescences and flowers on the plants it is impossible to tell whether the species recorded are the listed species or the unlisted species of the same genera. According to the Precautionary Principle (COMEST, 2005) (as indicated in IFC Performance Standard 6), until conclusive studies to the contrary can be conducted, it must be assumed that these species are present in the freshwater systems within the study area.

The faunal assessment was conducted in the wet and dry seasons between November 2011 and May 2015.

Non-chordate diversity within the study area was relatively high with a total of 124 arthropod species being recorded during the study. Most species recorded were common species with some specialised species being recorded in the mangrove communities. Although the mangrove species are highly specialised for this habitat type, they are locally common and not of conservation importance.Most of the species recorded are not restricted in terms of range and habitat preferences. Common species included Red Winged Dropwing (*Trithemis kirbyi*) and locust (*Locusta* sp.)

The herpetofauna of the region can be classified as having moderate diversity, of the 69 reptile species known to occur in Guinea Bissau, only 11 species recorded. This may be due to the proximity of the project area to the town of Farim and other settlements in the area. Common species occurring in the area include Ornate Monitor (*Varanus ornatus*) (Figure 14) and Tree Agama (*Agama agama*) (Figure 14).

The region can be classified as having low amphibian diversity, of the 34 amphibian species recorded in Guinea Bissau, 5 species were recorded during the 2011/12 surveys. Amphibian species do not appear to be utilized by the local community for food, although some species are said to have superstitious importance or medicinal uses. Of the 5 amphibian species recorded during the surveys, none are listed on the IUCN Red data list for the area. Amphibian species diversity was low. It must be noted that the rivers in the area are tidal and have a very high salinity. These are both characteristics to which amphibians are very sensitive. Due to the permeability of amphibian skin, saline water causes loss of fluids and dehydration in frog species (Vitt & Caldwell, 2009) or as found by Bentley and Schmidt-Nielsen (1971) due to sodium toxicity due to sodium entering through the permeable skin. During their study they found that Rana pipiens (Leopard frog) died within an hour of being placed in sea-water (Bentley & Schmidt-Nielsena, 1971). For this reason most of the rivers in the study area are uninhabitable for amphibian species, and only freshwater systems host this taxon. Five amphibian species were recorded, which included only common species such as *Ametia angolensis* and *Ametiophrynus regularis*, and none of the recorded species are listed as Red Data species or restricted in terms of range or habitat.

Avifaunal diversity in the study area was very high with a large number of upper trophic level species occurring in the area. The Hooded Vulture is currently listed as Endangered by the IUCN (2010). Seventy five species were recorded, these include Palmnut Vulture (*Gypohierax angolensis),* Long-crested eagle *(Lophaetus occipitalis),* Hooded vulture *(Necrosyrtes monachus) and* Gymnogene (*Polyboroides typus).* In general, species diversity was moderate to high throughout the study area with the rice paddies and natural forests showing the highest levels of species diversity.

Mammal species diversity was very low in the study area, probably due to severe subsistence hunting. Hunters were regularly seen or heard during the surveys often with animals ranging from snakes to monkeys. This not only reduces the number of animals and species in the area, but also causes the remaining animals to be very shy of humans, which in turn makes accurate survey of species occurring in the area very difficult.

Of the 192 mammal species known to occur in the study area, 15 species were recorded during the 2011 to 2015 surveys. The species recorded in the study area include Striped Ground Squirrel (*Xerus erythropus),* Musk shrew *(Crocidura* sp). Lesser Spot-nosed Guenon (*Cercopithecus petaurista),* Red colobus *(Procolobus badius).* Species trapped during the surveys included *Mastomys natalensis* and *Crocidura* sp. All species recorded are common species, with the exception of *Procolobus badius,* which is listed as **Endangered** (IUCN, 2010). It must be noted that this species was recorded dead and being transported by a hunter from some distance away in the natural forests to the north .

A total of 28 Red Data fauna species may occur in the area, according to the IUCN Red Data list. Some of the animals listed are believed to be locally extinct and suitable habitat for others is not available. The Red Data species that may occur in the study area consist of 2 reptile species, 15 avian species and 11 mammal species. The habitat suitability for Red Data species ranges from low to high with 4 species for which the habitat suitability can be classified as high. Only two Red Data species were recorded during the 2011 to 2015 surveys, namely the Red Colobus and the Hooded Vulture, the Red Colobus was, however, killed by a hunter just south of the Senegal border.

All indications of this study appear to show that the African slender –snouted crocodile and the West African dwarf crocodile do not occur in this area. Features of the demographics of the crocodile population in the Cacheu river system showed that the crocodile population increases exponentially with an increase in distance from the Cacheu River Mouth. Only two individuals were recorded in the Cacheu River downstream from Farim indicating the majority of individuals of this taxon occur upstream of the mining area, thereby making it unlikely that the development will have a significant effect on crocodile populations in the river.

The fact that young crocodiles use the area close to the mine site along the river as a nursery area may be a fact which will require more study as dewatering of the mangroves and loss of this habitat may impact crocodile populations.

Although *Necrosyrtes monachus* is currently listed on the IUCN Red Data List as critically endangered (CR), it is a locally common species in the area with a total of more than 600 individuals being recorded during the surveys. This species has become highly human commensal throughout West Africa and is well adapted to anthropogenic disturbance. *Necrosyrtes monachus* appears to be unaffected by the current anthropogenic activities in the area and it is unlikely that the mining will have a significant effect on these species. A monitoring program could be put in place in order to monitor any unforeseen effects.

Due to the specialised nature of *Gypohierax angolensis*, their range is very restricted in the study area. Although a small percentage of palm trees will be lost during the mining operations it is unlikely that this will affect the *Gypohierax angolensis* populations in the area.

Guinea-Bissau has a surprisingly low number of exotic species (one of the lowest in Africa with only eight exotic invasive species occurring in the country). The invasive exotic species known to occur in Guinea Bissau are:

- *Lantana camara*
- *Eichhornia crassipes* (aquatic plant)
- *Leucaena leucocephala* (tree)
- *Prosopis* spp. (tree, shrub)
- *Adenanthera pavonina* (tree)
- *Columba livia* (bird)
- *Rattus rattus* (mammal)
- *Mus domesticus* (Mammal)

During this study only *Lantana camara* was recorded in the wild, although some exotic species are resent in the settlement areas. In a country like Guinea-Bissau the introduction of exotic species is of less concern than other impacts, mainly due to the fact that the salinity of the soil and water will exclude many non-indigenous species. The increase in human population may, however, cause an explosion of human commensal species such as *Rattus rattus* and *Mus domesticus*, due to the increased food supply. This impact can be mitigated by the implementation of sanitary disposal.

The ecological function of the Farim mine study area can generally be described as moderate for the majority of the study area, although this does vary from low (in the highly transformed areas due to slash and burn cropping techniques) to high in the more inaccessible areas. Areas in which prospecting and slash and burn farming has taken place, as well as areas in which settlements have been established are considered as areas where ecological function is reduced. The cashew plantations and secondary forests appear to both have moderate ecological function, particularly in areas where indigenous species have been allowed to intersperse the Cashew trees. Although areas such as the rice paddies are transformed to some extent, the fauna species composition of these areas seem to indicate that the ecological integrity can still be considered high.

At the Ponta Chugue port site, the ecological integrity of the site varies between high for the *Rhizophora – Avicennia* Mangrove community, *Elias – Cyperus* Floodplain community and the less degraded *Dialium - Sterculia* coastal woodland vegetation community, moderate for the more degraded *Dialium - Sterculia* coastal woodland vegetation community and *Anadelphia afzeliana* seasonally wet grassland community and low for the *Oryza* Paddy vegetation community. The *Oryza* Paddy vegetation community in this area are considered more degraded than those at the Farim mine site due to the fact that there is a monoculture of *Oryza* spp. in these areas, whereas the *Oryza* Paddy vegetation community near the Farim mine site show far greater species diversity, with a large number of indigenous species resent in these areas.

The Farim mine study area falls within the dry tropical forest biome of the Guinean Forest zone and due to the high species diversity and intrinsic conservation value of the area it is classified as having high conservation importance. In order to show area of increased conservation importance due to the

presence of Red Data species or other intrinsic factors the area has been divided into areas of low, moderate and high conservation importance (Figure 41). Areas that have been severely disturbed such as settlements are considered of low conservation importance. These areas are, however, quite small in relation to the overall study area (>30% of the study area). Areas that have been disturbed by farming are considered of moderate conservation importance due to the fact that rehabilitation of these areas is possible. The natural forest, floodplain and mangrove areas are considered of very high conservation importance due to the presence of Red Data species in these areas and the intrinsic importance of these areas. Finally, the rice paddies may host two of the red data plant species endemic to the region (*Floscopa axillaris* and *Digitaria patagiata*). During the May 2015 surveys an attempt was made to determine the presence/absence of these species within rice paddies, but the first rains had not yet begun and these annual species were not yet emergent. In keeping with the Precautionary Principle (COMEST, 2005), we need to assume these species are present in these areas until a conclusive study can be conducted

The conservation importance at the Ponta Chugue port site can generally be described as moderate due to the disturbance in the area. The larger population in the surrounding areas and, subsequently, the increased population pressure placed on many of the vegetation communities in the area have resulted in the suitability of these vegetation communities to host Red Data or protected species has been greatly reduced. Two vegetation communities can be considered as having a high conservation importance, these are the less degraded *Dialium - Sterculia* coastal woodland vegetation community and the *Rhizophora – Avicennia* Mangrove community. The presence or absence of listed species in these areas could not be confirmed, due to the studies being conducted during an inappropriate season and it is suggested that studies be conducted to gain more clarity on the presence or absence of listed species in this area.

8 RECOMMENDATIONS

Determination of presence or absence of red data plant species

Two IUCN listed species (Floscopa axillaris and Digitaria patagiata) have a high probability of occurrence in two of the vegetation communities likely to be affected by developments at Farim and Ponta Chugue. Due to factors arising during the studies (exceptional weather conditions and incorrect timing of site visits), the presence/absence of these species has not been confirmed. It is recommended that a study be conducted during the flowering season of these two species (July – August/early September) in order to confirm their presence or absence.

9 ACRONYMS

2D	two dimensional
3D	three dimensional
asl	above sea level
BOD	biological oxygen demand
CAIA	Cellule d'Evaluation de l'Impact Environnemental
DGMGB	Directorate of Geology and Mines of Guinea-Bissau
EHS Guidelines	World Bank Group Environment, Health and Safety Guidelines
EMP	environmental management plan
ESIA	environmental and social impact assessment
ESMP	Environmental and Social Management Plan
GAA	Golder Associates Africa Pty Ltd
GB Minerals	GB Minerals Ltd
Golder	Golder Associates (UK) Ltd.
IAP	interested and affected parties

IFC	International Finance Corporation
IGN	Institut Géographique National
IOB	in-pit overburden backfill
IRR	internal rate of return
IUCN	International Union for Conservation of Nature
LOM	life of mine
LOMP	life of mine plan
masl	metres above sea level
n/a	not applicable
OPA	open pit area
OSA	overburden storage area
OSF	overburden storage facility
PGBZC-GB	Biodiversity and Coastal Zone of Guinea Bissau
PS	performance standard
QA	quality assurance
QC	quality control
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UTM	universal transverse mercator
WB	World Bank
WD	waste dump

Adrian Hudson (Senior Ecologist)

10 REFERENCES

Alves, P., 2000. *A geologia da Guiné-Bissau no contexto da evolução regional do Cenozóico.Novasmetodologias e resultados obtidos..* Lisbon: Thesis IICT.

Bayliss, P. et al., 1986. Estimating the Abundance of Saltwater Crocodiles, Crocodylus porosus Schneider, in Tidal Wetlands of the Northern Territory. *Australian,* Issue 13, pp. 309-320.

Begon, M., Harper, J. & Townsend, C., 1996. *Ecology: Individuals, Populations and Communities.* 3rd ed. Oxford: Blackwell Science Ltd..

Bentley, P. & Schmidt-Nielsena, K., 1971. Acute effects of sea water on frogs (Rana pipiens). *Comparative Biochemistry and Physiology Part A: Physiology,* 40(2), p. 547–548.

Bibby, C., Burgess, N. & Hill, D., 1993. *Bird Census Techniques.* London: Harcourt Brace & Company.

BirdLife International , 2013. *Gypohierax angolensis. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2..* [Online]
Available at: www.iucnredlist.org
[Accessed 28 09 2013].

BirdLife International , 2012. *Necrosyrtes monachus. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2.* [Online]
Available at: www.iucnredlist.org
[Accessed 28 09 2013].

Branch, W., 1996. *Snakes and other reptiles of Southern Africa.* 2nd Edition ed. Cape Town: Struik.

Broadley, D., 1971. *The reptiles and amphibians of Zambia.* s.l.:Puku.

Casey, D. & Hein, D., 1994. Effects of heavy browsing on a bird community indeciduous forest. *Journal of Wildlife Management,* Issue 47, pp. 829-836.

Catarino, L., 2004. *Fitogeografia da Guiné-Bissau. PhD thesis.* Lisbon: Agronomy Institute of the Technical University of Lisbon.

Catarino, L., Martins, E., Pinto Basto, M. & Diniz, M., 2008. An annotated checklist of the vascular flora of Guinea Bissau. *Blumea,* p. 53: 1– 222.

Caughley, G., 1977. *Analysis of Vertebrate Populations.* London: John Wiley & Sons, Wiley Interscience.

Combrink, A., 2004. *Population Status of Crocodylus niloticus (Nile crocodile) at Lake Sibaya, Republic of South Africa. MSc Thesis.* s.l.:University of KwaZulu Natal.

COMEST, 2005. *The Precautionary Principle.* Paris: United Nations Educational Scientific and Cultural Organization.

Costa, J., 1946. Meio físico da Guiné Portuguesa. *Junta Missões Geográficas e Invest,* p. 1: 11–31..

Crocodile Specialist Group, 1996a. *Crocodylus niloticus. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1.,* s.l.: IUCN.

Crocodile Specialist Group, 1996b. *Osteolaemus tetraspis. In: IUCN 2003. 2003 IUCN Red List of Threatened Species.* [Online]
Available at: http://www.redlist.org
[Accessed 28 10 2013].

Crocodile Specialist Group, 1996c. *Crocodylus cataphractus. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1.* [Online]
Available at: www.iucnredlist.org
[Accessed 28 10 2013].

De Walt, S., Maliakal, S. & Denslow, J., 2003. Changes in vegetation structure and composition along a tropical forest chronosequence: Implications For Wildlife. *Forest Ecology and Management,* Issue 182, pp. 139-151.

Dean, W., 2000. Factors affecting bird diversity patterns in the Karoo, South Africa. *South African Journal of Science,* Issue 96, pp. 609-616.

DeGraaf, R. et al., 1991. *Forest and Rangeland Birds of the United States natural history and habitat use. U.S. Department of Agriculture, Forest Service, Agricultural Handbook 688,* s.l.: USDAF.

Diop, F., 2010. *Floscopa axillaris.* [Online]
Available at: www.iucnredlist.org

Diop, F. & Mahamane, A., 2010. *Digitaria patagiata.* [Online]
Available at: www.iucnredlist.org

Du Preez, L. & Carruthers, V., 2009. *A Complete Guide to the Frogs of Southern Africa.* Cape Town: Struik.

Ferguson-Lees, J. & Christie, D., 2001. *Raptors of the World.* London: Christopher Helm.

Flather, C., Brady, S. & lnkley, D., 1992. Regional habitat appraisals of wildlife communities: A landscape-level evaluation of a resource planning model using avian distribution data. *Landscape Ecology,* Issue 7, pp. 137-147.

Fosberg, F., B.J, G. & Küchler, A., 1961. D elimitation of the humid tropics.. *Geogr. Rev.,* p. 51: 333–347..

Games, I., Zohlo, R. & Chande, B., 1992. Utilization of the Crocodile Resource of Lake Cahora Bassa, Mozambique, 1987 and 1988.. In: *The CITES Nile Crocodile Project.* Lausanne-Switzerland: Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, p. 133.

Guggisberg, C., 1972. *Crocodiles: Their Natural History, Folklore, and Conservation.* s.l.:ISBN 0-7153-5272-5.

Harrison, J. et al., 1997. *The Atlas of Southern African Birds.* Johannesburg: BirdLife South Africa.

Hekkala, E. et al., 2011. An ancient icon reveals new mysteries: mummy DNA resurrects a cryptic species within the Nile crocodile. *Molecular Ecology,* 20(20), p. 4199–4215.

Hockey, P., 2003. Land Invasions. *Africa Birds and Birding,* Issue 8, pp. 35-41.

Hockey, P., Dean, W. & Ryan, P., 2005. *Roberts Birds of Southern Africa.* 7th Edition ed. Cape Town: The Trustees of the John Voelker Bird Book Fund.

Hudson, A. & Bouwman, H., 2007. Different land-use types affect bird communities in the Kalahari, South Africa. *African Journal of Ecology,* Issue 45, p. 423–430.

Hudson, A. & Bouwman, H., 2008. Birds associated with a tailings storage facility and surrounding areas from a South African gold mine. *African Journal of Ecology,* pp. 46:276-28.

Hutton, J., 1992. *Report of the Coordinator of the CITES Nile Crocodile Project to the CITES Secretariat as Presented to the Parties at the Seventh Meeting of the Conferenceof the Parties.* Lausanne-Switzerland, Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Hutton, J. & Woolhouse, M., 1989. Mark-Recapture to Assess Factors Affecting the Proportion of a Nile Crocodile Population Seen During Spotlight Counts at Ngezi, Zimbabwe, and the Use of Spotlight Counts to Monitor Crocodile Abundance. *Journal of Applied Ecology,* Issue 26, pp. 381-395.

International, B., 2000. *Threatened birds of the world.* Barcelona and Cambridge: Lynx Edicions and BirdLife International.

IUCN, 2001. IUCN Red List Categories and Criteria.. In: *Red Data Book of the Mammals of South Africa: A Conservation Assessment..* s.l.:s.n.

IUCN, 2010. *IUCN Red List of Threatened Species.* [Online]
Available at: http://www.iucnredlist.org
[Accessed November 2010].

IUCN, 2011. [Online]
Available at: http://www.iucnredlist.org
[Accessed 08 July 2011].

IUCN, 2013. [Online]
Available at: http://www.iucnredlist.org
[Accessed 08 July 2013].

Johnson, M. & Sherry, T., 2001. Effects of food availability on the distribution of migratory warblers among habitats in Jamaica. *Journal of Animal Ecology,* Issue 70, pp. 546-560.

Keyser, A., 2002. Nest predation in fragmented forests: landscape matrix by distance from edge interactions. *The Wilson Bulletin,* Issue 114, pp. 186-191.

Lack, D., 1933. Habitat selection in birds. *Journal of Animal Ecology,* Issue 2, pp. 239-262.

MacArthur, R. & MacArthur, J., 1961. On Bird species diversity. *Ecology,* Issue 42, pp. 594-599.

Maclean, G., 1993. *Roberts Birds of Southern Africa.* 6th ed. Cape Town: Trustees of the John Voelcker Bird Book Fund.

Maesetas, J., Knight, R. & Gilgert, W., 2003. Biodiversity across a Rural Land-Use Gradient. *Conservation Biology,* Issue 17, pp. 1425-1434.

McCune, B. & Grace, J. B., 2002. *Analysis of Ecological Communities.* Gleneden Beach, Oregon, USA (www.pcord.com) With a contribution by Dean L. Urban: MjM Software.

Mota, A., 1954. *Guiné Portuguesa. Agência Geral do Ultramar,,* Lisboa: s.n.

Naddra, R. & Nyberg, D., 2001. Effects of afforestation of pasture on bird abundance. *Transactions of the Illinois State Academy of Science,* Issue 94, pp. 243-250.

Nichols, J., 1992. Capture-Recapture Models: Using Marked Animals to Study Population Dynamics. *BioScience,* Issue 42, pp. 94-102.

Ogada, D. & Buij, R., 2011. Large declines of the Hooded Vulture Necrosyrtes monachus across its African range. *Ostrich ,* 82(2), pp. 101-113.

Otieno, P. O. et al., 2010. Carbofuran and its toxic metabolites provide forensic evidence for Furadan exposure in vultures (Gyps africanus) in Kenya. *Bulletin of Environmental Contamination and Toxicology,* Volume 84, pp. 536-544.

Picker, M., Griffiths, C. & Weaving, A., 2002. *Field Guide to Insects of South Africa.* Cape Town: Struik.

Pooley, A., 1969. Preliminary Studies on the Breeding of the Nile Crocodile Crocodylus niloticus, in Zululand. *The Lammergeyer,* Issue 10, pp. 22-44.

Ribeiro, O., 1950. Missão de geografia à Guiné em 1947. *Junta Missões Geográficas e Invest,* p. 5: 5–25..

Ross, J., 1998. *Crocodiles: Status Survey and Conservation Action Plan.* Gland, Switzerland: IUCN.

Sinclair, I., Hockey, P. & Tarboton, W., 2002. *Sasol Birds of Southern Africa.* 3rd Edition ed. Cape Town: Struik.

Sinclair, I. & Ryan, P., 2003. *A comprhensive illustrated field guides to Birds of Africa south of the Sahara.* Cape Town : Struik.

Smithers, R., 1983. *The mammals of the Southern African subregion.* Pretoria: University of Pretoria.

Somma, L., 2002. *Crocodylus niloticus Laurenti, 1768. USGS Nonindigenous Aquatic Species Database.* [Online]
[Accessed 28 10 2013].

Stuart, C. & Stuart, M., 2007. *Field Guide to the Mammals of Southern Africa.* 4th Edition ed. Cape Town: Struik Publishers.

Thomson, A. L. & Moreau, R. E., 1957. Feeding habits of the Palm-nut Vulture, Gypohierax. *Ibis,* 99(4), pp. 608-613.

Thorbjarnarson, J. & Eaton, M., 2003. Congo and Gabon Crocodile surveys. *Crocodile Specialist Group Newsletter,* 22 (1), pp. 3-11.

Tomoff, C., 1974. Avian species diversity in desert scrub. *Ecology,* Issue 55, pp. 396-403.

Virani, M., Kendall, C., Njoroge, P. & Thomsett, S., 2011. Major declines in the abundance of vultures and other scavenging raptors in and around the Masai Mara ecosystem, Kenya. *Biological Conservation,* Volume 144, pp. 746-752.

Vitt, L. & Caldwell, J., 2009. *Herpetology, Fourth Edition: An Introductory Biology of Amphibians and Reptiles.* 4th ed. Oklahoma: Elsevier. ISBN-13: 978-0123869197.

White, F., 1983. *The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa3 plates, Northwestern Africa, Northeastern Africa, and Southern Africa, 1:5,000,000..* Paris: UNESCO.

Whitford, W., 1997. Desertification and Animal Biodiversity in the desert Grasslands of North America. *Journal of Arid Environments,* Issue 37, pp. 709-720.

Willson, M., 1974. Avian community organization and habitat structure. *Ecology,* Issue 55, pp. 1017-1029.

WWF & IUCN, 1994. *Centres of plant diversity. A guide and strategy for their conservation.* Cambridge: IUCN Publications Unit.

APPENDIX A

Plant species recorded during the 2011 to 2015 surveys

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
ACANTHACEAE	*Asystasia gangetica*		X		X		X
ACANTHACEAE	*Barleria oenotheroides*			X		X	
ACANTHACEAE	*Blepharis maderaspatensis*		X			X	
ACANTHACEAE	*Dicliptera verticillata*						
ACANTHACEAE	*Dyschoriste perrottettii*						
ACANTHACEAE	*Hygrophila auriculata*						
ACANTHACEAE	*Hygrophila barbata*						
ACANTHACEAE	*Hygrophila brevituba*						
ACANTHACEAE	*Hygrophila odora*						
ACANTHACEAE	*Hygrophila senegalensis*						
ACANTHACEAE	*Hypoestes cancellata*		X	X		X	
ACANTHACEAE	*Justicia kotschyi*						
ACANTHACEAE	*Justicia ladanoides*						
ACANTHACEAE	*Lepidagathis chevalieri*						
ACANTHACEAE	*Lepidagathis collina*						
ACANTHACEAE	*Lepidagathis fimbriata*						
ACANTHACEAE	*Lepidagathis sericea*					X	
ACANTHACEAE	*Monechma ciliatum*						
ACANTHACEAE	*Nelsonia canescens*		X	X		X	
ACANTHACEAE	*Phaulopsis falcisepala*				X	X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
ACANTHACEAE	*Phaulopsis imbricata*					X	
ACANTHACEAE	*Rungia eriostachya*						
ACANTHACEAE	*Rungia grandis*			X		X	
ACANTHACEAE	*Rungia guineensis*						
ACANTHACEAE	*Ruspolia hypocrateriformis*						
ACANTHACEAE	*Thunbergia erecta*		X			X	
AIZOACEAE	*Sesuvium portulacastrum*						
AIZOACEAE	*Trianthema portulacastrum*		X	X			
ALISMATACEAE	*Sagittaria guayanensis*						
AMARANTHACEAE	*Achyranthes aspera*						
AMARANTHACEAE	*Amaranthus cruentus*						
AMARANTHACEAE	*Amaranthus spinosus*						
AMARANTHACEAE	*Blutaparon vermiculare*		X		X	X	X
AMARANTHACEAE	*Celosia trigyna*		X	X	X	X	
AMARANTHACEAE	*Cyathula prostrata*		X	X			
AMARANTHACEAE	*Pandiaka angustifolia*						
AMARANTHACEAE	*Pandiaka involucrata*						
AMARANTHACEAE	*Pupalia lappacea*						
ANACARDIACEAE	*Anacardium occidentale*			X			
ANACARDIACEAE	*Heeria insignis*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
ANACARDIACEAE	*Lannea acida*			X		X	
ANACARDIACEAE	*Lannea nigritana*					X	
ANACARDIACEAE	*Lannea velutina*					X	
ANACARDIACEAE	*Mangifera indica*			X			
ANACARDIACEAE	*Ozoroa insignis*						
ANACARDIACEAE	*Pseudospondias microcarpa*						
ANACARDIACEAE	*Sclerocarya birrea*						
ANACARDIACEAE	*Sorindeia juglandifolia*			X	X	X	
ANACARDIACEAE	*Spondias mombin*		X	X	X	X	
ANCISTROCLADACEAE	*Ancistrocladus barteri*					X	
ANISOPHYLLEACEAE	*Anisophyllea laurina*						
ANNONACEAE	*Annona glauca*			X		X	
ANNONACEAE	*Annona senegalensis*			X		X	
ANNONACEAE	*Artabotrys velutinus*			X		X	
ANNONACEAE	*Hexalobus monopetalus*		X				
ANNONACEAE	*Monanthotaxis barteri*			X	X	X	
ANNONACEAE	*Monanthotaxis vogelii*		X				
ANNONACEAE	*Monodora tenuifolia*						
ANNONACEAE	*Uvaria chamae*			X		X	
ANNONACEAE	*Xylopia longipetala*		X	X		X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
APOCYNACEAE	*Adenium obesum*						
APOCYNACEAE	*Alafia benthamii*						
APOCYNACEAE	*Alafia scandens*					X	
APOCYNACEAE	*Anisopus efulensis*						
APOCYNACEAE	*Baissea leonensis*						
APOCYNACEAE	*Baissea multiflora*				X	X	
APOCYNACEAE	*Cryptolepis sanguinolenta*			X		X	
APOCYNACEAE	*Isonema smeathmannii*		X			X	
APOCYNACEAE	*Landolphia dulcis*		X		X	X	
APOCYNACEAE	*Landolphia heudelotii*					X	
APOCYNACEAE	*Oncinotis nitida*						
APOCYNACEAE	*Pleiocarpa pycnantha*						
APOCYNACEAE	*Rauvolfia vomitoria*		X	X		X	
APOCYNACEAE	*Saba senegalensis*		X		X	X	X
APOCYNACEAE	*Strophanthus hispidus*			X		X	
APOCYNACEAE	*Strophanthus sarmentosus*		X			X	X
APOCYNACEAE	*Tabernaemontana africana*					X	
APOCYNACEAE	*Voacanga africana*						
APOCYNACEAE	*Voacanga thouarsii*		X			X	
ARACEAE	*Cercestis afzelii*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
ARACEAE	Cercestis afzelii						
ARACEAE	*Pistia stratiotes*						
ARACEAE	Pistia stratiotes						
ARACEAE	*Stylochiton lancifolium*						
ARECACEAE	*Borassus aethiopum*						
ARECACEAE	Borassus aethiopum						
ARECACEAE	*Hyphaene thebaica*		X	X	X	X	X
ARECACEAE	*Phoenix reclinata*		X		X		X
ARECACEAE	*Elias guineensis*		X	X	X		
ARECACEAE	*Raphia palma-pinus*	DD	X			X	
ASCLEPIADACEAE	*Aspidoglossum connatum*						
ASCLEPIADACEAE	*Calotropis procera*			X		X	
ASCLEPIADACEAE	*Ceropegia nigra*					X	
ASCLEPIADACEAE	*Cynanchum longipes*						
ASCLEPIADACEAE	*Ectadiopsis oblongifolia*						
ASCLEPIADACEAE	*Gymnema sylvestre*		X			X	
ASCLEPIADACEAE	*Raphionacme brownii*		X		X		
ASCLEPIADACEAE	*Secamone afzelii*		X	X		X	
ASCLEPIADACEAE	*Tacazzea apiculata*						
ASPARAGACEAE	*Asparagus flagellaris*					X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
ASPARAGACEAE	*Chlorophytum blepharophyllum*						
ASPARAGACEAE	*Chlorophytum filipendulum*					X	
ASPARAGACEAE	*Chlorophytum immaculatum*						
ASPARAGACEAE	*Chlorophytum macrophyllum*			X			
ASPARAGACEAE	*Sansevieria senegambica*					X	
ASTERACEAE	*Acanthospermum hispidum*			X			
ASTERACEAE	*Adenostemma perrottetii*						
ASTERACEAE	*Ageratum conyzoides*						
ASTERACEAE	*Bidens borianiana*			X			
ASTERACEAE	*Bidens engleri*						
ASTERACEAE	*Bidens pilosa*			X			
ASTERACEAE	*Blumea axillaris*						
ASTERACEAE	*Blumea viscosa*						
ASTERACEAE	*Centaurea perrottetii*						
ASTERACEAE	*Elephantopus mollis*		X	X	X		
ASTERACEAE	*Ethulia conyzoides*						
ASTERACEAE	*Galinsoga quadriradiata*						
ASTERACEAE	*Galinsoga quadriradiata*						
ASTERACEAE	*Herderia truncata*						
ASTERACEAE	*Melanthera gambica*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
ASTERACEAE	*Microglossa pyrifolia*						
ASTERACEAE	*Mikania cordata*		X		X	X	
ASTERACEAE	*Pentanema indicum*						
ASTERACEAE	*Pentanema indicum*						
ASTERACEAE	*Pleiotaxis chlorolepis*			X			
ASTERACEAE	*Pleiotaxis newtonii*						
ASTERACEAE	*Porphyrostemma chevalieri*						
ASTERACEAE	*Sphaeranthus senegalensis*		X		X		
ASTERACEAE	*Vernonia adoensis*						
ASTERACEAE	*Vernonia ambigua*						
ASTERACEAE	*Vernonia galamensis*						
ASTERACEAE	*Vernonia galamensis*		X	X		X	
ASTERACEAE	*Vernonia nigritiana*					X	
ASTERACEAE	*Vernonia tenoreana*						
BEGONIACEAE	*Begonia rostrata*						
BIGNONIACEAE	*Markhamia tomentosa*					X	
BIGNONIACEAE	*Newbouldia laevis*					X	
BIGNONIACEAE	*Spathodea campanulata*						
BIGNONIACEAE	*Stereospermum acuminatissimum*						
BIGNONIACEAE	*Stereospermum kunthianum*					X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
BOMBACACEAE	*Adansonia digitata*			X		X	
BOMBACACEAE	*Bombax costatum*						
BOMBACACEAE	*Ceiba pentandra*						
BORAGINACEAE	*Coldenia procumbens*		X				
BORAGINACEAE	*Rotula aquatica*		X			X	
BRASSICACEAE	*Rorippa humifusa*						
BURSERACEAE	*Canarium schweinfurthii*		X			X	
CAMPANULACEAE	*Wahlenbergia lobelioides*						
CAMPANULACEAE	*Wahlenbergia perrottetii*						
CAPPARACEAE	*Cleome gynandra*						
CAPPARACEAE	*Cleome viscosa*						
CAPPARACEAE	*Maerua duchesnei*		X	X		X	
CAPPARACEAE	*Ritchiea capparoides*					X	
CAPPARACEAE	*Ritchiea duchesnei*			X		X	
CAPPARACEAE	*Ritchiea longipedicellata*						
CARYOPHYLLACEAE	*Polycarpaea eriantha*						
CARYOPHYLLACEAE	*Polycarpaea linearifolia*				X		X
CARYOPHYLLACEAE	*Polycarpaea tenuifolia*						
CARYOPHYLLACEAE	*Polycarpon prostratum*		X		X		X
CELASTRACEAE	*Apodostigma pallens*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
CELASTRACEAE	*Reissantia indica*		X		X	X	
CELASTRACEAE	*Salacia debilis*					X	
CELASTRACEAE	*Salacia senegalensis*		X		X		
CHRYSOBALANACEAE	*Chrysobalanus icaco*		X	X	X	X	X
CHRYSOBALANACEAE	*Neocarya macrophylla*				X		X
CHRYSOBALANACEAE	*Parinari curatellifolia*			X		X	
CHRYSOBALANACEAE	*Parinari excelsa*			X		X	
CLUSIACEAE	*Garcinia elliotii*						
CLUSIACEAE	*Psorospermum alternifolium*						
CLUSIACEAE	*Psorospermum glaberrimum*						
COMBRETACEAE	*Combretum adenogonium*					X	
COMBRETACEAE	*Combretum bipindense*						
COMBRETACEAE	*Combretum collinum*			X		X	
COMBRETACEAE	*Combretum conchipetalum*						
COMBRETACEAE	*Combretum glutinosum*						
COMBRETACEAE	*Combretum grandiflorum*			X		X	
COMBRETACEAE	*Combretum micranthum*					X	
COMBRETACEAE	*Combretum mucronatum*						
COMBRETACEAE	*Combretum nigricans*						
COMBRETACEAE	*Combretum nioroense*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
COMBRETACEAE	*Combretum paniculatum*			X		X	
COMBRETACEAE	*Combretum racemosum*					X	
COMBRETACEAE	*Combretum rochetianum*						
COMBRETACEAE	*Combretum tomentosum*						
COMBRETACEAE	*Conocarpus erectus*						
COMBRETACEAE	*Pteleopsis suberosa*						
COMBRETACEAE	*Terminalia albida*			X		X	
COMBRETACEAE	*Terminalia macroptera*			X		X	
COMBRETACEAE	*Terminalia scutifera*					X	
COMMELINACEAE	*Aneilema beniniense*						
COMMELINACEAE	Aneilema beniniense						
COMMELINACEAE	*Aneilema paludosum*						
COMMELINACEAE	*Commelina benghalensis*						
COMMELINACEAE	*Commelina capitata*			X		X	
COMMELINACEAE	*Commelina congesta*			X			
COMMELINACEAE	*Commelina lagosensis*						
COMMELINACEAE	*Commelina nigritana*						
COMMELINACEAE	*Cyanotis lanata*						
COMMELINACEAE	*Cyanotis longifolia*						
COMMELINACEAE	*Floscopa glomerata*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
COMMELINACEAE	Floscopa axillaris	DD					
COMMELINACEAE	*Palisota hirsuta*						
COMMELINACEAE	Palisota hirsuta						
CONNARACEAE	*Agelaea pentagyna*						
CONNARACEAE	*Cnestis corniculata*						
CONNARACEAE	*Cnestis ferruginea*						
CONNARACEAE	*Connarus africanus*			X		X	
CONNARACEAE	*Rourea coccinea*			X	X	X	
CONNARACEAE	*Rourea minor*						
CONNARACEAE	*Rourea thomsonii*						
CONVOLVULACEAE	*Aniseia martinicensis*						
CONVOLVULACEAE	*Bonamia thunbergiana*			X		X	
CONVOLVULACEAE	*Calycobolus heudelotii*						
CONVOLVULACEAE	*Cressa cretica*						
CONVOLVULACEAE	*Evolvulus alsinoides*						
CONVOLVULACEAE	*Ipomoea cairica*		X	X		X	
CONVOLVULACEAE	*Ipomoea eriocarpa*						
CONVOLVULACEAE	*Ipomoea imperati*						
CONVOLVULACEAE	*Ipomoea mauritiana*						
CONVOLVULACEAE	*Ipomoea obscura*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
CONVOLVULACEAE	*Lepistemon owariensis*						
CONVOLVULACEAE	*Lepistemon owariensis*						
CONVOLVULACEAE	*Merremia aegyptia*						
CONVOLVULACEAE	*Merremia aegyptica*						
CONVOLVULACEAE	*Merremia hederacea*						
CONVOLVULACEAE	*Merremia pinnata*						
CONVOLVULACEAE	*Stictocardia beraviensis*						
CONVOLVULACEAE	*Xenostegia tridentata*						
COSTACEAE	*Costus afer*						
COSTACEAE	Costus afer						
CUCURBITACEAE	*Cayaponia africana*						
CUCURBITACEAE	*Citrullus lanatus*						
CUCURBITACEAE	*Citrullus mucosospermus*						
CUCURBITACEAE	*Coccinia keayana*						
CUCURBITACEAE	*Cucumeropsis mannii*					X	
CUCURBITACEAE	*Cucurbita moschata*			X			
CUCURBITACEAE	*Cucurbita pepo*						
CUCURBITACEAE	*Luffa aegyptiaca*						
CUCURBITACEAE	*Melothria capillacea*						
CUCURBITACEAE	*Melothria deltoidea*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
CUCURBITACEAE	*Melothria maderaspatana*						
CUCURBITACEAE	*Melothria tridactyla*						
CUCURBITACEAE	*Mukia maderaspatana*						
CUCURBITACEAE	*Zehneria hallii*						
CUCURBITACEAE	*Zehneria thwaitesii*			X			
CYPERACEAE	*Cyperus amabilis*						
CYPERACEAE	Cyperus amabilis		X		X		
CYPERACEAE	*Cyperus crassipes*				X		X
CYPERACEAE	*Cyperus cyperoides*						X
CYPERACEAE	*Cyperus difformis*				X		
CYPERACEAE	*Cyperus dilatatus*		X		X	X	
CYPERACEAE	*Cyperus haspan*				X		
CYPERACEAE	*Cyperus ligularis*				X		X
CYPERACEAE	*Cyperus margaritaceus*		X		X		
CYPERACEAE	*Cyperus tenuiculmis*						
CYPERACEAE	*Eleocharis mutata*		X		X		
CYPERACEAE	*Fimbristylis dichotoma*					X	
CYPERACEAE	*Fimbristylis ferruginea*		X			X	
CYPERACEAE	*Fimbristylis schoenoides*				X		X
CYPERACEAE	*Fuirena ciliaris*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
CYPERACEAE	*Kyllinga squamulata*				X	X	
CYPERACEAE	*Pycreus acuticarinatus*						
CYPERACEAE	*Pycreus mundtii*		X				
CYPERACEAE	*Pycreus testui*				X	X	X
CYPERACEAE	*Rhynchospora candida*						
CYPERACEAE	*Schoenoplectus litoralis*		X		X		
CYPERACEAE	*Scleria catophylla*				X		X
CYPERACEAE	*Scleria depressa*				X		
DICHAPETALACEAE	*Dichapetalum heudelotii*						
DICHAPETALACEAE	*Dichapetalum toxicarium*						
DICRANALES	*Octoblepharum albidum*						
DILLENIACEAE	*Tetracera potatoria*			X			
DIOSCOREACEAE	*Dioscorea bulbifera*						
DIOSCOREACEAE	Dioscorea bulbifera						
DIOSCOREACEAE	*Dioscorea hirtiflora*						
DIOSCOREACEAE	*Dioscorea sagittifolia*						
DIOSCOREACEAE	Dioscorea sagittifolia						
DRYOPTERIDACEAE	*Bolbitis acrostichoides*						
EBENACEAE	*Diospyros ferrea*					X	X
EBENACEAE	*Diospyros sandwicensis*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
EBENACEAE	*Diospyros sandwicensis*						
ERIOCAULACEAE	*Mesanthemum prescottianum*						
ERIOCAULACEAE	Mesanthemum prescottianum						
ERIOCAULACEAE	*Mesanthemum radicans*						
ERIOCAULACEAE	Mesanthemum radicans						
EUPHORBIACEAE	*Acalypha fimbriata*						
EUPHORBIACEAE	*Alchornea cordifolia*						
EUPHORBIACEAE	*Anthostema senegalense*						
EUPHORBIACEAE	*Astraea lobata*						
EUPHORBIACEAE	*Astraea lobata*						
EUPHORBIACEAE	*Croton scarciesii*						
EUPHORBIACEAE	*Erythrococca anomala*						
EUPHORBIACEAE	*Euphorbia convolvuloides*						
EUPHORBIACEAE	*Euphorbia grandifolia*						
EUPHORBIACEAE	*Euphorbia hirta*			X			
EUPHORBIACEAE	*Euphorbia macrophylla*						
EUPHORBIACEAE	*Euphorbia prostrata*			X			
EUPHORBIACEAE	*Euphorbia trinervia*						
EUPHORBIACEAE	*Jatropha curcas*						
EUPHORBIACEAE	*Macaranga heterophylla*		X	X	X	X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
EUPHORBIACEAE	*Macaranga heudelotii*						
EUPHORBIACEAE	*Mareya micrantha*						
EUPHORBIACEAE	*Ricinodendron heudelotii*						
EUPHORBIACEAE	*Ricinus communis*			X			
FABACEAE	*Abrus canescens*		X			X	
FABACEAE	*Abrus fruticulosus*						
FABACEAE	*Abrus precatorius*					X	X
FABACEAE	*Abrus pulchellus*						
FABACEAE	*Acacia kamerunensis*			X		X	
FABACEAE	*Acacia macrostachya*					X	
FABACEAE	*Acacia nilotica*						
FABACEAE	*Acacia pentagona*						
FABACEAE	*Aeschynomene afraspera*						
FABACEAE	*Aeschynomene aspera*						
FABACEAE	*Aeschynomene indica*						
FABACEAE	*Aeschynomene lateritia*						
FABACEAE	*Aeschynomene pulchella*					X	
FABACEAE	*Aeschynomene schimperi*		X		X		
FABACEAE	*Aeschynomene sensitiva*		X				
FABACEAE	*Aeschynomene tambacoundensis*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Aeschynomene uniflora*						
FABACEAE	*Afzelia africana*	VU					
FABACEAE	*Aganope stuhlmannii*						
FABACEAE	*Albizia adianthifolia*			X		X	
FABACEAE	*Albizia altissima*						
FABACEAE	*Albizia ferruginea*	VU				X	
FABACEAE	*Albizia glaberrima glaberrima*			X		X	
FABACEAE	*Albizia rhombifolia*					X	
FABACEAE	*Albizia zygia*					X	
FABACEAE	*Alysicarpus ovalifolius*						
FABACEAE	*Alysicarpus rugosus*						
FABACEAE	*Anthonotha crassifolia*						
FABACEAE	*Arachis hypogaea*						
FABACEAE	*Bauhinia reticulata*						
FABACEAE	*Bauhinia rufescens*			X		X	
FABACEAE	*Bauhinia thonningii*			X		X	
FABACEAE	*Bobgunnia madagascariensis*						
FABACEAE	*Bryaspis lupulina*						
FABACEAE	*Burkea africana*						
FABACEAE	*Caesalpinia benthamiana*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Caesalpinia bonduc*						
FABACEAE	*Caesalpinia coriaria*						
FABACEAE	*Cajanus cajan*						
FABACEAE	*Cajanus scarabaeoides*						
FABACEAE	*Calopogonium mucunoides*						
FABACEAE	*Canavalia plagiosperma*						
FABACEAE	*Canavalia rosea*						
FABACEAE	*Cassia aldabrensis*						
FABACEAE	*Cassia sieberiana*			X	X	X	
FABACEAE	*Centrosema pubescens*						
FABACEAE	*Chamaecrista jaegeri*						
FABACEAE	*Chamaecrista mimosoides*						
FABACEAE	*Chamaecrista nigricans*					X	
FABACEAE	*Clitoria falcata*						
FABACEAE	*Copaifera salikounda*						
FABACEAE	*Cordyla africana*						
FABACEAE	*Cordyla pinnata*						
FABACEAE	*Crotalaria calycina*			X		X	
FABACEAE	*Crotalaria comosa*						
FABACEAE	*Crotalaria ebenoides*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Crotalaria glauca*					X	
FABACEAE	*Crotalaria glaucoides*			X			
FABACEAE	*Crotalaria goreensis*						
FABACEAE	*Crotalaria hyssopifolia*					X	
FABACEAE	*Crotalaria lathyroides*						
FABACEAE	*Crotalaria leprieurii*					X	
FABACEAE	*Crotalaria occidentalis*			X			
FABACEAE	*Crotalaria ochroleuca*						
FABACEAE	*Crotalaria ononoides*						
FABACEAE	*Crotalaria pallida*						
FABACEAE	*Crotalaria perrottetii*						
FABACEAE	*Crotalaria pseudotenuirama*						
FABACEAE	*Crotalaria retusa*						
FABACEAE	*Crudia senegalensis*						
FABACEAE	*Cyclocarpa stellaris*						
FABACEAE	*Cynometra vogelii*						
FABACEAE	*Dalbergia bignonae*						
FABACEAE	*Dalbergia boehmii*		X	X		X	X
FABACEAE	*Dalbergia ecastaphyllum*						
FABACEAE	*Dalbergia hostilis*			X		X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Dalbergia noldeae*						
FABACEAE	*Dalbergia rufa*						
FABACEAE	*Dalbergia saxatilis*					X	
FABACEAE	*Daniellia oliveri*						
FABACEAE	*Daniellia thurifera*						
FABACEAE	*Desmodium adscendens*						
FABACEAE	*Desmodium gangeticum*					X	
FABACEAE	*Desmodium hirtum*						
FABACEAE	*Desmodium laxiflorum*						
FABACEAE	*Desmodium linearifolium*			X			
FABACEAE	*Desmodium procumbens*					X	
FABACEAE	*Desmodium salicifolium*						
FABACEAE	*Desmodium setigerum*						
FABACEAE	*Desmodium tortuosum*			X			
FABACEAE	*Desmodium velutinum*						
FABACEAE	*Detarium microcarpum*						
FABACEAE	*Detarium senegalense*						
FABACEAE	*Dialium guianense*			X			
FABACEAE	*Dialium guineense*						
FABACEAE	*Dichrostachys cinerea*		X	X	X	X	X

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Dioclea reflexa*						
FABACEAE	*Dolichos schweinfurthii*						
FABACEAE	*Entada africana*						
FABACEAE	*Entada mannii*						
FABACEAE	*Entada rheedii*		X				
FABACEAE	*Entada rheedii*					X	
FABACEAE	*Entada wahlbergii*						
FABACEAE	*Eriosema afzelii*						
FABACEAE	*Eriosema glomeratum*						
FABACEAE	*Eriosema laurentii*		X				
FABACEAE	*Eriosema psoraleoides*						
FABACEAE	*Eriosema spicatum*						
FABACEAE	*Erythrina senegalensis*			X		X	
FABACEAE	*Erythrina sigmoidea*						
FABACEAE	*Erythrophleum africanum*						
FABACEAE	*Erythrophleum suaveolens*					X	
FABACEAE	*Erythrophleum suaveolens*						
FABACEAE	*Faidherbia albida*			X			
FABACEAE	*Faidherbia albida*						
FABACEAE	*Flemingia faginea*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Guibourtia copallifera*						
FABACEAE	*Guibourtia leonensis*			X		X	
FABACEAE	*Indigofera arrecta*						
FABACEAE	*Indigofera berhautiana*				X		
FABACEAE	*Indigofera capitata*						
FABACEAE	*Indigofera congesta*					X	
FABACEAE	*Indigofera congolensis*						
FABACEAE	*Indigofera dendroides*						
FABACEAE	*Indigofera elliotii*					X	
FABACEAE	*Indigofera heudelotii*			X			
FABACEAE	*Indigofera heudelotii heudelotii*						
FABACEAE	*Indigofera hirsuta*					X	
FABACEAE	*Indigofera leprieurii*						
FABACEAE	*Indigofera macrocalyx*						
FABACEAE	*Indigofera macrophylla*						
FABACEAE	*Indigofera nummulariifolia*			X			
FABACEAE	*Indigofera omissa*						
FABACEAE	*Indigofera paniculata*					X	
FABACEAE	*Indigofera pilosa*						
FABACEAE	*Indigofera pulchra*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Indigofera scarciesii*			X		X	
FABACEAE	*Indigofera secundiflora*						
FABACEAE	*Indigofera simplicifolia*						
FABACEAE	*Indigofera spicata*						
FABACEAE	*Indigofera stenophylla*					X	
FABACEAE	*Indigofera suffruticosa*						
FABACEAE	*Indigofera terminalis*						
FABACEAE	*Indigofera trita*			X		X	
FABACEAE	*Kotschya ochreata*						
FABACEAE	*Kotschya ochreata*					X	
FABACEAE	*Kotschya ochreata ochreata*			X			
FABACEAE	*Macrotyloma biflorum*						
FABACEAE	*Macrotyloma biflorum*					X	
FABACEAE	*Melliniella micrantha*						
FABACEAE	*Millettia barteri*						
FABACEAE	*Mimosa pigra*		X	X			
FABACEAE	*Mucuna pruriens*						
FABACEAE	*Nesphostylis holosericea*						
FABACEAE	*Ormocarpum sennoides*						
FABACEAE	*Ormocarpum verrucosum*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Ostryocarpus riparius*						
FABACEAE	*Parkia biglobosa*			X		X	
FABACEAE	*Pentaclethra macrophylla*						
FABACEAE	*Pericopsis laxiflora*						
FABACEAE	*Phaseolus vulgaris*						
FABACEAE	*Pisum sativum*						
FABACEAE	*Prosopis africana*			X		X	
FABACEAE	*Pseudarthria fagifolia*						
FABACEAE	*Psophocarpus monophyllus*						
FABACEAE	*Psophocarpus palustris*						
FABACEAE	*Pterocarpus erinaceus*						
FABACEAE	*Pterocarpus santalinoides*						
FABACEAE	*Rhynchosia buettneri*						
FABACEAE	*Rhynchosia pycnostachya*						
FABACEAE	*Rhynchosia viscosa*						
FABACEAE	*Rothia hirsuta*						
FABACEAE	*Samanea dinklagei*						
FABACEAE	*Samanea dinklagei*						
FABACEAE	*Senna alata*			X		X	
FABACEAE	*Senna insularis*			X			

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Senna obtusifolia*						
FABACEAE	*Senna obtusifolia*						
FABACEAE	*Senna occidentalis*			X		X	
FABACEAE	*Senna podocarpa*			X			
FABACEAE	*Sesbania bispinosa*			X			
FABACEAE	*Sesbania hepperi*						
FABACEAE	*Stylosanthes erecta*						
FABACEAE	*Stylosanthes fruticosa*						
FABACEAE	*Tamarindus indica*						
FABACEAE	*Tephrosia bracteolata*						
FABACEAE	*Tephrosia deflexa*		X				
FABACEAE	*Tephrosia elegans*						
FABACEAE	*Tephrosia flexuosa*					X	
FABACEAE	*Tephrosia linearis*						
FABACEAE	*Tephrosia lupinifolia*			X			
FABACEAE	*Tephrosia mossiensis*						
FABACEAE	*Tephrosia nana*						
FABACEAE	*Tephrosia pedicellata*				X		
FABACEAE	*Tephrosia purpurea*						
FABACEAE	*Teramnus labialis*		X				

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FABACEAE	*Teramnus micans micans*						
FABACEAE	*Teramnus uncinatus*					X	
FABACEAE	*Vigna adenantha*			X			
FABACEAE	*Vigna adenantha*						
FABACEAE	*Vigna gracilis*			X			
FABACEAE	*Vigna heterophylla*					X	
FABACEAE	*Vigna heterophylla*						
FABACEAE	*Vigna laurentii*						
FABACEAE	*Vigna luteola*		X				
FABACEAE	*Vigna racemosa*			X		X	
FABACEAE	*Vigna radiata*						
FABACEAE	*Vigna reticulata*						
FABACEAE	*Vigna unguiculata*						
FABACEAE	*Vigna venulosa*				X	X	
FABACEAE	*Xeroderris stuhlmannii*		X	X			
FABACEAE	*Zornia glochidiata*						
FLACOURTIACEAE	*Byrsanthus brownii*						
FLACOURTIACEAE	*Dovyalis zenkeri*		X		X		
FLACOURTIACEAE	*Flacourtia indica*			X		X	
FLACOURTIACEAE	*Oncoba spinosa*		X			X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
FLACOURTIACEAE	*Scottellia leonensis*		X		X		
GENTIANACEAE	*Schultesia guyanensis*						
GENTIANACEAE	*Schultesia stenophylla*		X				
GENTIANACEAE	*Swertia welwitschii*						
HYPNALES	*Taxithelium stenosekos*						
ICACINACEAE	*Icacina senegalensis*				X	X	
IRVINGIACEAE	*Klainedoxa gabonensis*					X	
LAMIACEAE	*Hoslundia opposita*		X			X	
LAMIACEAE	*Hyptis spicigera*						
LAMIACEAE	*Hyptis suaveolens*						
LAMIACEAE	*Leonotis nepetifolia*						
LAMIACEAE	*Leucas martinicensis*						
LAMIACEAE	*Ocimum canum*						
LAMIACEAE	*Ocimum cuanzae*						
LAMIACEAE	*Platostoma africanum*						
LAURACEAE	*Cassytha filiformis*						
LENTIBULARIACEAE	*Utricularia stellaris*						
LINACEAE	*Hugonia planchoni*						
LOGANIACEAE	*Anthocleista djalonensis*						
LOGANIACEAE	*Anthocleista nobilis*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
LOGANIACEAE	*Mostuea hirsuta*						
LOGANIACEAE	*Strychnos afzelii*						
LOGANIACEAE	*Strychnos congolana*						
LOGANIACEAE	*Strychnos spinosa*			X	X	X	
LOGANIACEAE	*Strychnos splendens*					X	
LOGANIACEAE	*Usteria guineensis*						
LORANTHACEAE	*Agelanthus brunneus*						
LORANTHACEAE	*Agelanthus dodoneifolius*						
LORANTHACEAE	*Englerina parviflora*					X	
LORANTHACEAE	*Globimetula cupulata*					X	
LORANTHACEAE	*Phragmanthera leonensis*						
LORANTHACEAE	*Tapinanthus bangwensis*			X		X	
LORANTHACEAE	*Tapinanthus pentagonus*						
LYGODIACEAE	*Lygodium microphyllum*						
LYTHRACEAE	*Nesaea angustifolia*						
LYTHRACEAE	*Nesaea radicans*		X				
LYTHRACEAE	*Nesaea santoi*						
MALPIGHIACEAE	*Acridocarpus plagiopterus*				X	X	
MALPIGHIACEAE	*Acridocarpus smeathmannii*		X	X		X	
MALPIGHIACEAE	*Acridocarpus spectabilis*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
MALPIGHIACEAE	*Flabellaria paniculata*			X		X	
MALPIGHIACEAE	*Stigmaphyllon bannisterioides*						
MALVACEAE	*Gossypium barbosanum*						
MALVACEAE	*Hibiscus asper*						
MALVACEAE	*Hibiscus sterculiifolius*			X			
MALVACEAE	*Hibiscus surattensis*				X		
MALVACEAE	*Sida acuta*		X	X			
MALVACEAE	*Urena lobata*			X			
MALVACEAE	*Wissadula rostrata*						
MELASTOMATACEAE	*Dissotis senegambiensis*						
MELASTOMATACEAE	*Tristemma mauritianum*				X		
MELIACEAE	*Khaya anthotheca*						
MELIACEAE	*Khaya senegalensis*	VU					
MELIACEAE	*Trichilia prieureana*			X		X	
MELIACEAE	*Trichilia roka*						
MENISPERMACEAE	*Triclisia patens*						
MENYANTHACEAE	*Nymphoides indica*		X				
MOLLUGINACEAE	*Glinus lotoides*						
MOLLUGINACEAE	*Glinus oppositifolius*						
MORACEAE	*Chlorophora regia*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
MORACEAE	*Ficus dicranostyla*					X	
MORACEAE	*Ficus glumosa*					X	
MORACEAE	*Ficus lutea*			X		X	
MORACEAE	*Ficus ottoniifolia*				X	X	
MORACEAE	*Ficus ovata*			X		X	
MORACEAE	*Ficus sagittifolia*						
MORACEAE	*Ficus scott-elliotii*					X	
MORACEAE	*Milicia regia*	VU					
MORINGACEAE	*Moringa oleifera*						
MYRTACEAE	*Callistemon viminalis*						
MYRTACEAE	*Eugenia calophylloides*						
MYRTACEAE	*Syzygium guineense*					X	
NYCTAGINACEAE	*Boerhavia coccinea*						
NYCTAGINACEAE	*Boerhavia diffusa*						
NYCTAGINACEAE	*Boerhavia erecta*						
NYMPHAEACEAE	*Nymphaea lotus*		X				
NYMPHAEACEAE	*Nymphaea micrantha*		X				
OCHNACEAE	*Lophira alata*						
OCHNACEAE	*Lophira lanceolata*			X	X	X	
OCHNACEAE	*Sauvagesia erecta*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
OLACACEAE	*Ximenia americana*				X	X	
OLEACEAE	*Schrebera arborea*						
ONAGRACEAE	*Ludwigia hyssopifolia*						
ONAGRACEAE	*Ludwigia octovalvis*						
OPILIACEAE	*Opilia amentacea*						
ORCHIDACEAE	*Calyptrochilum christyanum*						
ORCHIDACEAE	Calyptrochilum christyanum						
ORCHIDACEAE	*Eulophia cucullata*						
ORCHIDACEAE	*Eulophia juncifolia*					X	
ORCHIDACEAE	*Eulophia rosea*				X	X	
ORCHIDACEAE	*Graphorkis lurida*						
ORCHIDACEAE	*Habenaria buettneriana*						
ORCHIDACEAE	*Habenaria zambesina*				X	X	
ORCHIDACEAE	*Platylepis glandulosa*						
OXALIDACEAE	*Biophytum petersianum*						
PANDANACEAE	*Pandanus guineabissauensis*				X		
PASSIFLORACEAE	*Adenia dinklagei*			X		X	
PASSIFLORACEAE	*Adenia lobata*					X	
PASSIFLORACEAE	*Paropsia laevigata*						
PASSIFLORACEAE	*Smeathmannia laevigata*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
PEDALIACEAE	*Sesamum orientale*						
PEDALIACEAE	*Sesamum orientale*						
PHYLLANTHACEAE	*Antidesma membranaceum*						
PHYLLANTHACEAE	*Bridelia micrantha*						
PHYLLANTHACEAE	*Hymenocardia acida*						
PHYLLANTHACEAE	*Hymenocardia heudelotii*						
PHYLLANTHACEAE	*Hymenocardia lyrata*						
PHYLLANTHACEAE	*Phyllanthus muellerianus*		X	X	X	X	
PHYLLANTHACEAE	*Phyllanthus niruroides*					X	
PHYLLANTHACEAE	*Phyllanthus odontadenius*						
PHYLLANTHACEAE	*Phyllanthus reticulatus*					X	
POACEAE	*Anadelphia afzeliana*		X	X	X		
POACEAE	*Anadelphia trepidaria*						
POACEAE	*Axonopus compressus*		X	X		X	
POACEAE	*Brachiaria villosa*		X	X	X	X	X
POACEAE	*Cenchrus biflorus*			X		X	
POACEAE	*Centotheca lappacea*		X		X		
POACEAE	*Digitaria ciliaris*			X		X	
POACEAE	*Digitaria exilis*			X			
POACEAE	*Digitaria horizontalis*			X			

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
POACEAE	*Digitaria nuda*			X			
POACEAE	*Digitaria patagiata*	DD		X			
POACEAE	*Echinochloa colona*		X		X	X	
POACEAE	*Echinochloa crus-galli*						
POACEAE	Echinochloa crus-galli		X				
POACEAE	*Echinochloa pyramidalis*						
POACEAE	*Echinochloa stagnina*					X	
POACEAE	*Eleusine indica*		X				
POACEAE	*Elymandra androphila*			X	X	X	
POACEAE	*Eragrostis ciliaris*						
POACEAE	*Eragrostis japonica*		X	X		X	
POACEAE	*Hackelochloa granularis*						
POACEAE	Leersia hexandra						
POACEAE	*Loudetia annua*						
POACEAE	*Oryza glaberrima*		X			X	
POACEAE	*Oryza longistaminata*		X			X	
POACEAE	*Oryza sativa*		X			X	
POACEAE	*Oxytenanthera abyssinica*						
POACEAE	*Panicum hymeniochilum*		X	X			
POACEAE	*Panicum laxum*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
POACEAE	*Panicum repens*				X	X	
POACEAE	*Panicum tenellum*						
POACEAE	*Paratheria prostrata*		X				
POACEAE	*Paspalum scrobiculatum*					X	
POACEAE	*Paspalum vaginatum*						
POACEAE	*Pennisetum hordeoides*						
POACEAE	*Pennisetum pedicellatum*		X				
POACEAE	*Pennisetum polystachion*					X	
POACEAE	*Perotis scabra*		X		X		
POACEAE	*Rhytachne triaristata*			X		X	
POACEAE	*Rottboellia cochinchinensis*		X	X	X		
POACEAE	*Sacciolepis cymbiandra*					X	
POACEAE	*Sacciolepis interrupta*						
POACEAE	*Sacciolepis micrococca*						
POACEAE	*Schizachyrium brevifolium*		X				
POACEAE	*Schizachyrium platyphyllum*				X		
POACEAE	*Setaria megaphylla*			X		X	
POACEAE	*Setaria pumila*		X				
POACEAE	*Sorghastrum incompletum*			X			
POACEAE	*Sorghum bicolor*			X		X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
POACEAE	*Sporobolus robustus*						
POACEAE	*Sporobolus virginicus*		X		X		
POACEAE	*Streptogyna crinita*						
POALES	*Acroceras zizanioides*		X				
PODOSTEMACEAE	Ledermanniella adamesii	DD					
POLYGALACEAE	*Atroxima afzeliana*						
POLYGALACEAE	*Carpolobia alba*						
POLYGALACEAE	*Polygala arenaria*					X	
POLYGALACEAE	*Polygala multiflora*						
POLYGALACEAE	*Securidaca longepedunculata*						
PONTEDERIACEAE	*Monochoria brevipetiolata*		X				
PORTULACACEAE	*Portulaca oleracea*						
PORTULACACEAE	*Portulaca quadrifida*						
RANUNCULACEAE	*Clematis hirsuta*						
RHAMNACEAE	*Ventilago africana*		X				
RHAMNACEAE	*Ziziphus mauritiana*			X	X	X	
RHIZOPHORACEAE	*Rhizophora mangle*				X		X
RHIZOPHORACEAE	*Rhizophora racemosa*			X			X
RUBIACEAE	*Argocoffeopsis subcordata*						
RUBIACEAE	*Bertiera spicata*		X			X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
RUBIACEAE	*Chassalia afzelii*						
RUBIACEAE	*Craterispermum laurinum*						
RUBIACEAE	*Crossopteryx febrifuga*						
RUBIACEAE	*Diodella serrulata*			X			X
RUBIACEAE	*Diodella serrulata*		X				
RUBIACEAE	*Euclinia longiflora*					X	
RUBIACEAE	*Gardenia nitida*						
RUBIACEAE	*Gardenia ternifolia*			X			
RUBIACEAE	*Ixora laxiflora*						
RUBIACEAE	*Kohautia grandiflora*						X
RUBIACEAE	*Macrosphyra longistyla*						
RUBIACEAE	*Mitracarpus hirtus*				X		
RUBIACEAE	*Mitracarpus hirtus*			X		X	X
RUBIACEAE	*Mitragyna inermis*						
RUBIACEAE	*Morelia senegalensis*					X	
RUBIACEAE	*Mussaenda elegans*						X
RUBIACEAE	*Oldenlandia corymbosa*		X		X		
RUBIACEAE	*Oldenlandia herbacea*			X			
RUBIACEAE	*Oxyanthus racemosus*						
RUBIACEAE	*Oxyanthus speciosus*					X	

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
RUBIACEAE	*Pauridiantha afzelii*				X	X	
RUBIACEAE	*Pauridiantha hirtella*		X	X			
RUBIACEAE	*Pavetta corymbosa*						
RUBIACEAE	*Pavetta oblongifolia*					X	
RUBIACEAE	*Pouchetia africana*		X				
RUBIACEAE	*Psychotria peduncularis*						
RUBIACEAE	*Rothmannia whitfieldii*			X			
RUBIACEAE	*Sabicea discolor*						
RUBIACEAE	*Sabicea venosa*				X	X	
RUBIACEAE	*Sarcocephalus latifolius*			X			
RUBIACEAE	*Spermacoce exilis*						
RUBIACEAE	*Spermacoce exilis*					X	
RUBIACEAE	*Spermacoce ruelliae*		X				
RUBIACEAE	*Tarenna nitidula*						
RUBIACEAE	*Tricalysia reticulata*					X	
RUBIACEAE	*Uncaria africana*						
RUBIACEAE	*Vangueriella discolor*			X			
RUTACEAE	*Afraegle paniculata*					X	
RUTACEAE	*Fagara leprieurii*						
RUTACEAE	*Fagara rubescens*		X				

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
RUTACEAE	*Zanthoxylum zanthoxyloides*						
SAPINDACEAE	*Allophylus africanus*						
SAPINDACEAE	*Aporrhiza lastoursvillensis*					X	
SAPINDACEAE	*Blighia sapida*						
SAPINDACEAE	*Blighia unijugata*			X			
SAPINDACEAE	*Cardiospermum halicacabum*						
SAPINDACEAE	*Dodonaea viscosa*			X			
SAPINDACEAE	*Eriocoelum kerstingii*		X				
SAPINDACEAE	*Lecaniodiscus cupanioides*					X	
SAPINDACEAE	*Lepisanthes senegalensis*						
SAPINDACEAE	*Paullinia pinnata*						
SAPINDACEAE	*Placodiscus riparius*					X	
SAPOTACEAE	*Pouteria alnifolia*						
SAPOTACEAE	*Synsepalum brevipes*			X			
SAPOTACEAE	*Vitellaria paradoxa*					X	
SCROPHULARIACEAE	*Alectra rigida paludosa*						
SCROPHULARIACEAE	*Bacopa crenata*		X				
SCROPHULARIACEAE	*Buchnera hispida*						
SCROPHULARIACEAE	*Craterostigma guineense*			X		X	
SCROPHULARIACEAE	*Crepidorhopalon gracilis*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
SCROPHULARIACEAE	*Lindernia crustacea*						
SCROPHULARIACEAE	*Lindernia senegalensis*			X		X	
SCROPHULARIACEAE	*Micrargeria barteri*						
SCROPHULARIACEAE	*Micrargeria filiformis*			X		X	
SCROPHULARIACEAE	*Rhamphicarpa fistulosa*						
SCROPHULARIACEAE	*Scoparia dulcis*						
SCROPHULARIACEAE	*Striga hermonthica*						
SCROPHULARIACEAE	*Striga klingii*						
SCROPHULARIACEAE	*Striga macrantha*			X			
SIMAROUBACEAE	*Hannoa undulata*			X		X	
SIMAROUBACEAE	*Quassia undulata*						
SOLANACEAE	*Physalis angulata*		X				
SOLANACEAE	*Schwenckia americana*					X	
SOLANACEAE	*Solanum distichum*						
SOLANACEAE	*Solanum lycopersicum*					X	
SOLANACEAE	*Solanum terminale*						
STERCULIACEAE	*Cola cordifolia*						
STERCULIACEAE	*Cola laurifolia*						
STERCULIACEAE	*Waltheria indica*			X		X	
THYMELAEACEAE	*Dicranolepis disticha*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
THYMELAEACEAE	*Synaptolepis retusa*						
TILIACEAE	*Corchorus olitorius*						
ULMACEAE	*Trema orientalis*			X			
URTICACEAE	*Urera oblongifolia*					X	
VERBENACEAE	*Avicennia africana*						X
VERBENACEAE	*Avicennia germinans*						X
VERBENACEAE	*Clerodendrum capitatum*						
VERBENACEAE	*Clerodendrum sinuatum*						
VERBENACEAE	*Stachytarpheta angustifolia*					X	
VERBENACEAE	*Vitex doniana*		X				
VERBENACEAE	*Vitex ferruginea*						
VIOLACEAE	*Rinorea aylmeri*						
VIOLACEAE	*Rinorea microdon*					X	
VITACEAE	*Ampelocissus africana*						
VITACEAE	*Ampelocissus pentaphylla*						
VITACEAE	*Cissus aralioides*		X			X	
VITACEAE	*Cissus populnea*			X			
VITACEAE	*Cissus quadrangularis*					X	
VITACEAE	*Cissus rufescens*		X			X	
VITACEAE	*Cissus waterloti*						

FAMILY	SPECIES	IUCN STATUS	RICE PADDIES	SECONDARY FOREST	FLOODPLAIN	NATURAL FOREST	MANGROVE
VITACEAE	*Cyphostemma adenocaule*			X			
VITACEAE	*Cyphostemma rubrosetosa*						
XYRIDACEAE	*Xyris anceps*						
ZINGIBERACEAE	*Aframomum alboviolaceum*				X	X	
ZINGIBERACEAE	Aframomum alboviolaceum						
XYRIDACEAE	Xyris anceps						

APPENDIX B

Non-chordate species recorded during the 2011 to 2015 surveys.

ORDER	FAMILY	SPECIES NAME	COMMON NAME	IUCN STATUS
ACTINIARIA	HORMATHIIDAE	*Calliactis brevicornis*	Hermit Crab	Not Listed
DECAPODA	OCYPODIDAE	*Uca tangeri*	Fiddler Crab	Not Listed
ARACHNIDA	ARANEAE	*Echemus incinctus*		Not Listed
ARACHNIDA	ASTIGMATA	*Dentocarpus chaerephon*		Not Listed
INSECTA	COLEOPTERA	*Caelostomus punctifrons*		Not Listed
INSECTA	COLEOPTERA	*Stenus*	Stenus frigidus	Not Listed
INSECTA	COLEOPTERA	*Stenolophus unicolor*		Not Listed
INSECTA	COLEOPTERA	*Cybister immarginatus*		Not Listed
DIPLOPODA	STEMMIULIDA	*Diopsiulus latens*		Not Listed
DIPLOPODA	STEMMIULIDA	*Diopsiulus feae*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge perplicata*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge pervittata*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge trauni*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Peridontopyge guineae*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Ophistreptus penetrans*		Not Listed
DIPLOPODA	SPIROSTREPTIDA	*Urotropis perpunctata*		Not Listed
GASTROPODA	NEOTAENIOGLOSSA	*Tympanotonus radula*	West African Mud Creeper (Snail)	Not Listed
GASTROPODA	NEOTAENIOGLOSSA	*Tympanotonus fuscatus*	Mud-flat Periwinkle	Not Listed
INSECTA	HEMIPTERA	*Platymeris biguttata*		Not Listed
INSECTA	COLEOPTERA	*Berosus undatus*		Not Listed
INSECTA	COLEOPTERA	*Helochares normatus*		Not Listed
INSECTA	COLEOPTERA	*Hydrocanthus texanus*		Not Listed
INSECTA	COLEOPTERA	*Ataenius insolitus*		Not Listed
INSECTA	COLEOPTERA	*Rhyssemus senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Rhyssemus archambaulti*		Not Listed
INSECTA	COLEOPTERA	*Ruteloryctes morio*		Not Listed
INSECTA	COLEOPTERA	*Pseudosyrichthus senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Heteroligus meles*		Not Listed
INSECTA	COLEOPTERA	*Diplognatha gagates*		Not Listed
INSECTA	COLEOPTERA	*Eudicella frontalis*		Not Listed
INSECTA	COLEOPTERA	*Tiniocellus spinipes*		Not Listed
INSECTA	COLEOPTERA	*Garreta nitens*		Not Listed
INSECTA	COLEOPTERA	*Pinacotarsus dohrni*		Not Listed
INSECTA	COLEOPTERA	*Gymnopleurus fulgidus*		Not Listed
INSECTA	COLEOPTERA	*Catharsius sesostris*		Not Listed
INSECTA	COLEOPTERA	*Catharsius guineensis*		Not Listed
INSECTA	COLEOPTERA	*Catharsius achates*		Not Listed

ORDER	FAMILY	SPECIES NAME	COMMON NAME	IUCN STATUS
INSECTA	COLEOPTERA	*Heliocopris antenor*		Not Listed
INSECTA	COLEOPTERA	*Anachalcos convexus*		Not Listed
INSECTA	COLEOPTERA	*Anachalcos aurescens*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus cupreus*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus thomsoni*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus bidens*		Not Listed
INSECTA	COLEOPTERA	*Pedaria ouangoensis*		Not Listed
INSECTA	COLEOPTERA	*Pedaria tuberculigera*		Not Listed
INSECTA	COLEOPTERA	*Pedaria criberrima*		Not Listed
INSECTA	COLEOPTERA	*Onitis cupreus*		Not Listed
INSECTA	COLEOPTERA	*Rhyzopertha dominica*		Not Listed
INSECTA	COLEOPTERA	*Mallodon downesii*		Not Listed
INSECTA	COLEOPTERA	*Hypothenemus areccae*		Not Listed
INSECTA	HYMENOPTERA	*Braunsapis foveata*		Not Listed
INSECTA	HYMENOPTERA	*Leptacis longiciliata*		Not Listed
INSECTA	HYMENOPTERA	*Platyscelio africanus*		Not Listed
INSECTA	HYMENOPTERA	*Trithemis kirbyi*		Not Listed
INSECTA	HYMENOPTERA	*Fusicornia bambeyi*		Not Listed
INSECTA	DIPTERA	*Physocephala gracilis*		Not Listed
INSECTA	DIPTERA	*Anopheles gambiae*		Not Listed
INSECTA	DIPTERA	*Anopheles melas*		Not Listed
INSECTA	DIPTERA	*Anopheles arabiensis*		Not Listed
INSECTA	ORTHOPTERA	*Catantopsilus hintzi*		Not Listed
INSECTA	ORTHOPTERA	*Parga bissauensis*		Not Listed
INSECTA	ORTHOPTERA	*Locusta migratoria*	Migrating Locust	Not Listed
INSECTA	COLEOPTERA	*Xyloperthella picea*		Not Listed
INSECTA	COLEOPTERA	*Sinoxylon ruficorne*		Not Listed
INSECTA	COLEOPTERA	*Enochrus natalensis*		Not Listed
INSECTA	COLEOPTERA	*Sternolophus solieri*		Not Listed
INSECTA	COLEOPTERA	*Stenus fuscipes*		Not Listed
INSECTA	COLEOPTERA	*Korynetes coxalis*		Not Listed
INSECTA	COLEOPTERA	*Gonocephalum assimile*		Not Listed
INSECTA	COLEOPTERA	*Gonocephalum prolixum*		Not Listed
INSECTA	COLEOPTERA	*Pachnephorus bistriatus*		Not Listed
INSECTA	COLEOPTERA	*Cybister vulneratus*		Not Listed
INSECTA	COLEOPTERA	*Cybister tripunctatus*		Not Listed
INSECTA	COLEOPTERA	*Mesomorphus darwini*		Not Listed

ORDER	FAMILY	SPECIES NAME	COMMON NAME	IUCN STATUS
INSECTA	COLEOPTERA	*Gonocephalum insulanum*		Not Listed
INSECTA	COLEOPTERA	*Leichenum canaliculatum*		Not Listed
INSECTA	COLEOPTERA	*Cordylomera torrida*		Not Listed
INSECTA	COLEOPTERA	*Berosus approximans*		Not Listed
INSECTA	COLEOPTERA	*Strandius obliquus*		Not Listed
INSECTA	COLEOPTERA	*Hydrochus variolatus*		Not Listed
INSECTA	COLEOPTERA	*Eretes sticticus*		Not Listed
INSECTA	COLEOPTERA	*Hyperaspis senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Tribolium castaneum*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus mosambicus*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus parumpunctatus*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus licas*		Not Listed
INSECTA	COLEOPTERA	*Heteronychus fossor*		Not Listed
INSECTA	COLEOPTERA	*Phyllognathus burmeisteri*		Not Listed
INSECTA	COLEOPTERA	*Oryctes boas*		Not Listed
INSECTA	COLEOPTERA	*Sisyphus costatus*		Not Listed
INSECTA	COLEOPTERA	*Xyleborus ferrugineus*		Not Listed
INSECTA	COLEOPTERA	*Xyleborus affinis*		Not Listed
INSECTA	COLEOPTERA	*Hydaticus leander*		Not Listed
INSECTA	COLEOPTERA	*Myriochila melancholica*		Not Listed
INSECTA	COLEOPTERA	*Cybister vicinus*		Not Listed
INSECTA	COLEOPTERA	*Cybister marginicollis*		Not Listed
INSECTA	COLEOPTERA	*Hydaticus dorsiger*		Not Listed
INSECTA	COLEOPTERA	*Hydroglyphus flavoguttatus*		Not Listed
INSECTA	COLEOPTERA	*Hydroglyphus geminodes*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus acuminatus*		Not Listed
INSECTA	COLEOPTERA	*Sinoxylon senegalense*		Not Listed
INSECTA	COLEOPTERA	*Hister aequatorius*		Not Listed
INSECTA	COLEOPTERA	*Laccophilus persimilis*		Not Listed
INSECTA	COLEOPTERA	*Laccophilus propinquus*		Not Listed
INSECTA	COLEOPTERA	*Yola cuspis*		Not Listed
INSECTA	COLEOPTERA	*Yola nigrosignata*		Not Listed
INSECTA	COLEOPTERA	*Hydroglyphus koppi*		Not Listed
INSECTA	COLEOPTERA	*Copelatus carinatus*		Not Listed
INSECTA	COLEOPTERA	*Hydaticus severini*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus senegalensis*		Not Listed
INSECTA	COLEOPTERA	*Hydrovatus reticuliceps*		Not Listed

ORDER	FAMILY	SPECIES NAME	COMMON NAME	IUCN STATUS
INSECTA	COLEOPTERA	*Hydrovatus perssoni*		Not Listed
INSECTA	COLEOPTERA	*Xylion inflaticauda*		Not Listed
INSECTA	COLEOPTERA	*Minthea obsita*		Not Listed
INSECTA	HYMENOPTERA	*Anteon lankanum*		Not Listed
INSECTA	COLEOPTERA	*Eutochia pulla*		Not Listed
INSECTA	COLEOPTERA	*Berosus elongatulus*		Not Listed
INSECTA	COLEOPTERA	*Helochares normatus*		Not Listed
INSECTA	COLEOPTERA	*Onthophagus thomsoni*		Not Listed
INSECTA	COLEOPTERA	*Mallodon downesii*		Not Listed
INSECTA	COLEOPTERA	*Cordylomera torrida*		Not Listed
INSECTA	COLEOPTERA	*Berosus approximans*		Not Listed
INSECTA	COLEOPTERA	*Phyllognathus burmeisteri*		Not Listed
INSECTA	COLEOPTERA	*Sisyphus costatus*		Not Listed

APPENDIX C

Reptile species occurring in Guinea Bissau

FAMILY	GENUS & SPECIES	STATUS	RECORDED
TYPHLOPIDAE	Afrotyphlops punctatus		
AGAMIDAE	Agama agama		x
AGAMIDAE	Agama weidholzi		
COLUBRIDAE	Amblyodipsas unicolor		
COLUBRIDAE	Atractaspis aterrima		
ELAPIDAE	Bitis arietans		x
ELAPIDAE	Bitis rhinoceros		
COLUBRIDAE	Boaedon fuliginosus		
COLUBRIDAE	Boaedon lineatus		
ELAPIDAE	Causus rhombeatus		x
SCINCIDAE	Chalcides armitagei		
CHAMAELEONIDAE	Chamaeleo senegalensis		
CHELONIIDAE	Chelonia mydas		
CROCODYLIDAE	Crocodylus niloticus		x
CROCODYLIDAE	*Crocodylus cataphractus*	DD	
CROCODYLIDAE	*Osteolaemus tetraspis*	VU	
TRIONYCHIDAE	Cyclanorbis senegalensis		
AMPHISBAENIDAE	Cynisca feae		
AMPHISBAENIDAE	Cynisca leonina		
AMPHISBAENIDAE	Cynisca oligopholis		
COLUBRIDAE	Dasypeltis confusa		
COLUBRIDAE	Dasypeltis fasciata		x
COLUBRIDAE	Dasypeltis gansi		
COLUBRIDAE	Dasypeltis scabra		
ELAPIDAE	Dendroaspis polylepis		
ELAPIDAE	Dendroaspis viridis		
ELAPIDAE	Elapsoidea semiannulata		
COLUBRIDAE	Gonionotophis grantii		
COLUBRIDAE	Gonionotophis stenophthalmus		
COLUBRIDAE	Grayia smithii		
COLUBRIDAE	Hapsidophrys lineatus		
COLUBRIDAE	Hapsidophrys smaragdina		
GEKKONIDAE	Hemidactylus angulatus		
TESTUDINIDAE	Kinixys belliana		
LACERTIDAE	Latastia ornata		
COLUBRIDAE	Lycophidion albomaculatum		
COLUBRIDAE	Lycophidion semicinctum		
GEKKONIDAE	Lygodactylus gutturalis		
GEKKONIDAE	Lygodactylus picturatus		

FAMILY	GENUS & SPECIES	STATUS	RECORDED
CROCODYLIDAE	Mecistops cataphractus		
LEPTOTYPHLOPIDAE	Myriopholis boueti		
LEPTOTYPHLOPIDAE	Myriopholis narirostris		
ELAPIDAE	Naja haje		
ELAPIDAE	Naja melanoleuca		x
ELAPIDAE	Naja nigricollis		x
ELAPIDAE	Naja senegalensis		
CROCODYLIDAE	Osteolaemus tetraspis	VU	
COLUBRIDAE	Philothamnus carinatus		
COLUBRIDAE	Philothamnus heterodermus		
COLUBRIDAE	Philothamnus irregularis		x
PROSYMNIDAE	Prosymna meleagris		
COLUBRIDAE	Psammophis elegans		
COLUBRIDAE	Psammophis lineatus		x
COLUBRIDAE	Psammophis phillipsi		
COLUBRIDAE	Psammophis praeornatus		
COLUBRIDAE	Psammophis sibilans		
PYTHONIDAE	Python regius		
PYTHONIDAE	Python sebae		
COLUBRIDAE	Rhamphiophis oxyrhynchus		
LEPTOTYPHLOPIDAE	Rhinoleptus koniagui		
GEKKONIDAE	Tarentola ephippiata		
COLUBRIDAE	Telescopus variegatus		
COLUBRIDAE	Thelotornis kirtlandii		
COLUBRIDAE	Toxicodryas blandingii		
SCINCIDAE	Trachylepis affinis		
SCINCIDAE	Trachylepis perrotetii		
SCINCIDAE	Trachylepis quinquetaeniata		
VARANUS	Varanus exanthematicus		x
VARANUS	Varanus ornatus		x

APPENDIX D

Amphibian species occurring in Guinea Bissau

FAMILY	GENUS & SPECIES	IUCN STATUS	RECORDED
ARTHROLEPTIDAE	Arthroleptis poecilonotus	Not Listed	
HYPEROLIIDAE	Leptopelis spiritusnoctis	Not Listed	
HYPEROLIIDAE	Leptopelis viridis	Not Listed	
BUFONIDAE	Amietophrynus regularis	Not Listed	x
DICROGLOSSIDAE	Hoplobatrachus occipitalis	Not Listed	
HEMISOTIDAE	Hemisus guineensis	Not Listed	
HEMISOTIDAE	Hemisus marmoratus	Not Listed	
HYPEROLIIDAE	Afrixalus quadrivittatus	Not Listed	
HYPEROLIIDAE	Afrixalus vittiger	Not Listed	
HYPEROLIIDAE	Afrixalus weidholzi	Not Listed	
HYPEROLIIDAE	Hyperolius fusciventris	Not Listed	
HYPEROLIIDAE	Hyperolius lamottei	Not Listed	
HYPEROLIIDAE	Hyperolius occidentalis	Not Listed	x
HYPEROLIIDAE	Hyperolius spatzi	Not Listed	
HYPEROLIIDAE	Kassina cassinoides	Not Listed	
HYPEROLIIDAE	Kassina fusca	Not Listed	
HYPEROLIIDAE	Kassina senegalensis	Not Listed	x
PHRYNOBATRACHIDAE	Phrynobatrachus francisci	Not Listed	
PHRYNOBATRACHIDAE	Phrynobatrachus gutturosus	Not Listed	
PHRYNOBATRACHIDAE	Phrynobatrachus latifrons	Not Listed	
PHRYNOBATRACHIDAE	Phrynobatrachus natalensis	Not Listed	x
PHRYNOBATRACHIDAE	Phrynobatrachus tokba	Not Listed	
PIPIDAE	Pseudhymenochirus merlini	Not Listed	
PIPIDAE	Silurana tropicalis	Not Listed	
PTYCHADENIDAE	Ptychadena arnei	Not Listed	
PTYCHADENIDAE	Ptychadena bibroni	Not Listed	
PTYCHADENIDAE	Ptychadena mascareniensis	Not Listed	
PTYCHADENIDAE	Ptychadena oxyrhynchus	Not Listed	
PTYCHADENIDAE	Ptychadena tournieri	Not Listed	
PTYCHADENIDAE	Ptychadena trinodis	Not Listed	
PYXICEPHALIDAE	Tomopterna cryptotis	Not Listed	
PYXICEPHALIDAE	Pyxicephalus edulis	Not Listed	
RANIDAE	Hylarana galamensis	Not Listed	
RANIDAE	Ametia angolensis	Not Listed	x

APPENDIX E

Avifauna species occurring in Guinea Bissau

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
ACCIPITRIDAE	*Accipiter badius*	Shikra		
ACCIPITRIDAE	*Accipiter erythropus*	Red-thighed Sparrowhawk		
ACCIPITRIDAE	*Accipiter melanoleucus*	Black Goshawk		
ACCIPITRIDAE	*Accipiter toussenelii*	Red-chested Goshawk		
ACCIPITRIDAE	*Aquila rapax*	Tawny Eagle		
ACCIPITRIDAE	*Aquila spilogaster*	African Hawk-Eagle		
ACCIPITRIDAE	*Aviceda cuculoides*	African Cuckoo-Hawk		
ACCIPITRIDAE	*Butastur rufipennis*	Grasshopper Buzzard		
ACCIPITRIDAE	*Buteo auguralis*	Red-necked Buzzard		
ACCIPITRIDAE	*Circaetus beaudouini*	Beaudouin's Snake-Eagle	VU	
ACCIPITRIDAE	*Circaetus cinerascens*	Banded Snake-Eagle		x
ACCIPITRIDAE	*Circaetus cinereus*	Brown Snake-Eagle		
ACCIPITRIDAE	*Circus aeruginosus*	Eurasian Marsh-Harrier		
ACCIPITRIDAE	*Circus macrourus*	Pallid Harrier	NT	
ACCIPITRIDAE	*Elanus caeruleus*	Black-shouldered Kite		
ACCIPITRIDAE	*Gypohierax angolensis*	Palm-nut Vulture		x
ACCIPITRIDAE	*Gyps africanus*	White-backed Vulture	NT	
ACCIPITRIDAE	*Gyps rueppellii*	Rueppell's Griffon	NT	
ACCIPITRIDAE	*Haliaeetus vocifer*	African Fish-Eagle		x
ACCIPITRIDAE	*Hieraaetus pennatus*	Booted Eagle		
ACCIPITRIDAE	*Hieraaetus wahlbergi*	Wahlberg's Eagle		
ACCIPITRIDAE	*Kaupifalco monogrammicus*	Lizard Buzzard		
ACCIPITRIDAE	*Lophaetus occipitalis*	Long-crested Eagle		x
ACCIPITRIDAE	*Macheiramphus alcinus*	Bat Hawk		
ACCIPITRIDAE	*Melierax metabates*	Dark Chanting-Goshawk		x
ACCIPITRIDAE	*Micronisus gabar*	Gabar Goshawk		
ACCIPITRIDAE	*Milvus migrans*	Black Kite		x
ACCIPITRIDAE	*Necrosyrtes monachus*	Hooded Vulture	EN	x
ACCIPITRIDAE	*Neophron percnopterus*	Egyptian Vulture	EN	
ACCIPITRIDAE	*Pernis apivorus*	European Honey-buzzard		
ACCIPITRIDAE	*Polemaetus bellicosus*	Martial Eagle		
ACCIPITRIDAE	*Polyboroides typus*	African Harrier-Hawk		
ACCIPITRIDAE	*Stephanoaetus coronatus*	Crowned Hawk-Eagle		
ACCIPITRIDAE	*Terathopius ecaudatus*	Bateleur		
ACCIPITRIDAE	*Trigonoceps occipitalis*	White-headed Vulture	VU	
FRINGILLIDAE	*Serinus leucopygius*	White-rumped Seedeater		x
FRINGILLIDAE	*Serinus mozambicus*	Yellow-fronted Canary		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
HELIORNITHIDAE	*Podica senegalensis*	African Finfoot		
SULIDAE	*Morus bassanus*	Northern Gannet		
ACROCEPHALIDAE	*Acrocephalus schoenobaenus*	Sedge Warbler		x
ACROCEPHALIDAE	*Acrocephalus scirpaceus*	Eurasian Reed-Warbler		
ACROCEPHALIDAE	*Hippolais pallida*	Eastern Olivaceous Warbler		
ACROCEPHALIDAE	*Hippolais polyglotta*	Melodious Warbler		
ALAUDIDAE	*Galerida cristata*	Crested Lark		
ALAUDIDAE	*Galerida modesta*	Sun Lark		
ALAUDIDAE	*Mirafra rufocinnamomea*	Flappet Lark		
ALAUDIDAE	*Pinarocorys erythropygia*	Rufous-rumped Lark		
ALCEDINIDAE	*Alcedo quadribrachys*	Shining-blue Kingfisher		
ALCEDINIDAE	*Ceryle rudis*	Pied Kingfisher		
ALCEDINIDAE	*Corythornis cristatus*	Malachite Kingfisher		x
ALCEDINIDAE	*Halcyon chelicuti*	Striped Kingfisher		x
ALCEDINIDAE	*Halcyon leucocephala*	Gray-headed Kingfisher		
ALCEDINIDAE	*Halcyon malimbica*	Blue-breasted Kingfisher		
ALCEDINIDAE	*Halcyon senegalensis*	Woodland Kingfisher		x
ALCEDINIDAE	*Ispidina picta*	African Pygmy-Kingfisher		
ALCEDINIDAE	*Megaceryle maximus*	Giant Kingfisher		
ANATIDAE	*Alopochen aegyptiaca*	Egyptian Goose		
ANATIDAE	*Anas acuta*	Northern Pintail		
ANATIDAE	*Anas clypeata*	Northern Shoveler		
ANATIDAE	*Anas crecca*	Green-winged Teal		
ANATIDAE	*Anas penelope*	Eurasian Wigeon		
ANATIDAE	*Anas querquedula*	Garganey		
ANATIDAE	*Dendrocygna viduata*	White-faced Whistling-Duck		
ANATIDAE	*Nettapus auritus*	African Pygmy-Goose		
ANATIDAE	*Plectropterus gambensis*	Spur-winged Goose		
ANATIDAE	*Sarkidiornis melanotos*	Comb Duck		x
ANATIDAE	*Thalassornis leuconotus*	White-backed Duck		
ANHINGIDAE	*Anhinga rufa*	African Darter		x
APODIDAE	*Apus affinis*	Little Swift		
APODIDAE	*Apus apus*	Common Swift		
APODIDAE	*Apus caffer*	White-rumped Swift		
APODIDAE	*Apus pallidus*	Pallid Swift		
APODIDAE	*Cypsiurus parvus*	African Palm-Swift		
APODIDAE	*Telacanthura ussheri*	Mottled Spinetail		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
ARDEIDAE	*Ardea alba*	Great Egret		x
ARDEIDAE	*Ardea cinerea*	Gray Heron		x
ARDEIDAE	*Ardea goliath*	Goliath Heron		
ARDEIDAE	*Ardea melanocephala*	Black-headed Heron		
ARDEIDAE	*Ardea purpurea*	Purple Heron		
ARDEIDAE	*Ardeola ralloides*	Squacco Heron		
ARDEIDAE	*Bubulcus ibis*	Cattle Egret		x
ARDEIDAE	*Butorides striata*	Striated Heron		
ARDEIDAE	*Egretta ardesiaca*	Black Heron		
ARDEIDAE	*Egretta garzetta*	Little Egret		
ARDEIDAE	*Egretta gularis*	Western Reef-Heron		
ARDEIDAE	*Gorsachius leuconotus*	White-backed Night-Heron		x
ARDEIDAE	*Ixobrychus minutus*	Little Bittern		
ARDEIDAE	*Ixobrychus sturmii*	Dwarf Bittern		
ARDEIDAE	*Mesophoyx intermedia*	Intermediate Egret		x
ARDEIDAE	*Nycticorax nycticorax*	Black-crowned Night-Heron		
ARDEIDAE	*Tigriornis leucolopha*	White-crested Bittern		
BUCEROTIDAE	*Bucorvus abyssinicus*	Abyssinian Ground-Hornbill		
BUCEROTIDAE	*Ceratogymna elata*	Yellow-casqued Hornbill	NT	
BUCEROTIDAE	*Ceratogymna fistulator*	Piping Hornbill		
BUCEROTIDAE	*Tockus erythrorhynchus*	Northern Red-billed Hornbill		x
BUCEROTIDAE	*Tockus fasciatus*	African Pied Hornbill		
BUCEROTIDAE	*Tockus nasutus*	African Gray Hornbill		x
BUPHAGIDAE	*Buphagus africanus*	Yellow-billed Oxpecker		
BURHINIDAE	*Burhinus senegalensis*	Senegal Thick-knee		
CAMPEPHAGIDAE	*Campephaga phoenicea*	Red-shouldered Cuckoo-shrike		
CAMPEPHAGIDAE	*Coracina pectoralis*	White-breasted Cuckoo-shrike		
CAPRIMULGIDAE	*Caprimulgus climacurus*	Long-tailed Nightjar		
CAPRIMULGIDAE	*Caprimulgus europaeus*	Eurasian Nightjar		
CAPRIMULGIDAE	*Caprimulgus inornatus*	Plain Nightjar		
CAPRIMULGIDAE	*Caprimulgus nigriscapularis*	Black-shouldered Nightjar		
CAPRIMULGIDAE	*Caprimulgus pectoralis*	Fiery-necked Nightjar		x
CAPRIMULGIDAE	*Caprimulgus ruficollis*	Red-necked Nightjar		
CAPRIMULGIDAE	*Macrodipteryx longipennis*	Standard-winged Nightjar		
CAPRIMULGIDAE	*Macrodipteryx vexillarius*	Pennant-winged Nightjar		
CERTHIIDAE	*Salpornis spilonotus*	Spotted Creeper		
CHARADRIIDAE	*Charadrius alexandrinus*	Kentish Plover		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
CHARADRIIDAE	*Charadrius dubius*	Little Ringed Plover		
CHARADRIIDAE	*Charadrius forbesi*	Forbes's Plover		
CHARADRIIDAE	*Charadrius hiaticula*	Common Ringed Plover		
CHARADRIIDAE	*Charadrius pecuarius*	Kittlitz's Plover		x
CHARADRIIDAE	*Pluvialis squatarola*	Black-bellied Plover		
CHARADRIIDAE	*Vanellus albiceps*	White-headed Lapwing		
CHARADRIIDAE	*Vanellus lugubris*	Senegal Lapwing		
CHARADRIIDAE	*Vanellus senegallus*	Wattled Lapwing		
CHARADRIIDAE	*Vanellus spinosus*	Spur-winged Plover		
CHARADRIIDAE	*Vanellus tectus*	Black-headed Lapwing		
CICONIIDAE	*Ciconia ciconia*	White Stork		
CICONIIDAE	*Ciconia episcopus*	Woolly-necked Stork		
CICONIIDAE	*Ciconia nigra*	Black Stork		
CICONIIDAE	*Ephippiorhynchus senegalensis*	Saddle-billed Stork		
CICONIIDAE	*Leptoptilos crumeniferus*	Marabou Stork		
CICONIIDAE	*Mycteria ibis*	Yellow-billed Stork		
CISTICOLIDAE	*Camaroptera brachyura*	Green-backed Camaroptera		
CISTICOLIDAE	*Camaroptera chloronota*	Olive-green Camaroptera		
CISTICOLIDAE	*Cisticola brachypterus*	Siffling Cisticola		
CISTICOLIDAE	*Cisticola cantans*	Singing Cisticola		x
CISTICOLIDAE	*Cisticola dorsti*	Dorst's Cisticola		
CISTICOLIDAE	*Cisticola erythrops*	Red-faced Cisticola		
CISTICOLIDAE	*Cisticola eximius*	Black-necked Cisticola		
CISTICOLIDAE	*Cisticola galactotes*	Winding Cisticola		
CISTICOLIDAE	*Cisticola juncidis*	Zitting Cisticola		x
CISTICOLIDAE	*Cisticola lateralis*	Whistling Cisticola		
CISTICOLIDAE	*Cisticola natalensis*	Croaking Cisticola		x
CISTICOLIDAE	*Cisticola ruficeps*	Red-pate Cisticola		
CISTICOLIDAE	*Cisticola rufus*	Rufous Cisticola		
CISTICOLIDAE	*Eremomela pusilla*	Senegal Eremomela		
CISTICOLIDAE	*Hypergerus atriceps*	Oriole Warbler		
CISTICOLIDAE	*Prinia erythroptera*	Red-winged Prinia		
CISTICOLIDAE	*Prinia subflava*	Tawny-flanked Prinia		
COLIIDAE	*Urocolius macrourus*	Blue-naped Mousebird		
COLUMBIDAE	*Columba guinea*	Speckled Pigeon		
COLUMBIDAE	*Oena capensis*	Namaqua Dove		x
COLUMBIDAE	*Streptopelia decipiens*	Mourning Collared-Dove		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
COLUMBIDAE	*Streptopelia hypopyrrha*	Adamawa Turtle-Dove		
COLUMBIDAE	*Streptopelia semitorquata*	Red-eyed Dove		
COLUMBIDAE	*Streptopelia senegalensis*	Laughing Dove		x
COLUMBIDAE	*Streptopelia turtur*	European Turtle-Dove		x
COLUMBIDAE	*Streptopelia vinacea*	Vinaceous Dove		
COLUMBIDAE	*Treron calvus*	African Green-Pigeon		x
COLUMBIDAE	*Treron waalia*	Bruce's Green-Pigeon		
COLUMBIDAE	*Turtur abyssinicus*	Black-billed Wood-Dove		
COLUMBIDAE	*Turtur afer*	Blue-spotted Wood-Dove		
COLUMBIDAE	*Turtur tympanistria*	Tambourine Dove		
CORACIIDAE	*Coracias abyssinicus*	Abyssinian Roller		
CORACIIDAE	*Coracias cyanogaster*	Blue-bellied Roller		x
CORACIIDAE	*Coracias naevius*	Rufous-crowned Roller		x
CORACIIDAE	*Eurystomus glaucurus*	Broad-billed Roller		
CORACIIDAE	*Eurystomus gularis*	Blue-throated Roller		
CORVIDAE	*Corvus albus*	Pied Crow		
CUCULIDAE	*Centropus grillii*	Black Coucal		
CUCULIDAE	*Centropus leucogaster*	Black-throated Coucal		
CUCULIDAE	*Centropus monachus*	Blue-headed Coucal		
CUCULIDAE	*Centropus senegalensis*	Senegal Coucal		x
CUCULIDAE	*Ceuthmochares aereus*	Yellowbill		
CUCULIDAE	*Chrysococcyx caprius*	Dideric Cuckoo		x
CUCULIDAE	*Chrysococcyx cupreus*	African Emerald Cuckoo		
CUCULIDAE	*Chrysococcyx klaas*	Klaas's Cuckoo		
CUCULIDAE	*Clamator glandarius*	Great Spotted Cuckoo		
CUCULIDAE	*Clamator jacobinus*	Pied Cuckoo		
CUCULIDAE	*Clamator levaillantii*	Levaillant's Cuckoo		
CUCULIDAE	*Cuculus canorus*	Common Cuckoo		
CUCULIDAE	*Cuculus clamosus*	Black Cuckoo		x
CUCULIDAE	*Cuculus gularis*	African Cuckoo		
CUCULIDAE	*Cuculus solitarius*	Red-chested Cuckoo		
DICRURIDAE	*Dicrurus adsimilis*	Fork-tailed Drongo		x
DICRURIDAE	*Dicrurus ludwigii*	Square-tailed Drongo		
EMBERIZIDAE	*Emberiza affinis*	Brown-rumped Bunting		
EMBERIZIDAE	*Emberiza cabanisi*	Cabanis's Bunting		
EMBERIZIDAE	*Emberiza tahapisi*	Cinnamon-breasted Bunting		
ESTRILDIDAE	*Amadina fasciata*	Cut-throat		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
ESTRILDIDAE	*Estrilda caerulescens*	Lavender Waxbill		
ESTRILDIDAE	*Estrilda melpoda*	Orange-cheeked Waxbill		x
ESTRILDIDAE	*Estrilda troglodytes*	Black-rumped Waxbill		
ESTRILDIDAE	*Euodice cantans*	African Silverbill		
ESTRILDIDAE	*Lagonosticta larvata*	Black-faced Firefinch		
ESTRILDIDAE	*Lagonosticta rubricata*	African Firefinch		
ESTRILDIDAE	*Lagonosticta rufopicta*	Bar-breasted Firefinch		
ESTRILDIDAE	*Lagonosticta senegala*	Red-billed Firefinch		
ESTRILDIDAE	*Nesocharis capistrata*	Gray-headed Oliveback		
ESTRILDIDAE	*Nigrita bicolor*	Chestnut-breasted Negrofinch		
ESTRILDIDAE	*Ortygospiza atricollis*	Black-faced Quailfinch		
ESTRILDIDAE	*Pyrenestes sanguineus*	Crimson Seedcracker		
ESTRILDIDAE	*Pytilia melba*	Green-winged Pytilia		x
ESTRILDIDAE	*Pytilia phoenicoptera*	Red-winged Pytilia		
ESTRILDIDAE	*Spermestes bicolor*	Black-and-white Mannikin		
ESTRILDIDAE	*Spermestes cucullatus*	Bronze Mannikin		
ESTRILDIDAE	*Spermestes fringilloides*	Magpie Mannikin		
ESTRILDIDAE	*Spermophaga haematina*	Western Bluebill		
ESTRILDIDAE	*Sporaeginthus subflavus*	Zebra Waxbill		
ESTRILDIDAE	*Uraeginthus bengalus*	Red-cheeked Cordonbleu		
FALCONIDAE	*Falco alopex*	Fox Kestrel		
FALCONIDAE	*Falco ardosiaceus*	Gray Kestrel		
FALCONIDAE	*Falco biarmicus*	Lanner Falcon		
FALCONIDAE	*Falco chicquera*	Red-necked Falcon		
FALCONIDAE	*Falco cuvierii*	African Hobby		
FALCONIDAE	*Falco naumanni*	Lesser Kestrel	VU	
FALCONIDAE	*Falco peregrinus*	Peregrine Falcon		
FALCONIDAE	*Falco tinnunculus*	Eurasian Kestrel		
GLAREOLIDAE	*Cursorius temminckii*	Temminck's Courser		
GLAREOLIDAE	*Glareola pratincola*	Collared Pratincole		
GLAREOLIDAE	*Pluvianus aegyptius*	Egyptian Plover		
GLAREOLIDAE	*Rhinoptilus chalcopterus*	Bronze-winged Courser		
GRUIDAE	*Balearica pavonina*	Black Crowned-Crane	VU	
GRUIDAE	*Grus grus*	Common Crane		
HAEMATOPODIDAE	*Haematopus ostralegus*	Eurasian Oystercatcher		
HIRUNDINIDAE	*Cecropis abyssinica*	Lesser Striped-Swallow		
HIRUNDINIDAE	*Cecropis daurica*	Red-rumped Swallow		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
HIRUNDINIDAE	*Cecropis semirufa*	Rufous-chested Swallow		
HIRUNDINIDAE	*Cecropis senegalensis*	Mosque Swallow		
HIRUNDINIDAE	*Delichon urbicum*	Common House-Martin		
HIRUNDINIDAE	*Hirundo leucosoma*	Pied-winged Swallow		
HIRUNDINIDAE	*Hirundo lucida*	Red-chested Swallow		
HIRUNDINIDAE	*Hirundo nigrita*	White-throated Blue Swallow		
HIRUNDINIDAE	*Hirundo rustica*	Barn Swallow		
HIRUNDINIDAE	*Hirundo smithii*	Wire-tailed Swallow		
HIRUNDINIDAE	*Petrochelidon preussi*	Preuss's Swallow		
HIRUNDINIDAE	*Psalidoprocne obscura*	Fanti Sawwing		
HIRUNDINIDAE	*Pseudhirundo griseopyga*	Gray-rumped Swallow		
HYDROBATIDAE	*Hydrobates pelagicus*	European Storm-Petrel		
HYDROBATIDAE	*Oceanites oceanicus*	Wilson's Storm-Petrel		
HYLIOTIDAE	*Hyliota flavigaster*	Yellow-bellied Hyliota		
INDICATORIDAE	*Indicator exilis*	Least Honeyguide		
INDICATORIDAE	*Indicator indicator*	Greater Honeyguide		
INDICATORIDAE	*Indicator maculatus*	Spotted Honeyguide		
INDICATORIDAE	*Indicator minor*	Lesser Honeyguide		x
INDICATORIDAE	*Indicator willcocksi*	Willcock's Honeyguide		
INDICATORIDAE	*Melichneutes robustus*	Lyre-tailed Honeyguide		
JACANIDAE	*Actophilornis africanus*	African Jacana		x
LANIIDAE	*Corvinella corvina*	Yellow-billed Shrike		
LANIIDAE	*Lanius gubernator*	Emin's Shrike		
LARIDAE	*Anous minutus*	Black Noddy		
LARIDAE	*Anous stolidus*	Brown Noddy		
LARIDAE	*Chlidonias hybrida*	Whiskered Tern		
LARIDAE	*Chlidonias leucopterus*	White-winged Tern		
LARIDAE	*Chlidonias niger*	Black Tern		
LARIDAE	*Chroicocephalus cirrocephalus*	Gray-hooded Gull		
LARIDAE	*Gelochelidon nilotica*	Gull-billed Tern		
LARIDAE	*Hydroprogne caspia*	Caspian Tern		
LARIDAE	*Larus fuscus*	Lesser Black-backed Gull		
LARIDAE	*Onychoprion anaethetus*	Bridled Tern		
LARIDAE	*Onychoprion fuscatus*	Sooty Tern		
LARIDAE	*Sterna dougallii*	Roseate Tern		
LARIDAE	*Sterna hirundo*	Common Tern		
LARIDAE	*Sterna paradisaea*	Arctic Tern		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
LARIDAE	*Sternula albifrons*	Little Tern		
LARIDAE	*Thalasseus maximus*	Royal Tern		
LARIDAE	*Thalasseus sandvicensis*	Sandwich Tern		
LARIDAE	*Xema sabini*	Sabine's Gull		
LEIOTHRICHIDAE	*Phyllanthus atripennis*	Capuchin Babbler		
LEIOTHRICHIDAE	*Turdoides plebejus*	Brown Babbler		
LEIOTHRICHIDAE	*Turdoides reinwardtii*	Blackcap Babbler		
LYBIIDAE	*Lybius bidentatus*	Double-toothed Barbet		
LYBIIDAE	*Lybius dubius*	Bearded Barbet		x
LYBIIDAE	*Lybius vieilloti*	Vieillot's Barbet		
LYBIIDAE	*Pogoniulus bilineatus*	Yellow-rumped Tinkerbird		
LYBIIDAE	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird		
MACROSPHENIDAE	*Melocichla mentalis*	Moustached Grass-Warbler		
MACROSPHENIDAE	*Sylvietta brachyura*	Northern Crombec		
MALACONOTIDAE	*Dryoscopus gambensis*	Northern Puffback		
MALACONOTIDAE	*Laniarius barbarus*	Common Gonolek		
MALACONOTIDAE	*Laniarius turatii*	Turati's Boubou		
MALACONOTIDAE	*Malaconotus blanchoti*	Gray-headed Bushshrike		
MALACONOTIDAE	*Nilaus afer*	Brubru		
MALACONOTIDAE	*Tchagra senegalus*	Black-crowned Tchagra		x
MALACONOTIDAE	*Telophorus sulfureopectus*	Sulphur-breasted Bushshrike		
MEROPIDAE	*Merops albicollis*	White-throated Bee-eater		
MEROPIDAE	*Merops apiaster*	European Bee-eater		x
MEROPIDAE	*Merops bulocki*	Red-throated Bee-eater		
MEROPIDAE	*Merops hirundineus*	Swallow-tailed Bee-eater		
MEROPIDAE	*Merops nubicus*	Northern Carmine Bee-eater		
MEROPIDAE	*Merops orientalis*	Green Bee-eater		
MEROPIDAE	*Merops persicus*	Blue-cheeked Bee-eater		
MEROPIDAE	*Merops pusillus*	Little Bee-eater		x
MONARCHIDAE	*Ptilostomus afer*	Piapiac		
MONARCHIDAE	*Terpsiphone rufiventer*	Black-headed Paradise-Flycatcher		
MONARCHIDAE	*Terpsiphone viridis*	African Paradise-Flycatcher		
MOTACILLIDAE	*Anthus leucophrys*	Plain-backed Pipit		
MOTACILLIDAE	*Macronyx croceus*	Yellow-throated Longclaw		
MOTACILLIDAE	*Motacilla aguimp*	African Pied Wagtail		x
MOTACILLIDAE	*Motacilla clara*	Mountain Wagtail		
MOTACILLIDAE	*Motacilla flava*	Western Yellow Wagtail		x

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
MUSCICAPIDAE	*Alethe diademata*	Fire-crested Alethe		
MUSCICAPIDAE	*Bradornis pallidus*	Pale Flycatcher		
MUSCICAPIDAE	*Cercotrichas podobe*	Black Scrub-Robin		x
MUSCICAPIDAE	*Cossypha albicapilla*	White-crowned Robin-Chat		
MUSCICAPIDAE	*Cossypha niveicapilla*	Snowy-crowned Robin-Chat		
MUSCICAPIDAE	*Ficedula hypoleuca*	European Pied Flycatcher		x
MUSCICAPIDAE	*Fraseria cinerascens*	White-browed Forest-Flycatcher		
MUSCICAPIDAE	*Luscinia megarhynchos*	Common Nightingale		
MUSCICAPIDAE	*Melaenornis edolioides*	Northern Black-Flycatcher		
MUSCICAPIDAE	*Monticola saxatilis*	Rufous-tailed Rock-Thrush		
MUSCICAPIDAE	*Muscicapa aquatica*	Swamp Flycatcher		
MUSCICAPIDAE	*Muscicapa striata*	Spotted Flycatcher		
MUSCICAPIDAE	*Myioparus plumbeus*	Gray Tit-Flycatcher		
MUSCICAPIDAE	*Myrmecocichla albifrons*	White-fronted Black-Chat		
MUSCICAPIDAE	*Oenanthe oenanthe*	Northern Wheatear		
MUSCICAPIDAE	*Phoenicurus phoenicurus*	Common Redstart		
MUSCICAPIDAE	*Saxicola rubetra*	Whinchat		
MUSOPHAGIDAE	*Corythaeola cristata*	Great Blue Turaco		x
MUSOPHAGIDAE	*Crinifer piscator*	Western Plantain-eater		x
MUSOPHAGIDAE	*Musophaga violacea*	Violet Turaco		
MUSOPHAGIDAE	*Tauraco persa*	Guinea Turaco		
NECTARINIIDAE	*Anthreptes gabonicus*	Mouse-brown Sunbird		
NECTARINIIDAE	*Anthreptes longuemarei*	Western Violet-backed Sunbird		
NECTARINIIDAE	*Chalcomitra senegalensis*	Scarlet-chested Sunbird		
NECTARINIIDAE	*Cinnyris chloropygius*	Olive-bellied Sunbird		
NECTARINIIDAE	*Cinnyris coccinigastrus*	Splendid Sunbird		
NECTARINIIDAE	*Cinnyris cupreus*	Copper Sunbird		
NECTARINIIDAE	*Cinnyris pulchellus*	Beautiful Sunbird		
NECTARINIIDAE	*Cinnyris venustus*	Variable Sunbird		
NECTARINIIDAE	*Cyanomitra obscura*	Western Olive Sunbird		x
NECTARINIIDAE	*Cyanomitra olivacea*	Eastern Olive Sunbird		
NECTARINIIDAE	*Cyanomitra verticalis*	Green-headed Sunbird		
NECTARINIIDAE	*Hedydipna collaris*	Collared Sunbird		
NECTARINIIDAE	*Hedydipna platura*	Pygmy Sunbird		
NICATORIDAE	*Nicator chloris*	Yellow-spotted Nicator		
NUMIDIDAE	*Guttera pucherani*	Crested Guineafowl		
NUMIDIDAE	*Numida meleagris*	Helmeted Guineafowl		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
ORIOLIDAE	*Oriolus auratus*	African Golden Oriole		x
ORIOLIDAE	*Oriolus oriolus*	Eurasian Golden Oriole		
OTIDIDAE	*Eupodotis senegalensis*	White-bellied Bustard		
OTIDIDAE	*Lissotis melanogaster*	Black-bellied Bustard		
OTIDIDAE	*Neotis denhami*	Stanley Bustard	NT	
PANDIONIDAE	*Pandion haliaetus*	Osprey		
PARIDAE	*Melaniparus guineensis*	White-shouldered Black-Tit		
PASSERIDAE	*Passer domesticus*	House Sparrow		x
PASSERIDAE	*Passer griseus*	Northern Gray-headed Sparrow		
PASSERIDAE	*Petronia dentata*	Bush Petronia		
PELECANIDAE	*Pelecanus onocrotalus*	Great White Pelican		
PELECANIDAE	*Pelecanus rufescens*	Pink-backed Pelican		
PELLORNEIDAE	*Illadopsis fulvescens*	Brown Illadopsis		
PELLORNEIDAE	*Illadopsis puveli*	Puvel's Illadopsis		
PHALACROCORACIDAE	*Phalacrocorax africanus*	Long-tailed Cormorant		
PHALACROCORACIDAE	*Phalacrocorax carbo*	Great Cormorant		x
PHASIANIDAE	*Francolinus ahantensis*	Ahanta Francolin		
PHASIANIDAE	*Francolinus bicalcaratus*	Double-spurred Francolin		x
PHASIANIDAE	*Ptilopachus petrosus*	Stone Partridge		
PHOENICOPTERIDAE	*Phoenicopterus minor*	Lesser Flamingo	NT	
PHOENICOPTERIDAE	*Phoenicopterus roseus*	Greater Flamingo		
PHOENICULIDAE	*Phoeniculus purpureus*	Green Woodhoopoe		
PHOENICULIDAE	*Rhinopomastus aterrimus*	Black Scimitar-bill		
PHYLLOSCOPIDAE	*Phylloscopus sibilatrix*	Wood Warbler		
PHYLLOSCOPIDAE	*Phylloscopus trochilus*	Willow Warbler		
PICIDAE	*Campethera abingoni*	Golden-tailed Woodpecker		x
PICIDAE	*Campethera caroli*	Brown-eared Woodpecker		
PICIDAE	*Campethera maculosa*	Little Green Woodpecker		
PICIDAE	*Campethera nivosa*	Buff-spotted Woodpecker		
PICIDAE	*Campethera punctuligera*	Fine-spotted Woodpecker		
PICIDAE	*Dendropicos fuscescens*	Cardinal Woodpecker		x
PICIDAE	*Dendropicos goertae*	Gray Woodpecker		
PICIDAE	*Dendropicos obsoletus*	Brown-backed Woodpecker		
PICIDAE	*Jynx torquilla*	Eurasian Wryneck		
PLATYSTEIRIDAE	*Batis senegalensis*	Senegal Batis		x
PLATYSTEIRIDAE	*Bias musicus*	Black-and-white Shrike-flycatcher		
PLATYSTEIRIDAE	*Platysteira cyanea*	Brown-throated Wattle-eye		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
PLOCEIDAE	*Anaplectes rubriceps*	Red-headed Weaver		x
PLOCEIDAE	*Bubalornis albirostris*	White-billed Buffalo-Weaver		
PLOCEIDAE	*Euplectes afer*	Yellow-crowned Bishop		
PLOCEIDAE	*Euplectes franciscanus*	Orange Bishop		x
PLOCEIDAE	*Euplectes hordeaceus*	Black-winged Bishop		x
PLOCEIDAE	*Euplectes macroura*	Yellow-shouldered Widowbird		
PLOCEIDAE	*Malimbus nitens*	Gray's Malimbe		
PLOCEIDAE	*Malimbus rubricollis*	Red-headed Malimbe		
PLOCEIDAE	*Pachyphantes superciliosus*	Compact Weaver		
PLOCEIDAE	*Plocepasser superciliosus*	Chestnut-crowned Sparrow-Weaver		x
PLOCEIDAE	*Ploceus cucullatus*	Village Weaver		x
PLOCEIDAE	*Ploceus heuglini*	Heuglin's Masked-Weaver		
PLOCEIDAE	*Ploceus luteolus*	Little Weaver		
PLOCEIDAE	*Ploceus melanocephalus*	Black-headed Weaver		
PLOCEIDAE	*Ploceus nigricollis*	Black-necked Weaver		
PLOCEIDAE	*Quelea erythrops*	Red-headed Quelea		
PLOCEIDAE	*Quelea quelea*	Red-billed Quelea		x
PLOCEIDAE	*Sporopipes frontalis*	Speckle-fronted Weaver		
PODICIPEDIDAE	*Tachybaptus ruficollis*	Little Grebe		
PRIONOPIDAE	*Prionops plumatus*	White Helmetshrike		
PROCELLARIIDAE	*Calonectris diomedea*	Cory's Shearwater		
PROCELLARIIDAE	*Pterodroma feae*	Fea's Petrel	NT	
PROCELLARIIDAE	*Puffinus mauretanicus*	Balearic Shearwater	CR	
PROCELLARIIDAE	*Puffinus puffinus*	Manx Shearwater		
PSITTACIDAE	*Poicephalus robustus*	Brown-necked Parrot		
PSITTACIDAE	*Poicephalus senegalus*	Senegal Parrot		
PSITTACIDAE	*Psittacula krameri*	Rose-ringed Parakeet		
PSITTACIDAE	*Psittacus erithacus*	Gray Parrot	NT	
PTEROCLIDAE	*Pterocles quadricinctus*	Four-banded Sandgrouse		
PYCNONOTIDAE	*Atimastillas flavicollis*	Yellow-throated Greenbul		
PYCNONOTIDAE	*Bleda canicapillus*	Gray-headed Bristlebill		
PYCNONOTIDAE	*Chlorocichla simplex*	Simple Greenbul		
PYCNONOTIDAE	*Criniger calurus*	Red-tailed Greenbul		
PYCNONOTIDAE	*Eurillas virens*	Little Greenbul		
PYCNONOTIDAE	*Phyllastrephus scandens*	Leaf-love		
PYCNONOTIDAE	*Pycnonotus barbatus*	Common Bulbul		
PYCNONOTIDAE	*Stelgidillas gracilirostris*	Slender-billed Greenbul		

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
PYCNONOTIDAE	*Thescelocichla leucopleura*	Swamp Greenbul		
RALLIDAE	*Amaurornis flavirostra*	Black Crake		
RALLIDAE	*Crecopsis egregia*	African Crake		
RALLIDAE	*Gallinula chloropus*	Eurasian Moorhen		x
RALLIDAE	*Porphyrio alleni*	Allen's Gallinule		
RALLIDAE	*Porzana parva*	Little Crake		
RALLIDAE	*Porzana pusilla*	Baillon's Crake		
RALLIDAE	*Sarothrura pulchra*	White-spotted Flufftail		
RECURVIROSTRIDAE	*Himantopus himantopus*	Black-winged Stilt		
RECURVIROSTRIDAE	*Recurvirostra avosetta*	Pied Avocet		x
REMIZIDAE	*Anthoscopus parvulus*	Yellow Penduline-Tit		
ROSTRATULIDAE	*Rostratula benghalensis*	Greater Painted-snipe		
SAGITTARIIDAE	*Sagittarius serpentarius*	Secretary-bird		
SCOLOPACIDAE	*Actitis hypoleucos*	Common Sandpiper		x
SCOLOPACIDAE	*Arenaria interpres*	Ruddy Turnstone		
SCOLOPACIDAE	*Calidris alba*	Sanderling		
SCOLOPACIDAE	*Calidris alpina*	Dunlin		
SCOLOPACIDAE	*Calidris canutus*	Red Knot		
SCOLOPACIDAE	*Calidris ferruginea*	Curlew Sandpiper		
SCOLOPACIDAE	*Calidris minuta*	Little Stint		
SCOLOPACIDAE	*Calidris temminckii*	Temminck's Stint		
SCOLOPACIDAE	*Gallinago gallinago*	Common Snipe		
SCOLOPACIDAE	*Gallinago media*	Great Snipe	NT	
SCOLOPACIDAE	*Limosa lapponica*	Bar-tailed Godwit		
SCOLOPACIDAE	*Limosa limosa*	Black-tailed Godwit	NT	
SCOLOPACIDAE	*Lymnocryptes minimus*	Jack Snipe		
SCOLOPACIDAE	*Numenius arquata*	Eurasian Curlew	NT	
SCOLOPACIDAE	*Numenius phaeopus*	Whimbrel		
SCOLOPACIDAE	*Phalaropus fulicarius*	Red Phalarope		
SCOLOPACIDAE	*Philomachus pugnax*	Ruff		
SCOLOPACIDAE	*Tringa erythropus*	Spotted Redshank		
SCOLOPACIDAE	*Tringa glareola*	Wood Sandpiper		
SCOLOPACIDAE	*Tringa nebularia*	Common Greenshank		
SCOLOPACIDAE	*Tringa ochropus*	Green Sandpiper		
SCOLOPACIDAE	*Tringa stagnatilis*	Marsh Sandpiper		
SCOLOPACIDAE	*Tringa totanus*	Common Redshank		
SCOPIDAE	*Scopus umbretta*	Hamerkop		x

FAMILY	SCIENTIFIC NAME	COMMON NAME	IUCN STATUS	RECORDED
STENOSTIRIDAE	*Elminia longicauda*	African Blue-Flycatcher		
STERCORARIIDAE	*Stercorarius parasiticus*	Parasitic Jaeger		
STRIGIDAE	*Bubo cinerascens*	Grayish Eagle-Owl		
STRIGIDAE	*Bubo lacteus*	Verreaux's Eagle-Owl		
STRIGIDAE	*Glaucidium perlatum*	Pearl-spotted Owlet		
STRIGIDAE	*Otus scops*	European Scops-Owl		
STRIGIDAE	*Otus senegalensis*	African Scops-Owl		
STRIGIDAE	*Ptilopsis leucotis*	Northern White-faced Owl		
STRIGIDAE	*Scotopelia peli*	Pel's Fishing-Owl		
STRIGIDAE	*Strix woodfordii*	African Wood-Owl		
STURNIDAE	*Cinnyricinclus leucogaster*	Violet-backed Starling		
STURNIDAE	*Lamprotornis caudatus*	Long-tailed Glossy-Starling		x
STURNIDAE	*Lamprotornis chalcurus*	Bronze-tailed Glossy-Starling		
STURNIDAE	*Lamprotornis chloropterus*	Lesser Blue-eared Glossy-Starling		x
STURNIDAE	*Lamprotornis pulcher*	Chestnut-bellied Starling		
STURNIDAE	*Lamprotornis purpureus*	Purple Glossy-Starling		x
STURNIDAE	*Lamprotornis splendidus*	Splendid Glossy-Starling		
SYLVIIDAE	*Hylia prasina*	Green Hylia		
SYLVIIDAE	*Sylvia atricapilla*	Blackcap		
SYLVIIDAE	*Sylvia borin*	Garden Warbler		
THRESKIORNITHIDAE	*Bostrychia hagedash*	Hadada Ibis		x
THRESKIORNITHIDAE	*Platalea alba*	African Spoonbill		
THRESKIORNITHIDAE	*Plegadis falcinellus*	Glossy Ibis		
THRESKIORNITHIDAE	*Threskiornis aethiopicus*	Sacred Ibis		
TURDIDAE	*Turdus pelios*	African Thrush		x
TURNICIDAE	*Turnix sylvaticus*	Small Buttonquail		
TYTONIDAE	*Tyto alba*	Barn Owl		
UPUPIDAE	*Upupa epops*	Eurasian Hoopoe		
VIDUIDAE	*Vidua camerunensis*	Cameroon Indigobird		
VIDUIDAE	*Vidua chalybeata*	Village Indigobird		
VIDUIDAE	*Vidua funerea*	Variable Indigobird		x
VIDUIDAE	*Vidua larvaticola*	Baka Indigobird		
VIDUIDAE	*Vidua macroura*	Pin-tailed Whydah		
VIDUIDAE	*Vidua raricola*	Jambandu Indigobird		
VIDUIDAE	*Vidua wilsoni*	Pale-winged Indigobird		
ZOSTEROPIDAE	*Zosterops senegalensis*	African Yellow White-eye		x

APPENDIX F

Mammal species occurring in Guinea Bissau

FAMILY	GENUS	SPECIES	ENGLISH	IUCN STATUS	RECORDED
ANOMALURIDAE	Anomalurops	beechcrofti	Beechcroft's Scaly-tailed Squirrel		
BOVIDAE	Alcelaphus	buselaphus	Hartebeest		
BOVIDAE	Cephalophus	dorsalis	Bay Duiker		
BOVIDAE	Cephalophus	maxwellii	Maxwell's Duiker		
BOVIDAE	Cephalophus	monticola	Blue Duiker		x
BOVIDAE	Cephalophus	niger	Black Duiker		
BOVIDAE	Cephalophus	ogilbyi	Ogilby's Duiker		
BOVIDAE	Cephalophus	rufilatus	Red-flanked Duiker		
BOVIDAE	Cephalophus	silvicultor	Yellow-backed Duiker		
BOVIDAE	Cephalophus	zebra	Zebra Duiker		
BOVIDAE	Hippotragus	equinus	Roan Antilope		
BOVIDAE	Kobus	ellipsiprymnus	Waterbuck		
BOVIDAE	Neotragus	pygmaeus	Royal Antelope		
BOVIDAE	Ourebia	ourebi	Oribi		
BOVIDAE	Redunca	redunca	Bohor Reedbuck		
BOVIDAE	Silvicapra	grimmia	Common Duiker		
BOVIDAE	Syncerus	caffer	Cape (African) Buffalo, Bushcow		
BOVIDAE	Tragelaphus	eurycerus	Bongo		
BOVIDAE	Tragelaphus	spekii	Sitatunga		
BOVIDAE	Tragelaphus	scriptus	Bushbuck, Harnessed Antelope		
CANIDAE	Lycaon	pictus	African Wild Dog	EN	
CANIDAE	Vulpes	pallida	Pale Fox		
CERCOPITHECIDAE	Cercocebus	atys	Sooty Mangabey	VU	
CERCOPITHECIDAE	Cercocebus	torquatus	Collared Mangabey		
CERCOPITHECIDAE	Cercopithecus	campbelli	Campbell's Mona Monkey		
CERCOPITHECIDAE	Cercopithecus	aethiops	Vervet Monkey		x
CERCOPITHECIDAE	Cercopithecus	diana	Diana Monkey		
CERCOPITHECIDAE	Cercopithecus	petaurista	Lesser Spot-nosed Guenon		x
CERCOPITHECIDAE	Colobus	polykomos	King Colobus	VU	
CERCOPITHECOIDEA	Erythrocebus	patas	Patas, Hussar Monkey, Nisnas		
CERCOPITHECOIDEA	Papio	anubis	Olive Baboon		
CERCOPITHECOIDEA	Papio	papio	Guinea Baboon	NT	
CERCOPITHECOIDEA	Procolubus	badius	Red Colobus	EN	x
CERCOPITHECOIDEA	Procolubus	verus	Van Beden's Colobus		
ELEPHANTIDAE	Loxodonta	africana	African Bush Elephant	VU	
EMBALLONURIDAE	Coleura	afra	African Sheath-tailed Bat		
EMBALLONURIDAE	Saccolaimus	peli	Pel's Pouched Bat		
ERINACEIDAE	Atelerix	albiventris	Four-toed (African) Hedgehog		
FELIDAE	Caracal	caracal	Caracal		

FAMILY	GENUS	SPECIES	ENGLISH	IUCN STATUS	RECORDED
FELIDAE	Felis	silvestris	Common Wild Cat		
FELIDAE	Leptailurus	serval	Serval		
FELIDAE	Panthera	leo	Lion	VU	
FELIDAE	Panthera	pardus	Leopard	NT	
FELIDAE	Profelis	aurata	African Golden Cat		
GALAGIDAE	Galago	senegalensis	Senegal Bushbaby		x
GALAGIDAE	Galago	demidoff	Demidoff's dwarf Galago		
GIRAFFIDAE	Giraffa	cameliopardis	Giraffe		
HEPESTIDAE	Herpestes	ichneumon	Egyptian Mongoose		
HEPESTIDAE	Liberiictis	kuhni	Liberian Mongoose		
HIPPOPOTAMIDAE	Hippopotamus	amphibius	Common Hippopotamus	VU	
HOMINIDAE	Pan	troglodytes	Common Chimpanzee	EN	
HYAENIDAE	Crocuta	crocuta	Spotted Hyaena		
HYSTRICIDAE	Atherurus	africanus	African Bush-tailed Porcupine		x
LEPORIDAE	Lepus	capensis	Cape Hare		
LEPORIDAE	Lepus	microtis	African Savanna Hare		
LORISIDAE	Perodicticus	potto	Potto		
MANIDAE	Manis	gigantea	Giant Pangolin		
MANIDAE	Manis	tricuspis	Tree Pangolin		
MOLOSSIDAE	Chaerephon	bemmeleni	Gland-tailed Free-tailed Bat		
MOLOSSIDAE	Chaerephon	major	Lappet-eared Free-tailed Bat		
MOLOSSIDAE	Chaerephon	pumila	Little Free-tailed Bat		
MOLOSSIDAE	Mops	brachypterus	Sierra Leone Free-tailed Bat		
MOLOSSIDAE	Mops	condylurus	Angolan Free-tailed Bat		
MOLOSSIDAE	Mops	nanulus	Dwarf Free-tailed Bat		
MOLOSSIDAE	Mops	thersites	Railer Bat		
MOLOSSIDAE	Mops	trevori	Trevor's Free-tailed Bat		
MURIDAE	Arvicanthis	rufinus	Guinean Arvicanthus		
MURIDAE	Arvicanthis	ansorgei	Sudanian Arvicanthis		
MURIDAE	Dasymys	rufulus	West African Shaggy Rat		
MURIDAE	Dephomys	defua	Defua Rat		
MURIDAE	Grammomys	buntingi	Bunting's Thicket Rat		
MURIDAE	Grammomys	rutilans	Shining Thicket Rat		
MURIDAE	Hybomys	planifrons	Miller's striped Mous		
MURIDAE	Hybomys	trivirgatus	West African Habomys		
MURIDAE	Hylomyscus	alleni	Allen's Wood Mouse		
MURIDAE	Lemniscomys	bellieri	Zebra Mouse		
MURIDAE	Lemniscomys	linulus	Senegal Grass Mouse		
MURIDAE	Lemniscomys	striatus	Striped Grass Mouse		x

FAMILY	GENUS	SPECIES	ENGLISH	IUCN STATUS	RECORDED
MURIDAE	Lophuromys	sikapusi	Rusty-bellied Brush-furred Rat		
MURIDAE	Malacomys	edwardsi	Edward's Swamp Rat		
MURIDAE	Mastomys	erythroleucus	Gunea Multimammate Mouse		x
MURIDAE	Mastomys	natalensis	Multimammate Mouse		x
MURIDAE	Mus	baoulei	Baoule's Mouse		
MURIDAE	Mus	mattheyi	Matthew's Mouse		
MURIDAE	Mus	minutoides	African Pygmy Mouse		
MURIDAE	Mus	setulosus	Peter's Mouse		
MURIDAE	Mylomys	dybowskii	Mill Rat		
MURIDAE	Oenomys	ornatus	Ghana Rufous-nosed Rat		
MURIDAE	Praomys	daltoni	Dalton's Praomys		
MURIDAE	Praomys	jacksoni	Jackson's Soft-furred Rat		
MURIDAE	Praomys	rostratus	West African Praomys		x
MURIDAE	Praomys	tullbergi	Tullberg's Soft-furred Mouse		
MURIDAE	Tatera	guineae	Guinea Gerbil		
MURIDAE	Tatera	kempi	Kemp's Gerbil		
MURIDAE	Taterillus	gracilis	Slender Gerbil		
MURIDAE	Uranomys	ruddi	Rudd's Mouse		
MUSTELIDAE	Aonyx	capensis	African Clawless Otter		
MUSTELIDAE	Ictonyx	striatus	Striped Polecat, Zorilla		
MUSTELIDAE	Lutra	maculicollis	Speckle-throated Otter		
NANDINIIDAE	Nandinia	binotata	African Palm Civet		
NESOMVIDAE	Cricetomys	gambianus	Gambian Pouched Rat		x
NESOMVIDAE	Cricetomys	emini	Emin's Pouched Rat		
NESOMVIDAE	Dendromus	melanotis	Gray Climbing Mouse		x
NYCTERIDAE	Nycteris	arge	Bate's Slit Faced Bat		
NYCTERIDAE	Nycteris	gambiensis	Gambian Slit Faced Bat		x
NYCTERIDAE	Nycteris	grandis	Greater Slit-faced Bat		
NYCTERIDAE	Nycteris	hispida	Hairy Slit-faced Bat		
NYCTERIDAE	Nycteris	intermedia	Intermediate Slit-faced Bat		
NYCTERIDAE	Nycteris	macrotis	Greater Slit-faced Bat		
NYCTERIDAE	Nycteris	major	Ja Slit Faced Bat		
NYCTERIDAE	Nycteris	thebaica	Egiptian Slit-faced Bat		
PROCAVIIDAE	Dendrohyrax	dorsalis	Western Tree Hyrax		
PROCAVIIDAE	Procavia	capensis	Cape Hyrax		
PTEROPODIDAE	Eidolon	helvum	Straw-coloured Fruit Bat	NT	
PTEROPODIDAE	Epomophorus	gambianus	Gambian Epauletted Fruit Bat		
PTEROPODIDAE	Epomops	buettikoferi	Buettikofer's Epauletted Fruit Bat		
PTEROPODIDAE	Hypsignathus	monstrosus	Hammerhead Fruit Bat		

FAMILY	GENUS	SPECIES	ENGLISH	IUCN STATUS	RECORDED
PTEROPODIDAE	Lissonycteris	smithi	Smith's Fruit Bat		
PTEROPODIDAE	Megaloglossus	woermanni	Woermann's Fruit Bat		
PTEROPODIDAE	Mycropteropus	pusillus	Peter's Dwarf Epauletted Fruit Bat		
PTEROPODIDAE	Myonycteris	torquata	Little Collared Fruit Bat		
PTEROPODIDAE	Nanonycteris	veldkampi	Veldkamp's Bat		
PTEROPODIDAE	Rousettus	aegyptiacus	Egyptian Fruit Bat		
PTEROPODIDAE	Scotonycteris	zenkeri	Zenker's Fruit Bat		
RHINOLOPHIDAE	Hipposideros	abae	Alba Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	beatus	Benito Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	caffer	Sundevall's Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	cyclops	Cyclops Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	fuliginosus	Sooty Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	gigas			
RHINOLOPHIDAE	Hipposideros	jonesi	Jones's Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	lamottei	Lamotte's Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	marisae	Aellen's Roundleaf Bat		
RHINOLOPHIDAE	Hipposideros	ruber	Noack's Roundleaf Bat		
RHINOLOPHIDAE	Rhinolophus	alcyone			
RHINOLOPHIDAE	Rhinolophus	denti	Dent's Horseshoe Bat		
RHINOLOPHIDAE	Rhinolophus	fumigatus	Ruppell's Horseshoe Bat		
RHINOLOPHIDAE	Rhinolophus	guineensis	Guinean Horseshoe Bat		
RHINOLOPHIDAE	Rhinolophus	hillorum	Hill's Horseshoe Bat		
RHINOLOPHIDAE	Rhinolophus	landeri	Lander's Horseshoe Bat		
RHINOLOPHIDAE	Rhinolophus	maclaudi	Maclaud's Bat		
RHINOLOPHIDAE	Rhinolophus	simulator	Bushveld Horseshoe Bat		
RHINOLOPHIDAE	Rhinolophus	ziama			
SCIURIDAE	Funisciurus	pyrropus	Fire-footed Rope Squirrel		
SCIURIDAE	Heliosciurus	gambianus	Gambian Sun Squirrel		
SCIURIDAE	Heliosciurus	punctatus	Small Sun Squirrel		
SCIURIDAE	Paraxerus	poensis	Green Bush Squirrel		
SCIURIDAE	Xerus	erythropus	Striped Ground Squirrel		x
SCUIRIDAE	Heliosciurus	rufobrachium	Red-legged Sun Squirrel		
SORICIDAE	Crocidura	buettikoferi	Buettikofer's Forest Shrew		
SORICIDAE	Crocidura	crossei	Crosse's Musk Shrew		
SORICIDAE	Crocidura	denti	Dent's Shrew		
SORICIDAE	Crocidura	foxi	Fox's Shrew		
SORICIDAE	Crocidura	fuscomurina	Bicolored Shrew/Tiny Musk Shrew		
SORICIDAE	Crocidura	grassei	Grasse's Shrew		
SORICIDAE	Crocidura	lamottei	Lamotte's Shrew		

FAMILY	GENUS	SPECIES	ENGLISH	IUCN STATUS	RECORDED
SORICIDAE	Crocidura	lusitania	Mauritanian Shrew		
SORICIDAE	Crocidura	muricauda	Mouse-tailed Shrew		
SORICIDAE	Crocidura	nanilla	Tiny White-toothed Shrew		
SORICIDAE	Crocidura	nimbae	Nimba Shrew		
SORICIDAE	Crocidura	obscurior	Obscure Pygmy Shrew		
SORICIDAE	Crocidura	poensis	Fraser's Musk Shrew		x
SORICIDAE	Crocidura	theresae	Therese's Shrew		
SORICIDAE	Sylvisorex	megalura	Climbing Shrew		
SUIDAE	Hylochoerus	meinertzhageni	Giant forest Hog		
SUIDAE	Phacochoerus	africanus	Warthog		
SUIDAE	Potamochoerus	porcus	Red River Hog, African Bush Pig		
TANGULIDAE	Hyemoschus	aquaticus			
THRYONOMYIDAE	Thryonomys	swinderianus	Greater Cane Rat		
TRICHECHIDAE	Trichechus	senegalensis	African Manatee		
VESPERTILIONIDAE	Glauconycteris	poensis	Albo Bat		
VESPERTILIONIDAE	Hypsugo	crassulus	Broad-headed Pipistrelle		
VESPERTILIONIDAE	Kerivoula	cuprosa	Copper Woolly Bat		
VESPERTILIONIDAE	Kerivoula	lanosa	Lesser Woolly Bat		
VESPERTILIONIDAE	Kerivoula	phalaena	Spurell's Woolly Bat		
VESPERTILIONIDAE	Mimertillus	moloneyi	Moloney's Flat Headed Bat		
VESPERTILIONIDAE	Miniopterus	inflatus	Greater Long-fingered Bat		
VESPERTILIONIDAE	Miniopterus	schreibersi	Schreiber's Long-fingered Bat		
VESPERTILIONIDAE	Myotis	bocagii	Rufous Mouse-eared Bat		
VESPERTILIONIDAE	Myotis	welwitschii	Welwitch's Bat		
VESPERTILIONIDAE	Neoromicia	capensis	Cape Serotine		
VESPERTILIONIDAE	Neoromicia	guineensis	Tiny Serotine		
VESPERTILIONIDAE	Neoromicia	nanus	Banana Pipistrelle		
VESPERTILIONIDAE	Neoromicia	somalicus	Somali Serotine		
VESPERTILIONIDAE	Neoromicia	tenuipinnis	White-winged Serotine		
VESPERTILIONIDAE	Pipistrellus	nanulus	Tiny Pipistrelle		x
VESPERTILIONIDAE	Scotophilus	dinganii	African Yellow Bat		
VESPERTILIONIDAE	Scotophilus	leucogaster	White-bellied Yellow Bat		
VESPERTILIONIDAE	Scotophilus	nux	Nut-coloured Yellow Bat		
VIVERRIDAE	Civettictis	civetta	African Civet Cat		
VIVERRIDAE	Genetta	genetta	Common Genet		
VIVERRIDAE	Genetta	maculata	Rusty-spotted Genet		

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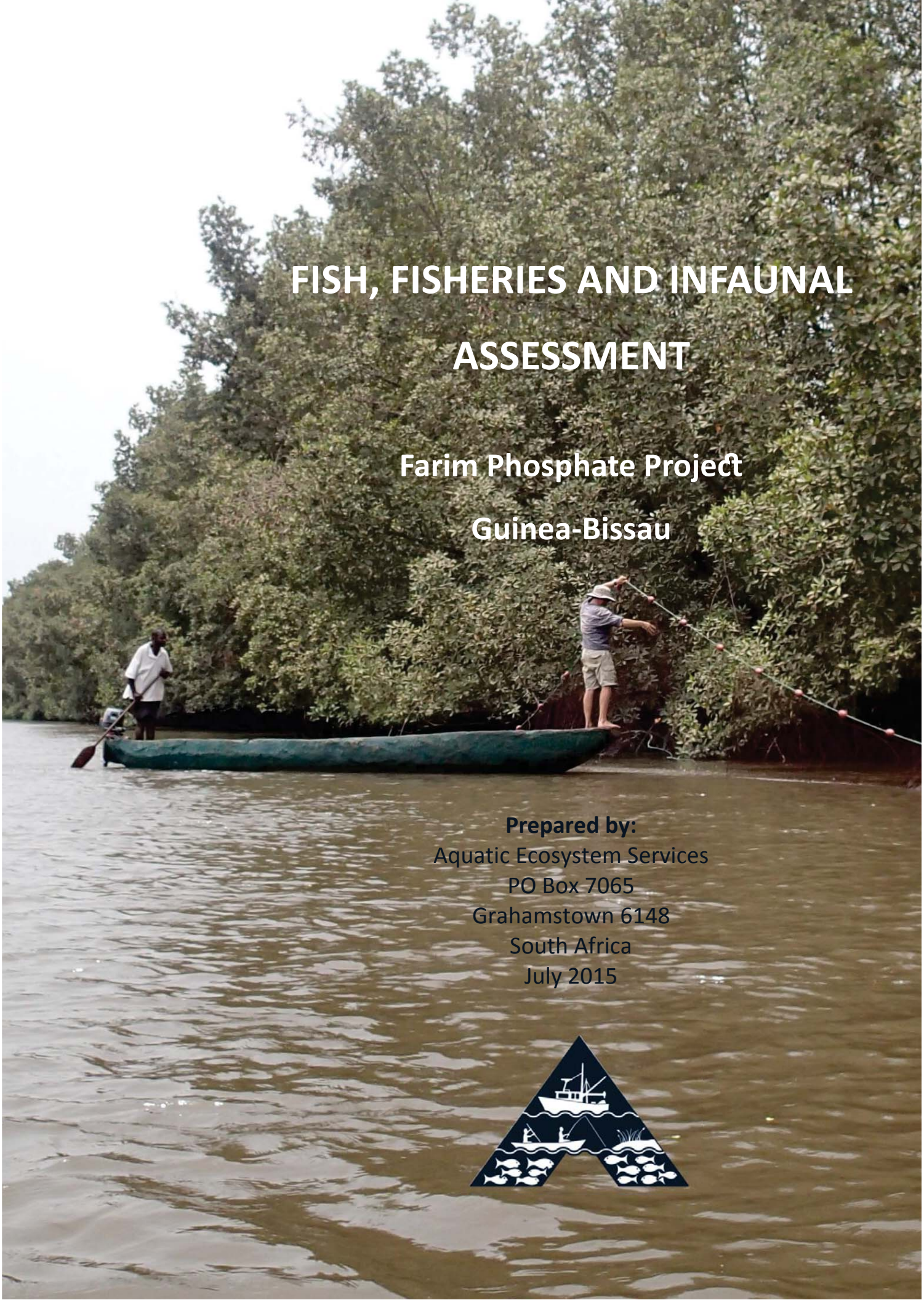

FISH, FISHERIES AND INFAUNAL ASSESSMENT

Farim Phosphate Project

Guinea-Bissau

Prepared by:
Aquatic Ecosystem Services
PO Box 7065
Grahamstown 6148
South Africa
July 2015

Executive Summary

Introduction

This study was commissioned to assess the baseline ichthyofaunal, benthic invertebrate, and fisheries characteristics of the Cacheu and Geba estuaries for the proposed GB Minerals Farim Phosphate Project (the Project) in Guinea-Bissau. The Project proposes to mine phosphate ore adjacent to the Cacheu Estuary near Farim, and develop a ship loading facility on the Geba Estuary at Ponta Chugue. The study was limited to a five day site assessment and a desktop review of available literature.

The Terms of Reference were as follows:

- Provide a description of the regional ichthyofauna and fisheries with the climatic and hydrological conditions with specific reference to potential sensitivity or unique habitats / species.
- Provide an overview of ichthyofaunal diversity and composition and associated interactions in the Regional Study Area (RSA) and Local Study Area (LSA).
- Provide an overview of the biological communities occurring within the RSA and LSA, focusing on fish and benthic invertebrates.
- Assess the potential impacts on fish and fisheries in relation to the various potential impacts, providing reasonable mitigation and recommendations in order to minimize the direct and residual impacts.
- Provide an assessment of the rehabilitation and closure phases after the life of mine.

Limitations

- The study was limited to a once off five day on site field assessment.
- A suitable vessel was not available to conduct beam trawling adjacent to the mine site near Farim therefore ichthyofaunal sampling was limited to the use of gill and fyke nets.
- Rough conditions on the Geba Estuary limited the amount of sampling which would be undertaken.
- No scientific literature is available on the ichthyofaunal ecology of estuaries in Guinea-Bissau, and little information is available for the broader region.
- Limited scientific information is available on fisheries in Guinea-Bissau, and none is available for the project affected areas.
- The assessment is based on the project description received on 26/7/2015.

Definitions

Regional Study Area

The regional study area is defined as the Guinea-Bissau coastline, including tidal estuaries. Due to the paucity of ecological information available for estuaries of Guinea-Bissau the desktop review was expanded to include large estuaries of tropical West Africa with similar general physical characteristics.

Local Study Area

The Local Study Area (LSA) for this assessment is comprised of two spatially separated estuarine environments, namely:

- Cacheu Estuary adjacent and downstream of the proposed mine site.
- Geba Estuary at Ponta Chugue where the proposed port and loading facilities will be constructed.

Desktop Review of Available Literature

Introduction

Guinea-Bissau is situated in Tropical West Africa on the edges of the Guinea Current Large Marine Ecosystem (LME) and the Canary Current LME (Belhabib and Pauly 2013). The coastline is relatively short, yet the continental shelf is large and shallow (Mendy and Lobban 2013) which contributes to turbulent coastal waters. Tidal currents are strong and the tidal range can reach up to 6m. High rainfall and freshwater input during the rainy season creates highly turbid coastal waters. Estuaries are lined by mangroves which provide important habitat for juvenile fish and crustacea. Despite having good fishery resources, the fishery sectors remain largely undeveloped, and income from fisheries is largely derived from licence fees received from foreign vessels.

Description of the Regional Estuarine Ecology

The tropical estuaries of West Africa have a rich ichthyofaunal diversity with over 200 species recorded from open and blind estuaries and coastal lakes (Blaber 2000). Species composition is influenced by the freshwater inputs during the wet season, with marine species using estuarine systems temporarily for feeding, spawning and shelter (Baran 2000). Estuaries in West Africa, and in particular the mangrove habitats, play an important role in the life histories of many species, especially the juvenile phases of many important fishery species. Clupeids typically dominate the fish fauna of West African estuaries numerically. The dominant ichthyofaunal families occurring in West African estuaries include the Ariidae (seacatfish), Bagridae (bagrid catfish), Carangidae (jacks), Cichlidae (cichlids), Clupeidae (sardines and shads), Elopidae (Elops), Gerreidae (mojarras), Haemulidae (grunts), Polynemidae (threadfins), Sciaenidae (drums), and Sphyraenidae (barracudas) (Blaber 2000).

The Gambia Estuary can be considered a suitable reference point for West Africa estuaries as it is one of the last aquatic ecosystems of the area that has not been affected by strong environmental or anthropogenic changes (Simier *et al*. 2006). It also has a near zero drainage gradient over the 500km,and therefore brackish waters and tidal floodplains with mangrove swamps occur over the last 180km (Daget 1960 in Simier *et al.* 2006) which is similar to that of the Cacheu and Geba estuaries in Guinea-Bissau.

Description of the Local Estuarine Ecology

Cacheu Estuary

The Cacheu estuary is considered to be in a natural state (Golder 2014a). The habitat along the length of the Cacheu estuary has few modifications or existing impacts and minimal clearing of mangroves which

extend beyond Farim. It is strongly influenced by the tidal regime with the tidal reach extending beyond Farim even during wet season (Golder 2014a). The tidal regime is semi-diurnal and surface currents are strong, ranging from 1 – 4 knots. Sediments near Farim are dominated by fine silts and clays (up to 90%) along the fringing banks, with gravel found in deeper channel areas. No seagrass beds or corals were identified anywhere along the length of Cacheu estuary (Golder 2014a). The estuary has a well-defined channel 100-250m in width, and a low gradient with a 5m drop over a distance of 160km which contributes to the strong tidal influence stretching beyond Farim. Water temperature ranged from 27 to 30°C along the entire length of the estuary during both dry and wet seasons with no thermal stratification. Salinity at Farim ranged from 2.4 in the dry season to 7.2ppt during the wet season. Dissolved oxygen near the mine site was greater than 4.3mg/l during wet and dry seasons.

Both marine and freshwater phytoplankton and zooplankton were present in the water column around the mine site region of the Cacheu estuary. Benthic invertebrate density was generally low but increased downstream. Thirty-three ichthyofaunal and 18 invertebrate species were sampled during the dry season survey, and tissue sample analysis indicated no contamination from anthropogenic sources, confirming the near natural state and health of the system (Golder 2014a).

Protected areas on the Cacheu estuary include the Rio Cacheu Mangrove Natural Park, the Vareal National Park and the Pelundo Faunal Reserve.

Previous baseline surveys for the Project have reported numerous fishermen present along the length of the river, indicating substantial artisanal fishing effort, however, no quantitative data has been collected to date.

Geba Estuary

There is a paucity of information available on the ecology of the Geba Estuary. The estuary is extremely large, with a width of 10-12km near Bissau. The tidal range is in the region of 5m, and tidal currents can reach speeds of up to 3 knots (Agardy 1997). Sediments are soft to very soft muds (van der Veer 1995). No know protected areas exist on the Geba Estuary.

Description of the Regional Fisheries

Artisanal Fishing

The coastal population of Guinea-Bissau does not have strong, long-standing fishing tradition (Baran & Tous 1999 in Campredon & Cuq 2001) and fishing has been an off-season activity for local farmers (Tvedten 1990, Chavance 2004 in Belhabib and Pauly 2015). Estuarine and riverine fishing effort is largely unknown, but it is estimated that 10 000 to 12 000, mostly foreign, fishermen harvest coastal resources in the estuaries and along the coast, with the Bijagós Archipelago on the continental shelf and the Cacheu River being particularly important areas (Megapesca 2010, Mendy and Lobban 2013). A 12 Nautical Mile (NM) zone adjacent to the coast is set aside for artisanal fishing (Mendy and Lobban 2013). The artisanal sector has two distinguishable sub-sectors, the first being the local domestic fishery, and the second the migrant, mainly Senegalese (with growing Guinean participation) fishery. Domestic artisanal fishing is limited to coastal waters within the 12NM zone, while the foreign migrant fishers travel more widely, beyond the 12NMindustrial exclusion zone. This migrant sector of the

artisanal fishery accounts for 70-80% of the artisanal harvest (Megapesca 2010). This sector contributes significantly to the food security of the coastal communities, however, little quantitative data is currently available.

Recreational Fishing

Recreational sport fishing comprises a large segment of the tourism industry in the Bijagós Archipelago (Anon 2010 in Belhabib and Pauly 2013), but there is little available information on tourism numbers and activities for the region (Belhabib and Pauly 2013). No sport fishing is reported to occur in the Local Study Area.

Industrial Fishing

The industrial sectors consists of foreign vessels chartered or re-flagged to Guinea Bissau (Belhabib and Pauly 2013), but are not considered domestic vessels (Gomes Barbosa 2009 in Belhabib and Pauly 2013). The majority of industrial harvest is transhipped at sea or landed outside of Guinea Bissau which only has one local fish processing facility. The industrial sector therefore only contributes to the Guinea-Bissau economy through compensation, access, observer and crew employment. Total annual harvest in 2008 was 53 000 tonnes. The industrial sector is comprised of 50 fish/cephalopod trawlers; 35-40 shrimp trawlers; 5 mid-water small pelagic trawlers; 23 tuna purse seiners; 14 pole and line tuna vessels; and 4 motherships – working with canoes, receive and process fish onboard (Megapesca 2010).

Description of the Local Fisheries

No information is available on the fisheries in the Cacheu or Geba estuaries. However, based on an understanding of the regional fisheries it is unlikely that any industrial or recreational fishing occurs near the Project sites in the Cacheu and Geba estuaries. Artisanal fishing effort from the local sub-sector, however, is likely to be high, with a high reliance on subsistence fishing.

Field Survey Methods

Cacheu Estuary – Mine and Conveyor Site

A site visit was undertaken to the Cacheu Estuary at Farim between the 7th and 9th of May 2015. Ichthyofauna were sampled using gill and fyke nets. All artisanal fishing canoes observed were approached and their catch inspected and methods of fishing recorded. Additional notes were maintained on the presence of nets and longlines along the course of the estuary. An interview was conducted with the head of the Farim Fishing Associate to obtain information on artisanal fishing activities. Benthic infaunal communities were sampled using a weighted 250cm^2 Van Veen grab and taxa were identified to lowest possible taxonomic level.

Geba Estuary - Port Site

A field survey to the Ponta Chugue region on the Geba Estuary was undertaken from the 9th to the 11th May 2015. Fyke nets and a beam trawl were used to sample the demersal ichthyofauna. Grab sampling was undertaken to assess benthic infauna. Interviews with, and observations of local artisanal fishermen were conducted to assess the types of fishing activities and catch composition.

Field Survey Results

Cacheu Estuary

The Cacheu Estuary near Farim was highly turbid with strong tidal currents. Estuary banks were lined with mangroves and dominated by fine muddy sediments with courser gravels and bed rock mid-channel. Ten ichthyofaunal species from nine families were captured with an additional three species from three additional families identified through interviews with artisanal fishermen. Grab sampling was undertaken at five sites in the Cacheu Estuary and eighteen infaunal taxa were identified. Numerous artisanal fishermen were observed during the field survey on the Cacheu estuary. The most common forms of fishing involved gillnetting and longlining.

Geba Estuary

The estuarine waters at Ponta Chugue were highly turbid with a strong tidal current (>3 knots) and large tidal range. Benthic sediments were very fine muds with rocky substrata limited to the immediate area around Ponta Chugue. Three species of fish were captured, two of which (*Arius latiscutatis* and *Pentanemus quinquarius*) were not captured in the Cacheu Estuary. Numerous Penaeids were also captured. Interviews with artisanal fishermen confirmed the difficult fishing conditions and indicated few species of estuarine fish are caught in the area. Despite low catches, based on the size and characteristics of the Geba Estuary, the ichthyofaunal diversity should in theory be high, with a greater presence of marine dependent species than the upper reaches of the Cacheu Estuary at Farim. Grab sampling was conducted at 8 sites of varying depth around the port site. Few of the grab samples from the Geba Estuary port site had infaunal species present, most probably due to the very fine and anoxic mud sediments present across most of the study area. Only one fisherman was observed actively fishing while conducting the field survey on the Geba estuary, however, several young fishermen were encountered at the landing beach at Chugue. Strong currents and large tidal range make fishing in the Geba difficult and the main gears used are longlines approximately 200m in length with up to 300 hooks. The main fishing area is located on the opposite bank of the Geba Estuary and the main season is from August to April when the currents are generally weaker and there is a lower abundance of large sharks. Approximately 30-40 fishermen use the Ponta Chugue landing beach where roughly 10 canoes are based during the fishing season. Larger ferry canoes also utlise the landing beach to load/unload supplies and transport people.

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1. Introduction

This study was commissioned to assess the baseline ichthyofaunal, benthic invertebrate, and fisheries characteristics of the Cacheu and Geba estuaries for the proposed GB Minerals Farim Phosphate Project (the Project) in Guinea-Bissau. The Project proposes to mine phosphate ore adjacent to the Cacheu Estuary near Farim, and develop a ship loading facility on the Geba Estuary at Ponta Chugue. The study was designed to obtain information on the ichthyofaunal and benthic infaunal ecology, and fisheries of each estuary at the Project affected sites in order to assess the significance of potential ecological impacts which may arise as a result of mining and transportation activities. The study was limited to a five day site assessment and a desktop review of available literature for the Project and region.

1.1 Terms of Reference

The Terms of Reference of this study are as follows:

- Provide a description of the regional ichthyofauna and fisheries with the climatic and hydrological conditions with specific reference to potential sensitivity or unique habitats / species. This will also include a review of any past studies conducted within the region and / or directly for this Project.
- Provide an overview of ichthyofaunal diversity and composition and associated interactions in the Regional Study Area (RSA) and Local Study Area (LSA).
- Provide an overview of the biological communities occurring within the RSA and LSA, focusing on fish and benthic invertebrates.
- Assess the potential impacts on fish and fisheries in relation to the various potential impacts, providing reasonable mitigation and recommendations in order to minimize the direct and residual impacts.
- Provide an assessment of the rehabilitation and closure phases after the life of mine.

1.2 Limitations

- The study was limited to a once off five day on site field assessment.
- A suitable vessel was not available to conduct beam trawling adjacent to the mine site near Farim therefore ichthyofaunal sampling was limited to the use of gill and fyke nets.
- Rough conditions on the Geba Estuary limited the amount of sampling which would be undertaken.
- No scientific literature is available on the ichthyofaunal ecology of estuaries in Guinea-Bissau, and little information is available for the broader region.
- Limited scientific information is available on fisheries in Guinea-Bissau, and none is available for the project affected areas.
- The assessment is based on the project description received on 26/7/2015.

1.3 Definitions

1.3.1 Regional Study Area

The regional study area is defined as the Guinea-Bissau coastline, including tidal estuaries. Due to the paucity of ecological information available for estuaries of Guinea-Bissau the desktop review was expanded to include large estuaries of tropical West Africa with similar general physical characteristics.

1.3.2 Local Study Area

The Local Study Area (LSA) for this assessment is comprised of two spatially separated estuarine environments, namely:

- Cacheu Estuary adjacent and downstream of the proposed mine site (Figure 1).
- Geba Estuary at Ponta Chugue where the proposed port and loading facilities will be constructed (Figure 2).

The assessment was undertaken within these areas taking the Project activities into account and within the constraints imposed by time and logistical difficulties during the field survey.

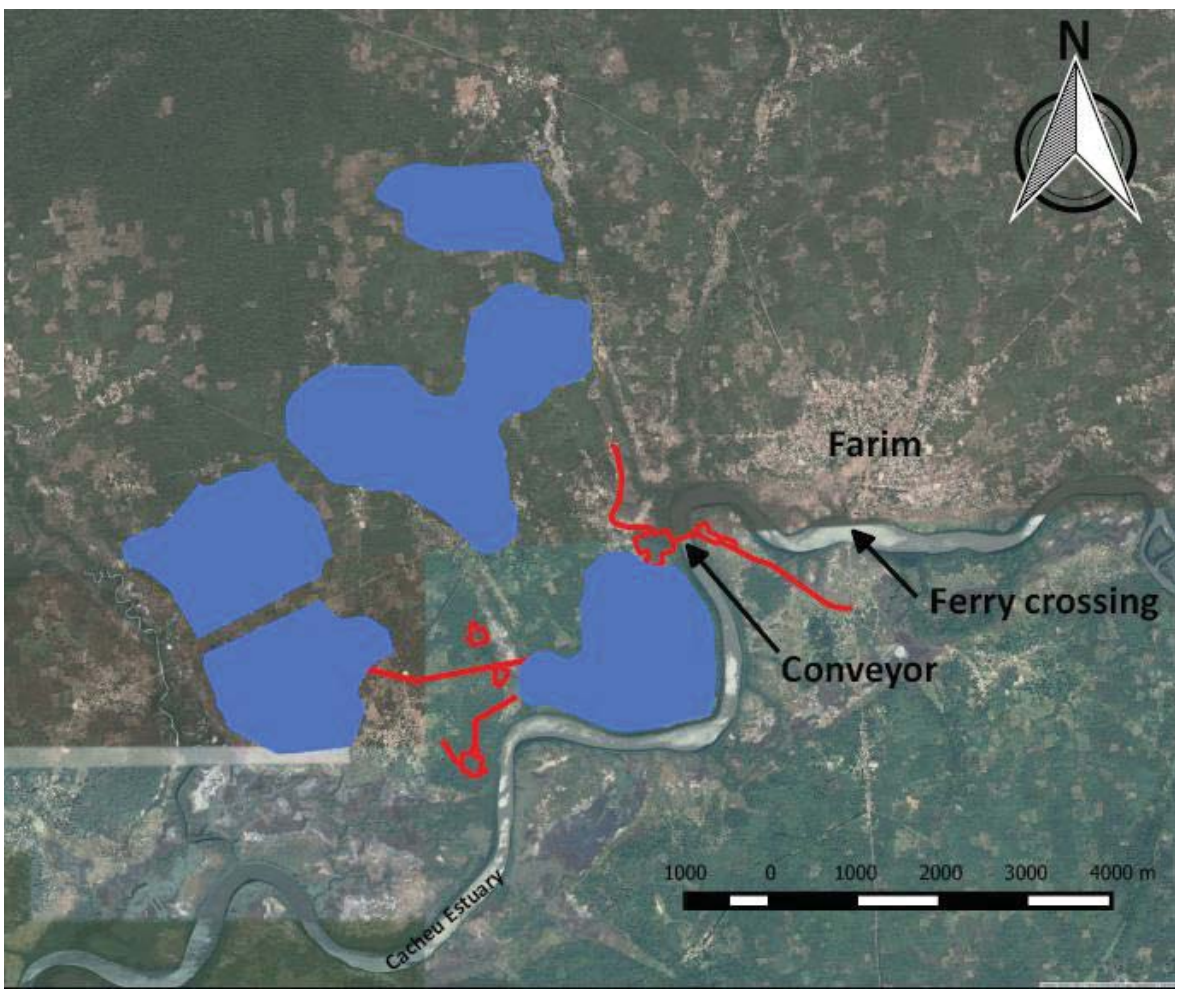


Figure 1: Layout of project infrastructure (blue = pit and waste sites; red = roads and conveyor infrastructure) on the Cacheu Estuary.

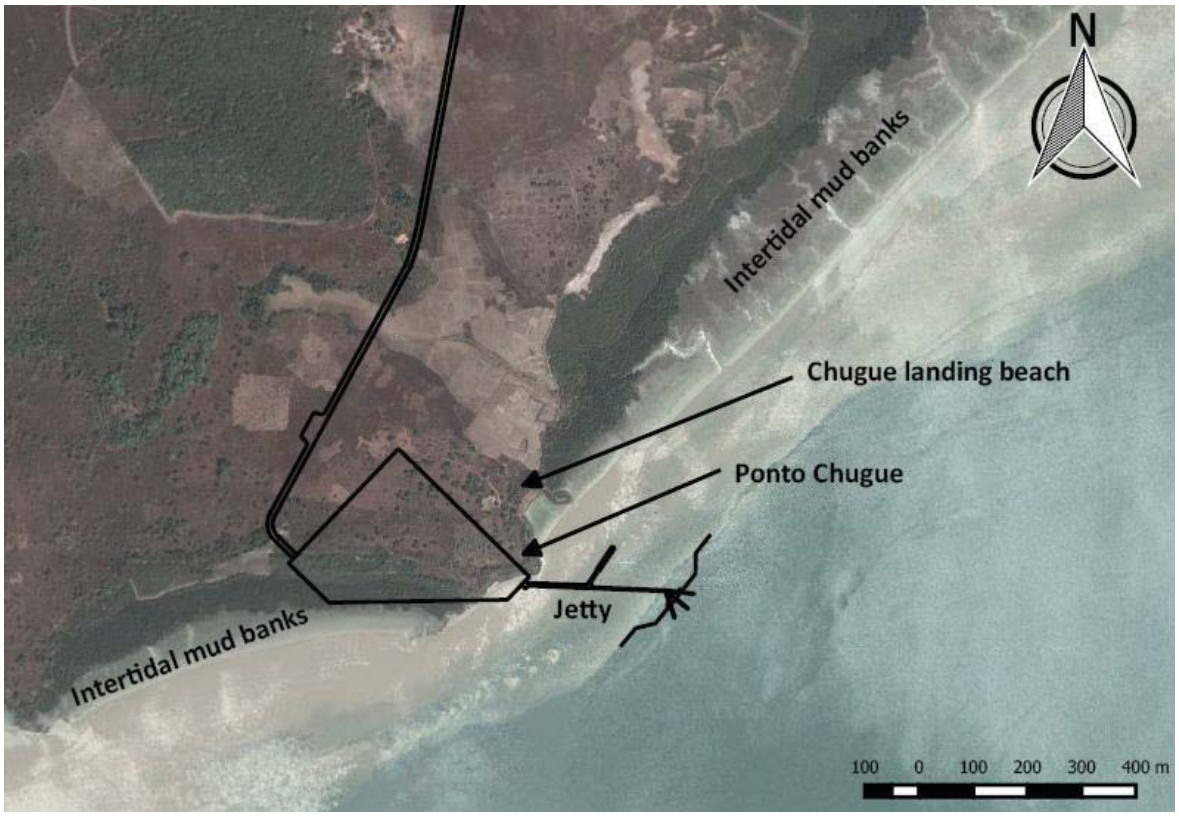


Figure 2: Layout of the project infrastructure on the Geba Estuary.

2. Desktop Review of Available Literature

2.1 Introduction

Guinea-Bissau is situated in Tropical West Africa on the edges of the Guinea Current Large Marine Ecosystem (LME) and the Canary Current LME (Belhabib and Pauly 2013). As a result the area is characterised by strong seasonal variations in oceanic conditions (Berrit and Rebert 1977 in Amorim *et al.* 2004). Although the coastline is relatively short at 280km in length, the shallow continental shelf is large at 45 000km^2 and accounts for 30% of the Exclusive Economic Zone (EEZ) of Guinea-Bissau waters (Mendy and Lobban 2013). Due to the shallow depths and large width of the continental shelf, the coastal waters are turbulent with strong tidal currents and a tidal range of up to 6m. This, in conjunction with high rainfall and freshwater input during the rainy season creates highly turbid coastal waters. The estuaries are lined by mangroves which create important refuges and nursery areas for juvenile fish crustacea and the Guinea-Bissau coastline therefore plays an important role in seeding regional fisheries (Yañez-Arancibia (1985) in Baran 2000). The Guinea Bissau coastal waters are highly productive, being rich in biodiversity and biomass due to a combination of environmental factors including the large shallow continental shelf, convergence of two major currents systems and coastal upwelling, extensive mangrove systems and many large rivers/estuaries discharges contributing nutrients into the coastal waters (Da Silva 1999 in Campredon and Cuq 2001). These factors support an estimated 1 million tonnes of fisheries resources within the EEZ (Belhabib and Pauly 2013).

The population in Guinea-Bissau is approximately 1.4 million people, 25% of whom reside in the capital, Bissau, situated on the Geba Estuary. The national economy is largely based on agriculture with most of

the revenue generated from cashew production exports. Despite having good shelf and coastal fishery resources, the fishery sectors remain largely undeveloped, and income from fisheries is largely derived from licence fees received from foreign vessels.

2.2 Description of the Regional Estuarine Ecology

The tropical estuaries of West Africa have a rich ichthyofaunal diversity with over 200 species recorded from open and blind estuaries and coastal lakes (Blaber 2000). Species composition is influenced considerably by the freshwater inputs during the wet season, with marine species using estuarine systems temporarily for feeding, spawning and shelter (Baran 2000). Estuaries in West Africa, and in particular the mangrove habitats, play an important role in the life histories of many species, especially the juvenile phases of many important fishery species. The dynamic nature of the ichthyofaunal composition in estuaries in this region is largely due to the large hydrological variability between the dry and wet seasons, leading to a large spatial variation in the extent of the brackish zone. During the wet season, the area defined as estuarine typically displays characteristics of a river, having very low salinities and the ichthyofaunal species composition being dominated by freshwater species. Conversely, during the dry season, limited freshwater input allows marine tidal waters to penetrate long distances up these estuaries which allow estuarine and marine fish species to temporarily move into and utilise these habitats. High rainfall in Guinea-Bissau contributes to large discharges from estuaries resulting in a permanent turbid brackish zone which may extend tens of kilometres. In Guinea species utilising estuaries permanently account for only 34% of the total species richness (Baran 2000).

West African estuaries are highly productive systems and annual fish production volumes of 15-16 tonnes.km^{-2} are possible (Blaber 1997). Clupeids typically dominate the fish fauna of West African estuaries numerically ranging from 61-85% of the catch (Baran 2000). The species of Clupeids, however, vary considerably between estuarine systems. *Ethmalosa fimbriata* and *Sardinella maderensis* are the two dominant clupeids in the Gambia Estuary, while *Ethmalosa fimbriata* and *Ilisha africana* dominate in the Saloume and Fatala estuaries (Darboe 2002).

The dominant ichthyofaunal families occurring in West African estuaries include the Ariidae (seacatfish), Bagridae (bagrid catfish), Carangidae (jacks), Cichlidae (cichlids), Clupeidae (sardines and shads), Elopidae (Elops), Gerreidae (mojarras), Haemulidae (grunts), Polynemidae (threadfins), Sciaenidae (drums), and Sphyraenidae (barracudas) (Blaber 2000). The species number varies based on local estuarine characteristics and anthropogenic pressures. There is a common group of approximately 25 species which occur ubiquitously across all types of estuaries in West Africa, these include Carangids (8 species), Sciaenids (6 species), Mugilids (six species), with the remainder being Ariidae and Clupeidae (Baran 1995). Open estuaries such as the Senegal and Fatal (Guinea) have rich diversity, with 133 and 102 species respectively (Diouf *el al*. 1991; Baran 1995). Diversity in coastal lakes is variable, with the Lagos lagoon having 79 species, compared to 150 species in the Ebrie lagoon (Ivory Coast) (Albaret 2004; Facade and Olaniyan 1974). Local conditions within each estuary influence the species diversity and abundance of ichthyofauna greatly.

The Gambia Estuary can be considered a suitable reference point for West Africa estuaries as it is one of the last aquatic ecosystems of the area that has not been affected by strong environmental or anthropogenic changes (Simier *et al*. 2006). It is only moderately exploited by artisanal fisheries (Lae *et al*. 2004 in Simier *et al.* 2006), does not receive any pollution from significant agricultural or industrial products, and it has a natural flood regime (Simier *et al.* 2006). The Gambia Estuary has a near zero drainage gradient for the last 500km, and it is therefore tidal for most of its length. As a result it has

similar brackish waters and tidal floodplains with mangrove swamps for the last 180km (Daget 1960 in Simier *et al.* 2006), as do the Cacheu and Geba estuaries in Guinea-Bissau.

Approximately 82 species have been reported from the Gambia Estuary (Vidy *et al.* 2004; Ecoutin *et al.* 2005, Darboe 2002; Albaret *et al.* 2004, Simier *et al.* 2006). Of these, at least 10 species are strongly associated with freshwater and are therefore unlikely to be captured in brackish estuarine systems during low flow periods. Carangidae, Sciaenidae, Mugilidae, Clupeidae and Haemulidae had the highest species diversity but many families were reported to be only represented by a single species (Albaret 2004). Similar species numbers (79 to 153 species) have been reported in the Lagos and Ebrie lagoons respectively.

As expected, species composition in the Gambia Estuary varies longitudinally along the estuarine gradient being influenced by environmental parameters, most notably salinity. Individual species tolerances, habitat preferences and life-histories dictate their distribution and temporal abundances in the estuarine environment. Certain species including *Pseudotolithus elongatus* occur throughout the system (Darboe 2002). *P. elongatus*, *P. motialis*, *Cynoglossus senegalensis*, *C. latimanus*, *E. fimbriata* and *S. maderensis* were encountered at almost all stations during the low flow period, and *Polydactylus quadrifilis*, *Pentanemous quinquarius* and *I. africana* occurred intermittently throughout the estuary being tolerant of varying levels of salinity. Species of *Ariidae* and *I. africana* were restricted to the lower reaches. Species richness was notably higher in the lower, salinity dominated reaches of the estuary (Darboe 2002) and the average number of species sampled per station ranged from 5 to 18 (Darboe 2002).

Two distinct communities in large West African estuaries are apparent from the species composition:

1) **Lower estuary** - comprised Sciaenidae (*P. elongates*), Clupeidae (*Ethmalosa africana, S. maderensis*), Pristigastridae (*I. africana*) and Ariidae (*Arius heudoloti*).
2) **Mid and upper reaches** – comprised euryhaline species including Polynemidae (*P.quadrifilis, P. quinquarius*), Mugilidae (*Liza grandisquamis, Liza falcipinnis*), Bagridae (*Chrysichthys nigrodigitatus, C. maurus and C. johnelsi*), Mochokidae (*Synodontis* sp.) and Schilbeidae (*Schilbe intermedius*) (Dardoe 2002).

2.3 Description of the Local Estuarine Ecology

2.3.1 Cacheu Estuary

The Cacheu estuary is considered to be in a natural state (Golder 2014a). The habitat along the length of the Cacheu estuary has few modifications or existing impacts and minimal clearing of mangroves between Farim and the mouth (Golder 2014a). The Cacheu has a large tidal influence extending beyond Farim, and hence mangroves line the majority of its length.

The Cacheu estuary is strongly influenced by the tidal regime with the tidal reach extending beyond Farim even during wet season, and flow is dominated by tidal conditions rather than runoff (Golder 2014a). The tidal regime is semi-diurnal with maximum tidal range of 2.8m measured at Port Cacheu (Golder 2014a) and the tidal range in the Project area near Farim varies seasonally from 1.5 to 2m (Golder 2013). Surface currents are strong, ranging from 1 – 4 knots, and sediment characteristics near Farim are dominated by fine silts and clays (up to 90%) along the fringing banks, with gravel found in deeper channel areas where there is hard bottom, and scouring occurs. The main estuarine channel is comprised or coarser substrata, with fine muds occurring in 5-10m bands along the estuary banks

adjacent to the mangrove stands. No seagrass beds or corals were identified anywhere along the length of Cacheu estuary (Golder 2014a). The estuary typically has a well-defined channel with a width ranging from 100-250m, with the cross-sectional depth near Farim ranging from 6-8m. The river bed has a low gradient with a 5m drop over a distance of 160km (similar to the Gambia Estuary), which accounts for the strong tidal influence stretching beyond Farim. Channel depth ranges from 4 to 14m, with a few deeper areas up to 20m.

Water temperature ranges from 27 to 30°C along the entire length of the estuary during both dry and wet seasons with no thermal stratification or temporal differentiation apparent. Dry season salinity ranges from 2.4 to 4.9ppt near Farim and from 3.6 to 7.2ppt during the wet season. Dissolved oxygen near the mine site was greater than 4.3mg/l during wet and dry seasons.

Both marine and freshwater phytoplankton were present in the water column around the mine site region of the Cacheu estuary during both dry and wet seasons, with the composition dominated by diatoms. Phytoplankton biovolume was significantly higher during the dry season compared to the wet.

During both dry and wet seasons, freshwater zooplankton dominated in the upper reaches of the Cacheu around the mine site, with the upper most reaches of the estuary having higher densities. Invertebrate eggs and larvae were recorded throughout the Cacheu estuary suggesting that they breed throughout the system. However, no or very few fish eggs or larvae were recorded in fine mesh tows in the river channel during the dry or wet season, suggesting that the habitat provided by the fringing mangroves is the main nursery area for the ichthyofauna (Golder 2014a). Benthic invertebrate density was generally low throughout the Cacheu estuary, but increased from approximately 7 taxa to up to 37 taxa downstream towards the estuary mouth. In all 33 ichthyofaunal and 18 invertebrate species were sampled during the dry season survey, and tissue sample analysis indicated no contamination from anthropogenic sources, confirming the near natural state and health of the system (Golder 2014a).

Protected areas on the Cacheu estuary include the Rio Cacheu Mangrove Natural Park, the Vareal National Park and the Pelundo Faunal Reserve.

Previous baseline surveys for the Project have reported numerous fishermen present along the length of the river, indicating substantial artisanal fishing effort, however, no quantitative data has been collected to date.

2.3.2 Geba Estuary

There is a paucity of information available on the ecology of the Geba Estuary. The estuary is extremely large, with a width of 10-12km near Bissau. The tidal range is in the region of 5m, and tidal currents can reach speeds of up to 3 knots (Agardy 1997). Sediments in the Geba are reportedly soft to very soft muds (van der Veer 1995). No information was available on any previous surveys conducted on the ichthyofauna or fisheries within the Geba estuary in the vicinity of Ponta Chugue near the Project site. A previous trawl and seine net survey conducted in the lower reaches of the Geba and Buba estuaries and around the Bijagós archipelago captured a total of 25 species (van der Veer *et al.* 1995). The catches were dominated (by number) by *Eucinostomus melanopterus* (41%), *Ethmalosa fimbriata* (22%), *Mugil cephalus* (6%), *Liza ramada* (6%), *Liza grandisquamis* (5%), *Sardinella aurita* (4%), *Mugil curema* (4%) and *Pomadasys peroteti* (3%). No know protected areas exist on the Geba Estuary.

2.4 Description of the Regional Fisheries

2.4.1 Artisanal Fishing

West African estuaries are important fishing areas for artisanal fishers who target molluscs, crustacea and fish for sale and local consumption (Albaret 1994, N'Goran 1998 in Koffi 2014). The coastal population of Guinea-Bissau does not have strong, long-standing fishing tradition (Baran & Tous 1999 in Campredon & Cuq 2001). Fishing has mainly been an off-season activity for local farmers and only started in the mid-1970s (Tvedten 1990, Chavance 2004 in Belhabib and Pauly 2015). Estuarine and riverine fishing effort is largely unknown. The annual harvest of the artisanal fishery has been estimated to be in the range of 30 000 – 50 000 tonnes.year^{-1} and there is a high dependence on the fisheries as a food source. The subsistence fishery consists of 10 000 to 12 000 fishermen who are mostly foreign but travel to Guinea-Bissau to fish the abundant coastal resources. Artisanal fishing activities are concentrated in the rivers and estuaries along the coast, with the Bijagós Archipelago on the continental shelf and the Cacheu River being important areas (Megapesca 2010, Mendy and Lobban 2013). A 12 Nautical Mile (NM) zone adjacent to the coast is set aside for artisanal fishing (Mendy and Lobban 2013).

The artisanal sector has two distinguishable sub-sectors, the first being the local domestic fishery, and the second the migrant, mainly Senegalese (with growing Guinean participation) fishery. The local domestic artisanal fishery utilises small dugout canoes, mostly unmotorised, and use simple traditional gears including cast nets, traps, lines, drift and bottom set nets and small seines (Irvine 1947, Megapesca 2010). The domestic artisanal fishing is limited to coastal waters within the 12NM zone. A lack of any recent data precludes an assessment of the size of the artisanal fleet (Megapesca 2010). Species caught by artisanal sector are those used for local consumption including estuarine and demersal species such as *E. fimbriata*, *Argyrosomus regius*, *Penaeidae*, *Cynoglossus spp.*, *Carlarius heudelotii*, *Caranx spp*., *Pomadasys jubelini* (Belhabid and Pauly 2013). Molluscs, generally gathered in estuaries by women, form an important fishery and source of protein. The molluscan fishery includes oysters (*Crassostrea gasar*), arks (*Anadara senilis*) and murex (*Murex sp.*) (Anon 1994 in Campredon) and comprises an important component of the subsistence harvest.

The second sub-sector of the artisanal fishery includes the migrant fishers who use Senegalese *nhominka* pirogues which have three times the capacity of local dugout canoes (Tvedten 1990). Between 30 and 50% or artisanal fishermen are unlicensed foreign fishers from Senegal and Guinea-Conakry (Mendy and Lobban 2013). Reportedly 83% of the large Senegalese *nhominka* are motorised (Belahbib and Pauly 2013) and they travel more widely, beyond the 12NMindustrial exclusion zone. This migrant sector of the artisanal fishery accounts for 70-80% of the artisanal harvest (Megapesca 2010). The fishermen set up temporary seasonal camps in the Bijagós Archipelago which is their main fishing area. Their catch is either transhipped at sea to larger foreign vessels and transported to overseas markets, or it is landed by the fishers themselves in neighbouring countries outside of Guinea-Bissau (Mendy and Lobban 2013).

Coastal fishing has largely been conducted by fishermen who migrate from the Saloum- Senegal region during the dry season to set up camps and fish the Bissau waters. These camps have become semi-permanent and the type of fishing has shifted to targeting sharks and rays for fins (Campredon 2001). These migratory fishermen utilise large motorised canoes and large seine and drift nets in comparison to the artisanal fishermen who utlise non-motorised canoes and traditional fishing gears (traps, lines, cast nets, small gill nets)(Tvedten 1990). More recently fishermen have also begun to migrate from

Guinea to Guinea-Bissau to fish. These semi-permanent camps and fishermen target the coastal resources around Bijagós Islands.

This sector fishes actively throughout the coastal region of Guinea-Bissau and contributes significantly to the food security of the coastal communities, however, little quantitative data is currently available.

2.4.2 Recreational Fishing

Recreational sport fishing comprises a large segment of the tourism industry in the Bijagós Archipelago (Anon 2010 in Belhabib and Pauly 2013), but there is little available information on tourism numbers and activities for the region (Belhabib and Pauly 2013). Catch of the recreational sector includes barracuda (*Sphyraena barracuda*), kingfish (*Carangidae*), cobia (*Rachycentro canadum*), leervis (*Lichia amia*), Guinean snapper (*Lutjanus agennes*), groupers (*Epinephelus spp.*), meagre (*Argyrosomus regius*), guitarfish (*Rhinobatos cemiculus*), nurse shark (*Ginglymostoma cirratum*), bream (*Sparidae*) and requiem sharks (*Carcharhinus spp.*) (Belhabib and Pauly 2013). This sector appears to only be active around the Bijagós Archipelago where high densities of game fish occur, and no fishing is reported to occur in the Local Study Area.

2.4.3 Industrial Fishing

The industrial sectors consists of foreign vessels chartered or re-flagged to Guinea Bissau (Belhabib and Pauly 2013), but are not considered domestic vessels (Gomes Barbosa 2009 in Belhabib and Pauly 2013). The majority of industrial harvest is transhipped at sea or landed outside of Guinea Bissau which only has one local fish processing facility. The industrial sector therefore only contributes to the Guinea-Bissau economy through compensation, access, observer and crew employment. Fees from foreign fishing agreements account for 40% of government revenue (Belhabib and Pauly 2013). Total annual harvest in 2008 was 53 000 tonnes. The harvest consisted of 50% small pelagics (mackerel, horse mackerel, sardinellas), 40% demersal species (croakers, breams, sweetlips, catfish and soles), 4% cephalopods (cuttlefish and octopus); 4% large tuna species and 2% crabs.

The industrial sector is comprised of the following:

1. 50 fish/cephalopod trawlers.
2. 35-40 shrimp trawlers.
3. 5 mid-water small pelagic trawlers.
4. 23 tuna purse seiners.
5. 14 pole and line tuna vessels
6. 4 motherships – working with canoes, receive and process fish onboard (Megapesca 2010).

The demersal trawl fishery targets bream (Sparidae), soles (Soleidae), grunts (Haemulidae), sea catfish (Ariidae) and croakers and drums (Sciaenidae)(Megapesca 2010). Important species include *Dicologoglossa cuneata*, *A. regius*, *Pomadasys jubelini*, *Arius heudeloti and Cloroscombrus chrysus* (IRD 2015). Cephalopods landed by the trawl fishery include common octopus (*Octopus vulgaris*) and cuttlefish (*Sepia officinalis*).

The shrimp fishery targets southern pink shrimp (*Penaeus notalis*) and Caramote shrimp (*Penaeus kerathurus*) on shelf waters to 100m, and deep water rose shrimp (*Parapenaeus longirostris*) to depths of 500m. Crabs are also landed by this sector.

The mid-water small pelagic trawlers and artisanal sector target sardinellas (*Sardinella spp., E. fimbriata*) and anchovies (*Engraulis spp.*), scombrids (*Scomber japonicus*) and carangids (*Decapterus rhonchus; Caranx senegallus*). These stocks are highly migratory and move throughout the North Eastern tropical Atlantic from Morrocco to Liberia (Megapesca 2010).

The tuna purse seiners, pole and line vessels target highly migratory tunas including yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) with bycatch of juvenile bigeye (*Thunnus obesus*), swordfish (*Xiphias gladius*) and sharks (shortfin mako *Isurus oxyrinchus* and blue shark *Prionace glauca*) (Megapesca 2010).

It is unlikely that any of these forms of industrial fishing occur within the Local Study Area.

2.5 Description of the Local Fisheries

No information is available on the fisheries in the Cacheu or Geba estuaries. However, based on an understanding of the regional fisheries it is unlikely that any industrial or recreational fishing occurs near the Project sites in the Cacheu and Geba estuaries. Artisanal fishing effort from the local sub-sector, however, is likely to be high, with a high reliance on subsistence fishing.

3. Field Survey Methods

3.1 Cacheu Estuary – Mine and Conveyor Site

A site visit was undertaken to the Cacheu Estuary at Farim between the 7th and 9th of May 2015. Two local canoes with 15hp outboards were provided to undertake the fieldwork. Visual assessment of the riparian estuarine habitats was undertaken for approximately 12km downstream and 3km upstream from the Farim ferry crossing.

Ichthyofauna were sampled using gill and fyke nets (Plate 1). Small and large mesh multifilament research gillnets were used. Small mesh nets consisted of panels of 12, 16, 22, 28, 35, 45, 57mm stretched mesh while the large mesh nets comprised 75, 73, 93 and 118mm stretched mesh panels. Four large and two small mesh nets were set overnight downstream of the Farim ferry crossing (Figure 3). Two double ended fyke nets, with 75cm D-ends separated by an 8m leader were also set overnight. Due to time constraints sampling was only undertaken over one night, with nets set for a minimum of 12 hours. An experienced local fisherman and head of the Farim Fishing Association skippered the canoes during the field survey and assisted in selecting sites for deployment of the nets based on his local knowledge of the estuarine system. Due to the strong tidal currents and the small vessel available for the survey, beam trawling could not be conducted in the Cacheu estuary for safety reasons. This means that the benthic species of the Cacheu estuary were not sampled using fisheries independent methods.

During the field survey, all artisanal fishing canoes observed engaged in fishing activity on the Cacheu estuary were approached, their catch inspected and methods of fishing recorded. Additional notes were maintained on the presence of nets and longlines along the course of the estuary. An interview was conducted with the head of the Farim Fishing Associate to obtain information on artisanal fishing activities.

Benthic infaunal communities were sampled using a weighted 250cm^2 Van Veen grab. Three replicate samples were collected at each site (Figure 4), with each being photographed prior to sieving through a 500µm mesh screen to remove fine muds and clays. The remaining sample was preserved in 10% formalin solution and transported to South Africa for identification to lowest possible taxonomic level.

3.2 Geba Estuary – Port Site

A field survey to the Ponta Chugue region on the Geba Estuary was undertaken from the 9th to the 11th May 2015. Due to strong tidal currents and large tidal range gillnets could not be deployed. Strong winds and rough conditions on the water limited the time available for field sampling.

Fyke nets and a beam trawl with mouth opening of 2.5m and 38mm stretched mesh were used to sample the demersal ichthyofauna. Fyke nets were set for up to 8 hours during daylight hours only. Beam trawling was conducted roughly parallel to the shoreline over 100m distances as measured by handheld GPS. Grab sampling using a Van Veen grab was undertaken to assess benthic infauna. All infaunal samples were sieved through 500µm in the field before being preserved in 10% formalin for identification in the laboratory. Interviews with, and observations of local artisanal fishermen were conducted to assess the types of fishing activities and catch composition.

Setting a gillnet in a side channel in the Cacheu Estuary close to low tide

Gillnet in a similar side channel the following morning close to high tide

Checking gillnets after initial setting

Fyke net set on a shallow muddy bank at low tide

Van Veen grab sampler used in the current study

Van Veen grab ready for deployment on the Geba Estuary

Muddy sample collected using the Van Veen grab

Plate 1: Sampling methods and equipment used in the survey of the Cacheu and Geba estuaries.

4. Field survey results

4.1 Cacheu Estuary

The estuarine waters of the Cacheu Estuary near Farim were highly turbid and tidal currents were strong (>2 knots). Estuary banks were lined with large mangroves with fine muddy sediments dominating on the edges, with courser graves and bed rock prevalent in mid-channel.

4.1.1 Ichthyofauna

A total of ten species of fish from nine families were captured in the research sampling nets with an additional three species from three additional families identified through interviews with artisanal anglers (Plate 2). Basic information on each species is presented in Plate 2 and an extensive list of species captured in West African estuaries is presented in Appendix 1.

Previous surveys conducted for the Project (Golder 2014a) captured 26 species (Appendix 1) however, these surveys were conducted between the mouth and Farim and hence covered a broader geographic area which included the full range of estuarine habitats and estuarine gradient present. A total of 12 fish species were captured in the upper Farim area (Stations 1-6) during the dry season survey, and 9 species during the wet season survey. This previous study captured four species in the Farim region not sampled in the current survey. Species captured in the Cacheu estuary near Farim on previous surveys not captured in this survey included Senegalese tonguesole (*Cynoglossus senegalensis,* Family Cynoglossidae), Bonga shad (*E. fimbriata,* Family Clupeidae*)*, sicklefin mullet (*Liza falcipinnis,* Family Mugilidae), estuarine goby (*Porogobius schlegelii,* Family Gobiidae).

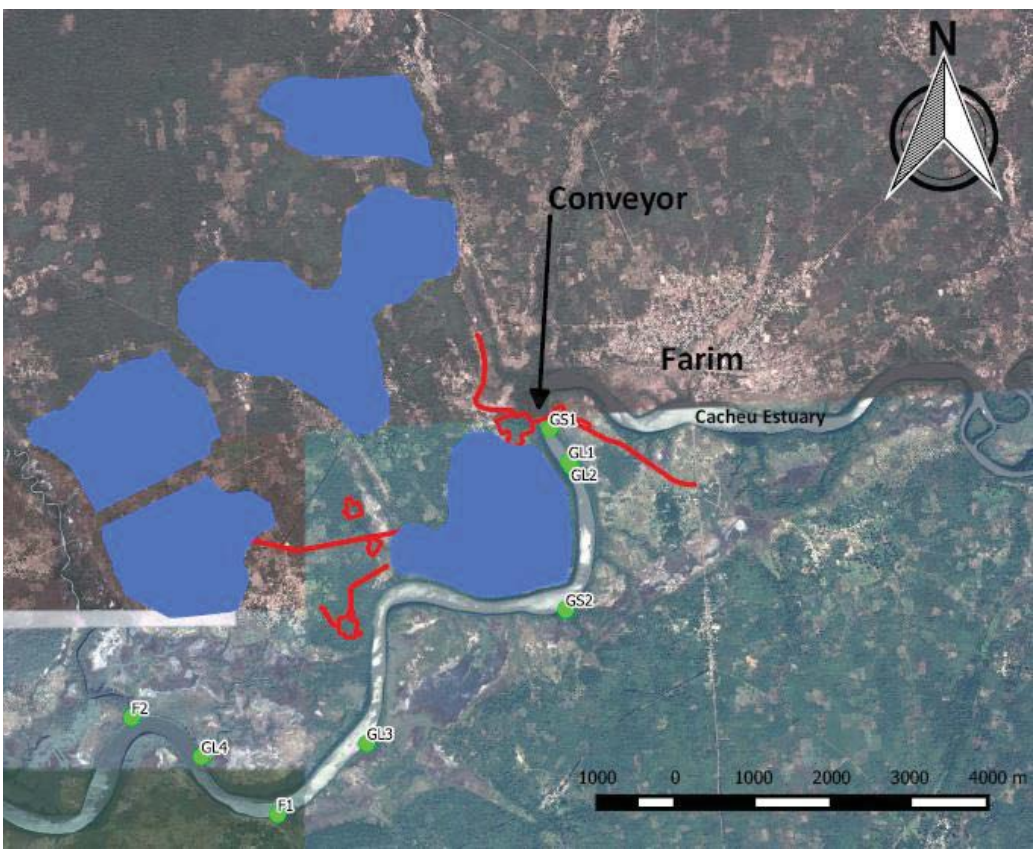


Figure 3: Ichthyofaunal small (GS) and large (GL) mesh gill and fyke (F) net sampling sites on the Cacheu Estuary.

Species captured in research gears	
	Sphyraena afra Family: Sphyraenidae **IUCN Red list:** Not evaluated Marine and brackish; common in lagoons and estuaries; pelagic; piscivorous; widespread eastern Atlantic, Senegal to Namibia;
	Polydactylus quadrifilis Family: Polynemidae **IUCN Red list:** Not evaluated Marine, brackish and freshwater; demersal over sandy and muddy bottoms; feeds on fish and crustaceans; enters estuaries; Eastern Atlantic, Senegal to Angola.
	Liza grandisquamis Family: Mugilidae **IUCN Red list:** Not evaluated Marine, fresh and brackish waters; pelagic-neritic; catadromous; very common in lagoons and estuaries of West Africa; Eastern Atlantic, Senegal to Congo.
	Pellonula leonensis Family: Clupeidae **IUCN Red list:** Not evaluated Marine, fresh and brackish waters; pelagic-neritic; anadromous; most widely distributed freshwater clupeid in West Africa; found in lagoons, lakes and upper rivers; feed on insects, ostracods, larvae; West Africa, Senegal to Cameroon.
	Monodactylus sebae Family: Monodactylidae **IUCN Red list:** Not evaluated Marine, fresh and brackish waters; pelagic-neritic; very common in estuaries and lagoons; widely distributed along west African coastline, Cape Verde to Angola; feeds on fish, zooplankton, shrimps.
	Pseudotolithus elongatus Family: Sciaenidae **IUCN Red list:** Not evaluated Marine and brackish waters; demersal; widespread along western coast of Africa, Senegal to Angola; coastal waters close to shore and estuaries over mud bottom; feeds on fish and shrimp.

	Pseudotolithus senegalensis Family: Sciaenidae **IUCN Red list:** Not evaluated Marine waters; demersal; coastal waters over mud, sand or rock substrates; rarely enters estuaries; feeds of fish, shrimps and crabs; Eastern Atlantic, Morocco to Angola;
	Pomadasys peroteti Family: Haemulidae **IUCN Red list:** Not evaluated Marine and brackish waters; benthopelagic; Common over sand and mud and in estuaries; feeds on fihs, crabs, shrimps, zooplankton and detritus; Eastern Atlantic Senegal to Angola.
	Butis koilomatodon Family: Eleotridae **IUCN Red list:** Not evaluated Marine fresh and brackish waters; demersal; amphidromous; found in estuaries, rivers and mangrove creeks; Feeds on crustaceans and small fish; Eastern Atlantic and Indo-Pacific.
	Chrysichthys spp. Family: Claroteidae **IUCN Red list:** 'Least concern' Freshwater; demersal; potamodromous; coastal rivers from Senegal to Ghana.
Species identified from artisanal catches	
	Eucinostomus malanopterus Family: Gerreidae **IUCN Red list:** Not evaluated Marine, fresh and brackish waters; dermsal; amphidromous; coastal entering estuaries; common over sand and mud bottoms; feeds on fish, shrimp, zooplankton, detritus; eastern Atlantic, Senegal to Angola.
	Ilisha africana Family: Pristigasteridae **IUCN Red list:** Not evaluated Marine and brackish waters; pelagic-meritic; found offshore, estuaries and lagoons; feeds on plankton, fish, detritus and invertebrates; eastern Atlantic, Senegal to Angola.
	Dasyatis spp. Family: Dasyatidae Marine and brackish waters; demersal; widespread on eastern Atlantic.

Callinectes spp.
Family: Portunidae

Family: Penaeidae

Plate 2: Species captured in the Cacheu Estuary

4.1.2 Benthic Infauna

Grab sampling to assess benthic infauna was undertaken at five sites in the Cacheu Estuary. Sites ranged in depth from 4 to 8m and substrate composition was variable, being fine muds, gravel and sand (Table 1). Images of grab sample sediments prior to sieving are shown in Plate 3. Eighteen infaunal taxa were distinguished (Table 2).

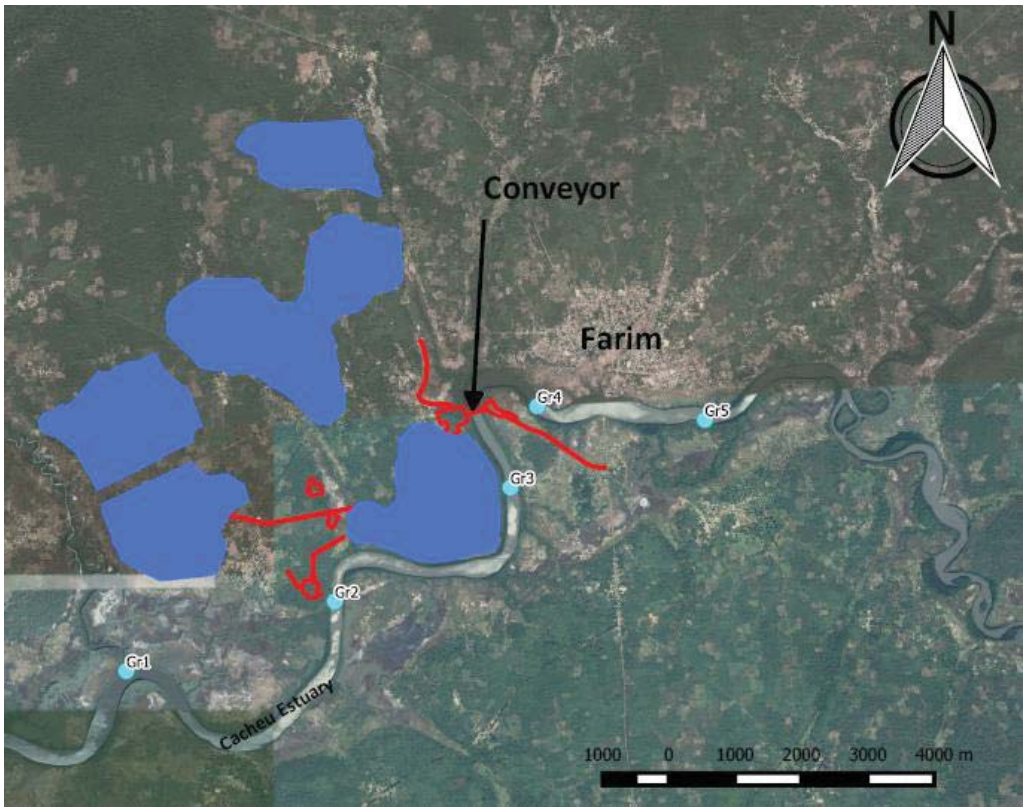


Figure 4: Benthic infaunal grab (Gr1-5) sampling sites on the Cacheu Estuary.

Table 1: Site information for the Cacheu Grab samples

Site	Infaunal assessment	Substrate
Cacheu1	Yes	Mud and some gravel
Cacheu2	Yes	Sand and mud
Cacheu3	Yes	Gravel
Cacheu4	Yes	Fine mud
Cacheu5	Yes	Sand

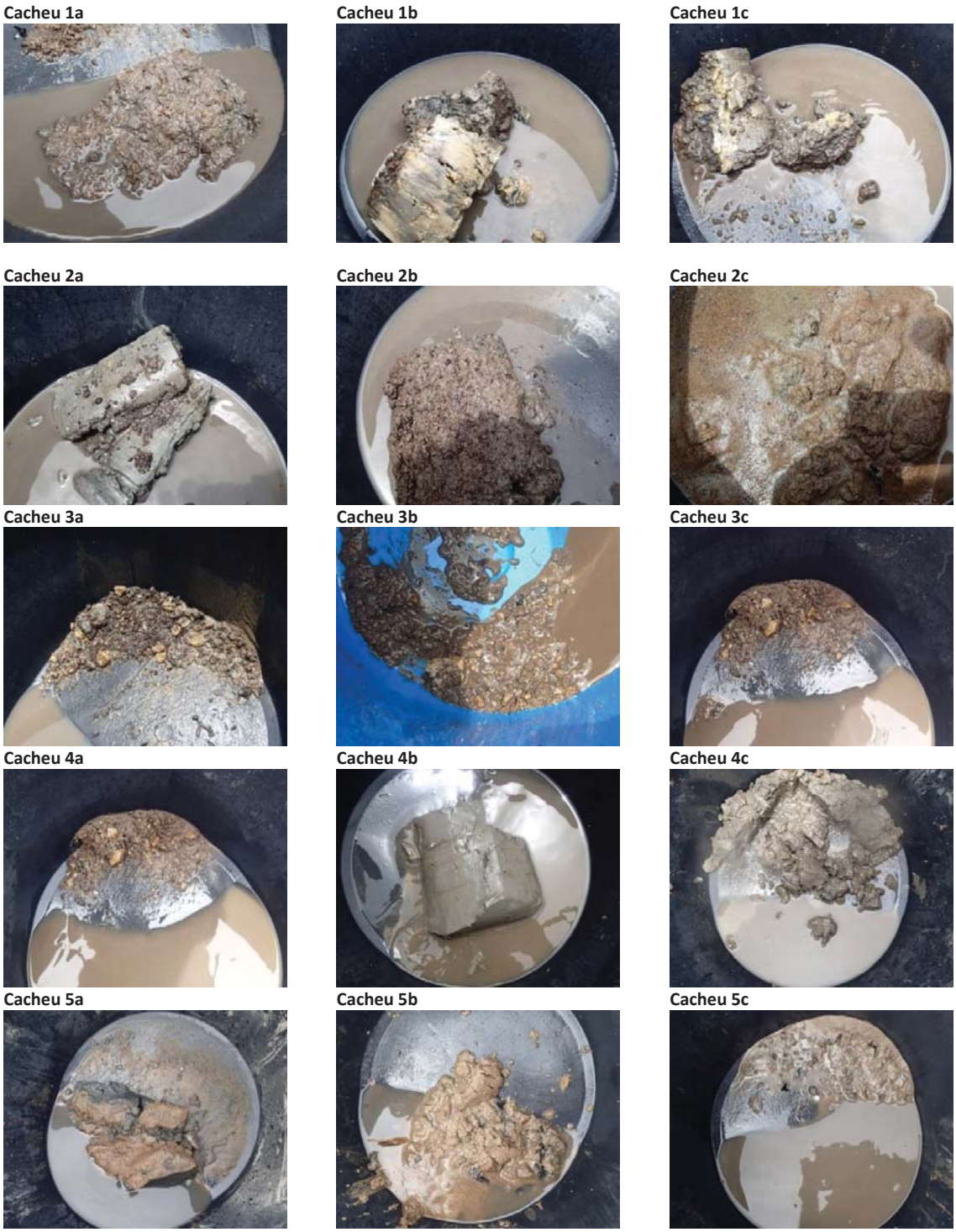


Plate 3: Photographic records of triplicate grab samples from the Cacheu Estuary.

Table 2: Infaunal species composition in the Cacheu Estuary

TAXA	C1a	C1b	C1c	C2a	C2b	C2c	C3a	C3b	C3c	C4a	C4b	C4c	C5a	C5b	C5c
Polychaeta															
Capitellidae				1											
Lumbrineridae									2						
Nephtyidae															
Nereidae		2	1				7	3	5	1		4			
Onuphidae							3								
Polychaeta sp 1 (cf Hesionidae)					1										
Sabellaridae	8	4	7	1	1		15	20	222	3				2	
Isopoda															
Anthuridae		3		1		1									1
Amphipoda															
Amphipoda sp1								1							
Amphipoda sp2							1								
cf Corophiidae							3	5	4	1		7			
Decapoda															
Thaumastoplax spiralis													2		
Bivalvia															
Bivalve larvae/juvenile	1	1		1		1			2	1	1		1		1
Bivalve sp1					3				3						
cf Donacidae sp 1			4	5	2		6		1	1	3	1			
cf Donacidae sp 2	2		1					3			5				
Mytilidae			1	2				1		1					
Echinodermata															
Ophiuroidea sp1							1								
Abundance	**11**	**10**	**14**	**11**	**7**	**2**	**36**	**33**	**239**	**8**	**9**	**12**	**3**	**2**	**2**
No. Taxa	**3**	**4**	**5**	**6**	**4**	**2**	**7**	**6**	**7**	**6**	**3**	**3**	**2**	**1**	**2**

4.1.3 Fishery

Numerous artisanal fishermen were observed during the field survey on the Cacheu estuary. The most common forms of fishing involved gillnetting and longlining.

Gillnets are attached to floating platforms strung between mangroves across the main estuary channel (Plate 4). Fishing occurs predominantly at night with fishermen returning with catch in the early morning. Gillnets are constructed of multifilament meshing of varying mesh sizes, but mesh sizes are generally large (Plate 4). Net lengths are in the region of 90m. During the field survey 10 permanent floating structures used by fishermen were observed over a 12km section downstream of Farim (Plate 4) (Figure 5).

Longlines (Plate 4) consist of a length of rope attached to either an anchor which is dropped in mid-channel and marked by a buoy, or the end is tied off to the mangroves and set out into the river channel. Each line has 150-200 hooks attached to a weighted bottom set line. It was not possible to

count longlines as they are difficult to see amongst the mangroves, however, over one short stretch (<2km) of the estuary more than 20 lines were counted.

The main artisanal species (from interviews) include *Chrysichthys spp*., *Sphyraena spp*. *Pseudotolithus spp.* and *Pomadasys spp* (Plate 5). Fishermen fish all year round, however, the peak period is from May to June and from August to December when catches are highest. There is a local fishing association, the Farim Association, with approximately 66 members.

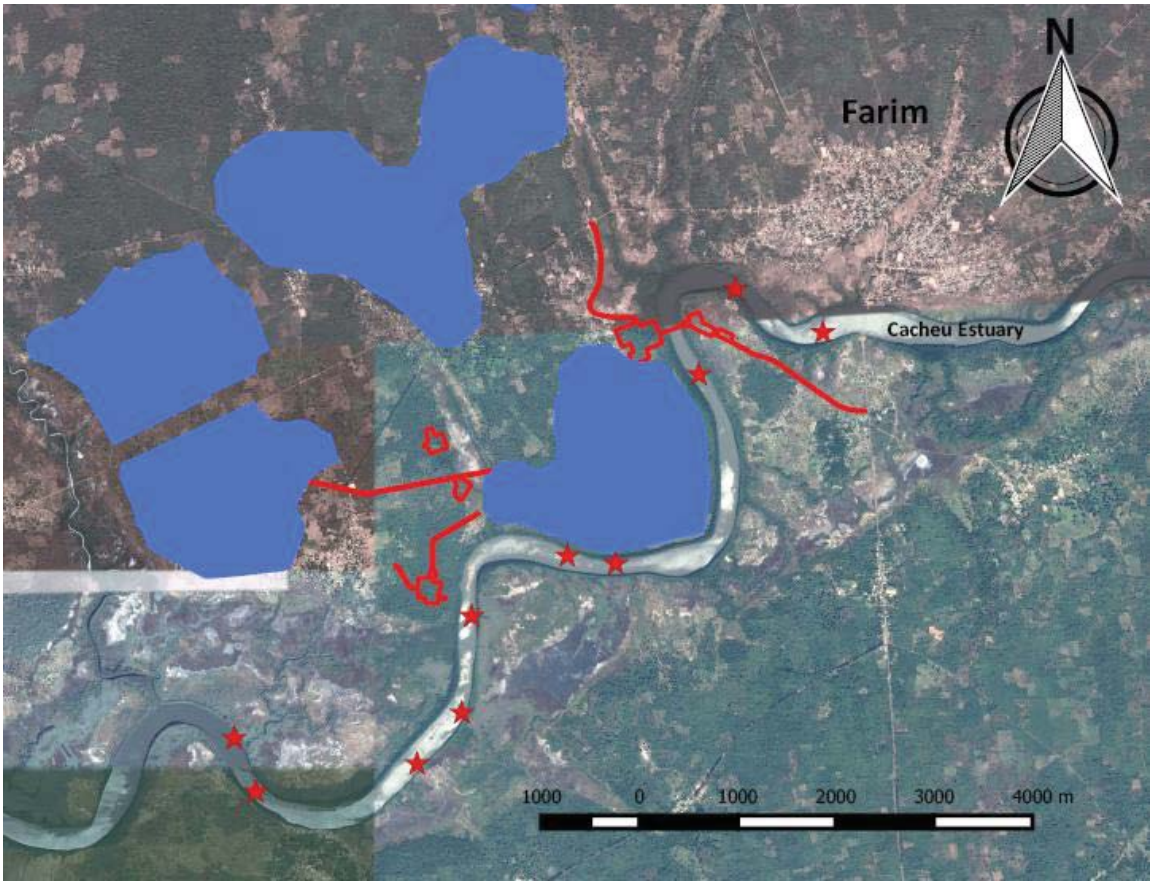


Figure 5: Location (stars) of permanent artisanal net mooring structures on the Cacheu Estuary (12km or estuary surveyed).

Permanent mooring lines and floats fixed across the main Cacheu estuary channel to which nets are attached.

Gillnets and anchors used by local artisanal fishermen

Large mesh multifilament gillnets used in the Cacheu estuary

Longlines set in the Cacheu Estuary

Longline traces used by artisanal fishermen

Plate 4: Artisanal fishing gears on the Cacheu Estuary in the Farim region.

Mixed catch or atisanal fishern on the Cacheu Estuary, dominated by *Pseudotolithus elongatus.*

Artisanal catch of Penaeids caught in a fine mesh net on the Cacheu Estuary

Callinectes pallidus* and *Pseudotolithus elongatus

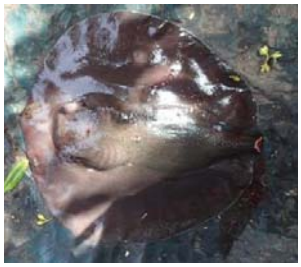
Monodactylus sebae

***Pseudotolithus elongatus* 'Joto'**

***Eucinostomus malanopterus* 'Pisprata'**

***Polydactylus quadrifilis* ' Barbine'**

Ilisha africana



Dasyatis spp.

Chrysichthys spp.

Plate 5: Artisanal catch in the Cacheu Estuary

4.2 Geba Estuary

The estuarine waters at Ponta Chugue were highly turbid and a strong tidal current (>3 knots) and large tidal range were observed. Benthic sediments appeared to be mostly very fine muds with rocky substrata limited to the immediate area around Ponta Chugue (Plate 6).

Landing beach at Chugue showing the rapid change from 'hard gravel' to very fine muds

Ponta Chugue approximately 2 hours before low tide

Ponta Chugue close to high tide

Plate 6: Site characteristics at Geba Estuary

4.2.1 Ichthyofauna

Only three species of fish were captured in the Geba Estuary at Ponta Chugue, two of which (*Arius latiscutatis* and *Pentanemus quinquarius*) were not captured in the Cacheu survey. Numerous Penaeids were also captured in the beam trawl. The fish species included *Arius latiscutatis*, *Pseudotolithus elongatus* and *Pentanemus quinquarius* (Plate 7). The low catch rates were due to the limited time available for sampling and due to the difficult sampling conditions typical of the lower Geba Estuary (strong tidal currents; large tidal range; rough wind chop). Interviews with artisanal fishermen based at Chugue confirmed the difficult fishing conditions and indicated few species of estuarine fish (*Arius spp.*, *Pomadasys spp., Liza / Mugil spp., E. fimbriata, I.africana, P. quinquarius, Pseudotolithus spp.*) are caught in gillnets in the area. Despite low catches, based on the size and characteristics of the Geba Estuary, the ichthyofaunal diversity should in theory be high, with a greater presence of marine dependent species than the upper reaches of the Cacheu Estuary at Farim. Sampling locations are shown in Figure 6 and trawl depths indicated in Table 3.

Table 3: Beam trawl station depths on the Geba Estuary

Trawl No.	Depth	Distance
1	5m	±100m
2	7-9m	±100m
3	3m	±100m
4	3-5m	±100m
5	4m	±100m
6	5m	±100m
7	6-9m	±100m
8	12m	±100m
9	19-20m	±100m
10	15-17m	±100m

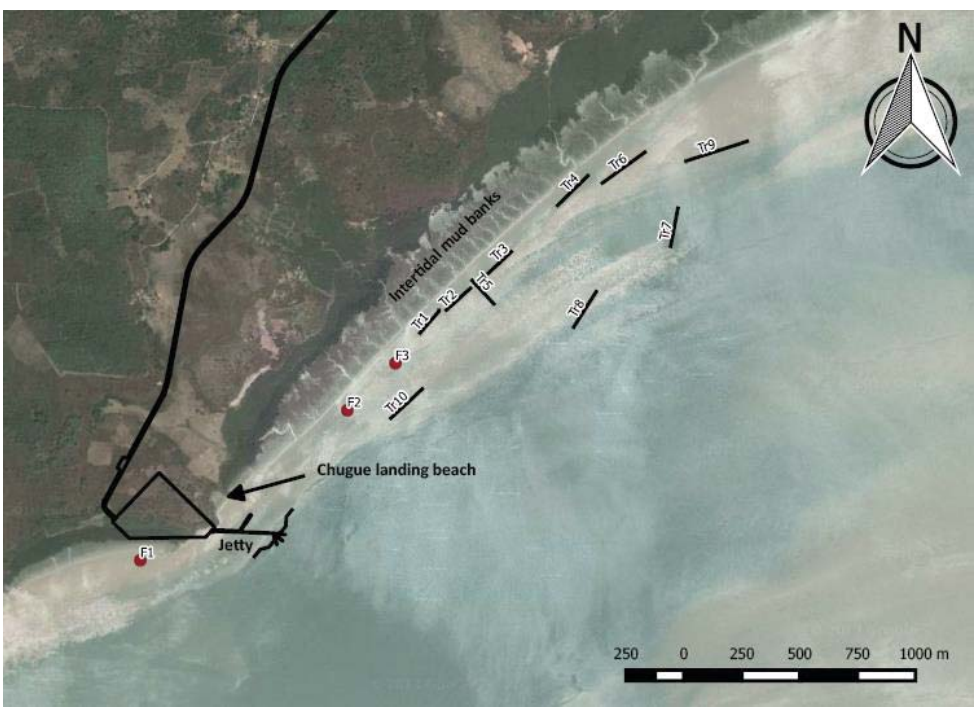


Figure 6: Demersal trawl (Tr1-10) and fyke net (F1-3) sampling locations on the Geba Estuary.

	Pentanemus quinquarius Family: Polynemidae **IUCN Red list**: Not evaluated Marine and brackish waters; demersal; occurs over sand and mud bottoms in shallow coastal waters and estuaries; Carnivorous, feeds on fish and shrimps; Eastern Atlantic, Senegal to Angola.
	Pseudotolithus elongates Family: Sciaenidae **IUCN Red list:** Not evaluated Marine and brackish waters; demersal; widespread along western coast of Africa, Senegal to Angola; coastal waters close to shore and estuaries over mud bottom; feeds on fish and shrimp.
	Arius latiscutatus Family: Ariidae **IUCN Red list: Not evaluated** Marine and brackish waters; demersal; mainly marine but frequent in brackish estuaries and lagoons; common during winter; Eastern Atlantic, Senegal to Angola
	Family: Penaeidae
	Family: Penaeidae

Plate 7: Species captured during the demeral strawl and fyke net survey on the Geba Estuary

4.2.2 Benthic Infauna

Eight sites of varying depth were sampled around the port site (Table 4). Few of the grab samples from the Geba Estuary port site had infaunal species present (Table 5). This is most probably due to the very fine and anoxic mud sediments present across most of the study area, and the presence of rock and large gravel at sites off Ponta Chugue which are not suitable habitat for infaunal species.

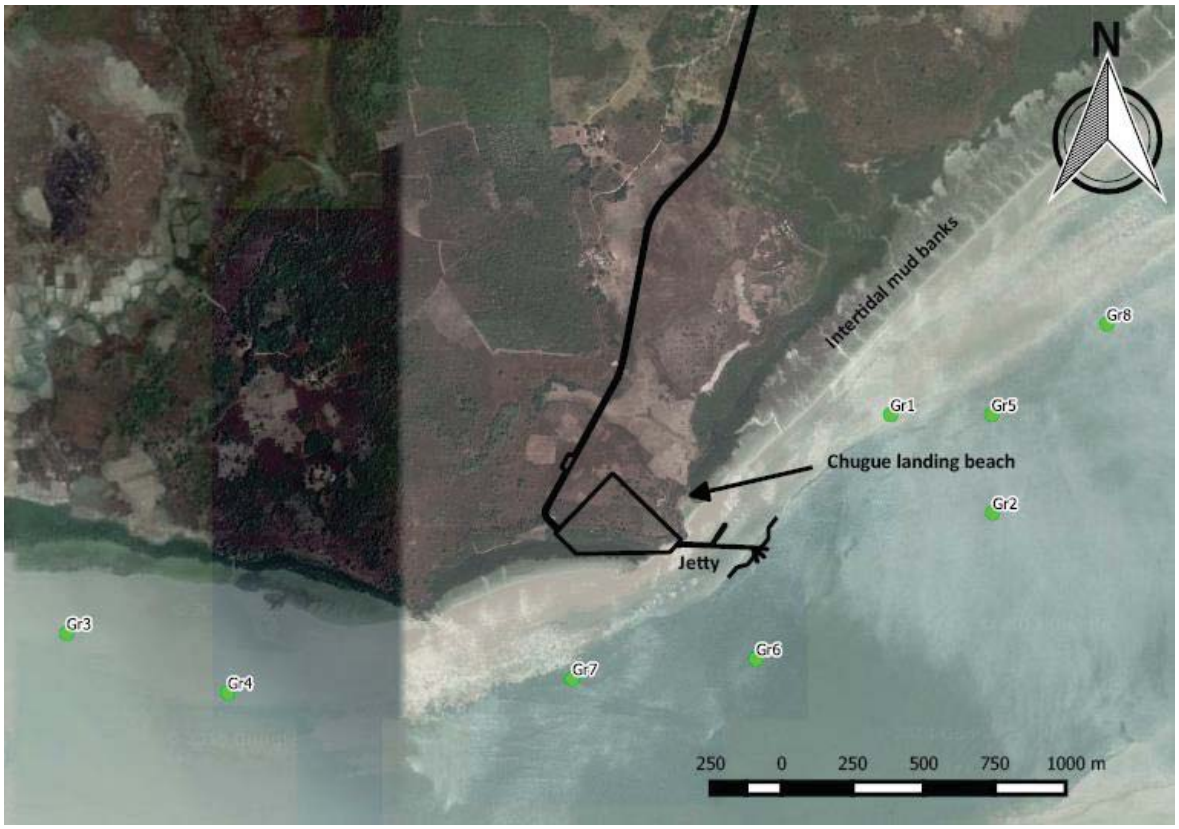


Figure 7: Grab (Gr1-8) sampling sites on the Geba Estuary.

Table 4: Site information for the Geba Grab samples

Site	Depth	Infaunal assessment	Substrate
Geba1	13m	Yes	Fine muds
Geba2	20m	Yes	Fine muds and gravel
Geba3	15m	Yes	Shell debris
Geba4	15m	Yes	Fine muds
Geba5	9m	Yes	Gravel and fine muds
Geba6	*17m*	*No*	*Hard rock*
Geba7	*18m*	*No*	*Gravel*
Geba8	12m	Yes	Fine muds

Geba 1a

Geba 1b

Geba 1c

Geba 2a

Geba 2b

Geba 2c

Geba 3a

Geba 3b

Geba 3c

Geba 4a

Geba 4b

Geba 4c

Geba 7a

Geba 7b

Geba 7c

Geba 5a

Geba 8a

Geba 8b

Plate 8: Sediment characteristics from grab samples at the Geba Estuary

Table 5: Infaunal composition of the Geba Estuary grab sites

TAXA	G1a	G1b	G1c	G2a	G2b	G2c	C3a	C3b	C3c	G4a	G4b	G4c	G7a	G8a	G8b
Polychaeta															
Lumbrineridae		2							2						
Nephtyidae		1											1		
Nereidae							7	3	5						
Onuphidae							3								
Sabellaridae							15	20	222				2		
Amphipoda															
Amphipoda sp1								1							
Amphipoda sp2							1								
cf Corophiidae							3	5	4				2		
Bivalvia															
Bivalve larvae/juvenile									2						
Bivalve sp1									3						
cf Donacidae sp 1							6		1						
cf Donacidae sp 2								3							
Mytilidae								1							
Echinodermata															
Ophiuroidea sp1							1								
Abundance	**0**	**3**	**0**	**0**	**0**	**0**	**36**	**33**	**239**	**0**	**0**	**0**	**5**	**0**	**0**
No. Taxa	**0**	**2**	**0**	**0**	**0**	**0**	**7**	**6**	**7**	**0**	**0**	**0**	**3**	**0**	**0**

4.2.3 Fisheries

Only one fisherman was observed actively fishing (Plate 9) while conducting the field survey on the Geba estuary, however, several young fishermen were encountered at the landing beach at Chugue (Plate 9). Interviews with the local fishing representative indicated that fishing in this region of the Geba Estuary is difficult due to the strong currents and large tidal range. Longline fishing is therefore the main type of fishing which occurs in the area. Longlines are approximately 200m in length with up to 300 hooks. Each fisherman has between 3 and 10 longlines. Due to the strong currents and deep channel at Ponta Chugue, the main fishing area is located on the opposite bank of the Geba Estuary. Fishing occurs between August and April when the currents are generally weaker and there is a lower abundance of large sharks which are avoided as they damage the fishing gear. Fishermen fish every day over this period setting longlines overnight, or over a full tidal cycle. Approximately 30-40 fishermen use the Ponta Chugue landing beach where roughly 10 canoes are based during the fishing season. Seacatfish (*Arius spp.*) is the main catch on the longlines, while more species including *Pomadasys spp.,* Mugilidae*, E. fimbriata, I. africana, P. quinquarius, Pseudotolithus spp* may be caught by gillnet fishermen. A gillnet fishermen was observed during the field survey, however, the habitat available for setting gillnets is limited as nets need to be carefully set in deeper channels in between shoals close to the shoreline to ensure that they are not washed away or pushed down by the strong tidal currents. Crab fishing using baskets is also undertaken. Larger ferry canoes also utlise the landing beach to load/unload supplies and transport people.

Longlines used by the local artisanal fishermen at Chugue landing beach

Young fishermen carrying large anchors and floats used in longline fishing

Artisanal fishermen at Chugue landing beach cleaning a grey nurse shark (*Ginglymostoma cirratum*).

Circular handnets seen at the homesteads at Chugue and used in the flooded wetlands during the wet season.

Gillnet fishermen observed checking his nets close to Chugue landing beach during the low tide.

Typical catch of *Arius* sp. From artisanal longlines

Chugue landing beach which is used by approximately 10 local fishing canoes.

Plate 9: Artisanal fishery at Ponta Chugue on the Geba Estuary

5. Conclusions

The limited time on site and difficulties encountered whilst on site have resulted in limited data being collected on the fish and fisheries of the two estuarine systems. There is also limited information available on these systems in the literature, as highlighted in the background information review.

The size and variability of these two estuaries are such that the only way in which to obtain representative data on the fish and fisheries in these systems would be to undertake a dedicated research survey using a variety of sampling strategies and over several seasons. However, the impacts of the Project on the fish and fisheries does not warrant this level of detail since the impacts will be limited in time and space and can be mitigated to an acceptable level using available risk management and assessment strategies. Adequate monitoring of dewatering water quality and careful active dialogue with the Geba and Cacheu fishermen during construction and operation of the conveyor and jetty should adequately mitigate Project related impacts on the fish and fisheries of both estuaries.

6. References

Albaret, J.J.. Simier, M., Darboe, F.S. Ecoutin, J.M., Raffray, J. and de Morais, L.T. 2004. Fish diversity and distribution in the Gambia Estuary, West Africa, in relation to environmental variables. Aquatic Living Resources 17: 35-46.

Amorim, P., Duarte, G., Guerra, M. Morato, T., Stobberup, K.A. 2004. Preliminary Ecopath model of the Guinea-Bissau continental shelf ecosystem (NW Africa), p. 95-112. In: Palomares, M.L.D., Pauly, D. (eds.) West African marine ecosystems: models and fisheries impacts. Fisheries Centre Research Reports 12(7). Fisheries Centre, UBC, Vancouver.

Anon. (2010) Guinea-Bissau. Cashew and beyond: diversification through trade. Diagnostic trade integration study for the Enhanced Integrated Framework for Trade-related Technical Assistance. 150 p.

Agardy, T. 1997. Marine protected areas and ocean conservation. Academic Press. 244pp.

Baran E. 1995. Dynamique spatio-temporelle des peuplements de poissons estuariens en Guinée – relations avec le milieu abiotique. TDM n°142. Editions ORSTOM, Paris. Disponible sur Internet à http://limnologie.univ-lyonl.fr/~baran/

Baran, E. & Tous, P. 1999. Pêche artisanale, développement et cogestion durables des ressources. Analyse d'un success en Afrique de l'Ouest. UICN, Bissau.

Baran, E. 2000. Biodiversity of Estuarine Fish Faunas in West Africa. The ICLARM Quarterly. Vol23, No4.

Belhabib, D. and Pauly, D. 2015. Fisheries in troubled waters: A catch reconstruction for Guinea-Bissau, 190-2010. University of British Columbia, Fisheries centre, Working paper #2015-72.

Berrit, G.R. and J.P Rebert. 1977. Océanographie physique et productivité primaire, p. 1-60. In: G.R. Berri (ed.) Le milieu marin de la Guinée Bissau et ses ressources vivantes. ORSTOM, Paris.

Blaber, S. J. M. 1997. Fish and fisheries of tropical estuaries. Fish and fisheries series, Chapman and Hall, London.

Blaber, S.J.M. 2000. Tropical estuaine fishes. Ecology, exploitation and conservation. Blackwell Science Ltd., London.

Campredon. P. and & Cuq, F. 2001. Artisanal fishing and coastal conservation in West Africa. Journal of Coastal Conservation. 7:91-100.

Chavance., P. 2004. Towards reconstructing half a century of change in West African fisheries. pp. 113-132 *In* Chavance P, Ba M, Gascuel D, Vakily JM and Pauly D (eds.), Pecheries maritimes, ecosystemes et societes en Afrique de l'ouest. Un demi-siecle de changement. Actes du symposium international Dakar — Sénégal — 24-28 Juin 2002. Collection des Rapports de recherche halieutique ACP-UE 15 (1)Bruxelles.

Daget, J. 1960. La faune ichtyologique du bassin de la Gambie. Bulletin de l'I.F.A.N 22 (2), 610e619.

Darboe, F.S. 2002. Fish species abundance and distribution in the Gambia estuary. United Nations University, Fisheries Training Report, 40pp.

Da Silva, A.S. 1999. Les mangroves de Guinée Bissau. In Conservation et utilisation rationnelle des forêts de mangrove de l'Amérique latine et de l'Afrique, vol. II. International Tropical Timber Organization / International. Society for Marine Ecology. UNESCO/COMARAF, Paris.

Dia, A.K., Bedingar, T., 2001. Fishing Sector Support Project. Republic of Guinea-Bissau. Appraisal Report. African Development Fund, p. 24.

Ecoutin, J.M., Albaret, J.J. and Trape, S. 2005. Length-weiht relationships for fish populations of a relatively undisturbed tropical estuary: The Gambia. Fisheries Research 72: 347-351.

Facade, S.O. and C.I.O. Olaniyan, 1974. Seasonal distribution of the fish fauna of the Lagos Lagoon. Bulletin de I'L FANT Ser. A, 36: 244-252.

Golder Associates (UK) Ltd. 2014a. River Cacheu Aquatic Ecology baseline Study. Farim Phoshate Project, Guinea-Bissau. Report Number: 13514950200.508/B.0.

Golder Associates (UK) Ltd. 2014b. Mine component environmental and social impact assessment Volume 2. Farim Phoshate Project, Guinea-Bissau. Report Number: 13514950201.550-2/A.0.

Golder Associates (UK) Ltd. 2013. River morphology and physical oceanography baseline study. Farim Phoshate Project, Guinea-Bissau. Report Number: 13514950220.503/B.0.

Gomes Barbosa, T. 2009. Republique de Guinee Bissau. Secrétariat d'état a l'environnement et développement durable Bissau. 99 p.

IRD. Accessed July 2015.

http://www.ird.fr/ecostproject/doku.php?id=case_study_9_guinee_bissau_inep_instituto_nacional_de_estudios_e_pesquisa

Irvine, F.R. 1947. The fishes and fisheries of the Gold Coast. University Press, Cambridge.

Koffi, B.K., Berté, S. and Koné, T. 2014. Length-weight relationships of 30 fish species in Aby Lagoon, southeastern Côte d' Ivoire. Current Research Journal of Biological Sciences 6(4): 173-178.

Laë, R., Ecoutin, J.-M., Mendy, A., Raffray, J.,Weigel, J.Y., Sadio, O. and Djobe, O. 2004. Effects of a targeted shrimp (*Penaeus notialis*) exploitation on fish catches in the Gambia estuary. Aquatic Living Resources 17: 75e85.

Megapesca. 2010. Contrat cadre fish/2006/20 Specific convention n°27: ex-post evaluation of The current protocol to the fisheries Partnership agreement between the European Union and Guinea Bissau and analysis of the Impact of the future protocol on sustainability. Final report, September 2010.

Mendy, P.K. & Lobban, R.A. 2013. Historical Dictionary of the Republic of Guinea-Bissau.

N'Goran, Y.N., 1998. Statistiques de pêche en lagune Aby (Côte d'Ivoire): évolution de l'effort et des captures de 1979 à 1990. J. Ivoir. Océanol. Limnol. Abdjan, 3(1): 25-37.

Simier, M., Laurent, C., Ecoutin, J.M. and Alabret, J.J. 2006. The Gambia River estuary: A reference point for estuarine fish assemblages studies in West Africa. Estuarine, Coastal and Shelf Science 69:616-628.

Tvedten, I. 1990. The difficult transition from subsistence to commercial fishing. The case of the Bijagós of Ginea Bissau. MAST 3(1):119-130.

Vidy, G., Darboe, F.S. and Mbye, E.M. 2004. Juvenile fish assemblages in the creeks of the Gambia Estuary, Aquatic Living Resources. 17:56-64.

van der Veer. H.W., Adriaans, E.J., Bolle, L.J., Dankers, N., Da Fonseca, L.M., Walker, P.A. and Witte, J.I.J. 1995. Ecological observations on juvenile flatfish in a tropical estuary: Arquipélago dos Bijagós, Guinea-Bissau.

Yañez-Arancibia A. 1985. Fish community ecology in estuaries and coastal lagoons; towards an ecosystem integration. UNAM Press, Mexico, 654pp.

Appendix 1: Ichthyofaunal species list for estuaries of West Africa based on literature surveys and field sampling undertaken for the current Project.

Cat.: bioecological category from Albaret et al. 2004 - Co: continental species, occasional in estuaries (dark blue highlight); Ce: estuarine species from continental origin (light blue highlight); Ec: estuarine species from continental origin; Es: strictly estuarine species; Em: estuarine species from marine origin; ME: marine-estuarine species; Ma: marine species accessory in estuaries; Mo: marine species occasional in estuaries),

Order	Family	Cat	Scientific name	Albaret et al. 2004	Vidy et al. 2004	van der Veer et al. 1995	Golder 2013	AES 2015	AES 2015
				Gambi Estuary	Gambia Estuary	Geba, Buba, Bijagós	Cacheu Estuary	Cacheu Estuary	Geba Estuary
Anguilliformes	Ophichthyidae	MO	*Pisonodophis semicinctus*	y	y				
Batrachoidiformes	Batrachoididae	MA	*Batrachoides liberiensis*	y			y		
Beloniformes	Belonidae	EM	*Strongylura senegalensis*	y	y				
		MO	*Tylosurus acus*	y					
	Hemiramphidae	EM	*Hyporhamphus picarti*		y				
Characiformes	Alestiidae	CO	*Alestes baremoze*	y					
		CO	*Brycinus nurse*	y					
		CO	*Hydrocynus brevis*	y					
	Hepsetidae	CO	*Hepsetus odoe*		y				
Clupeiformes	Albulidae		*Albula vulpes*			y			
	Clupeidae	EM	*Ethmalosa fimbriata*	y	y	y	Y	y	
		EM	*Ilisha africana*	y	y		Y	y	
		EC	*Pellonula leonensis*	y	y		Y	y	
			Sardinella aurita			y			
		ME	*Sardinella maderensis*	y	y	y			
			Sardinella rouxi			y			
Cyprinodontiformes	Poeciliidae	ES	*Aplocheilichthys spilauchen*		y				
Elopiformes	Elopidae	ME	*Elops lacerta*	y	y				
Osteoglossiformes	Mormyridae	CO	*Hyperopisus bebe*	y					
		CE	*Mormyrops anguilloides*	y					
Perciformes	Carangidae	ME	*Caranx hippos*	y	y	y			
		ME	*Caranx senegallus*	y		y			
		ME	*Chloroscombrus chrysurus*	y		y			

Order	Family	Cat	Scientific name	Albaret et al. 2004	Vidy et al. 2004	van der Veer et al. 1995	Golder 2013	AES 2015	AES 2015
				Gambi Estuary	Gambia Estuary	Geba, Buba, Bijagós	Cacheu Estuary	Cacheu Estuary	Geba Estuary
		MO	*Hemicaranx bicolor*	y					
		MA	*Lichia amia*	y					
			Selene dorsalis				y		
			Trachinotus maxillosus			y			
			Trachinotus ovatus			y			
		EM	*Trachinotus teraia*	y	y				
			Uraspis secunda			y			
	Cichlidae	EC	*Hemichromis fasciatus*		y				
		ES	*Sarotherodon melanotheron*	y	y				
		ES	*Tilapia guineensis*	y	y				
		ES	*Tylochromis jentinki*	y	y				
	Drepaneidae	ME	*Drepane africana*	y			y		
	Eleotridae	ES	*Bostrychus africanus*	y	y				
			Butis koilomatodon				y		
		ES	*Dormitator lebretoni*		y				
	Ephippidae	MA	*Chaetodipterus lippei*	y					
	Gerreidae	ME	*Eucinostomus melanopterus*	y	y	y	Y	y	
		ES	*Gerres nigri*	y	y				
	Gobiidae		*Gobioides ansorgii*			y			
		ES	*Gobionellus occidentalis*		y		y		
		ES	*Nematogobius maindroni*	y					
		ES	*Periophtalmus barbus*		y				
		ES	*Porogobius schlegelii*	y	y		y		
	Haemulidae	ME	*Brachydeuterus auritus*	y			Y		
		EM	*Plectorhinchus macrolepis*	y	y				
		EM	*Pomadasys jubelini*	y	y			y	
		EM	*Pomadasys perotaei*	y	y	y	Y	y	
	Monodactylidae	ES	*Monodactylus sebae*	y	y		Y	y	

Order	Family	Cat	Scientific name	Albaret et al. 2004	Vidy et al. 2004	van der Veer et al. 1995	Golder 2013	AES 2015	AES 2015
				Gambi Estuary	Gambia Estuary	Geba, Buba, Bijagós	Cacheu Estuary	Cacheu Estuary	Geba Estuary
	Mugilidae	EM	*Liza dumerili*	y	y				
		EM	*Liza falcipinnis*	y	y				
		EM	*Liza grandisquamis*	y	y	y	Y	y	
			Liza ramada			y			
		ME	*Mugil bananensis*	y	y				
		ME	*Mugil cephalus*	y		y			
			Mugil curema			y			
	Polynemidae	ME	*Galeoides decadactylus*	y	y	y	y		
		MA	*Pentanemus quinquarius*	y			y		y
		ME	*Polydactylus quadrifilis*	y	y		Y	y	
	Sciaenidae	ME	*Pseudotolithus brachygnathus*	y	y				
		EM	*Pseudotolithus elongatus*	y	y		Y	y	y
		MA	*Pseudotolithus senegalensis*	y			Y	y	
		ME	*Pseudotolithus typus*	y			y		
		ME	*Pteroscion peli*	y					
		MO	*Umbrina ronchus*	y					
	Scombridae		*Scomberomorus tritor*			y			
	Serranidae	ME	*Epinephelus aneus*		y				
	Sphyraenidae	ME	*Sphyraena afra*	y	y			y	
		ME	*Sphyraena guachancho*	y					
	Trichiuridae	ME	*Trichiurus lepturus*	y			y		
Pleuronectiformes	Bothidae		*Citharichthys stampflii*			y			
	Cynoglossidae	EM	*Cynoglossus senegalensis*	y	y		y		
	Paralichthyidae	EM	*Citharichthys stampflii*	y	y				
	Psettodidae		*Psettodes belcheri*			y			
			Psettodes bennetti			y			
	Soleidae	MO	*Synaptura cadenati*	y		y			
			Synaptura lusitanica				y		

Order	Family	Cat	Scientific name	Albaret et al. 2004	Vidy et al. 2004	van der Veer et al. 1995	Golder 2013	AES 2015	AES 2015
				Gambi Estuary	Gambia Estuary	Geba, Buba, Bijagós	Cacheu Estuary	Cacheu Estuary	Geba Estuary
Rajiformes	Dasyatidae	EM	*Dasyatis margarita*	y		y			
		EM	*Dasyatis margaritella*	y			y	y	
		MO	*Dasyatis ukpam*	y					
	Gymnuridae	MO	*Gymnura micrura*	y					
Siluriformes	Ariidae	ME	*Arius heudelotii*	y			Y	y	
		ME	*Arius latiscutatus*	y					y
		ME	*Arius parkii*	y	y				
	Clariidae	CO	*Clarias anguillaris*	y					
	Claroteidae	EC	*Chrysichthys maurus*	y	y				
		EC	*Chrysichthys nigrodigitatus*	y	y				
		CE	*Chrysichthys johnelsi*	y	y				
	Mochokidae	CO	*Synodontis batensoda*	y					
		CE	*Synodontis gambiensis*	y	y				
	Schilbeidae	CE	*Schilbe intermedius*	y	y				
Tetraodontiformes	Tetraodontidae	ME	*Ephippion guttifer*	y	y	y	y		
		ME	*Sphoeroides spengleri*		y				

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

AQUATIC PHYSICAL-CHEMICAL

BASELINE ASSESSMENT

Prepared for:

Knight Piésold Ltd.

1650 Main Street West

North Bay, Ontario, Canada

P1B 8G5

Prepared by:

Scherman Colloty & Associates

Postnet Suite 25

Private Bag 1672

GRAHAMSTOWN

6140

Scherman Colloty and Associates cc

Environmental and Aquatic Management Consulting

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SPECIALIST REPORT DETAILS

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ACRONYMS

AES	Aquatic Ecosystem Services cc
ANZECC	Australian New Zealand Environmental Conservation Council
ESHIA	Environmental, Health and Social Impact Assessment
GIS	Geographic Information System
NM	Nautical Mile
EMP	Environmental Management Plan
SC&A	Scherman Colloty and Associates cc
IUCN	International Union for Conservation of Nature
AL	Action Level
SCL	Special Conditions Level
EL-R	Screening Level – Effects Low Range
ER-M	Effect range Median – Maximum Level
TSS	Total Suspended Solids
IMO	International Maritime Origination
EMSA	European Maritime Safety Agency

1 INTRODUCTION

This study was commissioned to assess the baseline water quality, phytoplankton, characteristics of the Cacheu and Geba estuaries for the proposed GB Minerals Farim Phosphate Project (the Project) in Guinea-Bissau (Figure 1). The Project not only proposes to mine phosphate ore adjacent to the Cacheu Estuary near Farim, but develop a ship loading facility on the Geba Estuary at Ponto Chugue. The study was designed to obtain additional information on the physical-chemical parameters within the site (water quality & sediment characteristics), phytoplankton, as well as comment based on the previous work conducted on the regional bathymetry and hydrology. Aspects on the ichthyofauna, benthic infaunal ecology, and fisheries of each estuary at the Project affected sites was assessed in a separate assessment conducted by Aquatic Ecosystem Services (AES), 2015. Both studies were limited to a five day site assessment and a desktop review of available literature for the Project and region in order to fill any data gaps, while assessing any impacts based on the revised project layouts and transport options. The Status of the Mangroves and the potential impacts on these ecosystems is contained in the Terrestrial Ecological report (Hudson, 2015).

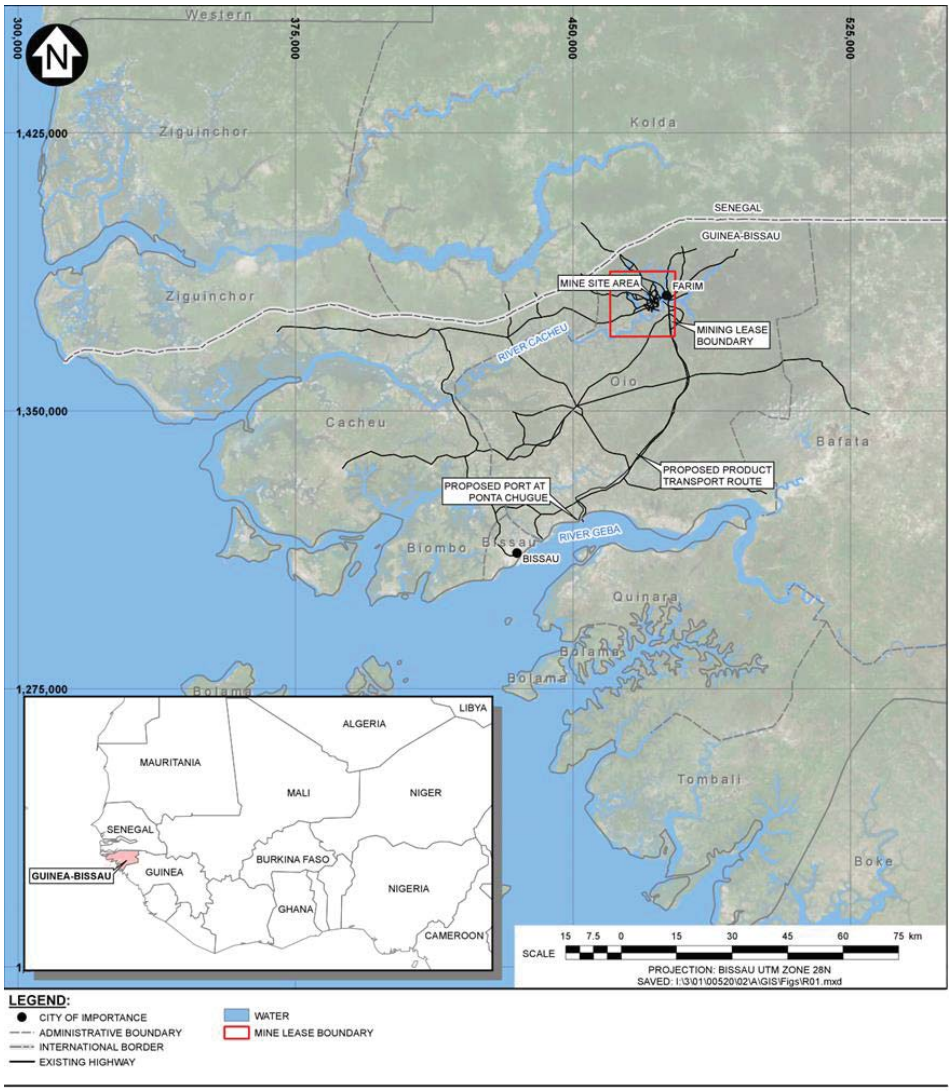


Figure 1: Project locality map (Source: Knight Piésold)

1.1 Study Objectives

- Provide a presentation of available bathymetric information on any of these systems that may need to be crossed.
- Provide details regarding estuarine surface and subsurface current patterns, currents velocities, waves, storm surges and tides in the port LSA
- Provide a high level description of the bottom sediment quality and include grain size, grain mobility, and estuarine bottom stability. A small number of grab samples will be collected, but most of the results will be based on camera tows. This will also be used to identify any reef structures. Where required samples can be collected for further analysis and allowance has been made for 10 samples for physic-chemical testing in an accredited laboratory.
- Provide a description of physical and chemical of the water column properties including temperature, salinity, suspended solids and dissolved solutes
- Provide an overview of the estuarine biological communities occurring within the RSA and LSA, with regard marine mammals and reptiles.

1.1.1 Assumptions:

- No transhipment therefore no marine assessments will be conducted but observations will be made during the surveys with regard the potential impact of increased shipping traffic.
- No dredging will be required (loading facilities and or approach channels) therefore detailed sediment sampling and analyses will not be conducted.

1.1.2 Limitations

- The study was limited to a once off five day on site field assessment.
- Rough conditions on the Geba Estuary limited the amount of sampling which would be undertaken.

2 PROJECT LOCALITY

The regional mine study area, and the Ponta Chugue, the proposed port site as shown in Figure 1, are located on the banks of the River Cacheu and River Geba respectively. Mining product will be transported via a conveyor over the River Cacheu to a truck loading facility and then transported via the existing road to the port site. At the port additional processing and handling will occur, and then loaded onto ships using a ship loader installed on a trestle / wharf structure, with mooring dolphins.

Both aquatic ecosystems represent natural habitats with the banks lined with mangrove forests which have a high conservation value, while the port site also contains a rocky headland, with beach area that is presently utilised by the local fishing groups.

Presently little is known of the long term state and condition of these systems other than the data collected during the Golder 2012/2013 assessments (Golder, 2014a) and the Baird investigations in 2012.

2.1 Relevant legislation and policy

The current Guinea-Bissau national legislation relevant to the proposed project includes the following:

- The National Environmental Management Plan (NFSP, 2004)
- The National Strategy and Action Plan for Biodiversity (2004) sets out the national guidance and areas for conservation and sustainable use of biological diversity
- Law No 1/2011 of 2 March – Approving the Basic Legislation on the Environment. This includes definitions of sanitation, effluents, wetlands and waters
- Law No 10/2011 of 24 September - Environmental Impact Assessment Regulation. This details the projects requiring EIA, which includes mining, construction of roads and abstraction of groundwater, all of which are relevant to the Project.

International

The following international laws are also applicable to this project:

- Convention on Biological Diversity (CBD)
- Convention on Migratory Species (CMS)
- The Basal Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal 1989
- Bamako Convention
- International Convention for the Prevention of Pollution from Ships and Protocol (MARPOL)
- The Rotterdam Convention on Prior Informed Consent (PIC) for certain Hazardous Chemicals and Pesticides in International trade
- Stockholm Convention on Persistent Organic Pollutants (POPs)
- Vienna Convention for the Protection of the Ozone Layer
- Cartagena Protocol on Bio-safety to the Convention on Biological Diversity
- Framework Convention on Climate Change (FCCC)
- Kyoto Protocol of the Climate Change Convention 1997

Similar to the national legislation, the IFC Performance Standards for Environmental and Social Sustainability (IFC, 2012a) provides general guidance by stipulating that impacts that on water resources should be mitigated.

3 METHODS

3.1 Study terms of reference

Bathymetry, wind and wave conditions
• A description of the regional setting within which the proposed conveyor and mooring facility is situated, including climatic conditions, • Details regarding surface and subsurface current patterns, currents velocities, waves, storm surges, and tides in the study area • Assess the baseline and impact of the currents, temperature, waves, and tides linked to regional bathymetry. This data will be supplied by the client • Produce a concise report indicating the baseline conditions within the area • Assess any fatal flaws or risks in the above assessment, identifying any sensitive or no-go areas
Water quality
• Assess the baseline water quality at a minimum of ten selected sites based on the minimum requirements with regard the proposed project actions. This will be dependent on the construction activities and depths at which the activities will occur • Review past studies for the area to provide a better estimate of the regional water quality over a longer term • Conduct a once of survey collecting samples at the surface and at depth • Produce a concise report indicating the baseline conditions within the area • Assess any fatal flaws or risks in the above assessment, identifying any sensitive or no-go areas
Benthic sediments
• Assess the baseline benthic sediment quality at a minimum of ten selected sites based on the minimum requirements with regard the proposed project actions. This will be dependent on the construction activities and depths at which the activities will occur. • Conduct a once of survey collecting samples at the 10 sites identified in collaboration with other specialists • Produce a concise report indicating the baseline conditions within the area • Assess any fatal flaws or risks in the above assessment, identifying any sensitive or no-go areas
Marine mammals & reptiles
• Conduct a once off survey to identify any new or existing populations / migration routes known to occur within the study area • Review any previous studies that were conducted within the area, with special reference to any potential impacts brought about by local shipping traffic. • Produce a concise report indicating the baseline conditions within the area • Assess any fatal flaws or risks in the above assessment, identifying any sensitive or no-go areas.

3.2 Study methods

The survey, five sites within each of the river systems was undertaken was undertaken using available vessels during a five day period in April / May 2015. This corresponds to the later part of the dry season.

Three grab samples were collected at each site using a weighted Van Veen grab (Figure 2 & 3, Plate 1). Two samples were sieved through 500µm mesh and the remaining sediment preserved in 95% ethanol and stored for the identification and assessment of the benthic infauna. These samples were exported to the South African Institute for Aquatic Biodiversity for further sieving and identification of benthic infauna. The third grab sample was stored in a plastic bag and was used for particle size and contaminant analyses. These samples were kept cool and exported to South Africa for further analysis at an accredited laboratory (SGS).

Water quality samples were collected at the same site, using a Niskin Bottle. The 2l samples per were immediately stored in cool box. These were then delivered for analysis at an accredited laboratory. In situ analyses such as temperature, pH and conductivity were taken using a calibrated Lovitech handheld meter. Immediately after the samples were brought to the surface. The results of the variables analysed are contained in Appendix A.

A range of assessment criteria or guidelines were reviewed for use in this study, with the focus being on African Development Bank (AfDB) and World Bank guidelines. However, the only AfDB guidelines that could be accessed were related specifically to mining, with a focus on drinking water and not marine or estuarine related activities. The focus of the World Bank guidelines is on processing wastewaters, stormwater run-off and domestic sewage, rather than activities impacting on the estuarine environment. Where available, results were therefore compared to the World Bank General Environmental Guidelines (World Bank Group, 1998). Where no World Bank standards were available, results were compared to the South Africa, Australian, Canadian, World Bank and World Health Organisation guidelines (Appendix A).

Plate 1: Collecting sediment samples using a Van Veen grab near Ponta Chugue

4 STUDY AREA DESCRIPTION AND RESULTS

4.1 Wind, rainfall, wave, tides and currents

4.1.1 General wind and rainfall

According to wind and precipitation data collected at the Bissau Airport (Station 617660) obtained from the National Oceanic and Atmospheric Administration (NOAA), and verified against Station 619950 in Ziguinchor, that south westerly winds at speeds of less than 6 m/s are most frequently recorded within the study region.

Daytime wind speeds are higher than night time wind speeds, however it would seem that storm winds are infrequent within the country,

Rainfall data recorded from 1973 to 1980 and again from 2007 – 2011, sourced from the Bissau Airport (Baird, 2012) indicated that approximately 95 % of the annual rainfall occurs with the wet season, June to December, with peak rainfall occurring in August and September. The average annual rainfall is approximately 800m for the country, but can vary between 200 and 2300 mm per year.

4.1.2 Wave

Hindcast wave data was used to model predicted wave heights calibrated using the ADCP data collected at three sites in the Geba Estuary (Baird, 2012). Mean wave heights at the Port site were estimated to range between 0.85m and 1.11m during normal wind conditions. During this survey, high winds were experienced, and coupled to the incoming tides, wave heights of between 1.5 and 1.8m were observed.

Due to the conveyor on the River Cacheu being approximately 180km upstream from the coastal region, waves are limited to wind chop less than 50cm in height and is not expected to have an effect on the project activities.

4.2 Bathymetry

4.2.1 River Geba

Several data sources were used by Baird to determine the water depths with regard proposing a suitable design for the ship loading facility and to determine the optimum / safe navigation routes for the shipping activities. Water depths vary between 0-8m near shore and increase to 25 – 30m further offshore near the proposed port site (Figure 2). It was also noted that several sand bars occur 4km from the Ponta Chugue in the main channel (Figure 2). These bars have remained relatively unchanged for the past 30 years based on Landsat imagery (Baird, 2012).

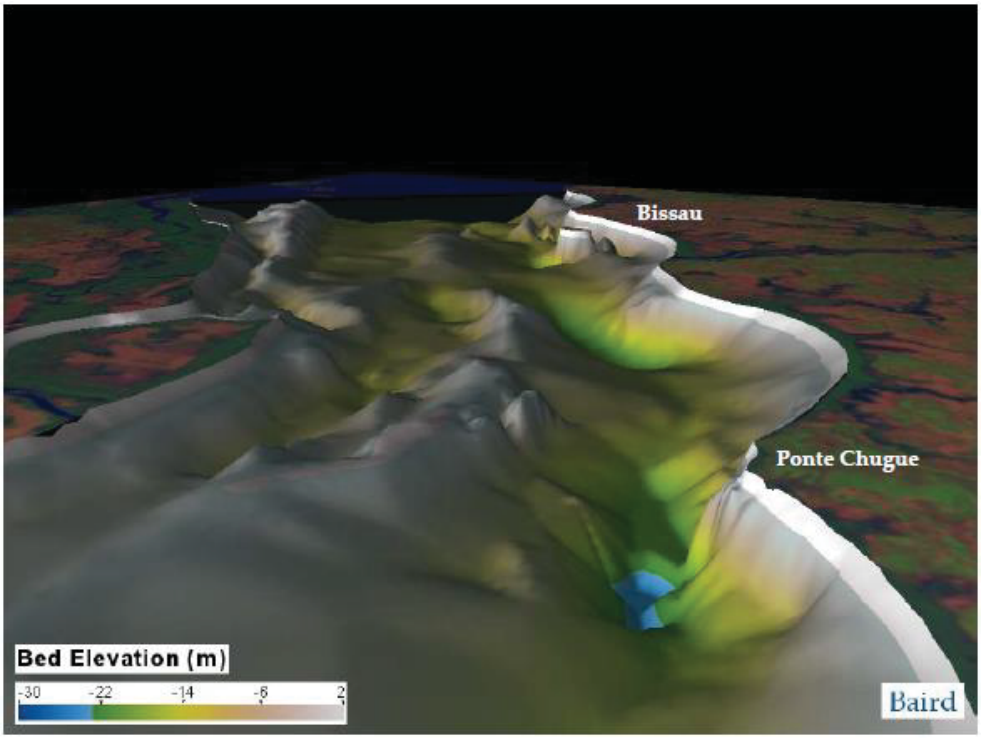


Figure 2: A 3d visualisation of the river bed near Ponta Chugue looking downstream towards Bissau and the coast.

4.2.2 River Cachue

No previous data exists with regard the bathymetry surrounding the proposed conveyor site on the River Cacheu. However depths of the various grab samples taken during the May 2015 surveys ranged between 5 and 20m (maximum) at slack tide.

4.3 Water temperature and salinity

Water temperature ranged from 28 to 28.9^{oC} over the two day sampling period, while the salinity ranged from 32 parts per trillion (ppt) in the dry season to 38 ppt, due to the large volumes of seawater that are exchanged on a daily basis near port (ca. 30km from the open ocean)in the River Geba. Very little variability was shown between the sites due to the strong winds and currents experienced during the survey period.

While in the Rive Cacheu, water temperature ranged from 27 to 30^{oC} along the entire length of the estuary during both dry and wet seasons with no thermal stratification. Salinity at Farim ranged from 2.4 parts per trillion (ppt) in the dry season to 7.2 ppt during the wet season. Dissolved oxygen near the mine site was greater than 4.3 mg/L during wet and dry seasons (Golder, 2014a).

4.4 Water quality

4.4.1 River Geba

No spatial variation could be determined between the 5 sites sampled for water quality (Figure 3), as they showed little variation in the results obtained, indicating the high level of mixing within the water column. Again the high Total Suspended Solids (TSS) values exceeded the World Bank aquatic guide limits, but as previously mentioned the relevance needs to be discussed in relation to the mean annual variation in TSS values. These were markedly higher than those observed in the Cacheu systems possibly due to the scale of the River Geba.

Similarly the River Geba also showed within some of the samples elevated levels of Aluminium, Boron, Manganese, Chromium and Uranium as well as Iron, Arsenic and Molybdenum. This will require additional investigation, but is possible related to the natural geology of the source catchments of these systems. Most these listed exceeded the WHO Drinking water standards, while only Iron, Chromium together with elevated Nutrients (Nitrates and Phosphorus) exceeded the South African marine water quality standards.

4.4.2 River Cacheu

Water column analyses conducted on samples collected both by Golder (2014a) and in the 2015 surveys (Figure 4). The results for the more recent surveys shown Appendix A, were largely similar in terms of metals and other inorganic constituents, and thus acceptable for aquatic life when compared to international aquatic ecological guidelines. Both surveys noted the high turbidity within the system, near Farim but based on the diversity and assemblages of the aquatic fauna, was not limiting to the overall abundance of fish and plankton.

The water quality results when compared to various international standards (South Africa, Australian, Canadian, World Bank and World Health Organisation) indicated that the five sites samples during the 2015 survey where below the acceptable limits for aquatic ecosystems (Appendix A). With one exception being World Bank guideline for Total Suspended Solids (<55mg/l), where three of the samples ranged between 64 – 77 mg/l. Most other guidelines prefer in determining the natural variability of the system, then allowing for a 10 % variation. Due to the natural variability in any given system this is a more acceptable mechanism that could then be used in the monitoring conditions rather than a set value.

Several of the metals analysed were elevated, and although no estuarine / marine related guidelines could be found for these, Aluminum, Boron and Uranium did exceed the World Health Organisation drinking water standards (SC&A, 2015). This is possibly due to the weathering of natural geological formations within the catchment, however the sources are still to be determined. It is unlikely that anyone makes use of the river as a potable water source due to the elevated salinities (Brackish) as most villages and towns make use of wells.

Figure 3: Water quality samples sites along the River Cacheu near Farim

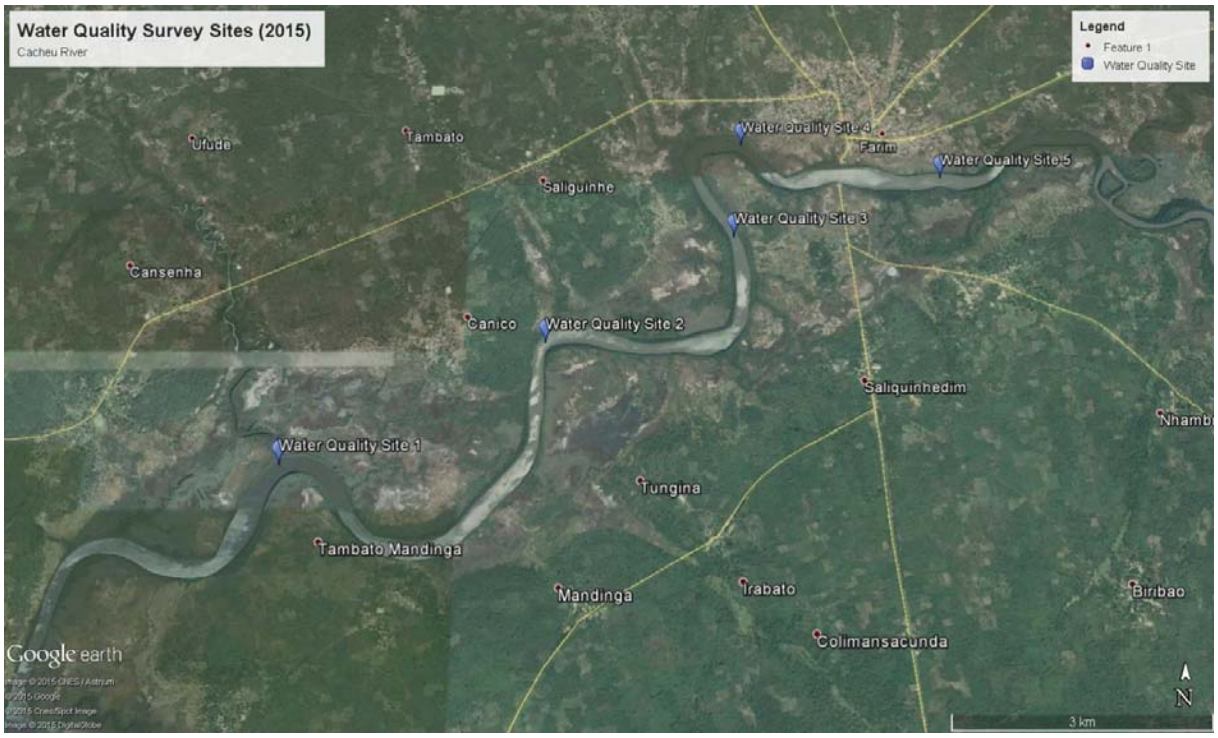


Figure 4: Water quality samples sites along the River Cacheu near Farim

4.5 Benthic sediments

4.5.1 River Geba

Analysis of particle size distribution and contaminant testing was conducted on samples from 5 samples within the 8 grabs sites as shown in Table 1, Figure 5 and Plate 2. Grab depths varied between 5 and 17m.

Three of the five samples were dominated by fine muds and silts and would seem typical of the region, while two sites were dominated by gravels which consisted mostly of weathered bed rock, together with shell fragments. The overall results were consistent with the preliminary geotechnical investigations conducted by Baird (2012). It should be noted although not a development option, these fine materials are difficult to manage when dredged, resulting in large plumes of anoxic material being suspended in the water column resulting in large plumes.

In this regard, according to criteria quoted in Long *et al.* (1995), if an element is below a certain minimum concentration, known as the Screening Level or Effects Low-Range (EL-R), it is deemed uncontaminated. If, however, the concentration level is above a maximum concentration, known as the Maximum Level or Effects Range-Median (ER-M), the material is deemed acutely toxic and not suitable for unconfined sea disposal or disturbance. When mean values lie between the Screening and Maximum Level, material is considered to be moderately contaminated and will require further investigation prior to the decision making process (Table 2).

Jackson (2000) proposed that specific levels be used to assess the sediment disturbance as actions required. These levels provide a range of values that act as a guide for management actions depending on levels of contaminants found in dredged material. All substances are assessed at two levels, with Annex I substances having an Action Level (AL) and Prohibition Level (PL), and Annex II substances having a Special Care Level (SCL) and PL. Sediments with Annex I and II substances at levels below AL and SCL values are considered uncontaminated. The PLs speak for themselves, and any substance present at concentrations exceeding these levels is not suitable for unconfined ocean disposal. Material containing substances at AL or SCL concentrations need to be managed or controlled prior to disturbance (e.g. silt curtains).

Table 2 thus shows that none of the sites sampled would exceed the ANZECC (2000) and Jackson (2000) prohibition levels. In other words, if the sediments are disturbed, particularly near the proposed jetty, none of the heavy metals contained in the fine sediments would pose a risk to any aquatic organisms, as well as humans.

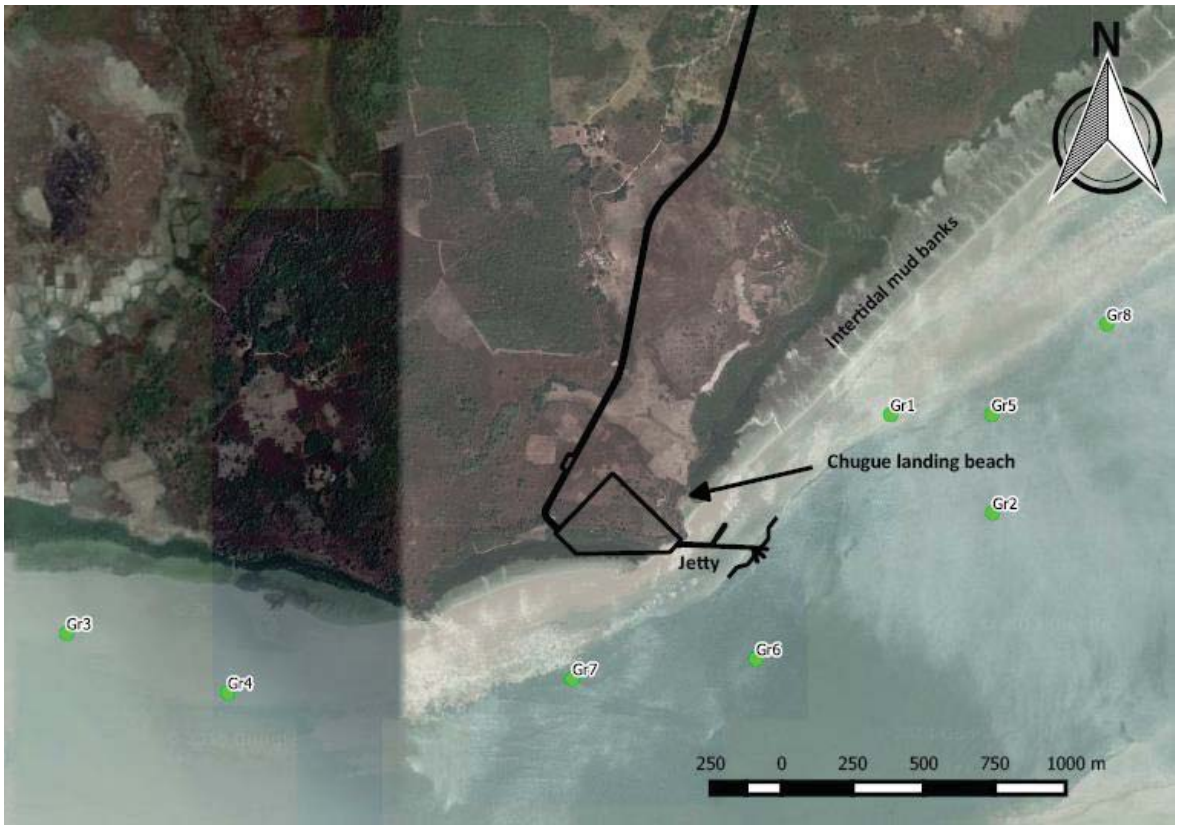


Figure 5: Grab sample localities on the River Geba taken in May 2015

Table 1: Sediment particle size fraction analysis results for the River Geba grab samples

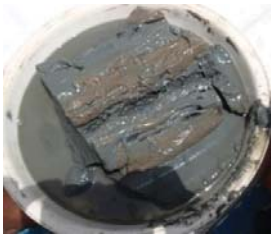
Site	% sediment particle size proportion per sample				
	Cobbles & Boulders	Gravel	Sand	Silt	Clay
1	0	0	0	18	82
2	0	1	0	15	84
3	0	45	0	10	45
7	0	0	0	17	83
8	0	35	0	5	60

Table 2: Results of the sediment samples analysed (metals) for the Geba Estuary when compared to international guidelines when possible disturbance is required

Element (µg/g)	EL-R	ER-M	Action Level/ Special Care	Prohibition	Canadian Environmental Quality Guidelines (CCME, 1999)		Sites				
	ANZECC (Long *et al 2000*)		Jackson (2000)		Interim Sediment Quality Guidelines	Probable Effects level	1	2	3	7	8
Arsenic	20	70	30 – 150	>150	5.9	17	1.2	4.2	3.1	1.8	4.5
Cadmium	1.5	10	1.5 – 10	>10	0.6	3.5	0.01	0.14	0.01	0.01	0.01
Chromium	80	370	50 – 500	>500	37.3	90	3.5	8.4	12.5	36.4	7.2
Copper	65	270	50 – 500	>500	35.7	197	2.4	4.1	5.6	8.4	4.2
Lead	50	220	100 – 500	>500	35	91.3	4.5	7.8	4.2	4.5	4.3
Mercury	0.15	1	0.5 – 5	>5	0.17	0.486	0.01	0.01	0.01	0.01	0.01
Nickel	21	52	50 – 500	>500	No data	No Data	5.1	6.7	3.91	5.7	2.4
Silver	1	3.7	No data	No Data	No Data	No Data	0.01	0.01	0.01	0.01	0.01
Zinc	200	410	150 – 750	>750	123	315	0.01	0.01	0.01	0.01	0.01

Geba 1a

Geba 1b



Geba 1c

Geba 2a

Geba 2b

Geba 2c

Geba 3a

Geba 3b

Geba 3c

Geba 4a

Geba 4b

Geba 4c

Geba 7a

Geba 7b

Geba 7c

Geba 5a

Geba 8a

Geba 8b

Plate 2: Sediment characteristics from grab samples at the Geba Estuary

4.5.2 River Cacheu

Five grab sample were also collected on the River Cacheu in close proximity to the mine and conveyor site (Figure 6). The results obtained are shown in Table 3 & 4 below, but were similar in composition when compared to the River Geba (chemically and in particle size distribution classes). The samples were thus dominated by (Plate 3) by silty clays and gravelly clays, that contained levels of metal elements that don't exceed any international guidelines with regard disturbance (Table 4) i.e. special care or prohibition levels, particularly Site 4, where the conveyor will be installed thus disturbing the river bed.

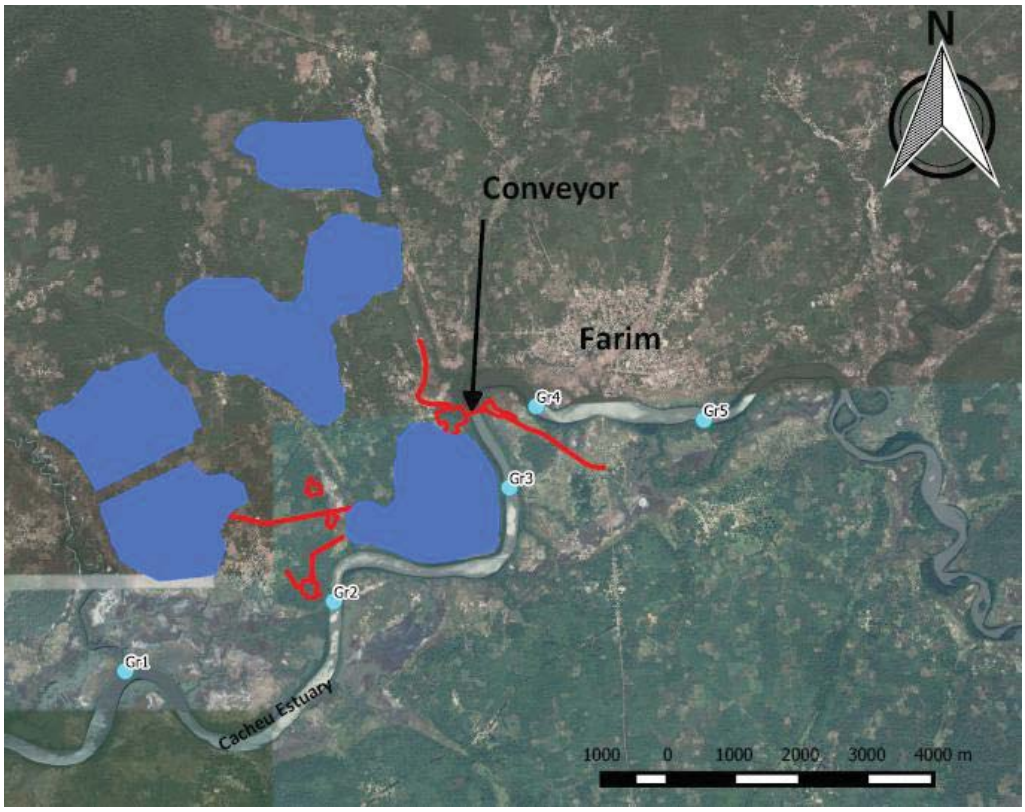


Figure 6: Grab sample sites on the Cacheu Estuary

Table 3: Sediment particle size fraction analysis results for the River Cacheu grab samples

Site	% sediment particle size proportion per sample				
	Cobbles & Boulders	Gravel	Sand	Silt	Clay
1	0	5	2	15	78
2	0	0	5	10	85
3	0	2	5	11	82
4	0	2	5	17	76
5	0	0	10	10	80

Cacheu 1a

Cacheu 1b

Cacheu 1c

Cacheu 2a

Cacheu 2b

Cacheu 2c

Cacheu 3a

Cacheu 3b

Cacheu 3c

Cacheu 4a

Cacheu 4b

Cacheu 4c

Cacheu 5a

Cacheu 5b

Cacheu 5c

Plate 3: Photographic records of triplicate grab samples from the Cacheu Estuary.

Table 4: Results of the sediment samples analysed (metals) for the Cacheu Estuary when compared to international guidelines when possible disturbance is required

Element (µg/g)	EL-R	ER-M	Action Level/ Special Care	Prohibition	Canadian Environmental Quality Guidelines (CCME, 1999)		Sites				
	ANZECC 2000(Long *et al 1995*)		Jackson (2000)		Interim Sediment Quality Guidelines	Probable Effects level	1	2	3	4	5
Arsenic	20	70	30 – 150	>150	5.9	17	4.2	3.5	4.12	2.2	3.1
Cadmium	1.5	10	1.5 – 10	>10	0.6	3.5	0.2	0.15	0.01	0.01	0.35
Chromium	80	370	50 – 500	>500	37.3	90	4.4	12.5	25.6	25.4	3.2
Copper	65	270	50 – 500	>500	35.7	197	2.1	3.2	1.2	0.4	0.01
Lead	50	220	100 – 500	>500	35	91.3	3.2	4.1	1.4	0.21	0.02
Mercury	0.15	1	0.5 – 5	>5	0.17	0.486	0.01	0.01	0.01	0.01	0.01
Nickel	21	52	50 – 500	>500	No data	No Data	4.5	8.1	3.21	4.56	2.01
Silver	1	3.7	No data	No Data	No Data	No Data	0.52	0.12	0.01	0.01	0.01
Zinc	200	410	150 – 750	>750	123	315	1.2	2.3	4.5	1.2	1.3

4.6 Marine mammals, birds and reptiles

The Government of Guinea-Bissau has protected the country's biodiversity by setting aside and managing approximately 536,972 hectares of its territory in six coastal and marine protected areas. Protected areas near the Project include the Rio Cacheu Mangrove Natural Park, the Varela National Park and the Pelundo Faunal Reserve (Figure 7).

These protected areas were largely defined to firstly protect the natural coastal habitats and forests, but more importantly provide protection for several important species of marine mammals and reptiles that occur in high numbers along the Guinea-Bissau coast line. None of these protected areas are located near the mine or proposed port site due to the lack of habitat for these particular species.

The West African sub region supports a diverse marine mammal fauna. Six baleen whale species and 22 toothed whale and dolphin species most likely occur in the region. Three of these whale species are endangered (blue and fin whales), two are vulnerable (i.e. humpback and sperm whales) and several others are in lower-risk categories. Coastal areas and offshore of West Africa are possible breeding and nursery areas for the humpback whale, which migrates along the coast of Southern Africa to mate, calve, and nurse its young during the austral winter.

Observations of these species within the Project area was assessed during the Golder baseline studies with particular reference to potential impact of shipping collisions with these species, water quality and food resources impacts and the disturbance of any turtle nesting sites within the Project area. This is due to the lack of available habitat such as sandy beaches for turtle nesting sites, as well as seagrass beds for food (turtles and West African manatee). However these maybe be encountered by shipping traffic from the proposed port area on route to the open ocean.

The presence of crocodiles was discussed in the Terrestrial report (Hudson, 2015), but no specimens were observed during the 2015 surveys near the Port site.

Source: Protected Planet, 2015

Figure 7: Guinea-Bissau Protected Areas

5 CONCLUSION AND RECOMMENDATIONS

The Project will interact with two estuarine environments: the Mine Site is located adjacent the River Cacheu, and the Port Site is located on the River Geba. Both aquatic ecosystems represent natural habitats with the banks lined with mangrove forests which have a high conservation value.

Potential impacts that will need to be assessed with regard the biophysical estuarine environments and will be addressed in the Section 14 of the ESHIA include:

- Construction of a closed conveyor over the river, which will be founded on concrete piers located within the River Cacheu
- Constructing the wharf at the Port Site during the construction phase
- Ship loading activities during the operation phase
- Discharges of mine effluent to the River Cacheu

However due to present day conditions, high silt and clay loads within the water column and sediments, which are low in pollutants, no fatal flaws or sensitive water column or benthic related habitats were observed in both river systems. This is also coupled to the fact that both systems are highly dynamic systems, which are large in extent and lack any aquatic habitat complexity such as reefs etc..

With regard Turtles and their breeding sites, observations of these species within the Project area were assessed during the Golder baseline studies with particular reference to potential impact of shipping collisions with these species, water quality and food resources impacts and the disturbance of any turtle nesting sites within the Project area. This is due to the lack of available habitat such as sandy beaches for turtle nesting sites, as well as seagrass beds for food (turtles and West African manatee) within the project area these are not anticipated. However these maybe be encountered by shipping traffic from the proposed port area on route to the open ocean.

The presence of crocodiles was discussed in the Terrestrial report (Hudson, 2015), but no specimens were observed during the 2015 surveys near the Port site.

6 REFERENCES

Aquatic Ecosystem Services (2015). Fish, Fisheries and Infaunal Assessment, Farim Phosphate Project, Guinea-Bissau.

Australian Water Quality Guidelines for Fresh and Marine Waters (2000). Australian and New Zealand Environment and Conservation Council, Australia.

Baird and Associates Coastal Engineers Ltd. (Baird). 2012. Farim Phosphate Beneficiation Option Study prepared for GBM MEC Minerals Engineering Consultants Limited on September 24, 2012. pp 120.

Golder Associates (UK) Ltd. 2013. River morphology and physical oceanography baseline study. Farim Phoshate Project, Guinea-Bissau. Report Number: 13514950220.503/B.0.

Golder Associates (UK) Ltd. 2014a. River Cacheu Aquatic Ecology baseline Study. Farim Phoshate Project, Guinea-Bissau. Report Number: 13514950200.508/B.0.

Golder Associates (UK) Ltd. 2014b. Mine component environmental and social impact assessment Volume 2. Farim Phoshate Project, Guinea-Bissau. Report Number: 13514950201.550-2/A.0.

Hudson Ecology (2015). Terrestrial ecology baseline study farim phosphate project, Guinea-Bissau Report Number: 2015/009/01

Long, E.R., MacDonald, D.D., Smith, S.L. and F.D. Calder. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments, Environmental Management, 19(1): 81-97.

7 APPENDIX A- WATER QUALITY RESULTS

		River Geba					River Cacheu								
Client Sample No		**Site1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 1 SL**	**Site 2 SL**	**Site 3 SL**	**Site 4 SL**	**Site 5 SL**	**World Bank Guidelines**	**SWAWQGL**	**International**	**WHO (Drinking water)**
Sample Date		09/06/2015	09/06/2015	09/06/2015	09/06/2015	11/06/2015	08/06/2015	08/06/2015	08/06/2015	08/06/2015	08/06/2015				
Bottom Depth															
Acid neutralizing capacity (alkalinity) as CaCO3 pH 4.5	mg CaCO3/L	107	104	108	107	105	110	107	104	102	104				
Aluminium	µg/L	2.66	5.20	39.8	7.55	2.25	<2.00	<2.00	9.08	<2.00	<2.00				100 - 200
Aluminium	µg/L	98.8	3970	9320	2740	5530	518	491	463	444	485				
Ammonia	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		<0,02	< 0,5 (Australia)	
Ammonia and ammonium ions	mg/L	0.112	0.096	0.081	0.072	0.072	0.084	0.075	0.153	0.095	0.064				
Ammonia as N	mg/L	0.087	0.075	0.063	0.056	0.056	0.065	0.058	0.119	0.074	0.050				
Antimony	µg/L	0.207	0.129	0.127	0.188	0.145	<0.050	<0.050	<0.050	<0.050	<0.050				20
Antimony	µg/L	0.270	0.196	0.199	0.257	0.165	0.054	<0.050	0.053	<0.050	<0.050				
Arsenic	µg/L	2.23	2.71	1.83	2.85	3.05	0.447	0.822	0.528	0.680	0.582		12		10
Arsenic	µg/L	2.95	5.87	11.0	4.84	8.69	1.06	1.15	1.13	1.49	0.842				
Barium	µg/L	10.9	10.0	8.83	10.2	10.9	58.3	55.1	48.7	44.6	38.6				700
Barium	µg/L	12.4	15.0	16.5	11.9	17.3	69.0	60.2	54.7	51.0	41.0				
Beryllium	µg/L	0.33	0.31	0.37	0.41	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20				
Beryllium	µg/L	1.15	0.64	1.21	0.53	0.87	0.47	0.38	0.31	0.28	0.28				
Bismuth	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0				
Bismuth	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0				
Boron	µg/L	3770	4200	3890	3940	3250	818	820	852	923	1050				500
Boron	µg/L	4220	4200	4610	4300	3770	920	1010	982	1080	1340				
Bromide	mg/L	65.7	61.9	66.6	65.3	70.4	13.9	16.6	15.4	15.2	22.1				
Cadmium	µg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	100	4		3
Cadmium	µg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020				
Calcium	mg/L	416	423	468	445	299	94.3	94.8	95.8	103	109				

Calcium	mg/L	416	423	468	445	358	113	127	124	132	156				
Calcium Hardness	mmol/L	10.4	10.6	11.7	11.1	7.47	2.35	2.37	2.39	2.57	2.72				
Chloride	mg/L	18000	17600	18100	17800	17900	3490	4340	4260	4360	5320				
Chromium	µg/L	0.424	0.206	0.383	0.261	0.291	<0.200	0.213	<0.200	<0.200	<0.200	500	8	0,05 (Australia - Hexavalent)	5
Chromium	µg/L	0.520	21.9	59.1	14.7	35.1	1.70	1.59	1.49	1.65	1.47				
Cobalt	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050				
Cobalt	µg/L	0.068	2.98	8.94	91.7	5.16	1.25	1.17	1.17	0.882	0.839				
Copper	µg/L	2.4	2.0	2.8	3.6	3.1	2.0	<1.0	1.5	1.0	<1.0	500	50		2000
Copper	µg/L	6.5	4.1	5.2	2.9	4.0	2.3	1.1	1.5	1.3	1.8				
Dissolved Organic Carbon	mg/L	<2.50	<2.50	<2.50	<2.50	<2.50	7.03	6.74	6.28	6.67	6.50				
Dissolved solids dried at 105 °C	mg/L	31400	32300	31800	32700	30700	7160	7260	7320	7900	9400				
Electrical Conductivity @ 25°C	µS/cm	77000	67900	80000	76900	80800	19200	19900	21000	22200	25200				
Hardness	mmol/L	53.2	55.4	53.8	53.8	45.6	12.1	12.3	12.8	14.1	15.3				
Hardness as CaCO3	mg CaCO3/L	5320	5540	5380	5380	4560	1210	1230	1280	1410	1530				
Iron	µg/L	2.6	2.6	7.2	2.4	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3500			3000
Iron	µg/L	25300	10400	27700	6200	16400	1670	1650	1380	1340	1410				
Lead	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	100	12		10
Lead	µg/L	0.091	2.75	7.20	1.98	4.30	1.02	0.470	0.614	0.702	0.344				
Lithium	µg/L	58.8	42.0	50.1	35.8	69.6	3.1	4.1	5.4	6.0	8.4				
Lithium	µg/L	74.8	71.4	73.2	61.8	61.4	<1.0	<1.0	<1.0	3.6	7.1				
Magnesium	mg/L	1040	1090	1020	1040	928	236	242	252	279	306				
Magnesium	mg/L	1130	1140	1200	1110	984	239	276	272	307	376				
Magnesium Hardness	mmol/L	42.8	44.9	42.1	42.7	38.2	9.72	9.95	10.4	11.5	12.6				
Manganese	µg/L	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100				400
Manganese	µg/L	2.03	145	436	93.2	252	305	243	194	161	124				
Mercury	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0,3		6
Mercury	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010				
Molybdenum	µg/L	8.9	4.3	1.8	5.4	2.4	<1.0	<1.0	<1.0	<1.0	<1.0				7
Molybdenum	µg/L	9.0	4.4	2.0	5.5	2.5	<1.0	<1.0	<1.0	<1.0	<1.0				
Nickel	µg/L	0.561	0.578	0.950	0.820	0.762	1.83	1.04	1.55	0.844	0.942	500	25		7

Nickel	µg/L	0.832	4.45	12.2	3.38	7.52	1.87	1.94	1.85	2.31	1.85				
Nitrate as N	mg/L	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300		<0,42	0,01-0,06 (Australia)	5000
Nitrates	mg/L	<1.33	<1.33	<1.33	<1.33	<1.33	<1.33	<1.33	<1.33	<1.33	<1.33				
Nitrite + Nitrate as N	mg/L	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300				
Nitrite as N	mg/L	<0.0200	<0.0200	<0.0200	<0.0200	<0.0200	<0.0200	<0.0200	<0.0200	<0.0200	<0.0200		<0,0014		3000
Nitrites	mg/L	<0.0658	<0.0658	<0.0658	<0.0658	<0.0658	<0.0658	<0.0658	<0.0658	<0.0658	<0.0658				
pH Value	-	7.63	7.71	7.77	7.79	7.79	7.69	7.69	7.70	7.68	7.64	6 - 9			
Phenol Index	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
Potassium	mg/L	451	442	477	435	502	109	128	128	134	152				
Potassium	mg/L	528	452	520	521	504	109	128	129	146	187				
Selenium	µg/L	0.995	0.736	1.16	1.30	1.47	<0.200	<0.200	<0.200	<0.200	<0.200				10
Selenium	µg/L	1.00	1.54	1.23	1.39	1.50	<0.200	<0.200	<0.200	<0.200	0.483				
Silicon	mg/L	2.69	2.56	2.43	2.17	1.98	1.60	1.53	1.51	1.68	2.04		<5,0		
Silicon	µg/L	24100	13700	26000	8790	16800	2600	2720	2560	2840	3670				
Silver	µg/L	1.0	1.2	<1.0	<1.0	2.1	<1.0	<1.0	<1.0	<1.0	<1.0		5		
Silver	µg/L	<1.0	<1.0	<1.0	<1.0	1.0	<1.0	<1.0	<1.0	<1.0	<1.0				
Sodium	mg/L	10600	10500	10200	10300	9710	2080	2280	2360	2560	2800				
Sodium	mg/L	11200	11700	11400	10400	10500	2210	2420	2390	2630	3300				
Strontium	mg/L	5.58	5.52	5.68	5.25	4.69	1.12	1.16	1.20	1.33	1.49				
Strontium	µg/L	6210	6840	6380	6580	6280	1410	1640	1650	1800	1950				
Sulphate as SO4 2-	mg/L	2410	2220	2320	2270	2320	258	336	358	349	551				
Suspended solids dried at 105 °C	mg/L	**1850**	**344**	**1520**	**229**	**1130**	**66.2**	**64.8**	**70.9**	48.8	42.5	**55**	Less than 10% natural variation in ambient conditions		
Thallium	µg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50				
Thallium	µg/L	<0.50	<0.50	0.58	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50				
Tin	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		0,5 - 3,0		
Tin	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0				
Titanium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010				
Titanium	µg/L	23.4	21.4	25.5	18.1	19.0	7.0	5.7	4.0	4.7	7.6				
Total Kjeldahl Nitrogen as N	mg/L	3.02	1.36	1.20	1.06	1.86	1.03	1.03	0.92	0.82	0.85				

Total Nitrogen as N	mg/L	3.0	1.4	1.2	1.1	1.9	1.0	1.0	<1.0	<1.0	<1.0				
Total Organic Carbon	mg/L	<2.50	<2.50	<2.50	<2.50	<2.50	7.56	6.81	6.56	6.82	6.56				
Total Phosphorus as P	mg/L	0.553	0.253	0.432	0.174	0.392	0.052	0.043	0.025	0.027	0.026		<0,07		
Turbidity	ZFn (NTU)	699	237	676	150	430	42.1	31.2	28.2	22.0	27.6		Less than 10% natural variation in ambient conditions		
Uranium	µg/L	3.54	3.27	3.20	3.30	3.39	<0.50	<0.50	<0.50	<0.50	<0.50				0,015
Uranium	µg/L	4.00	3.73	4.51	3.52	4.09	0.50	0.45	0.46	0.46	0.47				
Vanadium	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0				
Vanadium	µg/L	18.8	8.4	21.5	4.3	12.8	2.2	2.6	1.8	2.3	1.8				
Zinc	µg/L	10.8	8.1	21.8	15.4	5.4	2.1	4.3	<2.0	4.4	<2.0	2000	25		3000
Zinc	µg/L	42.2	13.6	27.4	19.4	24.9	24.4	12.2	9.6	9.1	4.8				

NOTES:

Metals analyses are presented for two different analytical methods

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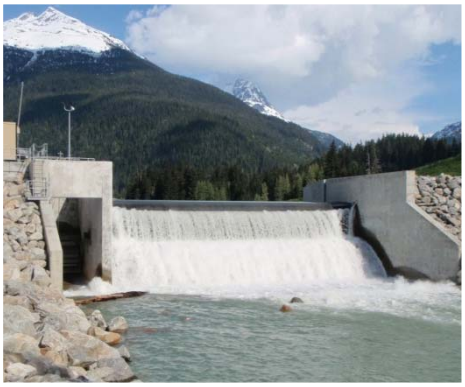

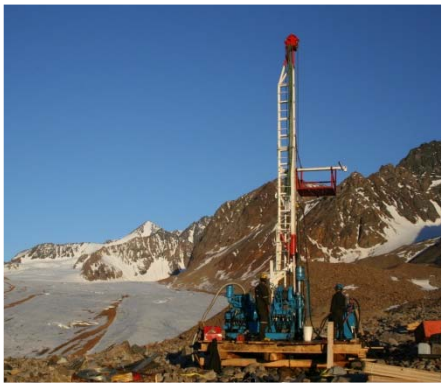

NOISE MODELLING
FINAL REPORT

PREPARED FOR:

Lycopodium Minerals Canada Ltd.
5060 Spectrum Way, Suite 400
Mississauga, Ontario
Canada, L4W 5N5

PREPARED BY:

Knight Piésold Consultores S.A.
Calle Aricota 106, 5° Piso, Santiago de Surco
Lima 33, Perú
t. +51.1.202.3777 • f. +51.1.202.3778

Knight Piésold
CONSULTING
www.knightpiesold.com

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Lycopodium Minerals Canada Ltd. Environmental and Social Impact Assessment for the Farim Phosphate Project

Noise Modelling Final Report

August 2015

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Lycopodium Minerals Canada Ltd.
Environmental and Social Impact Assessment for the Farim Phosphate Project

Noise Modelling
Final Report

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Noise Modelling
Final Report

1.0 Introduction

This report provides information on the effect of sound propagation produced by main sources throughout the operations stages, such as mining, haulage and storage activities during of year 2, 8, 15 and 25. The year 2 comprises the operating activities of South Open Pit, the year 8 comprises the exploitation of North and South Open Pit, and years 15 and 25 comprise only the exploitation of North Open Pit. The activities include the operation of the pit, mining of ore and waste, hauling equipment and transport of phosphate concentrate to the port Ponta Chugue for further shipment by vessel. As part of the Environmental and Social Impact Assessment (ESIA) for the Farim Phosphate Project, noise propagation has been modelled, which has allowed quantifying impacts caused by the project within the environmental baseline area.

The input data used to estimate noise propagation and specific for this project was provided by Lycopodium Minerals Canada Ltd (Lycopodium, 2014) in coordination with Knight Piésold North Bay (KP North Bay). This data is related to Life-of-Mine (LOM), type and number of equipment per year, isometric view of the facilities (port and mine facilities) and general arrangement of facilities.

In terms of methodology, the computer program used for modelling air quality noise propagation was SoundPLAN, version 7.2 (Braunstein+Berndt GMBH, 2012); which allowed the impacts quantification produced by project activities during different years of the project.

2.0 Objectives

The specific objectives of the study were:

- To prepare and inventory of noise emissions produced by the project's operating phases for year 2, 8, 15 and 25.
- To quantify impacts on noise quality induced by activities to be executed during the project's operating phases.

3.0 Noise Quality Standards – Farim Phosphate Project

The present section describes the applicable regulations related to protection of the environmental quality of noise. According to International Finance Corporation (IFC, 2007), noise impacts should not exceed the levels presented in Chart 3.1, or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site. The IFC Guidelines values, shown below, are for noise levels measured out of doors.

Chart 3.1
Noise Guideline Levels

Receptor	One hour L_{Aeq} (dBA)	
	Daytime 07:00 – 22:00	Night-time 22:00 – 07:00
Residential, institutional and educational	55	45
Industrial, commercial	70	70

Prepared by Knight Piésold Consultores
Source: IFC EHS Guidelines (IFC, 2007).

The criterion considered for assessing the results obtained at discrete receptors close to vehicle traffic was the one established by the OECD (Organization for Economic Cooperation and Development). This standard considers a value below 65 dB(A) to be an acceptable noise level for the daytime period, and a value below 55 dB(A) to be acceptable for the night-time period (OECD, 2001).

4.0 Methodology

4.1 Project information

The Farim Phosphate Project consists of phosphate extraction through mining of two open pits in a 25 year period. The South Open Pit will be mined between years 0 and 8, while the North Open Pit will be mined between years 8 and 26. Scenarios by year of operation, which were selected due to the maximum amount of ore extraction where high noise levels are expected due to earthmoving, use of machinery and vehicle traffic, as well as noise sources location close to adjacent towns, are shown in Graph 4.1.

According to project information, operation activities at the mine site will be conducted around the clock 365 days a year (Lycopodium, 2014). The list of equipment to be used in years 2, 8, 15 and 25 is shown in Chart 4.1.

Chart 4.1
Summary - Number of equipment units

Description	2	8	15	25	Engine power kW (1)
	2018	2024	2031	2041	
Caterpillar 374DL - Excavator	3	3	3	3	355
Caterpillar 336DL - Excavator	1	1	1	1	200
Caterpillar 992K - Wheel Loader	6	7	8	8	607
Caterpillar D9R - Dozer	5	6	6	7	302
Caterpillar 777G - End Dump Truck	17	19	32	20	704
Caterpillar 770 - End Dump Truck	6	8	8	12	355
Caterpillar 16M - Motor Grader (2)	3	3	3	3	221
Caterpillar CS-56 - Compactor	6	7	7	8	116
Caterpillar 428F - Backhoe Loader	1	1	1	1	66.2
Caterpillar 770 - Water Truck	2	2	2	2	355
Fuel/Lube Truck	3	4	4	4	-
Mechanic's Truck	2	2	3	2	-
Pickup Truck	12	12	12	12	-
Liebherr LTM 1095 - Mobile Crane	1	1	1	1	-
Welding Machine	2	2	2	2	-
Light Plant	10	12	13	14	-
Screening Plant	1	1	1	1	-

Prepared by Knight Piésold Consultores.
Notes:
(1) Technical sheet of equipment.

The mine area in Farim will comprise two open pits, process plant, topsoil stockpiles, tailings storage facilities, haulage roads, conveyor belts, phosphate concentrate loading zone and a paved road for phosphate concentrate transport. The mine area general layout is shown in Figure 4.1; the phosphate concentrate transport route between the mine site and Ponta Chugue Port, which have also been included in the noise levels inventory, is shown in Figure 4.2.

Concentrate storage and shipping facilities will be located in the Ponta Chugue Port area, as shown in Figure 4.3.

Regarding phosphate concentrate transport from the Farim mine site to Ponta Chugue Port, this activity will be carried out between 06:00 and 20:00 hours (Lycopodium, 2014). Concentrate storage facilities in Ponta Chugue Port will comprise covered conveyor belts as well as roofed storage areas and stockpile encapsulation.

4.2 Meteorological data

Meteorological data entered in the SoundPLAN model corresponds to average information from Farim Weather Station. Temperature was set at 25°C and relative humidity at 71%, which are considered meteorological values that are representative for the study area. The Chart 4.2 shows the frequency and wind speed according each wind direction sectors.

Chart 4.2
Wind data entered to SoundPLAN model
Farim Weather Station

Wind direction	Frecuency (%)	Mean wind speed (m/s)
0	4.2	1.6
30	6.4	1.7
60	8.3	1.7
90	3.1	1.5
120	2.5	1.3
150	2.6	1.2
180	3.0	1.2
210	9.1	1.4
240	14.8	1.6
270	9.1	1.5
300	3.4	1.3
330	3.1	1.4
Calm (*)	30.4	0

Prepared by Knight Piésold Consultores.
* Less than to 0.5 m/s
Base on the meteorological hourly data from Farim Weather Station.

4.3 Background of noise quality

According to noise baseline prepared by Golder, (2014), the noise environment across the area was dominated by natural noises with anthropogenic noise predominantly limited to the conversation and activities of villagers. Natural noise includes weather-induced noise (e.g., rustling of vegetation in wind), running water (rivers and waterfalls), and human and animal activity. There is no electricity in any of the villages in the study area, so little mechanical noise is generated.

Baseline noise monitoring by Golder (2014) was undertaken at twelve representative locations across the study area during the wet season of 2012, and two locations during the dry season was sampled by Knight Piésold (2015) for May 9th and 10th 2015. The lowest measured hourly background noise levels at each location during both the daytime and night-time periods are presented in Table 4.1.

The results corresponding to the wet season are representative of all conditions since the lowest average base line measurements were taken in order to disregard the influence of noise generated by rain and wind during monitoring performed in 2012. On the other hand, dry season conditions are considered to be representative of the year since no precipitation was recorded during monitoring.

Based on information provided and shown in Table 4.1, noise equivalent values have been determined per period (daytime and night-time), noise levels for the daytime period varied between 44.5 and 63.0 dB(A), while for the night-time period the values varied between 44.3 and 63.8 dB(A).

On the other hand, values exceeding IFC standards were recorded in majority during the night-time except in the Binta station. The higher evening noise level may be attributable to nocturnal wildlife activity, particularly toads and crickets, as was observed during the survey (Golder, 2014). During the daytime, the value recorded in Chief Village exceeds the IFC standards.

4.4 Noise emissions inventory of the Farim Phosphate Project

Preparation of the noise map generated by sources under consideration was based on the modeling methodology of ISO 9613 standard: Acoustics – Attenuation of sound during propagation outdoors, parts 1 and 2, which uses the principles of divergent attenuation along with additional attenuation introduced by obstacles and atmospheric attenuation. The ISO 9613 algorithms were used by executing the SoundPLAN 7.2 (software for noise propagation in the atmosphere). The SoundPLAN 7.2 is used by over 5,000 users including governments, consultants and researchers in more than 40 countries and is the leading program in the world for prediction of atmospheric propagation of noise (Hadzi-Nikolova, Mirakovski,

Ristova, & Ceravolo, 2012). Variables that influence propagation and that have been included in the SoundPLAN program are the following:

- Geometric divergence (Graphs 4.2 to 4.4);
- Atmospheric absorption;
- Ground effect;
- Surface reflections; and
- Shielding by obstacles.

The model input variables regarding noise emissions are the sound power of noise sources for each site considered. The exclusive contribution generated by the Project sources was modeled, based on data related to the spatial geometry of sources. Also, data from average meteorological behavior was entered based on records from the meteorological station at Farim Weather Station (2012 – 2015). Calculation of sound propagation was configured in the model for a resolution of 10 m grid cell size. Graphs 4.2 to 4.4 show the geometric design in Process Plant, Truck Loading Facility and the Port Site, according to general arrangement of the Farim Phosphate Project published by Lycopodium.

Installation of a concrete perimeter wall, 2 meter high, in order to reduce noise levels generated at Ponta Chugue Port, is shown in Graph 4.4.

In accordance with the ISO 9613 standard, propagation of noise generated by a given source towards a receptor is represented through the following mathematical expression:

$$L_{fT}(DW) = L_w + D_c - A$$

Where,

L_{fT} (DW)	: Equivalent sound pressure level by bands;
L_w	: Sound power level by octave bands in decibels produced by the point sound source relative to a reference sound power of 1 picowatt (1pW);
D_c	: Correction by directivity in decibels, describing the extent to which sound waves are diverted into a specific direction from the level of a point sound source.
A	: Attenuation by octave bands in decibels during propagation from a point source to the receptor.

The A attenuation term is given by the following equation:

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$$

Where,

A_{div}	: Attenuation by geometric divergence (ISO-9613);
A_{atm}	: Attenuation by atmospheric absorption (ISO-9613);
A_{gr}	: Attenuation by ground effect (ISO-9613);
A_{bar}	: Attenuation by barrier effect (ISO-9613);
A_{misc}	: Attenuation by other similar effects (ISO-9613)

4.4.1 Mines site

The sound power levels were obtained from the Guide "Update of noise database for prediction of noise on construction and open sites" (DEFRA, 2005). The emissions sources by each year of operation (years 2, 8, 15 and 25) are shown in the Figures 4.4 to 4.7.

The Table 4.2 shows noise emission estimations due to the use of heavy equipment which will be used in the Open Pits, Tailing Storage Facility and Integrated Waste Landform (IWL) during each year considered. These are excavators, wheel loaders, dozers, motor graders and compactors according to project information.

Noise emission estimation for equipment installed in Concentrator Plant is shown in Chart 4.3, where it is seen that emissions are mainly generated by conveyor belts, pressure pumps used in various processes and scrubbers. Estimation of spectral level emissions (frequencies between 63 Hz and 8 kHz) was determined by means of the ISO 8297:1994 standard and "Update of noise database for prediction of noise on construction and open sites" (Defra, 2005).

Estimations corresponding to material movement, loading and unloading are shown in Chart 4.4 and were performed for each material transport area and storage areas.

As to noise emissions from diesel generators at the mine zone, these were determined based on sound power levels from the guideline (DEFRA, 2005). The values are shown in Chart 4.5

The emission estimation method of the Guide du Bruit was used for daily traffic emissions estimation, which was calculated using the SoundPLAN model based on daily vehicle traffic data during 24 hours. Vehicle traffic values for material haulage at the mine site are shown in Chart 4.3.

Chart 4.3
Average daily traffic of heavy truck for haulage road in Mine Site

Scenario	Lineal source		Average daily traffic (ADT) [1]
	From	To	
Year 2	South Pit	Integrated Waste Landform (IWL)	27
		South Pit	40
		North-East Waste Dump	7
		ROM Stockpile	11
	ROM Stockpile	ROM bin grizzly	52
Year 8	South Pit	South Pit SOS	7
		South Pit	33
		ROM Stockpile	9
	North Pit	North Open Pit	47
		ROM Stockpile	2
	ROM Stockpile	ROM bin grizzly	52
Year 15	North Pit	Integrated Waste Landform (IWL)	41
		North Open Pit	51
		South Pit SOS	2
		North Pit SOS	2
		ROM Stockpile	11
	ROM Stockpile	ROM bin grizzly	52
Year 25	North Pit	North Open Pit	105
		ROM Stockpile	11
	ROM Stockpile	ROM bin grizzly	52

Prepared by Knight Piésold Consultores.
Notes:
[1] Estimated from quantity of material and truck capacity.

4.4.2 Port site

Emission sources entered in the model are shown in Figure 4.8 and they correspond to vehicle traffic, material transport, machinery operation and phosphate concentrate storage activities.

Noise emissions estimation due to equipment used in the Phosphate Process Plant is shown in Chart 4.6, where it is seen that emissions are mainly originated by the various conveyor belts from entry to the shiploader and pressure pumps used at the Port Wet Concentrate Dryer Shed. Emissions estimation at spectral level (frequencies between 63 Hz and 8 kHz) was determined by means of the ISO 8297:1994 standard and the guideline “Update of noise database for prediction of noise on construction and open sites” (Defra, 2005).

Estimations corresponding to material movement, loading and unloading are shown in Chart 4.7 and were prepared for each material transport area, from end dump into hopper to shiploader. Sound power levels were obtained from guideline “Update of noise database for prediction of noise on construction and open sites” (Defra, 2005).

Finally, noise emissions from diesel generators were estimated similarly to those in the mine site, in accordance with sound power levels from guideline “Update of noise database for prediction of noise on construction and open sites” (Defra, 2005). The values are shown in Chart 4.8.

The Guide du Bruit method for emissions estimation was used to estimate vehicle traffic emissions; these sound power emissions are calculated by the soundPLAN model based on daily vehicle traffic data for 14 hours (from 06:00 to 20 hours), as shown in Chart 4.4.

Chart 4.4
Daily traffic by heavy and light vehicles in paved roads
Mine site to Ponta Chugue port facility

Type of vehicle	Period	Vehicles	Vehicles per day (ADT)	Percentage
Light (1)	Daytime	156	168	92.9%
	Night-time	12		7.1%
Heavy (2)	Daytime	224	240	93.3%
	Night-time	16		6.7%

Prepared by Knight Piésold Consultores.
Notes:
(1) Estimated from list of equipment per year according to Lycopodium information.
(2) Estimated from quantity of material and truck capacity.

4.5 Model domain - Receptors

The SoundPLAN v. 7.2 model receptors were set up considering a calculation area that comprises the noise sampling stations, whose locations are shown in Table 4.9 and in Figure 4.9. The grid domain has a resolution of 10 m of size.

4.6 Topographic relief

Satellite topographic data from the ASTER Global (NASA) model was used, which has data for the entire earth surface in high resolution (15 m). The study area does not exhibit a complex topographic relief and, therefore, it is considered as a flat relief.

4.7 Output model configuration

The model was configured to provide equivalent daytime and night-time noise levels in dB(A), both at space level and in tabular values for discrete receptors.

The design of sound propagation contour areas generated for the project daytime period was configured up to a noise level of 50 dB(A), which is lower by 5 dB(A) than the standard value of 55 dB(A) for residential zones according to the IFC (2007). Likewise, the sound propagation generated by project for the night-time period was configured up to 40 dB(A),

which is lower by 5 dB(A) than the standard value of 45 dB(A) for residential zones, according to the IFC (2007).

5.0 Noise Propagation Results

This section shows results provided by SoundPLAN v. 7.2 noise modelling system related to noise propagation in the study area and noise levels at receptors. It is worth mentioning that the shown noise levels represent an exclusive contribution generated by noise sources considered by the project.

Sound propagation results from noise emission sources generated by each scenario are shown in Figures 5.1 to 5.14. Sound propagation results for each discrete receptor as caused by noise emissions according to each analyzed year, from mine site facilities, vehicle traffic on access roads and facilities at Ponta Chugue Port, are shown in Charts 5.1 and 5.2 show. In general, it is observed that the city of Farim may receive noise levels from 32.2 dB(A) to 35.6 dB(A); these values meet the standards for residential and commercial areas as they are below 55 dB(A) for the daytime period and 45 dB(A) for the night-time period.

5.1 Mine site

Sound propagation results during year 2 at mine site, where sound propagation does not exceed the standard limit value for the daytime period (55 dB(A) for residences), are shown in Figure 5.1. Receptors Ponta Zeca (R3), Saliquenhe (R4) and Tambato Mandinka (R6 will be relocated and therefore will not be receptors to receive project noise.

Sound propagation results during year 2 for the night-time period at the mine site are shown in Figure 5.2; out of all results obtained for receptors, only the village of Bani (R2) might receive noise contributions equivalent to 47.1 dB(A), exceeding by 2.1 dB(A) the standard value of 45 dB(A), according to the IFC (2007). However, this exceedance does not reach higher than 3 dB(A), which is considered as critical by the IFC (2007). On the other hand, only the village of Canico (R5) might receive low noise effects generated by project equal to 42.6 dB(A) in the night-time period, so it would be within the project area of influence.

Sound propagation results during year 8 for the daytime and night-time periods, respectively, at the mine site, are shown in Figures 5.3 and 5.4. Results indicate that nearby villages would not receive noise contributions exceeding the standard for residential zones. The village of Bani (R2) might receive a low noise effect equal to 42.5 dB(A) in the night-time period, which would originate from project activities; therefore, this village would be within the sound propagation area of influence of project.

Sound propagation results during year 15 for the daytime and night-time periods, respectively, at the mine site, are shown in Figures 5.5 and 5.6. Results indicate that villages, except for Bani, would not receive noise contributions exceeding the standard for residential zones. Bani (R2) might receive a noise level of 46.1 dB(A) in the night-time period from project, which is higher by 1.1 dB(A) than the noise standard limit value for residential zones

equal to 45 dB(A), according to the IFC (2007); this exceedance is not higher than 3 dB(A), which is considered as critical by the IFC (2007).

Sound propagation results during year 25 for the daytime and night-time period, respectively, at the mine site, are shown in Figures 5.7 and 5.8. Results indicate that villages would not receive noise contributions exceeding the standard for residential zones. Bani (R2) might receive a low noise effect equal to 42.0 dB(A) in the night-time period from project, so it would be within the sound propagation area of influence of project.

5.2 Access road

The results of sound propagation generated by the light and heavy vehicle traffic of the project are shown in Chart 5.2. 10 receptors that would be located within the area of influence of project-related vehicle traffic would receive noise levels above 40 dB (A), either in the night-time or daytime period. Of these 10 receptors, 3 would receive noise levels that might exceed the standard due to the houses close to the road, which are located 15 to 20 m from the road.

This would mean that the houses close to the road, 15 to 20 m from it, might receive between 55 dB (A) and 60 dB (A) noise levels along the concentrate transport route.

The sound propagation results along the transport route in the Dugal area for the night-time and daytime periods, respectively, are shown in Figures 5.9 and 5.10. In addition, Figures 5.11 and 5.12 show the sound propagation results along the transport route in the Cunteda area for the night-time and daytime periods, respectively. According to Chart 5.2, houses evaluated near the road (discrete receptors R54, R56 and R61) might receive noise levels exceeding the standard limit value for residential areas.

5.3 Port site

Chart 5.2 and Figures 5.13 and 5.14 show the noise results in the daytime and night-time periods from Ponta Chugue Port Facility, in which phosphate concentrate receipt, phosphate drying, concentrate transport, and concentrate shipment activities would be carried out. Discrete receptors evaluated are those of Village Chief (R69) and Fishing Beach (R70). The first corresponds to a residential area, whereas fishing activities are carried out in the second, therefore, it represents a commercial area. Of the two receptors evaluated, the first might receive high noise effects coming mainly from the influence of vehicle traffic-generated noise and activities in Ponta Chugue Port Facility (Figure 5.14).

6.0 Noise Propagation Results

In order to determine future noise levels, considering background noise and noise propagation from the project, these noise levels were determined by the energetic sum of noise generated by the project and the background noise, applying the following mathematical expression:

$$L_T = 10 \log \sum_i^n 10^{\frac{L_i}{10}}$$

Where L_T is the sum of all sound radiation, n is the number of noise levels, and L_i are each noise level (background noise and project noise), expressed in dB(A).

Thus, the impact of noise in the area, expressed as the increase in the number of decibels in relation to the background noise, was determined, and predicted noise levels were compared against standard limit values according to the IFC and OECD criteria.

6.1 Mine site

Noise impact analysis results for year 2 are shown in Chart 6.1. It is noted that in the Bani (R2) area, increase in noise might reach +2.4 dB (A), which is below 3 dB, in keeping with the IFC criteria.

Noise impact analysis results for year 8 are shown in Chart 6.2. It is noted that in the Bani (R2) area, increase in noise drops in relation to year 2 of the mine, which is below 3 dB, in keeping with the IFC criteria. Noise impact analysis results for year 15 are shown in Chart 6.3.

Noise impact analysis results for year 25 are shown in Chart 6.4, considering background noise. No significant changes above 3 dB were noted with respect to the background noise.

6.2 Access road and port site

Noise impact analysis results along the transport route between the mine site and the Ponta Chugue Port, considering background noise are shown in Chart 6.5. Predicted noise levels exceeding the standard, according to the OECD criteria, correspond to the night-time period for receptors in the Cunteda (R61) and Village Chief (R69) areas; however, increases in noise are +1.7 dB and +0.8 dB, below 3 dB, in keeping with the IFC criteria. Other receptors evaluated do not exceed the standard limit values, although some recorded noise level increases above +3 dB compared to background noise.

7.0 Conclusions and Recommendations

7.1 Conclusions

Inventories of noise were developed for years 2, 8, 15 and 25 of mining. According to results, earthmoving activities and dumping of material by trucks generate higher noise emissions than other activities.

With regard to the Project's impact on the background noise levels, the villages outside the mine area would not report noise increases above 3 dB (A), in keeping with the IFC standards. On the other hand, the noise level in most of the villages located along the concentrate transport route would report background noise increases meeting noise level standards, in keeping with the OECD (2001) criteria. However, some background noise increases between +1.7 dB and +0.8 dB would suffice to exceed the noise standard in the night- time period (55 dB (A) for R61 and R69 receptors, respectively.

7.2 Recommendations

The following measures are proposed to prevent and mitigate the impacts identified in Section 6.0 hereof:

- Perform regular technical maintenance on the machines used for earthmoving activities. It is suggested that the condition of silencers in machinery equipped with this system, including trucks and pick-up trucks, be frequently checked.
- It is suggested that noise levels in the village of Bani be monitored for 24 hours on a quarterly basis from year 1 of the mine. This will provide information of varying levels of background noise during the daytime period where an increase of +2.4 dB (A) is expected.
- It is suggested that daytime noise levels in the village of Cunteda (R61 receptor) as well as the Village Chief (R69) be monitored between 06:00 and 20:00 on a quarterly basis. This will allow monitoring the increase in background noise levels and identifying whether hours exceeding the standard value of 65 dB (A) occur, according to the OECD (2001) criteria, in order to establish mitigation measures. This might include evaluating options such as implementing vehicle silencers or evaluating houses that would be potentially affected by high noise levels.
- Build a two meter-high concrete perimeter wall around the Ponta Chugue Port Facility.

8.0 Bibliography

Braunstein+Berndt GMBH. (2012). *SoundPLAN User's Manual Software for Noise and Air Pollution Modelling.* Etzwiesenberg, Germany.

Defra. (2005). Update of Noise Database for Prediction of Noise on Construction and Open Sites. London - UK.

Golder. (2014). *Mine Component Environmental and Social Baseline Studies.* London - UK: Golder Associates (UK) LTD.

Hadzi-Nikolova, M., Mirakovski, D., Ristova, E., & Ceravolo, S. (2012). Modeling and Mapping of Urban Noise Pollution with SoundPLAN Software. *University "Goce Delcev,"* 38–41. Retrieved from http://eprints.ugd.edu.mk/796/

IFC. (2007). Environmental, Health, and Safety General Guidelines. World Bank Group.

Lycopodium. (2014). *Farim Phosphate Project - Process Design Criteria.*

OECD. (2001). *OECD Environmental Outlook.* Paris: Organisation for Economic CO-Operation and Development. doi:10.1787/9789264188563-en

Knight Piésold Consultores S.A.

Prepared by:

Alejandro Delgado
Environmental Engineer

Reviewed by:

Edgardo Enríquez
Project Manager

Approved by:

Claudia Sandoval
Environmental Manager

Tables

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 4.1
Background Noise Levels

Code	East - X (m)	North - Y (m)	Receptor [1]	Type of receptor	Distance from Mine / Mine Facility / Port	Background Noise Levels - L_{Aeq} [1]	
						Ld dB(A) Daytime (07:00 - 22:00 h)	Ln dB(A) Night-time (22:00 - 07:00 h)
MP1	475 993	1 380 092	Farim, GB Minerals Office Compound	Residential / adjacent to road	Approximately 3 km from proposed open pit area adjacent to road traffic	51,8	54,1
MP2	476 005	1 380 153	Farim	Residential / adjacent to road	Approximately 3 km from proposed open pit area adjacent to road traffic	54,4	52,2
MP3	465 777	1 372 979	Binta	Residential	Site of potential barge loading facility	44,5	44,3
MP4	470 656	1 377 078	Canico	Residential	1 km from southern extent of proposed mine pit	48,6	54,1
MP5	466 829	1 377 444	Cansenhe	Residential	Approximately 2 km of the future mine site	48,6	55,4
MP6	466 906	1 381 331	Sanjalo	Residential	3 km west of proposed mine pit	54,8	63,6
MP7	467 344	1 379 975	Ufude	Residential	3 km west of proposed mine pit	52,2	58,8
MP8	471 850	1 379 684	Saliquenhe	Residential	Within footprint of proposed mine pit	48,4	63,8
MP9	478 751	1 384 096	Sancalanco	Residential	Outside study area	50,3	61,3
MP10	474 156	1 383 458	Sarajobe	Residential	Near the centre of the village	50,5	60,1
MP11	471 955	1 384 718	Canico Tumane	Residential	Near the centre of the village	51,5	54,6
MP12	476 022	1 376 868	Saliquenhedim	Residential / adjacent to road	Approximately 2 km from southern open pit / Near to access road	51,9	53,5
KP1	452 394	1 320 961	Chief Village [2]	Residential	Near to future access road in Port Site	63,0	56,5
KP2	452 689	1 320 124	Port Site Beach [2]	Commercial	Near to future Port Site	48,9	-

Prepared by Knight Piésold Consulting.
Source: Golder (2014).
Datum UTM WGS84.
[1] Result of noise measured during site visits in September 10th and 14th of 2012 (Golder, 2014).
[2] Result of noise measured during site visits in May 9th and 10th of 2015 (Knight Piésold, 2015).

Legend for Daytime/Night-time:
> Residential Guideline according to IFC = Daytime: 55 dB(A) / Night-time: 45 dB(A).
> Residential Guideline according to OECD for residential close to roads - Daytime: 65 dB(A) / Night-time: 55 dB(A).
> Commercial and Industrial guideline according to IFC - Daytime: 70 dB(A) / Night-time: 70 dB(A).

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 4.2
Noise emissions estimation - Use of heavy equipment (vehicle exhaust)
Mine Site

Scenario	Source	Type of heavy equipment (1)	Average power - P (kW) (2)	Octave Band Sound Pressure/Power Levels - dB (3)								A-weighted Sound Pressure/Power dB(A) (3)
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Year 2	South Open Pit	CAT 374DL - Excavator	355	86,0	90,0	78,0	74,0	75,0	70,0	62,0	60,0	80,0
		CAT 336DL - Excavator	200	91,0	92,0	83,0	84,0	80,0	78,0	77,0	70,0	86,0
		CAT 992K - Wheel Loader	607	88,0	88,0	87,0	85,0	86,0	83,0	77,0	70,0	90,0
		CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Total		**95,7**	**96,7**	**90,4**	**88,4**	**89,1**	**85,4**	**81,2**	**74,0**	**93,0**
		Lw (Total)		**123,7**	**124,7**	**118,4**	**116,4**	**117,1**	**113,4**	**109,2**	**102,0**	**121,0**
	Integrated Waste Landform (IWL)	CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		Lw (Dozer)		**117,0**	**118,0**	**109,0**	**101,0**	**102,0**	**98,0**	**96,0**	**88,0**	**108,0**
	North-East Waste Dump	CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Lw (Motor Grader)		**116,0**	**115,0**	**111,0**	**107,0**	**112,0**	**106,0**	**102,0**	**93,0**	**114,0**
	Tailing Storage Facility	CAT CS-56 - Compactor	116	87,0	85,0	75,0	73,0	75,0	73,0	69,0	63,0	80,0
		Lw (Compactor)		**115,0**	**113,0**	**103,0**	**101,0**	**103,0**	**101,0**	**97,0**	**91,0**	**108,0**
Year 8	South Open Pit	CAT 374DL - Excavator	355	86,0	90,0	78,0	74,0	75,0	70,0	62,0	60,0	80,0
		CAT 336DL - Excavator	200	91,0	92,0	83,0	84,0	80,0	78,0	77,0	70,0	86,0
		CAT 992K - Wheel Loader	607	88,0	88,0	87,0	85,0	86,0	83,0	77,0	70,0	90,0
		CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Total		**95,7**	**96,7**	**90,4**	**88,4**	**89,1**	**85,4**	**81,2**	**74,0**	**93,0**
		Lw (Total)		**123,7**	**124,7**	**118,4**	**116,4**	**117,1**	**113,4**	**109,2**	**102,0**	**121,0**
	North Open Pit	CAT 374DL - Excavator	355	86,0	90,0	78,0	74,0	75,0	70,0	62,0	60,0	80,0
		CAT 336DL - Excavator	200	91,0	92,0	83,0	84,0	80,0	78,0	77,0	70,0	86,0
		CAT 992K - Wheel Loader	607	88,0	88,0	87,0	85,0	86,0	83,0	77,0	70,0	90,0
		CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Total		**95,7**	**96,7**	**90,4**	**88,4**	**89,1**	**85,4**	**81,2**	**74,0**	**93,0**
		Lw (Total)		**123,7**	**124,7**	**118,4**	**116,4**	**117,1**	**113,4**	**109,2**	**102,0**	**121,0**
	South Pit SOS	CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Total		**91,5**	**91,8**	**85,1**	**80,0**	**84,4**	**78,6**	**75,0**	**66,2**	**87,0**
		Lw (Total)		**119,5**	**119,8**	**113,1**	**108,0**	**112,4**	**106,6**	**103,0**	**94,2**	**115,0**
	Tailing Storage Facility	CAT CS-56 - Compactor	116	87,0	85,0	75,0	73,0	75,0	73,0	69,0	63,0	80,0
		Lw (Compactor)		**115,0**	**113,0**	**103,0**	**101,0**	**103,0**	**101,0**	**97,0**	**91,0**	**108,0**
Year 15	North Open Pit	CAT 374DL - Excavator	355	86,0	90,0	78,0	74,0	75,0	70,0	62,0	60,0	80,0
		CAT 336DL - Excavator	200	91,0	92,0	83,0	84,0	80,0	78,0	77,0	70,0	86,0
		CAT 992K - Wheel Loader	607	88,0	88,0	87,0	85,0	86,0	83,0	77,0	70,0	90,0
		CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Total		**95,7**	**96,7**	**90,4**	**88,4**	**89,1**	**85,4**	**81,2**	**74,0**	**93,0**
		Lw (Total)		**123,7**	**124,7**	**118,4**	**116,4**	**117,1**	**113,4**	**109,2**	**102,0**	**121,0**
	Integrated Waste Landform (IWL)	CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		Lw (Dozer)		**117,0**	**118,0**	**109,0**	**101,0**	**102,0**	**98,0**	**96,0**	**88,0**	**108,0**
	South Pit SOS	CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		Lw (Dozer)		**117,0**	**118,0**	**109,0**	**101,0**	**102,0**	**98,0**	**96,0**	**88,0**	**108,0**
	North Pit SOS	CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Lw (Motor Grader)		**116,0**	**115,0**	**111,0**	**107,0**	**112,0**	**106,0**	**102,0**	**93,0**	**114,0**
	Tailing Storage Facility	CAT CS-56 - Compactor	116	87,0	85,0	75,0	73,0	75,0	73,0	69,0	63,0	80,0
		Lw (Compactor)		**115,0**	**113,0**	**103,0**	**101,0**	**103,0**	**101,0**	**97,0**	**91,0**	**108,0**
Year 25	North Open Pit	CAT 374DL - Excavator	355	86,0	90,0	78,0	74,0	75,0	70,0	62,0	60,0	80,0
		CAT 336DL - Excavator	200	91,0	92,0	83,0	84,0	80,0	78,0	77,0	70,0	86,0
		CAT 992K - Wheel Loader	607	88,0	88,0	87,0	85,0	86,0	83,0	77,0	70,0	90,0
		CAT D9R - Dozer	302	89,0	90,0	81,0	73,0	74,0	70,0	68,0	60,0	80,0
		CAT 16M - Motor Grader	221	88,0	87,0	83,0	79,0	84,0	78,0	74,0	65,0	86,0
		Total		**95,7**	**96,7**	**90,4**	**88,4**	**89,1**	**85,4**	**81,2**	**74,0**	**93,0**
		Lw (Total)		**123,7**	**124,7**	**118,4**	**116,4**	**117,1**	**113,4**	**109,2**	**102,0**	**121,0**
	Tailing Storage Facility	CAT CS-56 - Compactor	116	87,0	85,0	75,0	73,0	75,0	73,0	69,0	63,0	80,0
		Lw (Compactor)		**115,0**	**113,0**	**103,0**	**101,0**	**103,0**	**101,0**	**97,0**	**91,0**	**108,0**

Prepared by Knight Piésold Consultores.

Notes:

(1) Source: GB Minerals.

(2) Source: Technique sheets

(3) Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.3
Noise emissions estimation - Process Plant (Equipment)
Mine Site

Scenario	Source [1]		Type of equipment [1]	Units	Parameter	Octave Band Sound Pressure/Power Levels @ 10 m - dB(A) [2]								A-weighted Sound Pressure/Power @ 10 m dB(A) [2]
						63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Years 1 - 25	Field Conveyor: from ROM Stockpile Feed Conveyor to Coarse Ore Stockpile		Field conveyor system	1	Lp	58	52	52	43	43	42	47	47	53
					Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Field Conveyor: from Coarse Ore Stockpile to Scrubbeer		Field conveyor system	1	Lp	58	52	52	43	43	42	47	47	53
					Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Field Conveyor: from Belt Filter Area to Concentrate Pipe Conveyor Feed		Field conveyor system	1	Lp	58	52	52	43	43	42	47	47	53
					Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Field Conveyor: from Concentrate Pipe Conveyor Feed to Truck loading facility		Field conveyor systemr	1	Lp	58	52	52	43	43	42	47	47	53
					Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Process Plant	Scrubbing	Horizontal Scrubber [4]	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Attrition Scrubber Agitator [4]	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Hidrozing	Hidrosizer Feed Pump	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Classification Cyclone Feed Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Dewatering Cyclone Feed Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Coarse Tailings Pump	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Reverse Flotation Column Cell Pumps	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Reverse flotation	Fine Concentrate Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Fine Concentrate Recirculation Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Fine Concentrate Thickener Underflow Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Plant Sump Pump	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Concentrate Filtration	Concentrate Filter Vacuum Pump	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Concentrate Filter Cloth Wash Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Concentrate Filter Filtrate Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Concentrate Filter Discharge Conveyor	1	Lp	58,0	52,0	52,0	43,0	43,0	42,0	47,0	47,0	53,0
			Concentrate Filter Cloth Wash Return Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Concentrate truck Wash Discharge Sump Pump	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Tailings Handling Process	Tailings Thickener Area Sump Pump	1	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Tilings Thickener Underflow Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Tilings Thickener Underflow Booster Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
			Return Water Pump	2	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Reagents Sheet	Transfer/Dosing/Drum/Sump Pumps	36	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		RAW Process, Fire Water Services and Treated Water Services	Water Pumps	16	Lp	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Determination of sound power levels of multisource industrial plants [3]		**Lp (Avergare) [dB(A)]**		**80,8**	**82,8**	**76,8**	**74,8**	**75,8**	**74,8**	**68,8**	**62,8**	**80,8**
				Atmospheric absorption (α) - dB/m (25ºC y 70% HR)		**7,7E-05**	**3,0E-04**	**1,1E-03**	**3,1E-03**	**6,2E-03**	**1,0E-02**	**2,2E-02**	**6,5E-02**	-
				ΔLα		**-4,4E-03**	**-1,7E-02**	**-6,1E-02**	**-1,8E-01**	**-3,6E-01**	**-6,0E-01**	**-1,3E+00**	**-3,8E+00**	-
				Lw (Process Plant)		**122,7**	**124,7**	**118,6**	**116,5**	**117,3**	**116,1**	**109,4**	**100,9**	-

Prepared by Knight Piésold Consultores.

Notes:

[1] Source: GB Minerals.

[2] Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

[3] Source: ISO 8297:1994 Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment - Engineering method.

[4] Sound Pressure Level similar to Water/Diesel Pumps

Data:

Sm - Measurement area (estimaded)	10900	m^2
Sp - Plant area (estimaded)	7800	m^2
h - Measurement height	1,5	m
l - Perimeter (estimaded)	430	m

Estimation:

ΔLs	43,5	
ΔLf	-1,65	
ΔLM	0	Omnidireccional

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TABLE 4.4
Noise emissions estimation - Unloading of material and handling
Mine Site

Scenario	Source [1]	Activity [1]	Parameter	Octave Band Sound Pressure/Power Levels @ 10 m - dB(A) [2]								A-weighted Sound Pressure/Power @ 10 m dB(A) [2]
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Year 2	Integrated Waste Landform (IWL)	Dumping by trucks	Lp	97	95	91	91	86	84	79	75	92
			Lw	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	South Open Pit	Loading in trucks	Lp	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	Lp	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	**Lp**	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
			Lw	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	North-East Waste Dump	Dumping by trucks	Lp	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
			Lw	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	ROM Stockpile	Loading in trucks	Lp	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	Lp	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	**Lp**	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
			Lw	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM bin grizzly	Dumping by trucks	Lp	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
			Lw	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	ROM belt feeder	Feed conveyor	Lp	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Unloading of material	Lp	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Handling by FEL	Lp	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
			Lw	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**
	Reject screen 1	Unloading of material	Lp	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Reject screen 2	Unloading of material	Lp	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate filter discharge conveyor	Feed conveyor	Lp	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate pipe conveyor feed bin	Feed conveyor	Lp	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Truck loading facility	Loading in trucks	Lp	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
			Lw	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**

Prepared by Knight Piésold Consultores.

Notes

[1] Source: GB Minerals.

[2] Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.4 (CONT.)
Noise emissions - Unloading of material and handling
Site Mine

Scenario	Source	Activity	Distance (m) (3)	Octave Band Sound Pressure/Power Levels - dB(A) (3)								A-weighted Sound Pressure dB(A) (3)
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Year 8	South Pit SOS	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	South Open Pit	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	North Open Pit	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM Stockpile	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM bin grizzly	Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Lw	10	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	ROM belt feeder	Feed conveyor	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Lw	10	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**
	Reject screen 1	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Reject screen 2	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate filter discharge conveyor	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate pipe conveyor feed bin	Feed conveyor	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Truck loading facility	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Lw	10	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**

Prepared by Knight Piésold Consultores.

Notes

(1) Source: GB Minerals.

(2) Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.4 (CONT.)
Noise emissions - Unloading of material and handling
Site Mine

Scenario	Source	Activity	Distance (m) [3]	Octave Band Sound Pressure/Power Levels - dB(A) [3]								A-weighted Sound Pressure dB(A) [3]
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Year 15	Integrated Waste Landform (IWL)	Dumping by trucks	10	97	95	91	91	86	84	79	75	92
		Lw	10	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	South Pit SOS	Loading in trucks	10	79	84	81	84	81	80	75	68	86
		Dumping by trucks	10	97	95	91	91	86	84	79	75	92
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	North Pit SOS	Loading in trucks	10	79	84	81	84	81	80	75	68	86
		Dumping by trucks	10	97	95	91	91	86	84	79	75	92
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	North Open Pit	Loading in trucks	10	79	84	81	84	81	80	75	68	86
		Dumping by trucks	10	97	95	91	91	86	84	79	75	92
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM Stockpile	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM bin grizzly	Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Lw	10	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	ROM belt feeder	Feed conveyor	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Lw	10	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**
	Reject screen 1	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Reject screen 2	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate filter discharge conveyor	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate pipe conveyor feed bin	Feed conveyor	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Truck loading facility	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Lw	10	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**

Prepared by Knight Piésold Consultores.

Notes

[1] Source: GB Minerals.

[2] Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.4 (CONT.)
Noise emissions - Unloading of material and handling
Site Mine

Scenario	Source	Activity	Distance (m) (3)	Octave Band Sound Pressure/Power Levels - dB(A) (3)								A-weighted Sound Pressure dB(A) (3)
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Year 25	North Open Pit	Loading in trucks	10	79	84	81	84	81	80	75	68	86
		Dumping by trucks	10	97	95	91	91	86	84	79	75	92
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM Stockpile	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	10	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
		Lw (Total)	10	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	ROM bin grizzly	Dumping by trucks	10	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Lw	10	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	ROM belt feeder	Feed conveyor	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Coarse ore stockpile	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Lw	10	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**
	Reject screen 1	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Reject screen 2	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate filter discharge conveyor	Unloading of material	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Concentrate pipe conveyor feed bin	Feed conveyor	10	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
		Lw	10	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Truck loading facility	Loading in trucks	10	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Lw	10	**107,0**	**112,0**	**109,0**	**112,0**	**109,0**	**108,0**	**103,0**	**96,0**	**114,0**

Prepared by Knight Piésold Consultores.

Notes

(1) Source: GB Minerals.

(2) Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.5
Noise emissions estimation - Diesel generators
Mine Site

Scenario	Source	Parameter	Octave Band Sound Pressure/Power Levels - dB(A) (2)								A-weighted Sound Pressure/Power dB(A) (2)
			63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Years 1 - 25	Generator 1	Lp	68,8	78,9	86,4	91,8	95	96,2	96	93,9	102
		Lw	**96,8**	**106,9**	**114,4**	**119,8**	**123,0**	**124,2**	**124,0**	**121,9**	**130,0**
	Generator 2	Lp	68,8	78,9	86,4	91,8	95	96,2	96	93,9	102
		Lw	**96,8**	**106,9**	**114,4**	**119,8**	**123,0**	**124,2**	**124,0**	**121,9**	**130,0**

Prepared by Knight Piésold Consultores.

Notes

(1) Source: GB Minerals.

(2) Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.6
Noise emissions estimation - Process Plant (Equipment)
Ponta Chugue Port Facility

Scenario	Source [1]	Type of equipment [1]	Parameter	Octave Band Sound Pressure/Power Levels - dB [2]								A-weighted Sound Pressure/Power - dB(A) [2]
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Years 1 - 25	Concentrate Dryer Feed Conveyor	Field conveyor system	Lp @ 10 m	58,0	52,0	52,0	43,0	43,0	42,0	47,0	47,0	53,0
			Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Dried Concentrate Conveyor	Field conveyor system	Lp @ 10 m	58,0	52,0	52,0	43,0	43,0	42,0	47,0	47,0	53,0
			Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Dried Concentrate Travelling Conveyor	Field conveyor system	Lp @ 10 m	58,0	52,0	52,0	43,0	43,0	42,0	47,0	47,0	53,0
			Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Port Concentrate Loadout Conveyor	Field conveyor systemr	Lp @ 10 m	58,0	52,0	52,0	43,0	43,0	42,0	47,0	47,0	53,0
			Lw	**86,0**	**80,0**	**80,0**	**71,0**	**71,0**	**70,0**	**75,0**	**75,0**	**81,0**
	Port Wet Concentrate Dryer Shed	Concentrate Dryer [3]	Lp @ 10 m	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Burner Air Supply Fan	Lp @ 10 m	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Concentrate Dryer Dust Collector [3]	Lp @ 10 m	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Concentrate Scrubber [3]	Lp @ 10 m	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Concentrate Dryer Scrubber Pump	Lp @ 10 m	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Concentrate Dryer Scrubber Fan	Lp @ 10 m	81,0	83,0	77,0	75,0	76,0	75,0	69,0	63,0	81,0
		Determination of sound power levels of multisource industrial plants	**Lp @ 10 m (Average)**	**81,0**	**83,0**	**77,0**	**75,0**	**76,0**	**75,0**	**69,0**	**63,0**	**81,0**
			Atmospheric absorption (α) - dB/m (25ºC y 70% HR)	**7,7E-05**	**3,0E-04**	**1,1E-03**	**3,1E-03**	**6,2E-03**	**1,0E-02**	**2,2E-02**	**6,5E-02**	-
			ΔLα	**-1,0E-03**	**-4,0E-03**	**-1,4E-02**	**-4,2E-02**	**-8,4E-02**	**-1,4E-01**	**-3,0E-01**	**-8,8E-01**	-
			Lw (Total)	**111,9**	**113,9**	**107,9**	**105,9**	**106,8**	**105,8**	**99,6**	**93,0**	**111,6**

Prepared by Knight Piésold Consultores.

Notes:

[1] Source: GB Minerals.

[2] Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

[3] Source: ISO 8297:1994 Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment - Engineering method.

[4] Sound Pressure Level similar to Water/Diesel Pumps

Data:

Sm - Measurement area (estimaded)	730	m^2
Sp - Plant area (estimaded)	2490	m^2
h - Measurement height	1,5	m
l - Perimeter (estimaded)	160	m

Estimation:

ΔLs	32,3	
ΔLf	-1,40	
ΔLM	0	omnidireccional

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TABLE 4.7
Noise emissions estimation - Unloading of material and handling
Ponta Chugue Port Facility

Scenario	Source [1]	Activity [1]	Parameter	Octave Band Sound Pressure/Power Levels - dB [2]								A-weighted Sound Pressure/Power - dB(A) [2]
				63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Years 1 to 25	End dump into hopper	Dumping by trucks	Lp @ 10 m	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
			Lw	**125,0**	**123,0**	**119,0**	**119,0**	**114,0**	**112,0**	**107,0**	**103,0**	**120,0**
	Feed conveyor (transfer 1)	Feed conveyor	Lp @ 10 m	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Wet concentrate dryer shed /stockpile	Unloading of material	Lp @ 10 m	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Wet concentrate dryer shed /unloading by FEL	Loading in trucks	Lp @ 10 m	79,0	84,0	81,0	84,0	81,0	80,0	75,0	68,0	86,0
		Dumping by trucks	Lp @ 10 m	97,0	95,0	91,0	91,0	86,0	84,0	79,0	75,0	92,0
		Total	Lp @ 10 m	**97,1**	**95,3**	**91,4**	**91,8**	**87,2**	**85,5**	**80,5**	**75,8**	**93,0**
			Lw	**125,1**	**123,3**	**119,4**	**119,8**	**115,2**	**113,5**	**108,5**	**103,8**	**121,0**
	Feed conveyor (transfer 2)	Feed conveyor	Lp @ 10 m	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Hooper 1	Feed conveyor	Lp @ 10 m	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Hopper 2	Feed conveyor	Lp @ 10 m	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Hooper 3	Feed conveyor	Lp @ 10 m	71,0	68,0	62,0	63,0	66,0	62,0	58,0	51,0	69,0
			Lw	**99,0**	**96,0**	**90,0**	**91,0**	**94,0**	**90,0**	**86,0**	**79,0**	**97,0**
	Shiploader	Grab Hopper Dredging Ship	Lp @ 10 m	83,0	91,0	80,0	78,0	78,0	73,0	66,0	58,0	82,0
			Lw	**111,0**	**119,0**	**108,0**	**106,0**	**106,0**	**101,0**	**94,0**	**86,0**	**110,0**

Prepared by Knight Piésold Consultores.

Notes

[1] Source: GB Minerals.

[2] Source: Technique sheets

[3] Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.8
Noise emissions estimation - Diesel generators
Ponta Chugue Port Facility

Scenario	Source	Parameter	Octave Band Sound Pressure/Power Levels - dB [2]								A-weighted Sound Pressure/Power - dB(A) [2]
			63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AeqT}
Years 1 - 25	Generator 3	Lp @ 10 m	68,8	78,9	86,4	91,8	95	96,2	96	93,9	102
		Lw	**96,8**	**106,9**	**114,4**	**119,8**	**123,0**	**124,2**	**124,0**	**121,9**	**130,0**
	Generator 4	Lp @ 10 m	68,8	78,9	86,4	91,8	95	96,2	96	93,9	102
		Lw	**96,8**	**106,9**	**114,4**	**119,8**	**123,0**	**124,2**	**124,0**	**121,9**	**130,0**

Prepared by Knight Piésold Consultores.

Notes

[1] Source: GB Minerals.

[2] Source: Department for Environment, Food and Rural Affairs (2005). Update of noise database for prediction of noise on construction and open sites.

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TABLE 4.9
Receptor locations for noise modelling

Zone	Code	East - X (m)	North - Y (m)	Receptor
Mine site	R2	473 539	1 380 590	Bani
	R3	472 822	1 379 808	Ponta Zeca
	R4	471 784	1 379 666	Saliquenhe
	R5	470 663	1 377 155	Canico
	R6	470 042	1 379 774	Tambato Mandinka
	R7	471 451	1 384 269	Canico Tumanna
	R8	475 307	1 381 393	Army Base (Nema)
	R9	475 727	1 380 498	Nema
	R10	476 526	1 379 984	Farim
	R11	467 479	1 379 940	Ufude
	R12	467 098	1 381 200	Sandjal
	R13	467 156	1 377 649	Cancenha
	R14	475 929	1 376 653	Saliquenhedim (K3)
	R15	474 211	1 383 392	Sara Loba
	R16	472 140	1 384 558	Urqui (Seidi)
	R17	478 600	1 384 226	Sancalanco
	R18	479 054	1 381 010	Fafaco
	R19	466 182	1 381 270	Tambandinto
	R20	469 292	1 385 691	Sintchan Maudie
	R21	480 633	1 384 258	Bolumbato
	R22	473 104	1 375 236	Tungina
Access road	R23	472 111	1 373 945	Mandinga
	R24	476 318	1 373 422	Colimessen Cunda
	R25	476 727	1 369 836	Djalicunda
	R26	478 044	1 366 292	Bironqui
	R27	479 863	1 363 349	Calingue Fula
	R28	481 403	1 359 002	Mansaba
	R29	481 019	1 357 093	Mansaba-Sutu
	R30	480 274	1 355 429	Serraco
	R31	478 415	1 353 750	Manbonco
	R32	474 753	1 345 041	Cutia
	R33	470 457	1 340 690	Querene
	R34	470 122	1 340 110	Cureyni

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 4.9 (CONT.)
Receptor locations for noise modelling

Zone	Code	East - X (m)	North - Y (m)	Receptor
Access road	R35	469 887	1 339 748	Cussac
	R36	469 086	1 338 540	San Saunto
	R37	465 535	1 334 500	Mansoa
	R38	463 910	1 332 112	-
	R39	463 997	1 331 985	-
	R40	463 691	1 331 694	-
	R41	462 525	1 330 718	-
	R42	461 739	1 330 377	-
	R43	458 118	1 328 830	Uaque
	R44	454 657	1 327 513	-
	R45	454 534	1 327 343	-
	R46	454 145	1 327 269	-
	R47	454 166	1 327 003	-
	R48	453 322	1 326 752	-
	R49	453 191	1 326 681	-
	R50	453 100	1 326 631	-
	R51	452 990	1 326 599	-
	R52	452 798	1 326 487	-
	R53	451 373	1 325 821	Dugal
	R54	451 451	1 325 785	Dugal
	R55	451 379	1 325 741	Dugal
	R56	451 764	1 325 439	-
	R57	451 724	1 325 217	-
	R58	452 239	1 325 348	-
	R59	451 954	1 324 457	-
	R60	453 350	1 324 081	Cunteda
	R61	453 361	1 323 771	Cunteda
	R62	453 616	1 323 520	Cunteda
	R63	453 272	1 323 441	Cunteda
	R64	452 801	1 322 155	Arote
	R65	452 894	1 322 028	Arote
	R66	452 923	1 321 807	-
	R67	452 421	1 321 384	-
	R68	452 429	1 320 949	Ancone
Port site	R69	452 474	1 320 599	Village Chief
	R70	452 716	1 320 121	Fishing Beach

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Datum UTM WGS84.

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.1
Noise propagation results in discrete receptors - Mine Site and Access Road

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	Scenario 1 - Year 2		Scenario 2 - Year 8		Scenario 3 - Year 15		Scenario 4 - Year 25	
						Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time
Mine Site	R2	473 539	1 380 590	Bani	Residential	47,1	47,1	42,5	42,5	45,3	46,1	42	42
	R3	472 822	1 379 808	Ponta Zeca	Industrial	59,4	59,5	47,7	47,8	53,9	55,7	46,2	46,4
	R4	471 784	1 379 666	Saliquenhe	Industrial	47,1	47,8	56,9	57	47,3	48,8	40,7	41,8
	R5	470 663	1 377 155	Canico	Residential	42,6	42,6	37,6	37,7	36,5	36,7	32,4	32,5
	R6	470 042	1 379 774	Tambato Mandinka	Industrial	40,8	41,8	36,3	36,4	40,4	41,4	47,2	48,3
	R7	471 451	1 384 269	Canico Tumanna	Residential	23,2	23,2	19,4	19,5	29,6	29,9	21,6	21,7
	R8	475 307	1 381 393	Army Base (Nema)	Residential	37,1	37	35,3	35,2	36,4	36,5	34,5	34,3
	R9	475 727	1 380 498	Nema	Residential	37,7	37,6	35,9	35,6	36,3	36,2	35,1	34,6
	R10	476 526	1 379 984	Farim	Residential	35,6	35,4	33,8	33,4	33,9	33,7	32,7	32,2
	R11	467 479	1 379 940	Ufude	Residential	28	28,4	23	23	30,4	30,8	32,8	32,9
	R12	467 098	1 381 200	Sandjal	Residential	23,7	23,9	20,8	20,8	26,6	26,7	29,7	29,8
	R13	467 156	1 377 649	Cancenha	Residential	30,8	30,9	23,9	24	35	35,1	26,2	26,3
	R14	475 929	1 376 653	Saliquenhedim (K3)	Residential	38,3	36,2	37,8	35,3	37,4	34,7	36,7	33,1
	R15	474 211	1 383 392	Sara Loba	Residential	30,8	30,8	28,2	28,2	32,2	32,4	27,3	27,3
	R16	472 140	1 384 558	Urqui (Seidi)	Residential	22,7	22,8	0	0	29,2	29,8	17,4	17,4
	R17	478 600	1 384 226	Sancalanco	Residential	0	0	0	0	0	0	0	0
	R18	479 054	1 381 010	Fafaco	Residential	11,4	4,1	11,4	4,1	11	3,8	11,4	4,1
	R19	466 182	1 381 270	Tambandinto	Residential	21	21,1	6,8	6,8	23,2	23,4	25,6	25,7
	R20	469 292	1 385 691	Sintchan Maudie	Residential	0	0	0	0	16,4	16,4	12,7	12,7
	R21	480 633	1 384 258	Bolumbato	Residential	0	0	0	0	0	0	0	0
	R22	473 104	1 375 236	Tungina	Residential	33,9	34	34,2	34,3	32,3	32,5	28,8	28,8
Access Road	R23	472 111	1 373 945	Mandinga	Residential	27,3	27,3	27,6	27,8	24,6	24,6	13	12,6
	R24	476 318	1 373 422	Colimessen Cunda	Residential	27,1	19,3	27,9	22,6	27,5	21,2	27,1	19,3

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.

Legend for Daytime:

- No effects of impact ≤ 50 dB(A)
- Low effects of impact for residential (50 < x ≤ 55) and industrial or commercial (50 < x ≤ 70).
- Hight effect of impact for residential (55 < x) and industrial or commercial (70 < x).

Legend for Night-time:

- No effects of impact ≤ 40 dB(A)
- Low effects of impact for residential (40 < x ≤ 45) and industrial or commercial (40 < x ≤ 70).
- Hight effect of impact for residential (45 < x) and industrial or commercial (70 < x).

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 5.2
Noise propagation results in discrete receptors - Access Road and Port Site

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	All scenarios	
						Ld dB(A) Daytime	Ln dB(A) Night-time
Access Road	R25	476 727	1 369 836	Djalicunda	Residential	29,7	21,7
	R26	478 044	1 366 292	Bironqui	Residential	23,9	15,5
	R27	479 863	1 363 349	Calingue Fula	Residential	36,4	29,3
	R28	481 403	1 359 002	Mansaba	Residential	21,2	13,2
	R29	481 019	1 357 093	Mansaba-Sutu	Residential	32,9	25,5
	R30	480 274	1 355 429	Serraco	Residential	23	15,9
	R31	478 415	1 353 750	Manbonco	Residential	22,3	14,4
	R32	474 753	1 345 041	Cutia	Residential	25,2	17,7
	R33	470 457	1 340 690	Querene	Residential	41,3	33,4
	R34	470 122	1 340 110	Cureyni	Residential	29,2	21,7
	R35	469 887	1 339 748	Cussac	Residential	27,4	20
	R36	469 086	1 338 540	San Saunto	Residential	20,2	12,4
	R37	465 535	1 334 500	Mansoa	Residential	36,2	28,8
	R38	463 910	1 332 112	-	Residential	39,9	32,6
	R39	463 997	1 331 985	-	Residential	42,3	34,8
	R40	463 691	1 331 694	-	Residential	38,3	31,2
	R41	462 525	1 330 718	-	Residential	24,7	17,4
	R42	461 739	1 330 377	-	Residential	43,1	35,6
	R43	458 118	1 328 830	Uaque	Residential	30,9	23,6
	R44	454 657	1 327 513	-	Residential	33,2	25,6
	R45	454 534	1 327 343	-	Residential	48,9	41,4
	R46	454 145	1 327 269	-	Residential	49,8	42,1
	R47	454 166	1 327 003	-	Residential	40,3	33,7
	R48	453 322	1 326 752	-	Residential	40,3	33
	R49	453 191	1 326 681	-	Residential	47,4	39,6
	R50	453 100	1 326 631	-	Residential	48,2	40,6
	R51	452 990	1 326 599	-	Residential	50,5	42,7
	R52	452 798	1 326 487	-	Residential	47,2	39,5
	R53	451 373	1 325 821	Dugal	Residential	52,3	43,9
	R54	451 451	1 325 785	Dugal	Residential	57,4	48,7
	R55	451 379	1 325 741	Dugal	Residential	47,9	40,3
	R56	451 764	1 325 439	-	Residential	57,1	48,5
	R57	451 724	1 325 217	-	Residential	42,1	35,2
	R58	452 239	1 325 348	-	Residential	24,2	17,6
	R59	451 954	1 324 457	-	Residential	29,1	25,1
	R60	453 350	1 324 081	Cunteda	Residential	43,7	36,6
	R61	453 361	1 323 771	Cunteda	Residential	58,8	50,2
	R62	453 616	1 323 520	Cunteda	Residential	39,1	32,8
	R63	453 272	1 323 441	Cunteda	Residential	40,9	34,7
	R64	452 801	1 322 155	Arote	Residential	32,8	31,2
	R65	452 894	1 322 028	Arote	Residential	31,2	26,9
	R66	452 923	1 321 807	-	Residential	37,8	34,3
	R67	452 421	1 321 384	-	Residential	40	37,7
	R68	452 429	1 320 949	Ancone	Residential	45,6	42,8
Port Site	R69	452 474	1 320 599	Village Chief	Residential	54,7	49,7
	R70	452 716	1 320 121	Fishing Beach	Commercial	55,7	55,7

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.

Legend for Daytime:

- No effects of impact ≤ 50 dB(A)
- Low effects of impact for residential (50 < x ≤ 55) and industrial or commercial (50 < x ≤ 70).
- Hight effect of impact for residential (55 < x) and industrial or commercial (70 < x).

Legend for Night-time:

- No effects of impact ≤ 40 dB(A)
- Low effects of impact for residential (40 < x ≤ 45) and industrial or commercial (40 < x ≤ 70).
- Hight effect of impact for residential (45 < x) and industrial or commercial (70 < x).

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.1
Noise impact assessment - Mine Site and Access Road
Scenario 1 - Year 2

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	Noise from Project (modelled)		Background noise		Predicted noise		Increment of noise dB(A)	
						Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time
Mine Site	R2 / MP8	473 539	1 380 590	Bani	Residential	47,1	47,1	48,4	63,8	50,8	63,9	2,4	0,1
	R3 / MP8	472 822	1 379 808	Ponta Zeca	Industrial	59,4	59,5	48,4	63,8	59,7	65,2	11,3	1,4
	R4 / MP8	471 784	1 379 666	Saliquenhe	Industrial	47,1	47,8	48,4	63,8	50,8	63,9	2,4	0,1
	R5 / MP4	470 663	1 377 155	Canico	Residential	42,6	42,6	48,6	54,1	49,6	54,4	1	0,3
	R6 / MP8	470 042	1 379 774	Tambato Mandinka	Industrial	40,8	41,8	48,4	63,8	49,1	63,8	0,7	0
	R7 / MP11	471 451	1 384 269	Canico Tumanna	Residential	23,2	23,2	51,5	54,6	51,5	54,6	0	0
	R8 / MP1	475 307	1 381 393	Army Base (Nema)	Residential (1)	37,1	37	51,8	54,1	51,9	54,2	0,1	0,1
	R9 / MP1	475 727	1 380 498	Nema	Residential (1)	37,7	37,6	51,8	54,1	52	54,2	0,2	0,1
	R10 / MP2	476 526	1 379 984	Farim	Residential (1)	35,6	35,4	54,4	52,2	54,5	52,3	0,1	0,1
	R11 / MP7	467 479	1 379 940	Ufude	Residential	28	28,4	52,2	58,8	52,2	58,8	0	0
	R12 / MP6	467 098	1 381 200	Sandjal	Residential	23,7	23,9	54,8	63,6	54,8	63,6	0	0
	R13 / MP5	467 156	1 377 649	Cancenha	Residential	30,8	30,9	48,6	55,4	48,7	55,4	0,1	0
	R14 / MP12	475 929	1 376 653	Saliquenhedim (K3)	Residential	38,3	36,2	51,9	53,5	52,1	53,6	0,2	0,1
	R15 / MP10	474 211	1 383 392	Sara Loba	Residential	30,8	30,8	50,5	60,1	50,5	60,1	0	0
	R16 / MP11	472 140	1 384 558	Urqui (Seidi)	Residential	22,7	22,8	51,5	54,6	51,5	54,6	0	0
	R17 / MP9	478 600	1 384 226	Sancalanco	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R18 / MP9	479 054	1 381 010	Fafaco	Residential	11,4	4,1	50,3	61,3	50,3	61,3	0	0
	R19 / MP6	466 182	1 381 270	Tambandinto	Residential	21	21,1	54,8	63,6	54,8	63,6	0	0
	R20 / MP11	469 292	1 385 691	Sintchan Maudie	Residential	0	0	51,5	54,6	51,5	54,6	0	0
	R21 / MP9	480 633	1 384 258	Bolumbato	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R22 / MP12	473 104	1 375 236	Tungina	Residential	33,9	34	51,9	53,5	52	53,5	0,1	0
Access Road	R23 / MP12	472 111	1 373 945	Mandinga	Residential (1)	27,3	27,3	51,9	53,5	51,9	53,5	0	0
	R24 / MP12	476 318	1 373 422	Colimessen Cunda	Residential (1)	27,1	19,3	51,9	53,5	51,9	53,5	0	0

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.
Notes:
(1) Receptors are adjacent to road traffic.
Legend:

> Residential Guideline according to IFC = Daytime: 55 dB(A) / Night-time: 45 dB(A), or increase in background levels greather than 3 dB.

> Residential Guideline according to OECD for residential close to roads - Daytime: 65 dB(A) / Night-time: 55 dB(A).

> Commercial and Industrial guideline according to IFC - Daytime: 70 dB(A) / Night-time: 70 dB(A).

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.2
Noise impact assessment - Mine Site and Access Road
Scenario 2 - Year 8

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	Noise from Project (modelled)		Background noise		Predicted noise		Increment of noise dB(A)	
						Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time
Mine Site	R2 / MP8	473 539	1 380 590	Bani	Residential	42,5	42,5	48,4	63,8	49,4	63,8	1	0
	R3 / MP8	472 822	1 379 808	Ponta Zeca	Industrial	47,7	47,8	48,4	63,8	51,1	63,9	2,7	0,1
	R4 / MP8	471 784	1 379 666	Saliquenhe	Industrial	56,9	57	48,4	63,8	57,5	64,6	9,1	0,8
	R5 / MP4	470 663	1 377 155	Canico	Residential	37,6	37,7	48,6	54,1	48,9	54,2	0,3	0,1
	R6 / MP8	470 042	1 379 774	Tambato Mandinka	Industrial	36,3	36,4	48,4	63,8	48,7	63,8	0,3	0
	R7 / MP11	471 451	1 384 269	Canico Tumanna	Residential	19,4	19,5	51,5	54,6	51,5	54,6	0	0
	R8 / MP1	475 307	1 381 393	Army Base (Nema)	Residential (1)	35,3	35,2	51,8	54,1	51,9	54,2	0,1	0,1
	R9 / MP1	475 727	1 380 498	Nema	Residential (1)	35,9	35,6	51,8	54,1	51,9	54,2	0,1	0,1
	R10 / MP2	476 526	1 379 984	Farim	Residential (1)	33,8	33,4	54,4	52,2	54,4	52,3	0	0,1
	R11 / MP7	467 479	1 379 940	Ufude	Residential	23	23	52,2	58,8	52,2	58,8	0	0
	R12 / MP6	467 098	1 381 200	Sandjal	Residential	20,8	20,8	54,8	63,6	54,8	63,6	0	0
	R13 / MP5	467 156	1 377 649	Cancenha	Residential	23,9	24	48,6	55,4	48,6	55,4	0	0
	R14 / MP12	475 929	1 376 653	Saliquenhedim (K3)	Residential	37,8	35,3	51,9	53,5	52,1	53,6	0,2	0,1
	R15 / MP10	474 211	1 383 392	Sara Loba	Residential	28,2	28,2	50,5	60,1	50,5	60,1	0	0
	R16 / MP11	472 140	1 384 558	Urqui (Seidi)	Residential	0	0	51,5	54,6	51,5	54,6	0	0
	R17 / MP9	478 600	1 384 226	Sancalanco	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R18 / MP9	479 054	1 381 010	Fafaco	Residential	11,4	4,1	50,3	61,3	50,3	61,3	0	0
	R19 / MP6	466 182	1 381 270	Tambandinto	Residential	6,8	6,8	54,8	63,6	54,8	63,6	0	0
	R20 / MP11	469 292	1 385 691	Sintchan Maudie	Residential	0	0	51,5	54,6	51,5	54,6	0	0
	R21 / MP9	480 633	1 384 258	Bolumbato	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R22 / MP12	473 104	1 375 236	Tungina	Residential	34,2	34,3	51,9	53,5	52	53,6	0,1	0,1
Access Road	R23 / MP12	472 111	1 373 945	Mandinga	Residential (1)	27,6	27,8	51,9	53,5	51,9	53,5	0	0
	R24 / MP12	476 318	1 373 422	Colimessen Cunda	Residential (1)	27,9	22,6	51,9	53,5	51,9	53,5	0	0

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.
Notes:
(1) Receptors are adjacent to road traffic.
Legend:

> Residential Guideline according to IFC = Daytime: 55 dB(A) / Night-time: 45 dB(A), or increase in background levels greather than 3 dB.

> Residential Guideline according to OECD for residential close to roads - Daytime: 65 dB(A) / Night-time: 55 dB(A).

> Commercial and Industrial guideline according to IFC - Daytime: 70 dB(A) / Night-time: 70 dB(A).

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.3
Noise impact assessment - Mine Site and Access Road
Scenario 3 - Year 15

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	Noise from Project (modelled)		Background noise		Predicted noise		Increment of noise dB(A)	
						Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time
Mine Site	R2 / MP8	473 539	1 380 590	Bani	Residential	45,3	46,1	48,4	63,8	50,1	63,9	1,7	0,1
	R3 / MP8	472 822	1 379 808	Ponta Zeca	Industrial	53,9	55,7	48,4	63,8	55	64,4	6,6	0,6
	R4 / MP8	471 784	1 379 666	Saliquenhe	Industrial	47,3	48,8	48,4	63,8	50,9	63,9	2,5	0,1
	R5 / MP4	470 663	1 377 155	Canico	Residential	36,5	36,7	48,6	54,1	48,9	54,2	0,3	0,1
	R6 / MP8	470 042	1 379 774	Tambato Mandinka	Industrial	40,4	41,4	48,4	63,8	49	63,8	0,6	0
	R7 / MP11	471 451	1 384 269	Canico Tumanna	Residential	29,6	29,9	51,5	54,6	51,5	54,6	0	0
	R8 / MP1	475 307	1 381 393	Army Base (Nema)	Residential (1)	36,4	36,5	51,8	54,1	51,9	54,2	0,1	0,1
	R9 / MP1	475 727	1 380 498	Nema	Residential (1)	36,3	36,2	51,8	54,1	51,9	54,2	0,1	0,1
	R10 / MP2	476 526	1 379 984	Farim	Residential (1)	33,9	33,7	54,4	52,2	54,4	52,3	0	0,1
	R11 / MP7	467 479	1 379 940	Ufude	Residential	30,4	30,8	52,2	58,8	52,2	58,8	0	0
	R12 / MP6	467 098	1 381 200	Sandjal	Residential	26,6	26,7	54,8	63,6	54,8	63,6	0	0
	R13 / MP5	467 156	1 377 649	Cancenha	Residential	35	35,1	48,6	55,4	48,8	55,4	0,2	0
	R14 / MP12	475 929	1 376 653	Saliquenhedim (K3)	Residential	37,4	34,7	51,9	53,5	52,1	53,6	0,2	0,1
	R15 / MP10	474 211	1 383 392	Sara Loba	Residential	32,2	32,4	50,5	60,1	50,6	60,1	0,1	0
	R16 / MP11	472 140	1 384 558	Urqui (Seidi)	Residential	29,2	29,8	51,5	54,6	51,5	54,6	0	0
	R17 / MP9	478 600	1 384 226	Sancalanco	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R18 / MP9	479 054	1 381 010	Fafaco	Residential	11	3,8	50,3	61,3	50,3	61,3	0	0
	R19 / MP6	466 182	1 381 270	Tambandinto	Residential	23,2	23,4	54,8	63,6	54,8	63,6	0	0
	R20 / MP11	469 292	1 385 691	Sintchan Maudie	Residential	16,4	16,4	51,5	54,6	51,5	54,6	0	0
	R21 / MP9	480 633	1 384 258	Bolumbato	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R22 / MP12	473 104	1 375 236	Tungina	Residential	32,3	32,5	51,9	53,5	51,9	53,5	0	0
Access Road	R23 / MP12	472 111	1 373 945	Mandinga	Residential (1)	24,6	24,6	51,9	53,5	51,9	53,5	0	0
	R24 / MP12	476 318	1 373 422	Colimessen Cunda	Residential (1)	27,5	21,2	51,9	53,5	51,9	53,5	0	0

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.
Notes:
(1) Receptors are adjacent to road traffic.
Legend:

> Residential Guideline according to IFC = Daytime: 55 dB(A) / Night-time: 45 dB(A), or increase in background levels greather than 3 dB.

> Residential Guideline according to OECD for residential close to roads - Daytime: 65 dB(A) / Night-time: 55 dB(A).

> Commercial and Industrial guideline according to IFC - Daytime: 70 dB(A) / Night-time: 70 dB(A).

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LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.4
Noise impact assessment - Mine Site and Access Road
Scenario 4 - Year 25

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	Noise from Project (modelled)		Background noise		Predicted noise		Increment of noise dB(A)	
						Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time
Mine Site	R2 / MP8	473 539	1 380 590	Bani	Residential	42	42	48,4	63,8	49,3	63,8	0,9	0
	R3 / MP8	472 822	1 379 808	Ponta Zeca	Industrial	46,2	46,4	48,4	63,8	50,4	63,9	2	0,1
	R4 / MP8	471 784	1 379 666	Saliquenhe	Industrial	40,7	41,8	48,4	63,8	49,1	63,8	0,7	0
	R5 / MP4	470 663	1 377 155	Canico	Residential	32,4	32,5	48,6	54,1	48,7	54,1	0,1	0
	R6 / MP8	470 042	1 379 774	Tambato Mandinka	Industrial	47,2	48,3	48,4	63,8	50,9	63,9	2,5	0,1
	R7 / MP11	471 451	1 384 269	Canico Tumanna	Residential	21,6	21,7	51,5	54,6	51,5	54,6	0	0
	R8 / MP1	475 307	1 381 393	Army Base (Nema)	Residential (1)	34,5	34,3	51,8	54,1	51,9	54,1	0,1	0
	R9 / MP1	475 727	1 380 498	Nema	Residential (1)	35,1	34,6	51,8	54,1	51,9	54,1	0,1	0
	R10 / MP2	476 526	1 379 984	Farim	Residential (1)	32,7	32,2	54,4	52,2	54,4	52,2	0	0
	R11 / MP7	467 479	1 379 940	Ufude	Residential	32,8	32,9	52,2	58,8	52,2	58,8	0	0
	R12 / MP6	467 098	1 381 200	Sandjal	Residential	29,7	29,8	54,8	63,6	54,8	63,6	0	0
	R13 / MP5	467 156	1 377 649	Cancenha	Residential	26,2	26,3	48,6	55,4	48,6	55,4	0	0
	R14 / MP12	475 929	1 376 653	Saliquenhedim (K3)	Residential	36,7	33,1	51,9	53,5	52	53,5	0,1	0
	R15 / MP10	474 211	1 383 392	Sara Loba	Residential	27,3	27,3	50,5	60,1	50,5	60,1	0	0
	R16 / MP11	472 140	1 384 558	Urqui (Seidi)	Residential	17,4	17,4	51,5	54,6	51,5	54,6	0	0
	R17 / MP9	478 600	1 384 226	Sancalanco	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R18 / MP9	479 054	1 381 010	Fafaco	Residential	11,4	4,1	50,3	61,3	50,3	61,3	0	0
	R19 / MP6	466 182	1 381 270	Tambandinto	Residential	25,6	25,7	54,8	63,6	54,8	63,6	0	0
	R20 / MP11	469 292	1 385 691	Sintchan Maudie	Residential	12,7	12,7	51,5	54,6	51,5	54,6	0	0
	R21 / MP9	480 633	1 384 258	Bolumbato	Residential	0	0	50,3	61,3	50,3	61,3	0	0
	R22 / MP12	473 104	1 375 236	Tungina	Residential	28,8	28,8	51,9	53,5	51,9	53,5	0	0
Access Road	R23 / MP12	472 111	1 373 945	Mandinga	Residential (1)	13	12,6	51,9	53,5	51,9	53,5	0	0
	R24 / MP12	476 318	1 373 422	Colimessen Cunda	Residential (1)	27,1	19,3	51,9	53,5	51,9	53,5	0	0

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.
Notes:
(1) Receptors are adjacent to road traffic.
Legend:

> Residential Guideline according to IFC = Daytime: 55 dB(A) / Night-time: 45 dB(A), or increase in background levels greather than 3 dB.

> Residential Guideline according to OECD for residential close to roads - Daytime: 65 dB(A) / Night-time: 55 dB(A).

> Commercial and Industrial guideline according to IFC - Daytime: 70 dB(A) / Night-time: 70 dB(A).

LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

TABLE 6.5
Noise propagation results in discrete receptors - Access Road and Port Site

Zone	Code	East - X (m)	North - Y (m)	Receptor	Type of receptor	Noise from Project (modelled)		Background noise		Predicted noise		Increment of noise dB(A)	
						Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time	Ld dB(A) Daytime	Ln dB(A) Night-time
Access Road	R25 / MP12	476 727	1 369 836	Djalicunda	Residential (1)	29,7	21,7	51,9	53,5	51,9	53,5	0	0
	R26 / MP12	478 044	1 366 292	Bironqui	Residential (1)	23,9	15,5	51,9	53,5	51,9	53,5	0	0
	R27 / MP12	479 863	1 363 349	Calingue Fula	Residential (1)	36,4	29,3	51,9	53,5	52	53,5	0,1	0
	R28 / MP12	481 403	1 359 002	Mansaba	Residential (1)	21,2	13,2	51,9	53,5	51,9	53,5	0	0
	R29 / MP12	481 019	1 357 093	Mansaba-Sutu	Residential (1)	32,9	25,5	51,9	53,5	52	53,5	0,1	0
	R30 / MP12	480 274	1 355 429	Serraco	Residential (1)	23	15,9	51,9	53,5	51,9	53,5	0	0
	R31 / MP12	478 415	1 353 750	Manbonco	Residential (1)	22,3	14,4	51,9	53,5	51,9	53,5	0	0
	R32 / MP12	474 753	1 345 041	Cutia	Residential (1)	25,2	17,7	51,9	53,5	51,9	53,5	0	0
	R33 / MP12	470 457	1 340 690	Querene	Residential (1)	41,3	33,4	51,9	53,5	52,3	53,5	0,4	0
	R34 / MP12	470 122	1 340 110	Cureyni	Residential (1)	29,2	21,7	51,9	53,5	51,9	53,5	0	0
	R35 / MP12	469 887	1 339 748	Cussac	Residential (1)	27,4	20	51,9	53,5	51,9	53,5	0	0
	R36 / MP12	469 086	1 338 540	San Saunto	Residential (1)	20,2	12,4	51,9	53,5	51,9	53,5	0	0
	R37 / MP12	465 535	1 334 500	Mansoa	Residential (1)	36,2	28,8	51,9	53,5	52	53,5	0,1	0
	R38 / MP12	463 910	1 332 112	-	Residential (1)	39,9	32,6	51,9	53,5	52,2	53,5	0,3	0
	R39 / MP12	463 997	1 331 985	-	Residential (1)	42,3	34,8	51,9	53,5	52,4	53,6	0,5	0,1
	R40 / MP12	463 691	1 331 694	-	Residential (1)	38,3	31,2	51,9	53,5	52,1	53,5	0,2	0
	R41 / MP12	462 525	1 330 718	-	Residential (1)	24,7	17,4	51,9	53,5	51,9	53,5	0	0
	R42 / MP12	461 739	1 330 377	-	Residential (1)	43,1	35,6	51,9	53,5	52,4	53,6	0,5	0,1
	R43 / MP12	458 118	1 328 830	Uaque	Residential (1)	30,9	23,6	51,9	53,5	51,9	53,5	0	0
	R44 / MP12	454 657	1 327 513	-	Residential (1)	33,2	25,6	51,9	53,5	52	53,5	0,1	0
	R45 / MP12	454 534	1 327 343	-	Residential (1)	48,9	41,4	51,9	53,5	53,7	53,8	1,8	0,3
	R46 / MP12	454 145	1 327 269	-	Residential (1)	49,8	42,1	51,9	53,5	54	53,8	2,1	0,3
	R47 / MP12	454 166	1 327 003	-	Residential (1)	40,3	33,7	51,9	53,5	52,2	53,5	0,3	0
	R48 / MP12	453 322	1 326 752	-	Residential (1)	40,3	33	51,9	53,5	52,2	53,5	0,3	0
	R49 / MP12	453 191	1 326 681	-	Residential (1)	47,4	39,6	51,9	53,5	53,2	53,7	1,3	0,2
	R50 / MP12	453 100	1 326 631	-	Residential (1)	48,2	40,6	51,9	53,5	53,4	53,7	1,5	0,2
	R51 / MP12	452 990	1 326 599	-	Residential (1)	50,5	42,7	51,9	53,5	54,3	53,8	2,4	0,3
	R52 / MP12	452 798	1 326 487	-	Residential (1)	47,2	39,5	51,9	53,5	53,2	53,7	1,3	0,2
	R53 / MP12	451 373	1 325 821	Dugal	Residential (1)	52,3	43,9	51,9	53,5	55,1	54	3,2	0,5
	R54 / MP12	451 451	1 325 785	Dugal	Residential (1)	57,4	48,7	51,9	53,5	58,5	54,7	6,6	1,2
	R55 / MP12	451 379	1 325 741	Dugal	Residential (1)	47,9	40,3	51,9	53,5	53,4	53,7	1,5	0,2
	R56 / MP12	451 764	1 325 439	-	Residential (1)	57,1	48,5	51,9	53,5	58,2	54,7	6,3	1,2
	R57 / MP12	451 724	1 325 217	-	Residential (1)	42,1	35,2	51,9	53,5	52,3	53,6	0,4	0,1
	R58 / MP12	452 239	1 325 348	-	Residential (1)	24,2	17,6	51,9	53,5	51,9	53,5	0	0
	R59 / MP12	451 954	1 324 457	-	Residential (1)	29,1	25,1	51,9	53,5	51,9	53,5	0	0
	R60 / MP12	453 350	1 324 081	Cunteda	Residential (1)	43,7	36,6	51,9	53,5	52,5	53,6	0,6	0,1
	R61 / MP12	453 361	1 323 771	Cunteda	Residential (1)	58,8	50,2	51,9	53,5	59,6	55,2	7,7	1,7
	R62 / MP12	453 616	1 323 520	Cunteda	Residential (1)	39,1	32,8	51,9	53,5	52,1	53,5	0,2	0
	R63 / MP12	453 272	1 323 441	Cunteda	Residential (1)	40,9	34,7	51,9	53,5	52,2	53,6	0,3	0,1
	R64 / MP12	452 801	1 322 155	Arote	Residential (1)	32,8	31,2	51,9	53,5	52	53,5	0,1	0
	R65 / MP12	452 894	1 322 028	Arote	Residential (1)	31,2	26,9	51,9	53,5	51,9	53,5	0	0
	R66 / MP12	452 923	1 321 807	-	Residential (1)	37,8	34,3	51,9	53,5	52,1	53,6	0,2	0,1
	R67 / MP12	452 421	1 321 384	-	Residential (1)	40	37,7	51,9	53,5	52,2	53,6	0,3	0,1
	R68 / MP12	452 429	1 320 949	Ancone	Residential (1)	45,6	42,8	51,9	53,5	52,8	53,9	0,9	0,4
Port Site	R69 / KP1	452 474	1 320 599	Village Chief	Residential (1)	54,7	49,7	63	56,5	63,6	57,3	0,6	0,8
	R70 / KP2	452 716	1 320 121	Fishing Beach	Commercial	55,7	55,7	48,9	48,9	56,5	56,5	7,6	7,6

Prepared by Knight Piésold Consultores.
Datum UTM WGS84.
Notes:
(1) Receptors are adjacent to road traffic.
Legend:

> Residential Guideline according to IFC = Daytime: 55 dB(A) / Night-time: 45 dB(A), or increase in background levels greather than 3 dB.

> Residential Guideline according to OECD for residential close to roads - Daytime: 65 dB(A) / Night-time: 55 dB(A).

> Commercial and Industrial guideline according to IFC - Daytime: 70 dB(A) / Night-time: 70 dB(A).

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Graphs

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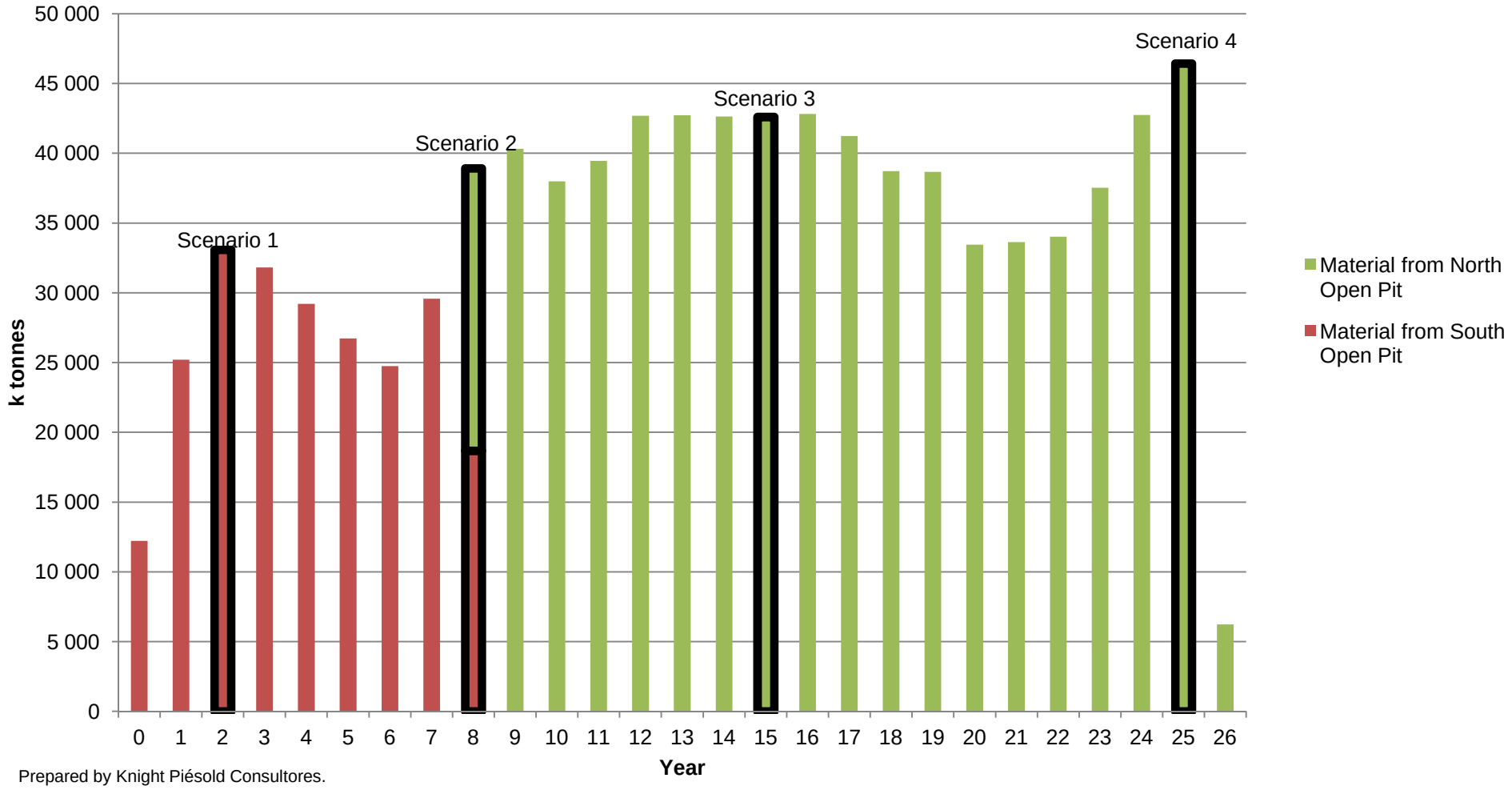
GRAPH 4.1
Mining planning - Farim Phosphate Project



Prepared by Knight Piésold Consultores.

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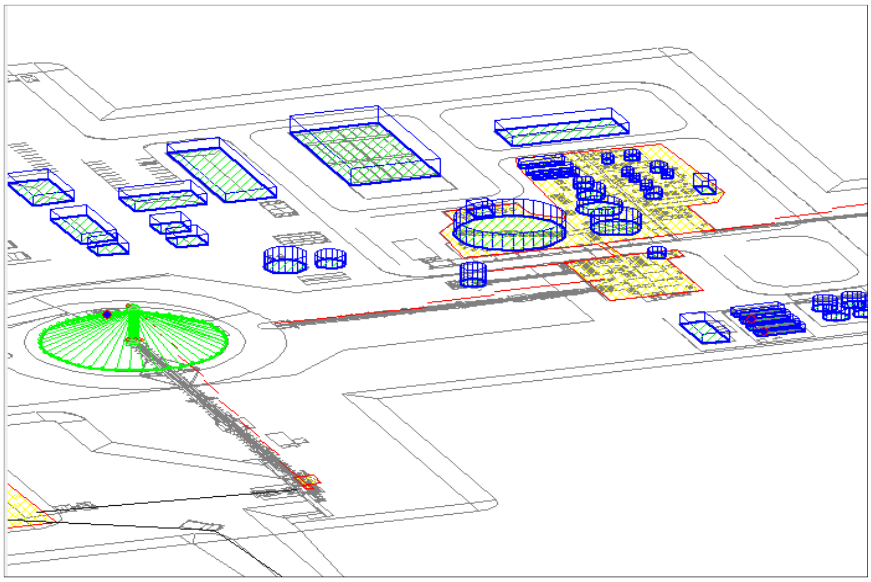
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.2
Geometric designs in SoundPLAN in Process Plant



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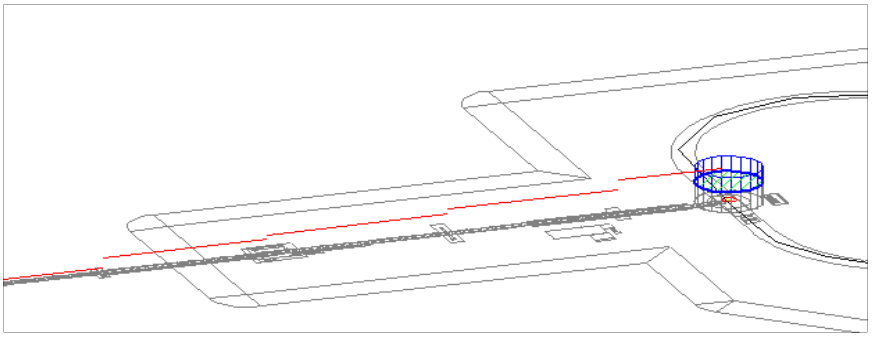
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.3
Geometric designs in SoundPLAN in Truck Loading Facility



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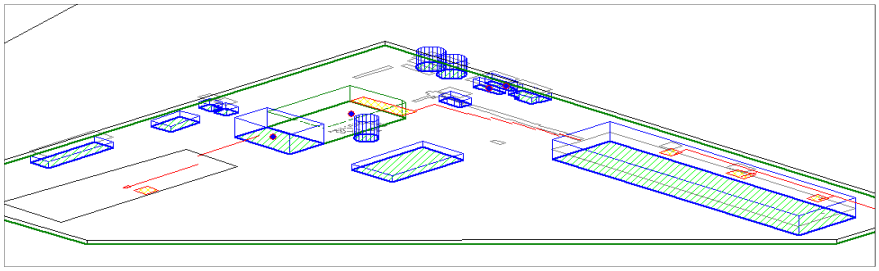
LYCOPODIUM MINERALS CANADA LTD.
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE FARIM PHOSPHATE PROJECT

GRAPH 4.4
Geometric designs in SoundPLAN in Port Site



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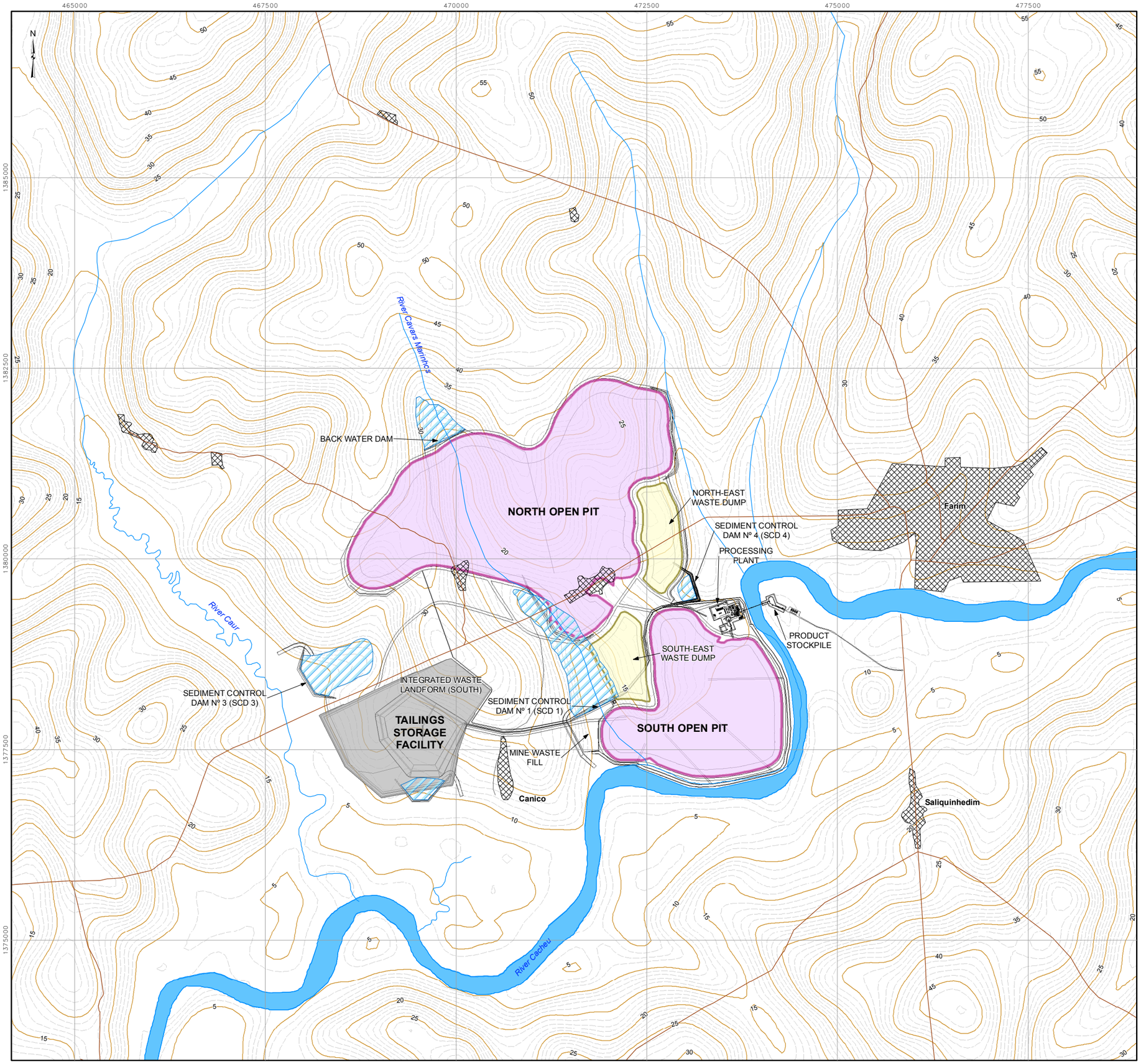
Figures



LEGEND

URBAN AREA
- EXISTING POPULATION

HYDROGRAPHY
- RIVER

TOPOGRAPHY
- PRINCIPAL CURVES
- SECONDARY CURVES

ROADS
- EXISTING ROAD

FACILITIES
- DAM WATER
- OPEN PIT
- WASTE DUMP
- STORAGE FACILITY

1 0 1 2 Km.

ESCALE = 1:50,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	GENERAL ARRANGEMENT PLAN – MINE SITE

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DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.1	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

09/06/2015 11:45:31 a.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.1.mxd

LEGEND

URBAN AREA

EXISTING POPULATION

ROADS

ACCESS ROAD FROM MINE SITE TO PONT CHUGUE PORT

5 0 5 10 Km.

ESCALE = 1:250,000

REFERENCE
-COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	ACCESS ROAD FROM MINE SITE TO PONT CHUGUE PORT

Knight Piésold
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DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.2	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

12/06/2015 03:39:30 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.2.mxd

LEGEND

PONTA CHUGUE PORT FACILITY

50 0 50 100 Meters

ESCALE = 1:2,000

REFERENCE
-COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

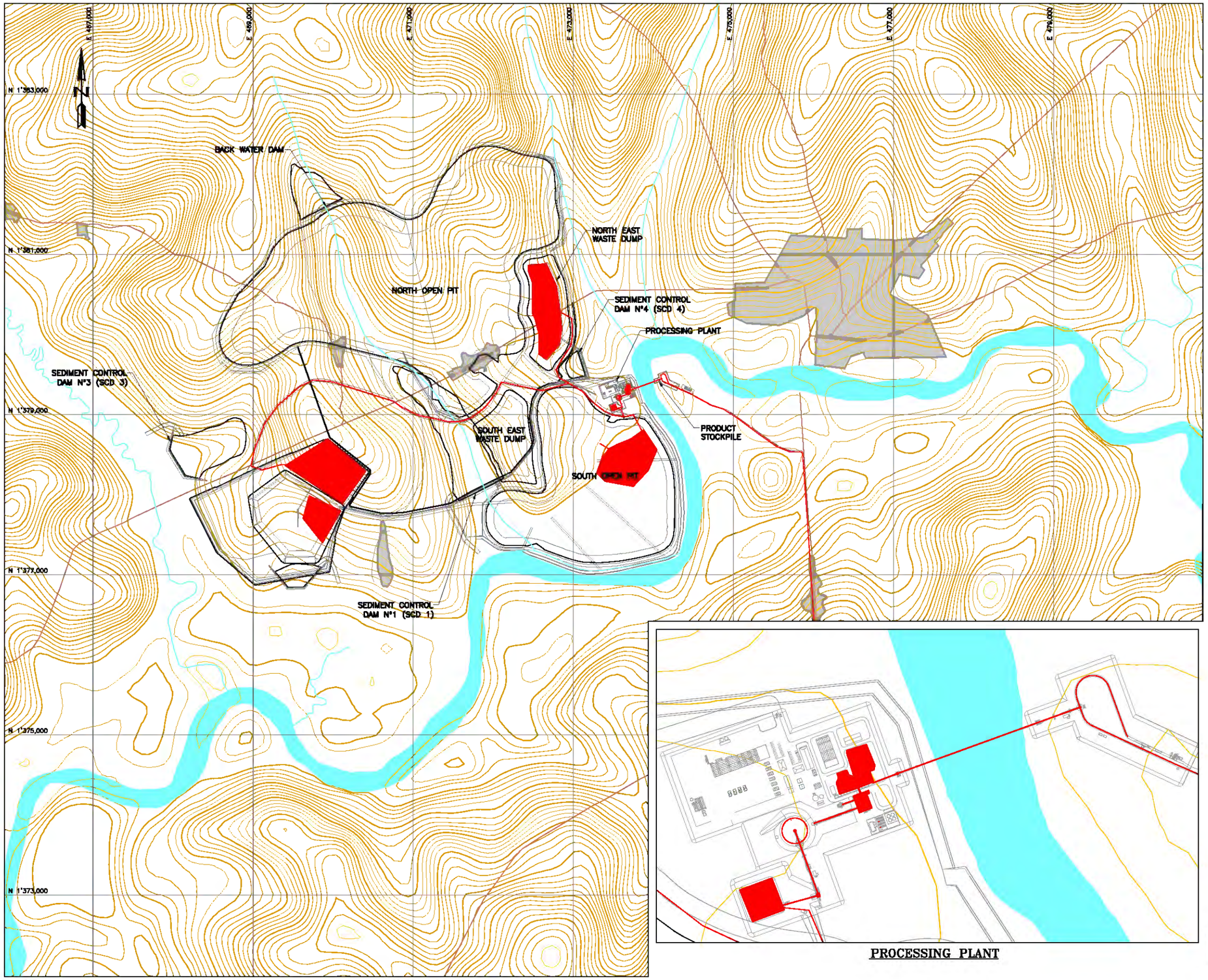
CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	PONTA CHUGUE PORT FACILITY

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.3	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

12/06/2015 03:58:21 p.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.3.mxd



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

PROCESSING PLANT

PLANT

100 0 100 200 METERS
SCALE = 1:5000

LEGEND:

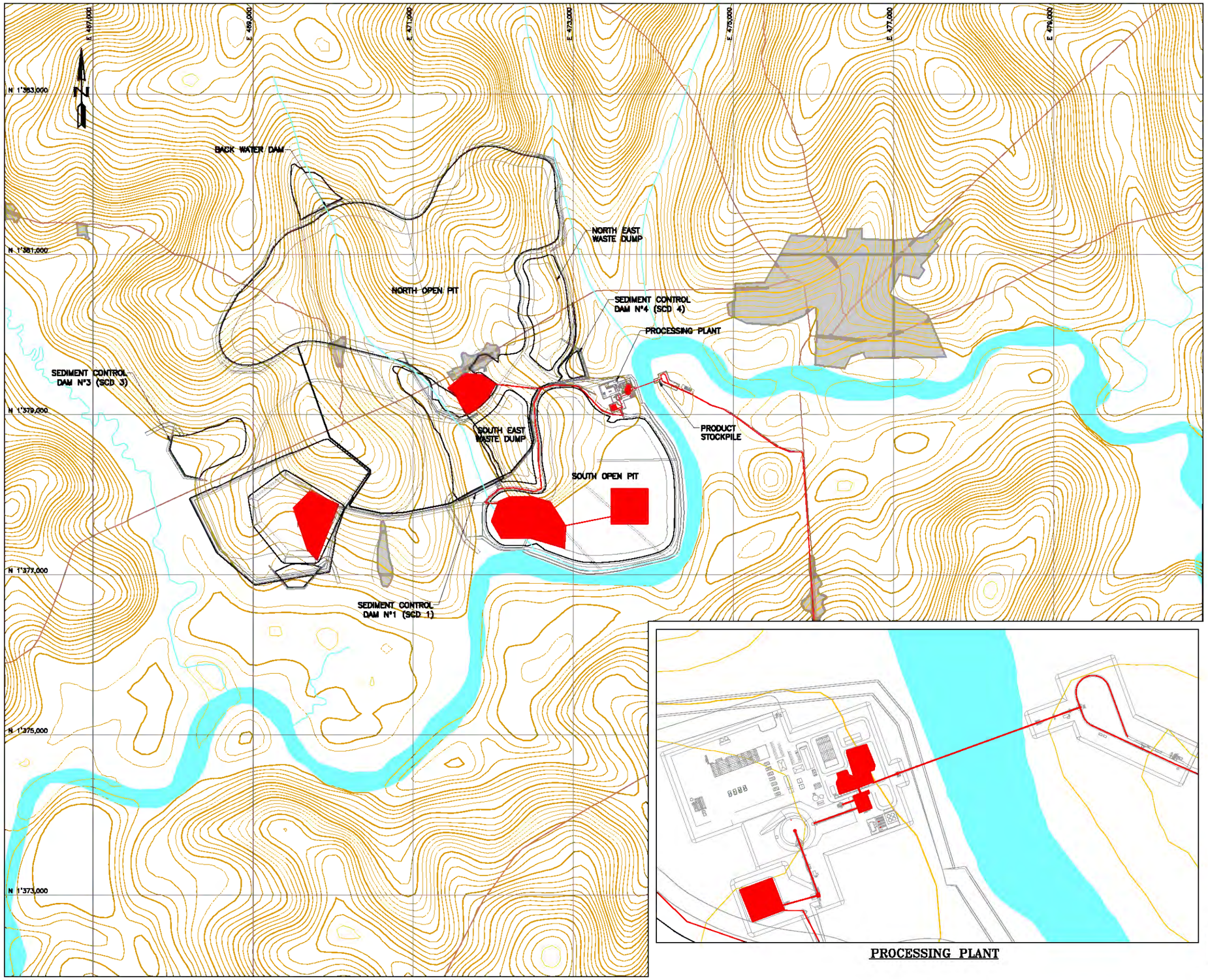
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- LINE SOURCES
- AREA SOURCES

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	EMISSION SOURCES IN MINE SITE SCENARIO 1 (YEAR 2)

Knight Piésold CONSULTING

DESIGNED BY		CHECKED BY		DATE	FIGURA 4.4	REV. A
DRAWN BY		APPROVED BY				

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURA 4.4 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURA 4.4 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

PROCESSING PLANT

PLANT

100 0 100 200 METERS
SCALE = 1:5000

LEGEND:

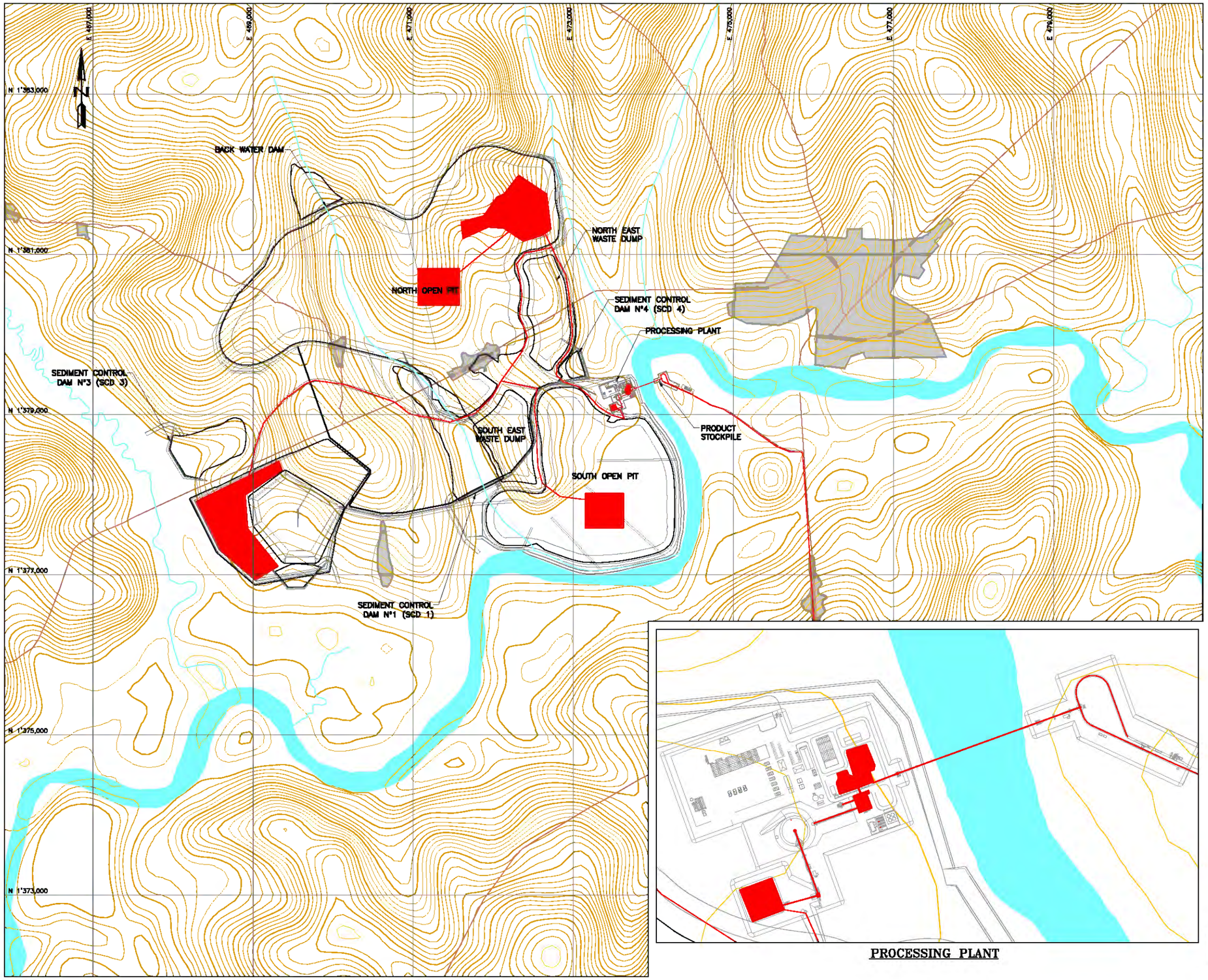
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- LINE SOURCES
- AREA SOURCES

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	EMISSION SOURCES IN MINE SITE SCENARIO 2 (YEAR 8)

Knight Piésold CONSULTING

DESIGNED BY		CHECKED BY		DATE	FIGURA 4.5	REV. A
DRAWN BY		APPROVED BY				

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURA 4.5 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURA 4.5 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

PROCESSING PLANT

PLANT

100 0 100 200 METERS

SCALE = 1:5000

LEGEND:

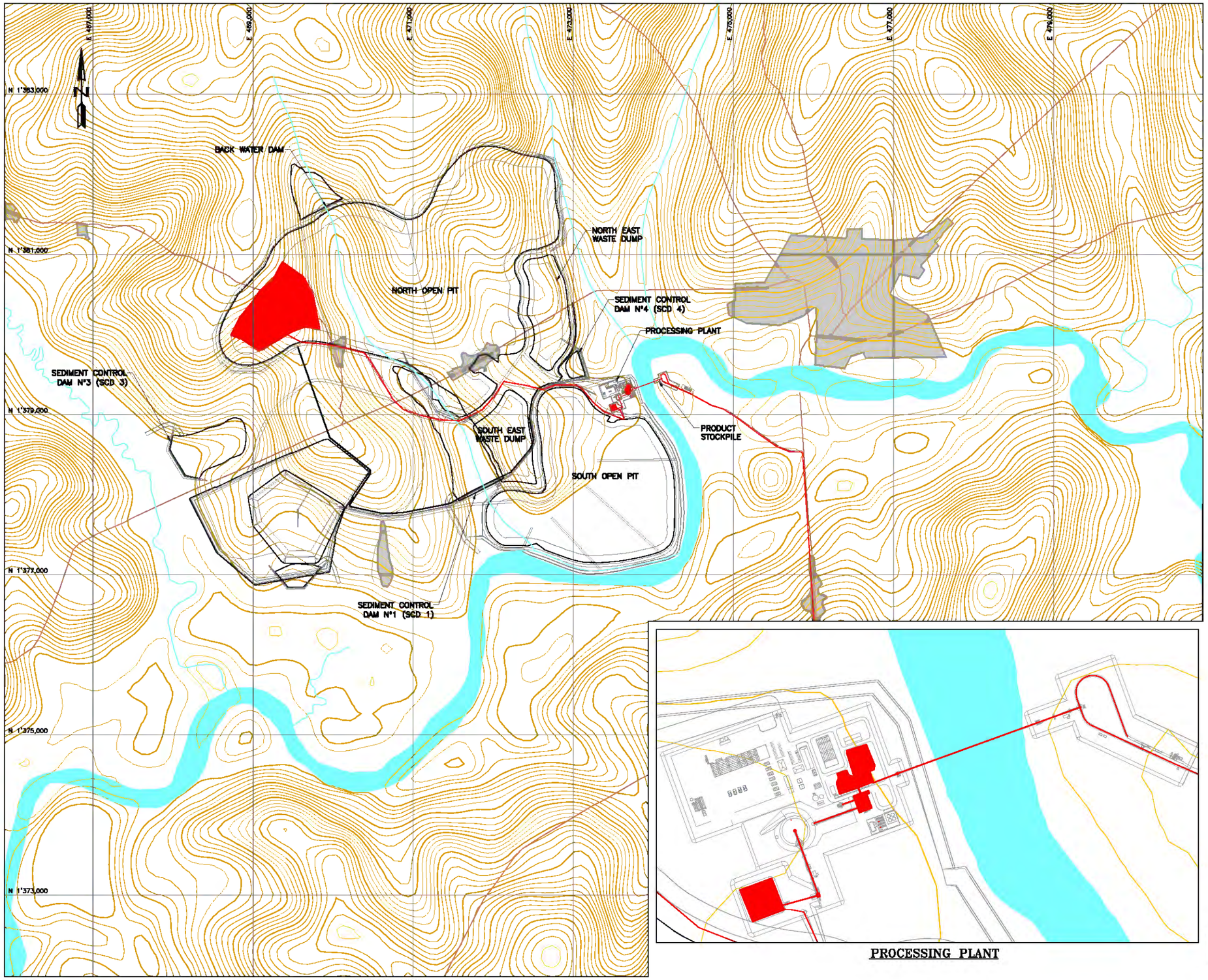
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- LINE SOURCES
- AREA SOURCES

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	EMISSION SOURCES IN MINE SITE SCENARIO 3 (YEAR 15)

Knight Piésold CONSULTING

DESIGNED BY		CHECKED BY		DATE	FIGURA 4.6	REV. A
DRAWN BY		APPROVED BY				

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURA 4.6 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURA 4.6 A.dwg



MINE SITE

PROCESSING PLANT

REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

PLANT

100 0 100 200 METERS
SCALE = 1:5000

LEGEND:

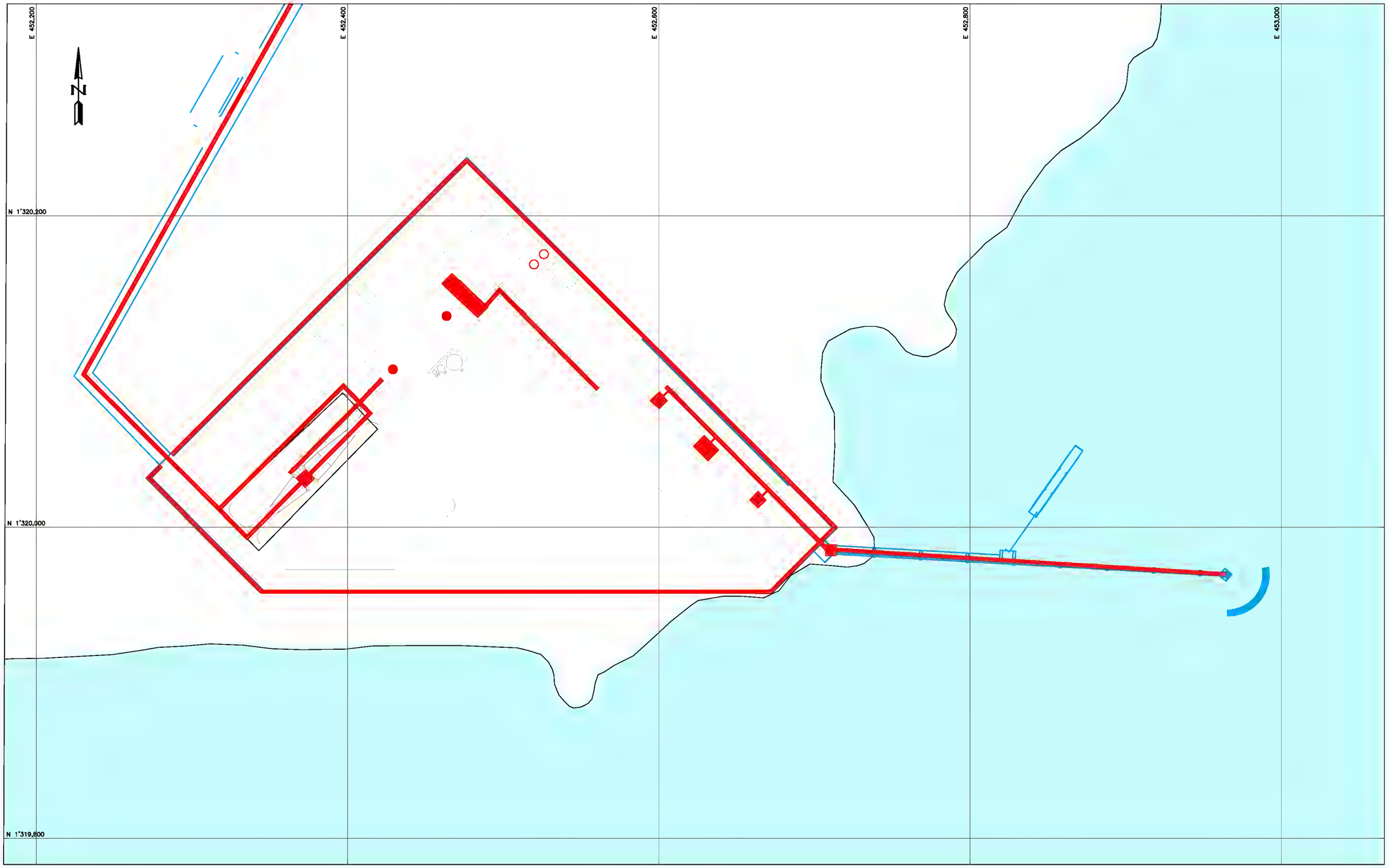
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- LINE SOURCES
- AREA SOURCES

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	EMISSION SOURCES IN MINE SITE SCENARIO 4 (YEAR 25)

Knight Piésold CONSULTING

DESIGNED BY		CHECKED BY		DATE	FIGURA 4.7	REV. A
DRAWN BY		APPROVED BY				

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURA 4.7 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURA 4.7 A.dwg



REFERENCE:
–COORDINATE SYSTEM UTM, DATUM WGS–84, ZONA 28N.

PORT FACILITY

PLANT

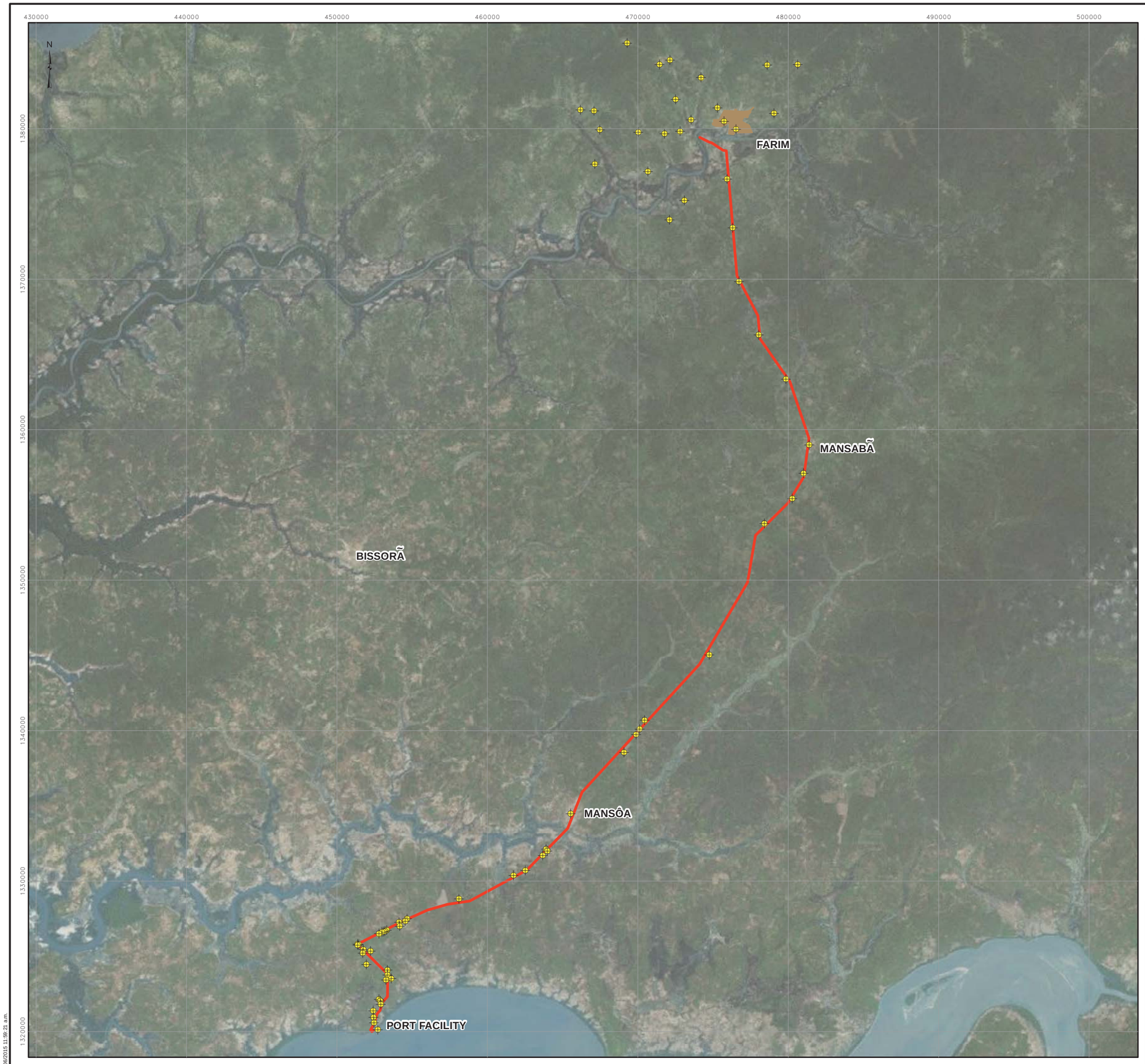
100 0 100 200 METERS
SCALE = 1:5000

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	EMISSION SOURCES IN ACCESS ROAD AND PORT SITE

Knight Piésold CONSULTING

DESIGNED BY		CHECKED BY		DATE	FIGURA 4.8	REV. A
DRAWN BY		APPROVED BY				

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURA 4.8 A | XREF | M:\ProjectFiles\NB301–520\05A\Acad Files\FIGURA 4.8 A.dwg



LEGEND

URBAN AREA
EXISTING POPULATION

POINT
RECEPTORS

ROADS
ACCESS ROAD FROM MINE SITE TO PONT CHUGUE PORT

5 0 5 10 Km.
ESCALE = 1:250,000

REFERENCE
–COORDINATE SYSTEM, DATUM WGS84, ZONE 28N

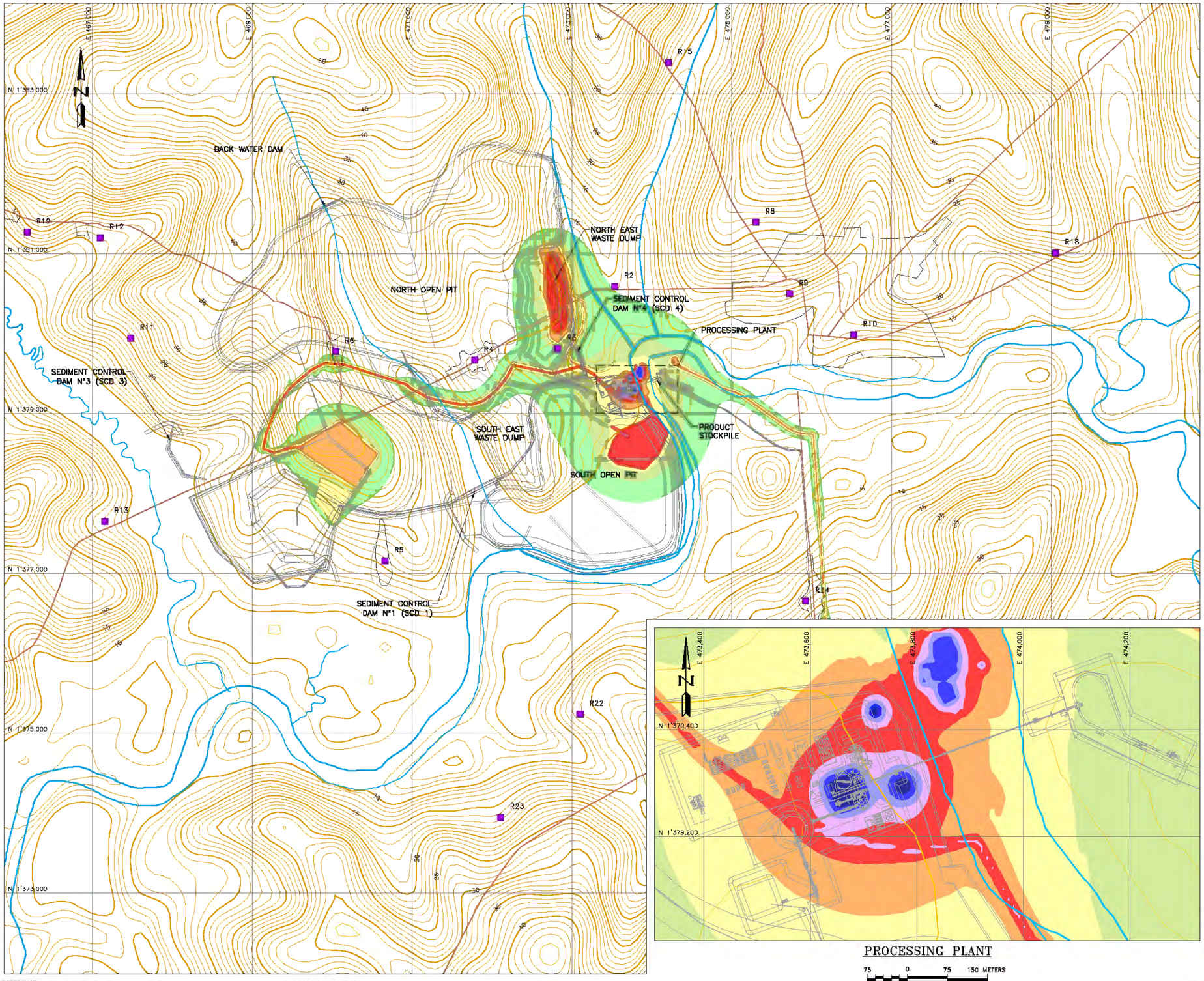
CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	LOCATION OF SENSITIVE RECEPTORS

Knight Piésold
CONSULTING

DESIGNED BY	AD	CHECKED BY	EE	DATE	FIGURE 4.9	REV.
DRAWN BY	GV	APPROVED BY		JUN 2015		0

11/06/2015 11:39:21 a.m.

LAS ESCALAS INDICADAS CORRESPONDEN A UNA HOJA DE TAMAÑO A3 | KP | K:\NB301_520\05A\Mxd\Reporte\FIGURE 4.9.mxd



REFERENCE:
–COORDINATE SYSTEM UTM, DATUM WGS–84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

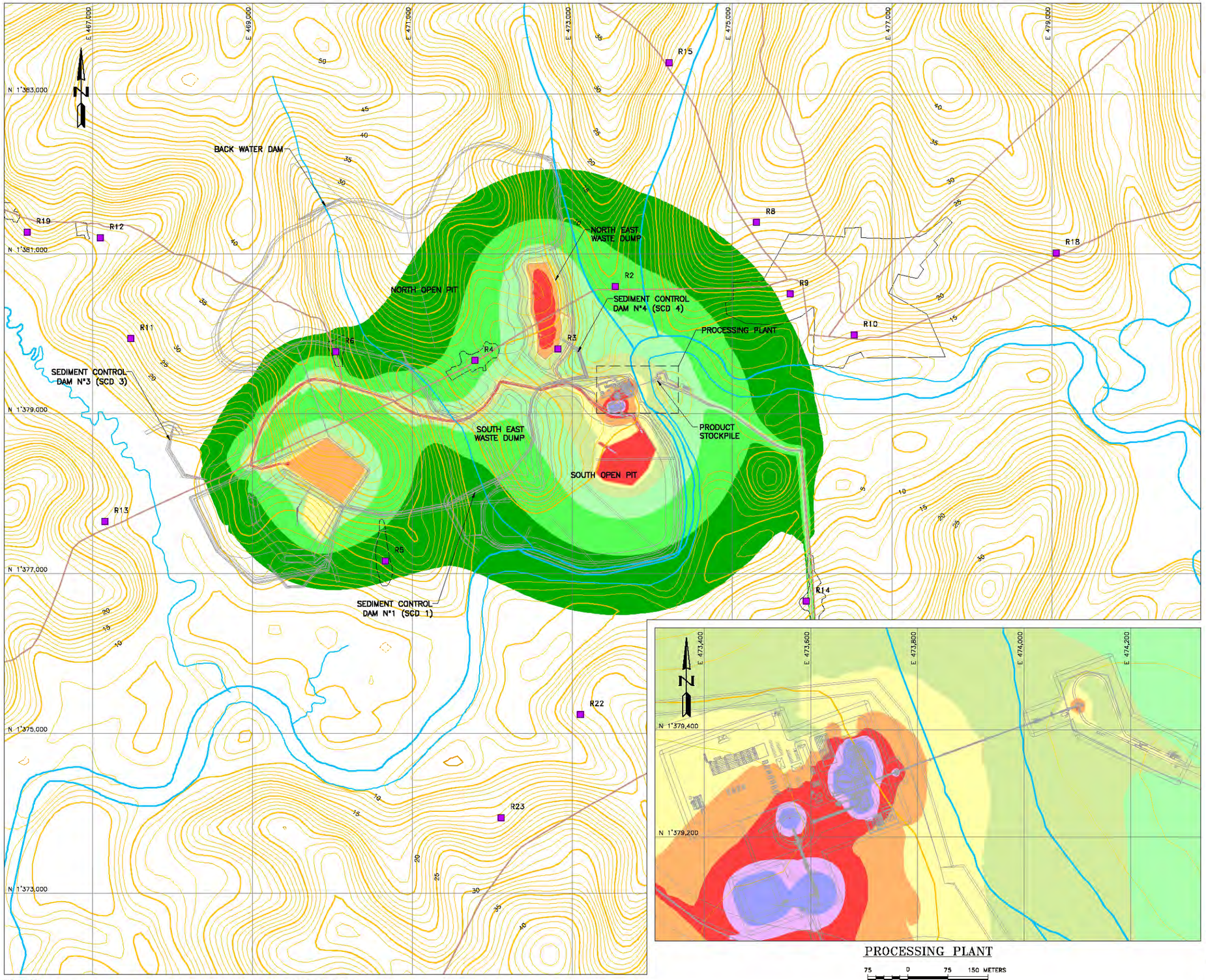
- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	DAYTIME NOISE PROPAGATION IN MINE SITE SCENARIO 1 (YEAR 2)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.1	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.1 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.1 A.dwg



REFERENCE:
–COORDINATE SYSTEM UTM, DATUM WGS–84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT–TIME (Ln) IN dB(A):

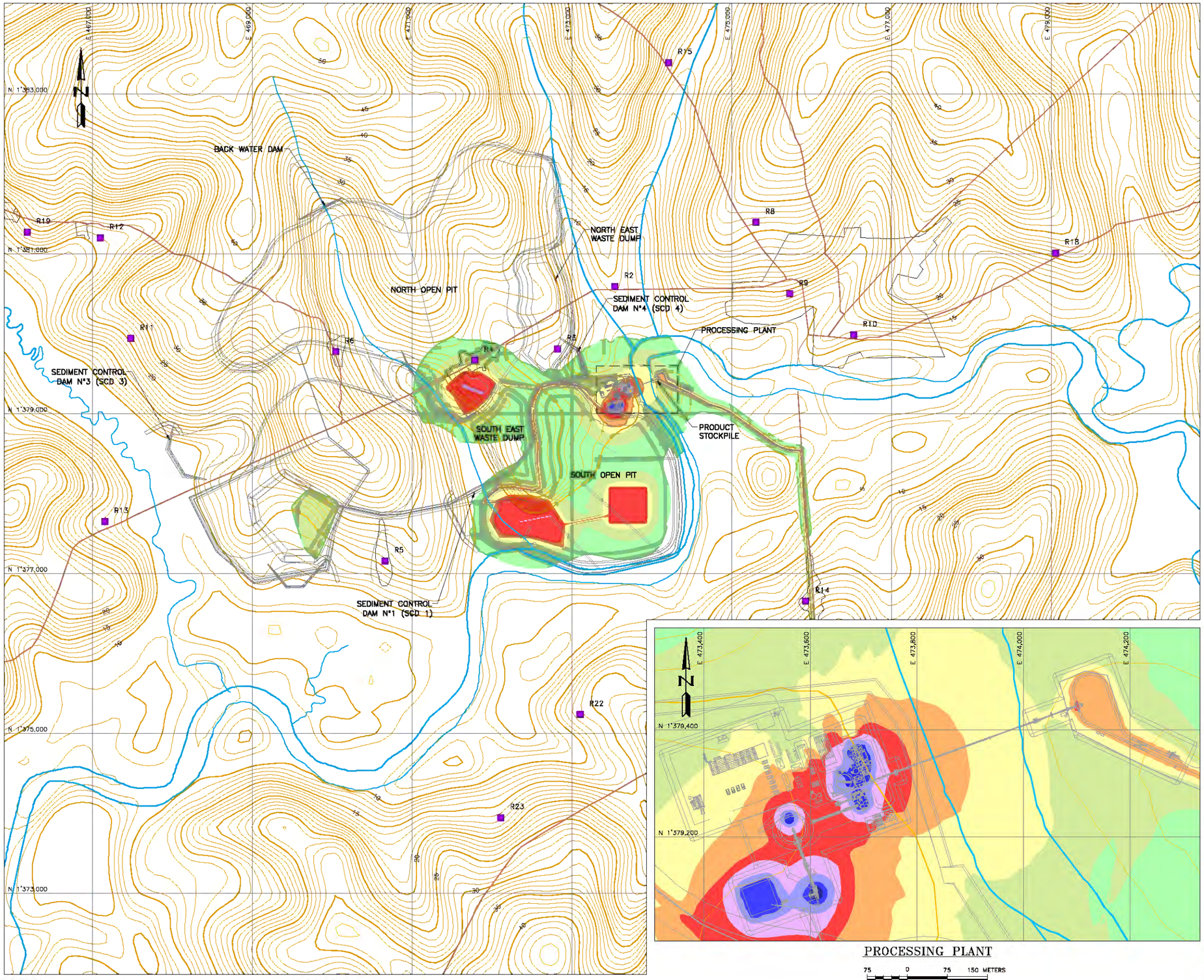
- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	NIGHT–TIME NOISE PROPAGATION IN MINE SITE SCENARIO 1 (YEAR 2)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.2	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.2 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.2 A.dwg



REFERENCE:
–COORDINATE SYSTEM UTM, DATUM WGS–84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT: LYCOPODIUM MINERALS CANADA LTD

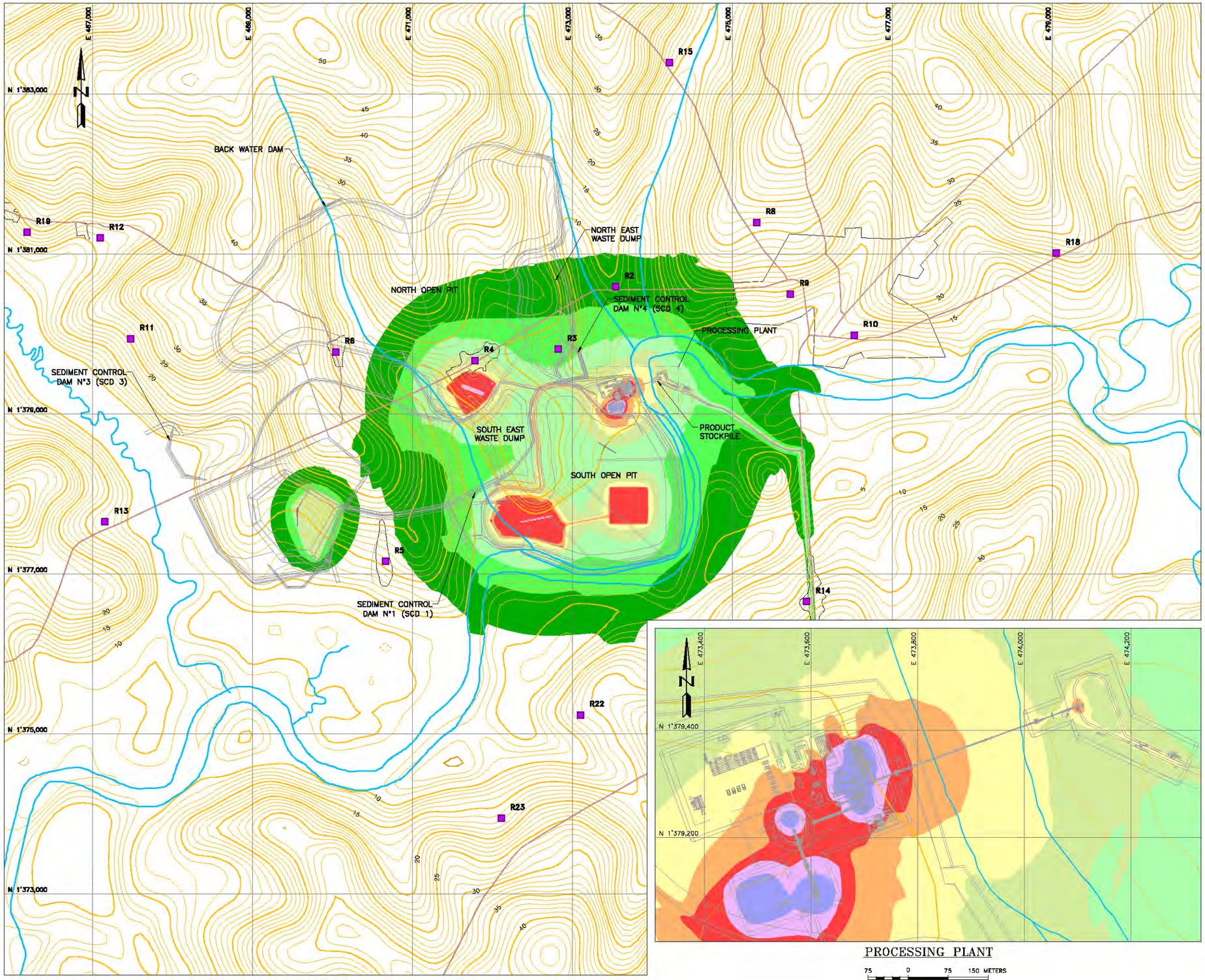
PROJECT: ESIA FOR THE FARIM PHOSPHATE PROJECT

TITLE: DAYTIME NOISE PROPAGATION IN MINE SITE SCENARIO 2 (YEAR 8)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.3	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.3 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.3 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT-TIME (Ln) IN dB(A):

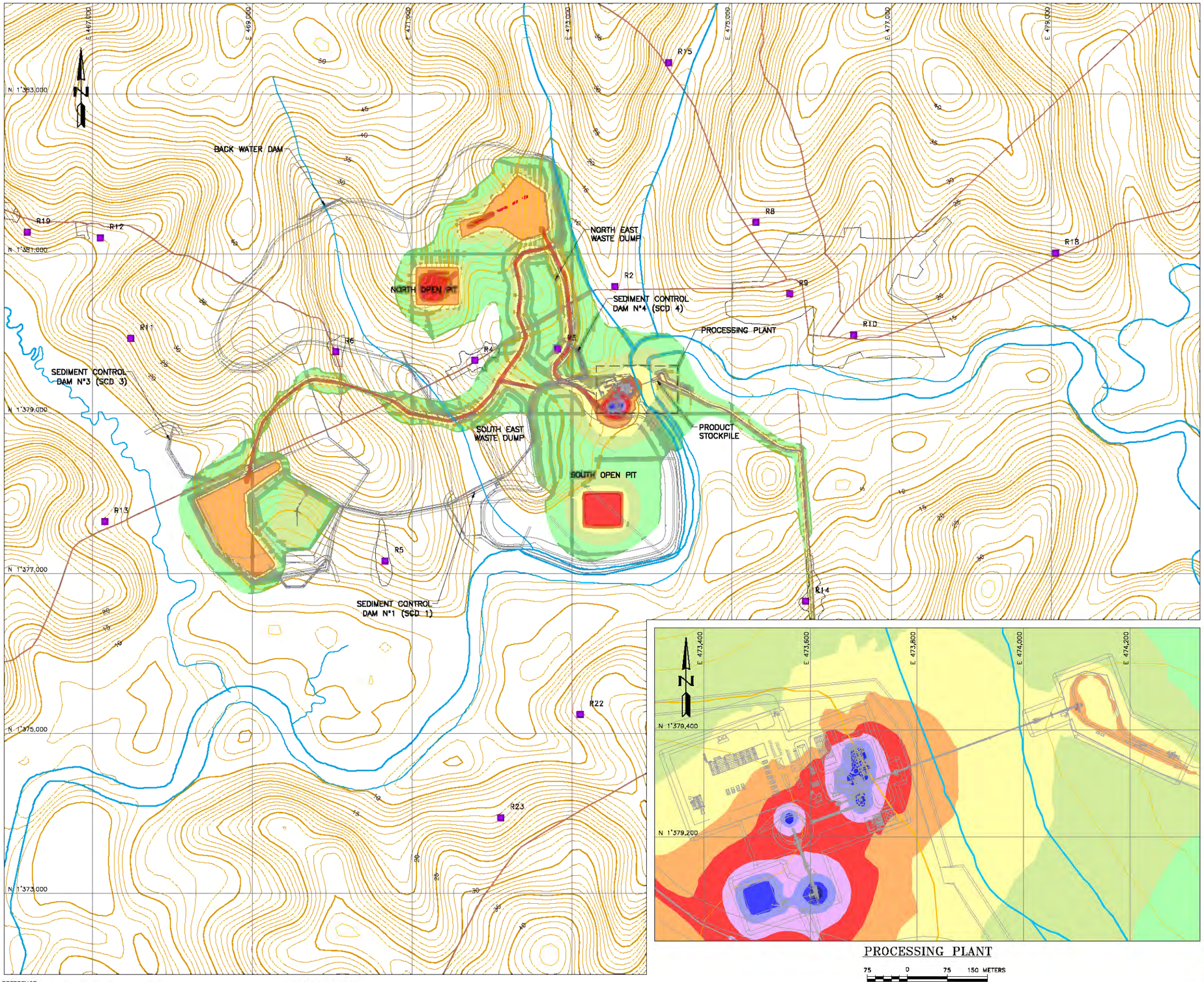
- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	NIGHT-TIME NOISE PROPAGATION IN MINE SITE SCENARIO 2 (YEAR 8)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.4	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.4 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.4 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT: LYCOPODIUM MINERALS CANADA LTD

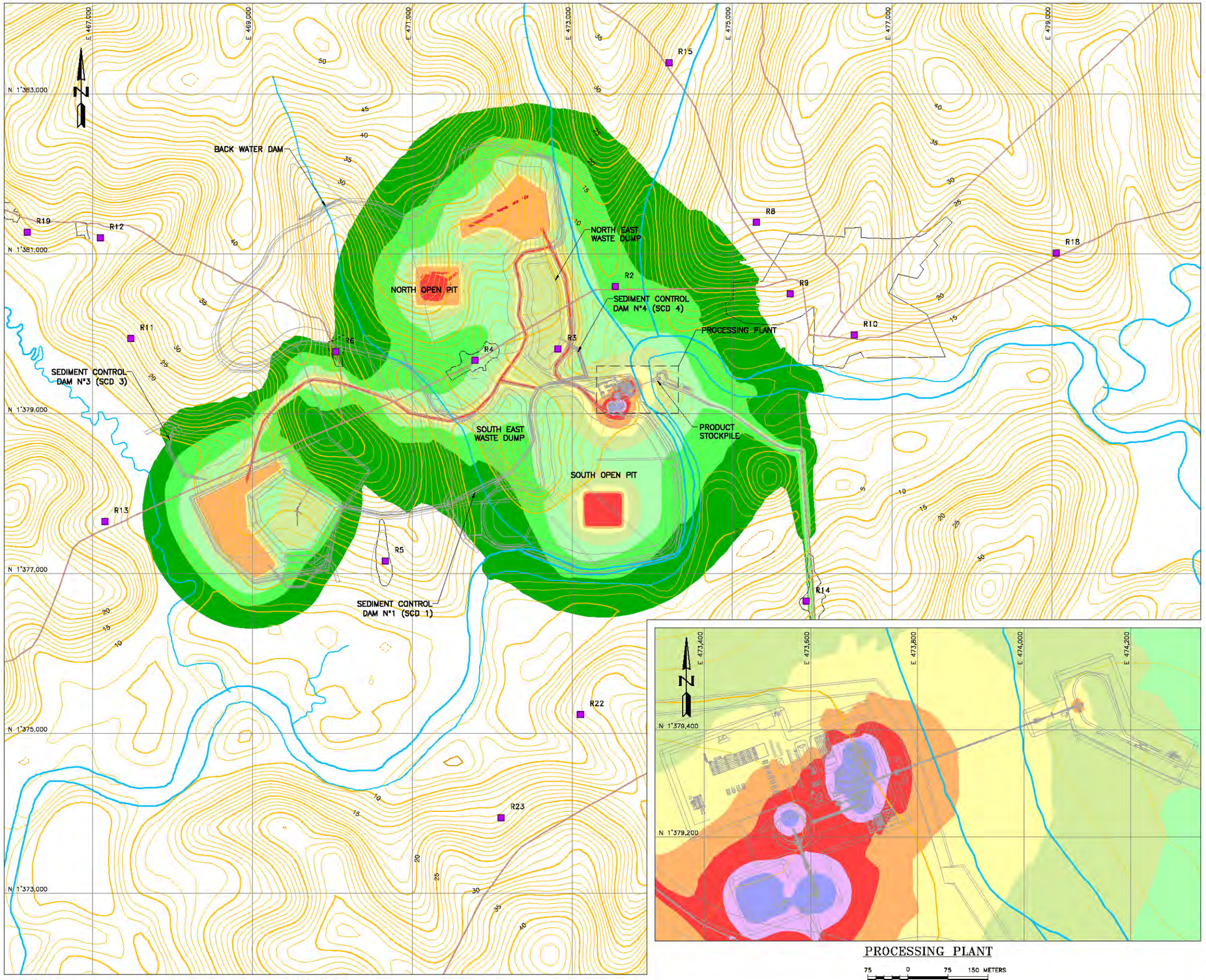
PROJECT: ESIA FOR THE FARIM PHOSPHATE PROJECT

TITLE: DAYTIME NOISE PROPAGATION IN MINE SITE SCENARIO 3 (YEAR 15)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.5	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.5 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.5 A.dwg



MINE SITE

PROCESSING PLANT

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT-TIME (Ln) IN dB(A):

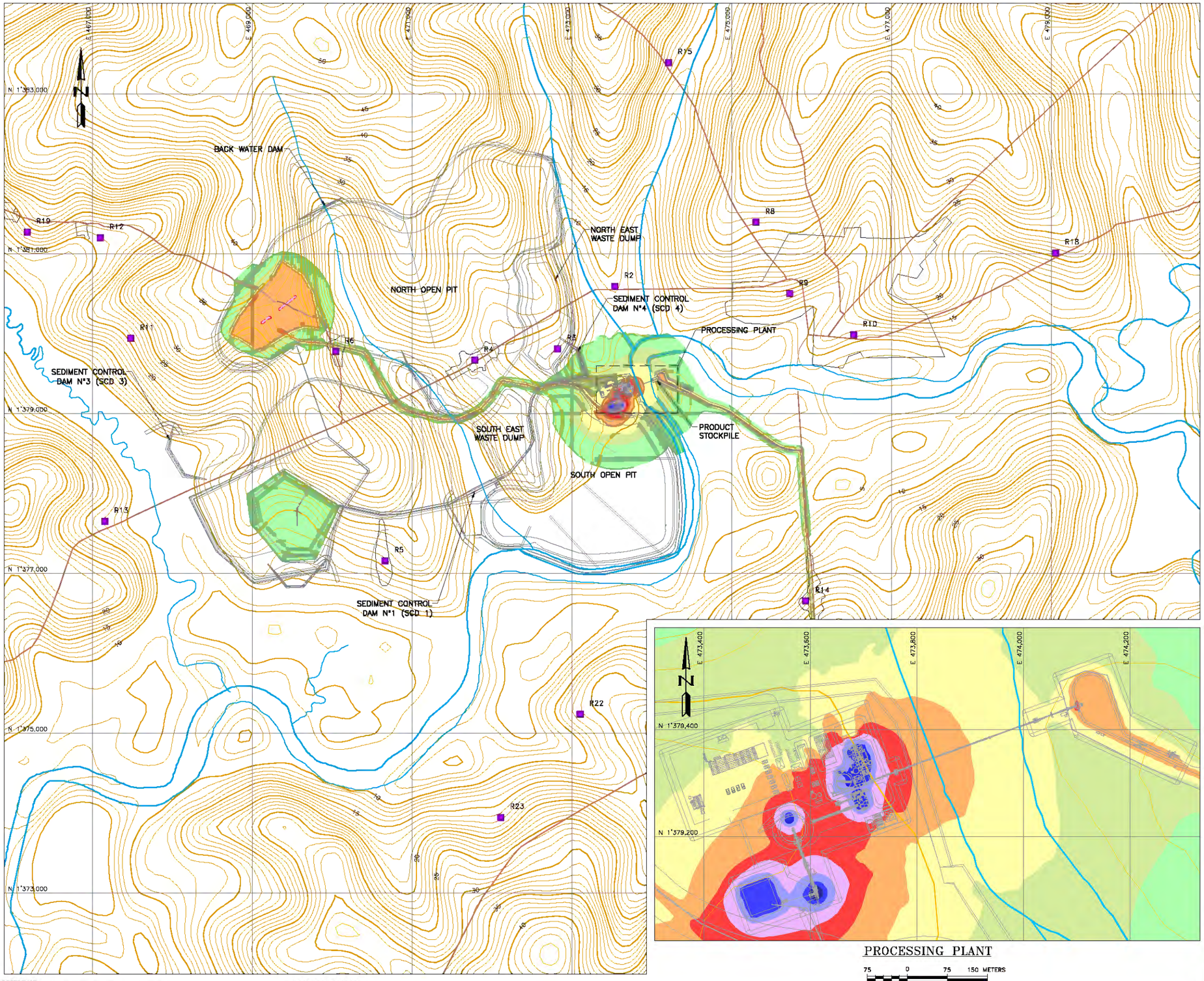
- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	NIGHT-TIME NOISE PROPAGATION IN MINE SITE SCENARIO 3 (YEAR 15)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.6	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.6 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.6 A.dwg



REFERENCE:
–COORDINATE SYSTEM UTM, DATUM WGS–84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

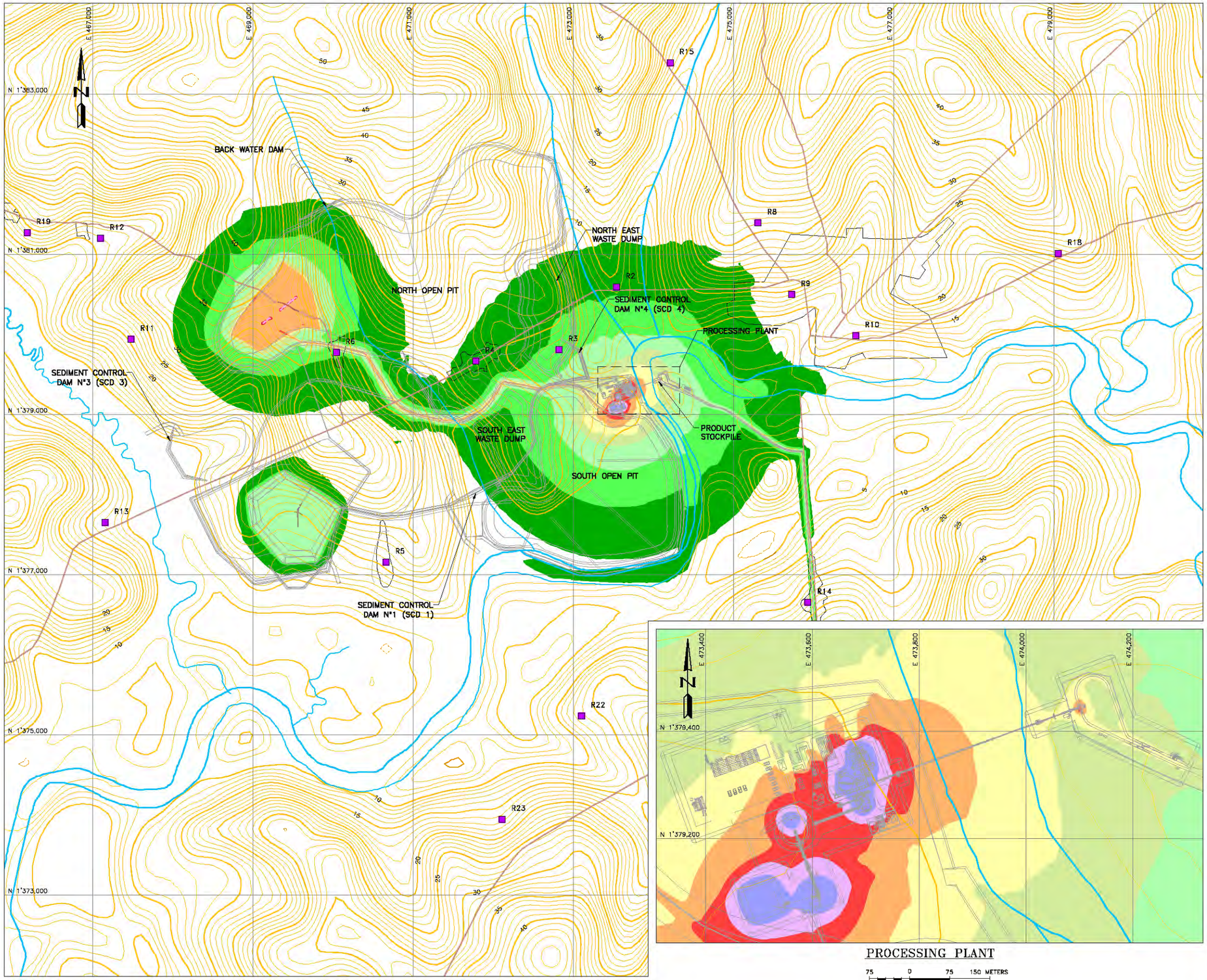
- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	DAYTIME NOISE PROPAGATION IN MINE SITE SCENARIO 4 (YEAR 25)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.7	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.7 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.7 A.dwg



REFERENCE:
-COORDINATE SYSTEM UTM, DATUM WGS-84, ZONA 28N.

MINE SITE

500 0 500 1000 METERS
1:50000

PROCESSING PLANT

75 0 75 150 METERS
1:7500

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND ELEVATIONS IN METERS
- URBAN AREA
- HYDROGRAPHY
- EXISTING ROAD
- FACILITIES
- RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT-TIME (Ln) IN dB(A):

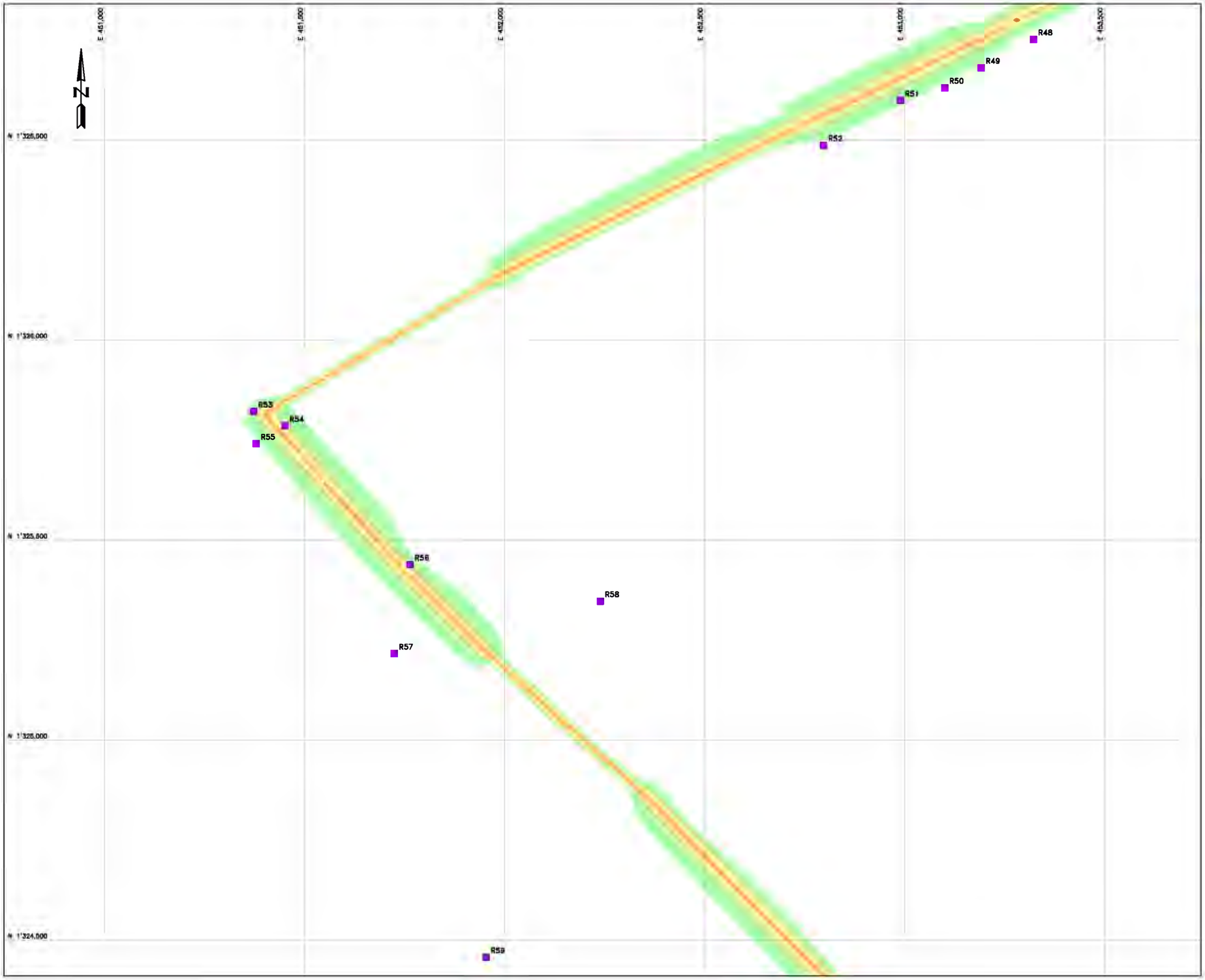
- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	NIGHT-TIME NOISE PROPAGATION IN MINE SITE SCENARIO 4 (YEAR 25)

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.8	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.8 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.8 A.dwg



PLAN

100 0 100 200 METERS
1:10000

LEGEND:

RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

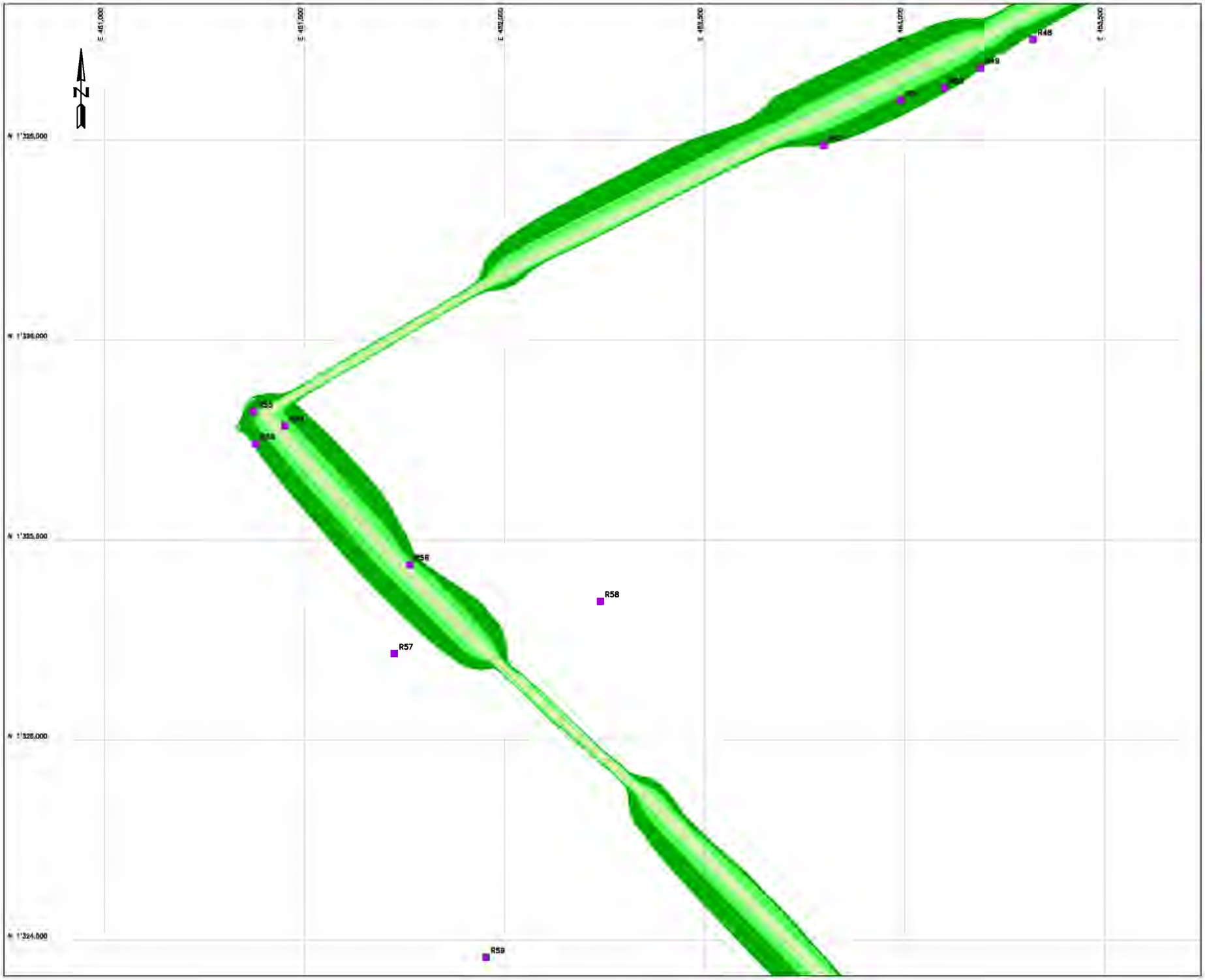
- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	DAYTIME NOISE PROPAGATION IN ACCESS ROAD IN DUGAL

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.9	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.9 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.9 A.dwg



PLAN

100 0 100 200 METERS
1:10000

LEGEND:

RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT-TIME (Ln) IN dB(A):

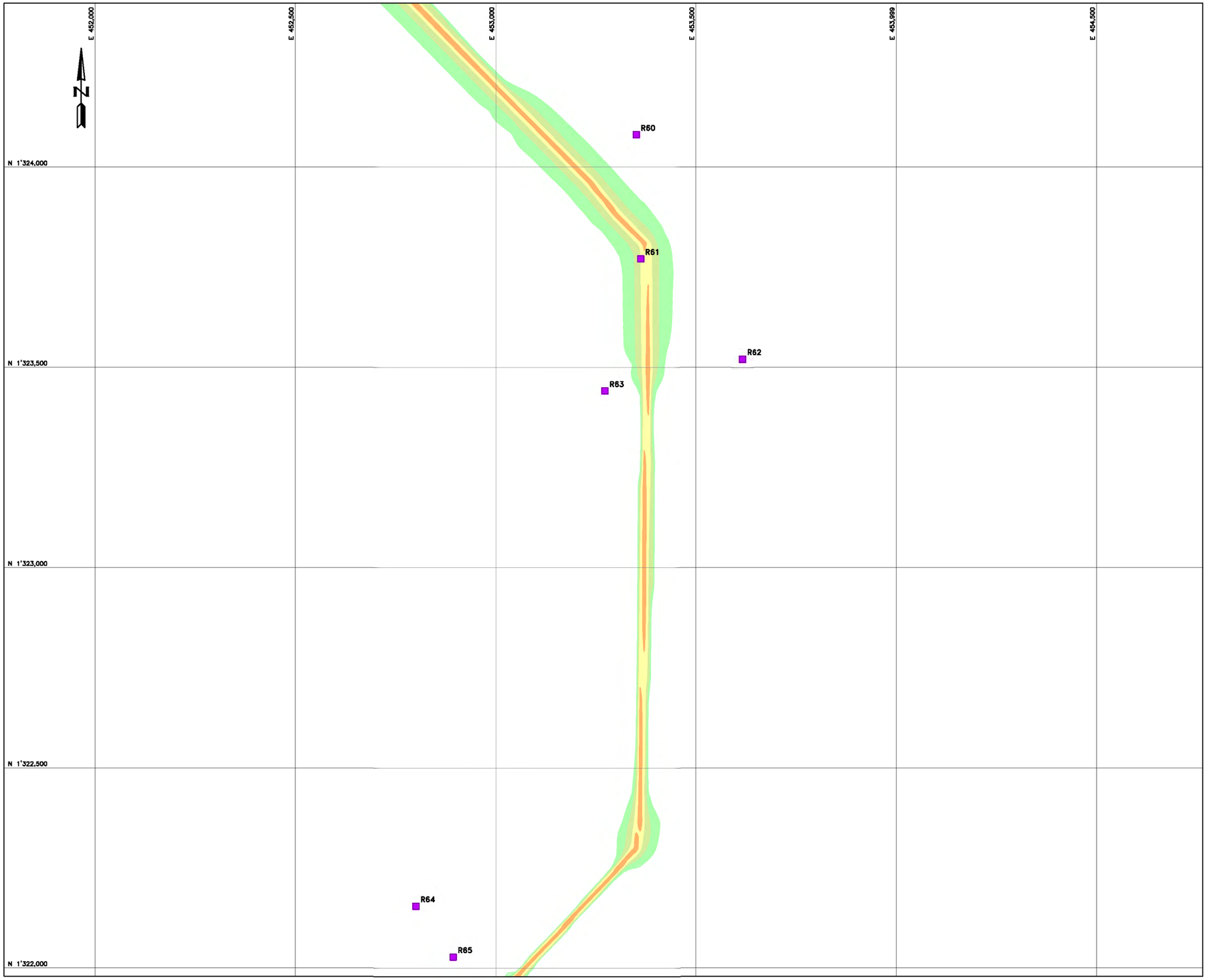
- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	NIGHT-TIME NOISE PROPAGATION IN ACCESS ROAD IN DUGAL

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.10	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.10 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.10 A.dwg



PLAN

100 0 100 200 METERS
1:10000

LEGEND:

RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

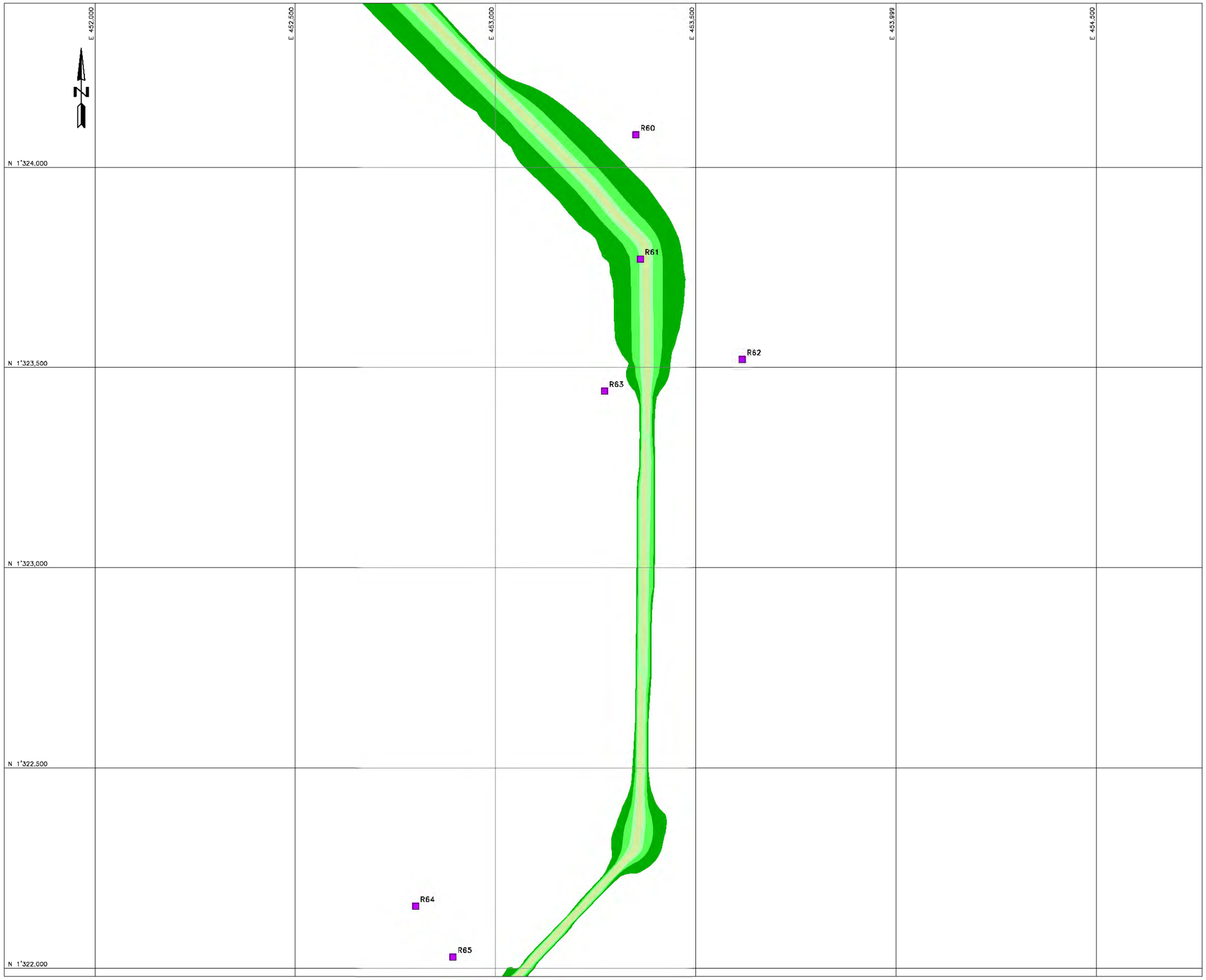
- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	DAYTIME NOISE PROPAGATION IN ACCESS ROAD IN CUNTEDA

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.11	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.11 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.11 A.dwg



PLAN

100 0 100 200 METERS
1:10000

LEGEND:

RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT-TIME (Ln) IN dB(A):

- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT: LYCOPODIUM MINERALS CANADA LTD

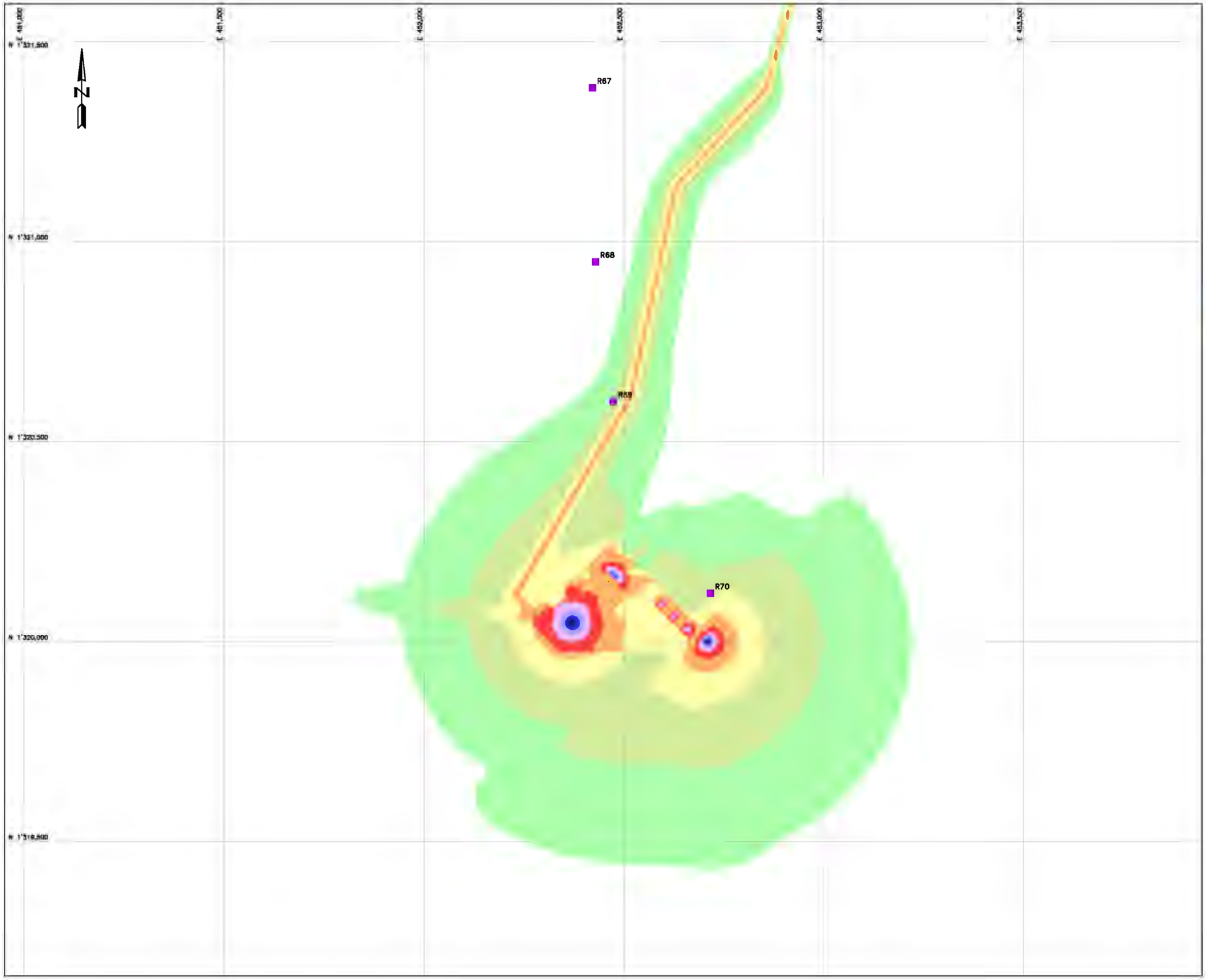
PROJECT: ESIA FOR THE FARIM PHOSPHATE PROJECT

TITLE: NIGHT-TIME NOISE PROPAGATION IN ACCESS ROAD IN CUNTEDA

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.12	REV. A
DRAWN BY	EA	APPROVED BY	–	06/18/15		

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.12 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.12 A.dwg



PLAN

100 0 100 200 METERS

1:10000

LEGEND:

■ RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR DAYTIME (Ld) IN dB(A):

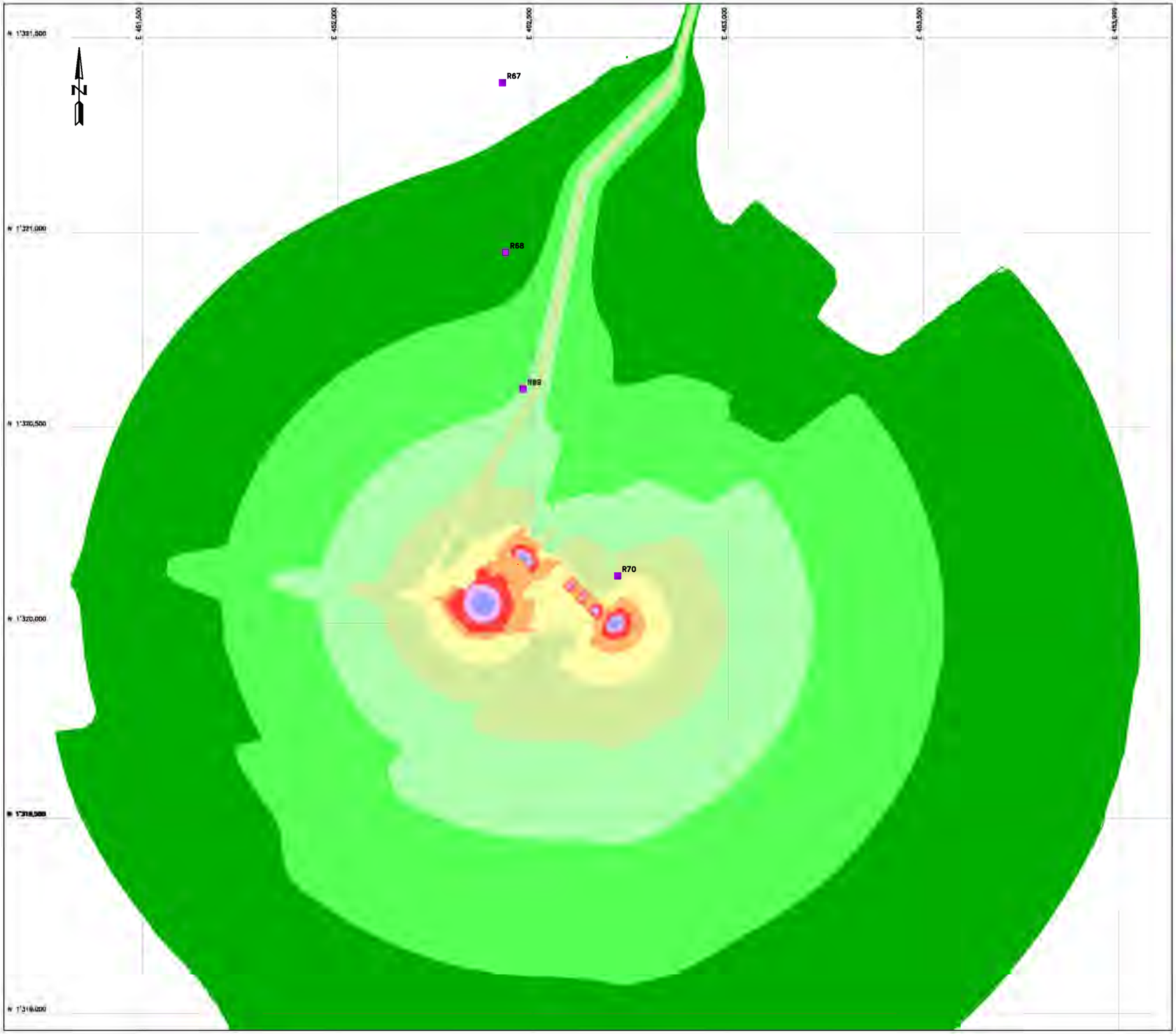
- < 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- 80 – 85
- 85 – 90
- >= 90

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	DAYTIME NOISE PROPAGATION IN PORT SITE

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.13	REV. A
DRAWN BY	EA	APPROVED BY	–	06/18/15		

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.13 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.13 A.dwg



PLAN

100 0 100 200 METERS

1:10000

LEGEND:

■ RECEPTOR LOCATIONS FOR NOISE MODELLING

LEVELS FOR NIGHT-TIME (Ln) IN dB(A):

- < 40
- 40 – 45
- 45 – 50
- 50 – 55
- 55 – 60
- 60 – 65
- 65 – 70
- 70 – 75
- 75 – 80
- >= 80

CLIENT	LYCOPODIUM MINERALS CANADA LTD
PROJECT	ESIA FOR THE FARIM PHOSPHATE PROJECT
TITLE	NIGHT-TIME NOISE PROPAGATION IN PORT SITE

Knight Piésold CONSULTING

DESIGNED BY	AD	CHECKED BY	RC	DATE	FIGURE 5.14	REV.
DRAWN BY	EA	APPROVED BY	–	06/18/15		A

INDICATED SCALES ARE FOR AN A3 SHEET SIZE | KP | FIGURE 5.14 A | XREF | M:\ProjectFiles\NB301-520\05A\Acad Files\FIGURE 5.14 A.dwg

Prepared For:

Knight Piésold CONSULTING

Cultural Heritage Baseline

Farim Phosphate Project

30 July 2015

Environmental Resources Management
1776 I Street, NW, Suite 200
Washington, DC 20006

www.erm.com

The world's leading sustainability consultancy.

ERM

REPORT

Prepared for:

Knight Piésold Ltd.

Cultural Heritage Baseline
Farim Phosphate Project

30 July 2015

Emlen Myers
Technical Fellow /Partner

Environmental Resources Management
1776 I Street, NW, Suite 200
Washington, DC 20006
202.466.9090 (p)
202.466.9191 (f)

http://www.erm.com

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1 CULTURAL HERITAGE

1.1 NATIONAL REGULATORY FRAMEWORK

Guinea-Bissau has a limited regulatory framework for cultural heritage. Article 17 of the Constitution of Guinea-Bissau (1984) states that: "The role of the State is to create and promote favourable conditions for the preservation of cultural identity as a factor that stimulates sustainable social development." There is no law in Guinea-Bissau, however, that specifically addresses cultural heritage. Guinea-Bissau is nonetheless a signatory to several international charters pertaining to the identification protection and promotion of cultural heritage, including:

- UNESCO Convention Concerning the Protection of World Cultural Heritage and Natural Heritage (1972): In 2006, Guinea-Bissau became a member state to the UNESCO convention. Article 5 of the convention states that member states shall endeavour to take the appropriate measures necessary for the identification, protection, and conservation of tangible cultural resources, including: monuments, buildings, archaeological sites, and natural features.
- Cotonou Agreement (2000): Member states commit to the preservation and enhancement of cultural heritage. It encourages the training of local specialists in the methods of preservation, protection, and exhibition of cultural heritage properties, monuments, and objects.
- Charter of African Cultural Renaissance (2006): Member states commit to promote cultural diversity and to inventory and develop tangible and intangible heritage.

1.2 INTERNATIONAL STANDARDS

1.2.1 International Finance Corporation

The objective of the International Finance Corporation's (IFC) Performance Standard 8 (PS 8) is to "protect cultural heritage from the adverse impacts of project activities and support its preservation…[and] promote the equitable sharing of benefits from the use of cultural heritage." PS 8 defines cultural heritage as "(i) tangible forms of cultural heritage, such as tangible moveable or immovable objects, property, sites, structures, or groups of structures, having archaeological (prehistoric), paleontological, historical, cultural, artistic, and religious values; (ii) unique natural features or tangible objects that embody cultural values, such as sacred groves, rocks, lakes, and waterfalls; and (iii) certain instances of intangible forms of culture that are proposed to be used for commercial purposes, such as cultural knowledge, innovations, and practices of communities embodying traditional lifestyles."

PS 8 differentiates between replicable, non-replicable, and critical cultural heritage, which are defined as follows:

- Replicable Cultural Heritage: Defined as "tangible forms of cultural heritage that can themselves be moved to another location or that can be replaced by a

similar structure or natural features to which the cultural values can be transferred by appropriate measures. Archaeological or historical sites may be considered replicable where the particular eras and cultural values they represent are well represented by other sites and/or structures."

- Non-replicable Cultural Heritage: Includes "(i) cultural heritage [that] is unique or relatively unique for the period it represents; or (ii) cultural heritage [that] is unique or relatively unique in linking several periods in the same site."
- Critical Cultural Heritage: Includes "(i) the internationally recognized heritage of communities who use, or have used within living memory the cultural heritage for long-standing cultural purposes; or (ii) legally protected cultural heritage areas, including those proposed by host governments for such designation."

The preferred mitigation measure for all cultural heritage impacts is avoidance. When this is not possible, PS 8 provides a mitigation hierarchy for replicable cultural heritage. Listed in order of preference, the measures are:

- Minimize adverse effects and implement *in situ* restoration measures;
- Restore the functionality of the cultural heritage in a different location;
- Permanent removal of historical and archaeological artifacts following national laws and internationally recognized practices by competent professionals; and
- Compensation for the loss of cultural heritage.

The removal of non-replicable cultural heritage should only take place if there is no technically or financially feasible alternative and the benefits of the project outweigh any heritage losses. The removal of critical cultural heritage should only take place in "exceptional circumstances" and after extensive consultation with affected communities and other stakeholders.

PS8 also requires that IFC projects develop and institute a chance finds procedure for handling the unanticipated discovery of cultural heritage during construction activities.

1.2.2 African Development Bank

The African Development Bank's (AfDB) Integrated Safeguards System (ISS) requires that when a project is likely to have adverse impacts on cultural heritage, the borrower or client identify appropriate measures for avoiding or mitigating these impacts as stipulated in the Integrated Environmental and Social Impact Assessment (IESIA) Guidance Notes. These measures may include avoidance, full site protection, and selective mitigation, including salvage documentation.

The ISS states that AfDB projects should not remove any tangible cultural heritage unless the following conditions are met:

- No technically or financially feasible alternatives to removal are available;
- The overall benefits of the project substantially outweigh the anticipated cultural heritage loss from removal; and

- Any removal is conducted in accordance with relevant provisions of national and/or local laws, regulations, and protected area management plans and uses internationally accepted best available techniques.

When the proposed location of a project is in an area where tangible cultural heritage is likely to be found, chance find procedures are included in the Environmental and Social Management Plan (ESMP). The ISS states that chance finds should not be disturbed until an assessment by qualified experts.

1.3 CULTURAL HERITAGE SENSITIVITY

In the absence any national regulatory criteria for assessing the sensitivity of cultural heritage, the IFC PS8 concepts of replicable, non-replicable, and critical cultural heritage will be applied by the Project (Table 1-1). The sensitivity of archaeological sites is based on the degree to which the type of resources is known or represented at the local, national, regional, and international level. The sensitivity of living heritage resources is based on the resource's importance to local stakeholders.

Table 1-1 Characteristics of Cultural Heritage Sensitivity

Cultural Heritage Resource Sensitivity	Sensitivity Definition
Low	Resource is classified as replicable cultural heritage. It can be moved to another location or replaced by a similar resource, or is of a type that is common in the surrounding region; it has limited or no cultural or historic value to local, national, or international stakeholders; and/or it has limited scientific value or similar information can be obtained at numerous resources.
Medium	Resource is classified as non-replicable cultural heritage. It can be moved or replaced, or data and artifacts recovered in consultation with stakeholders; it has considerable cultural or historic value for local and/or national stakeholders; and/or it has substantial scientific value but similar information can be obtained from a limited number of other resources.
High	Resource is classified minimally as non-replicable cultural heritage. Additional studies would be required to determine which if any of these resources are critical cultural heritage. Critical cultural heritage cannot be moved or replaced without major loss of cultural or historic value; site specific legal status specifically prohibits direct impacts or encroachment on resource and/or protection zone; it has substantial value to local, national, and international stakeholders; and/or it has exceptional scientific value and similar resource types are rare or non-existent.

2 RECEIVING ENVIRONMENT

2.1 CULTURAL CONTEXT

The cultural heritage baseline survey conducted as part of the Project's ESIA is one of the first such research efforts in Guinea-Bissau. The lack of previous research is not related to low resource potential, but is rather a reflection of academic research trends in West Africa. Archaeological research in West Africa has focused on the prehistoric cultures along the Niger and Senegal rivers, located to the east and north of Guinea-Bissau, respectively. Despite this gap in existing archaeological data, it is still possible to use established oral and written histories to reconstruct some general trends in the precolonial cultural patterns of the Project area.

According to oral histories collected during the baseline survey, the first ethnic group to arrive in both the Mine and Port areas was the Balande, who are known to have inhabited the region between the Cashew and Geba rivers. It is not possible to establish exactly when the Balande migrated to the Project area. Based on the earliest trends in population migrations to adjacent regions of West Africa, however, it is likely that they have been there since at least the 10th century AD, and possibly earlier.[1] Much like today, the early Balande population likely practiced simple agricultural production and resource gathering. They do not have a tradition of producing their own iron or ceramics. The second group to migrate to the Mine area is the Mandinga, who arrived during the expansions of the Malian and Songhay Empires between the 13th and 15th centuries. The Mandinga exchanged iron, ceramics, gold, and cloth with the local Balande groups for kola nuts, salt, and other local products. The third phase of settlement in the Mine area occurred between the 14th and 15th century, as Fula groups migrated from the Guinean plateau during the Kingdom of the Fouta Djallon. The Fula were merchants, which led to conflict with the Mandinga over trading rights with the Balande. Unlike the Mine area, the Port area has remained mostly inhabited by the Balande.

The Portuguese first arrived in Guinea-Bissau in the mid-15th century and established the *Casa de Guiné* in 1482, which functioned as a trading company interested in acquiring gold, salt, textiles, and slaves. In 1558, the Portuguese founded the city of Cacheu, located at the mouth of the Cacheu River. Cacheu served as the capital of Portuguese Guinea for about 150 years before being moved to Bissau. In 1641, the Portuguese founded Farim, located approximately 2 kilometers to the east of the Mine area. The initial purpose of the settlement was to move Portuguese merchants from the settlement of Geba to a location where they would be less vulnerable to attack by African tribes. Farim was fortified in 1696 with a garrison and artillery, neither of which exists today. In the early 20th century, Farim grew in importance as a trading city and several large villas

[1] Hawthorne, W. (2001) The Rise of Balanta Paddy-Rice Production in Guinea-Bissau. *Journal of African History,* Vol. 42, pp. 1-24

were built to house the growing Portuguese merchant class. Today, the Farim area no longer has a Portuguese population. The most populous group in the area is the Mandinga, followed by the Fula, Balande, and several other West African ethnic groups, including the Manjack and Mancanha.

2.2 *CULTURAL HERITAGE BASELINE*

2.2.1 *Tangible Cultural Heritage*

Previous cultural heritage baseline surveys of the Mine Site area were undertaken in March and September 2012 by the Senegalese Laboratoire d'Archéologie IFAN-UCAD. The results of this survey work is reported by Golder (2014a, 2014b), which cites two original reports by Tropica Environmental Consultants (2012a, 2012b). The Tropica reports were not available for review.

The 2012 cultural heritage studies included ethnographic meetings and interviews conducted in four villages in the vicinity of the Mine Site, along with field reconnaissance surveys. A total of 40 cultural heritage features were identified in the vicinity of the Mine Site and in the vicinity of Binta and the town of Casheu, which are no longer part of the current project design. Not including the features recorded in Binta and Casheu, 25 cultural heritage features appear to have been identified, including 12 archaeological sites, nine cemeteries, and four sacred sites (Golder, 2014b).

In April 2015, ERM was tasked to reassess the cultural heritage baseline in the Mine and Port areas, with a primary focus on archaeological resources and a secondary focus on living heritage. Eco Progresso also conducted a reassessment in May 2015, focusing on conducting in-depth village interviews to identify additional living heritage resources, such as mosques, cemeteries, and sacred sites. These three survey efforts were used, in combination, to develop the cultural heritage baseline.

ERM's field survey had two main goals: 1) to revisit and confirm cultural resources identified during the previous ESIA baseline survey; and 2) to record additional resources not previously identified. The field methodology consisted of high-level village interviews and an intensive archaeological survey within the proposed project areas. Nine villages were visited and 114 kilometres reconnoitred by the ERM cultural heritage specialist, for an average of about 19 kilometres per day. The types of data collected include ancestral village origin and foundation histories and intangible heritage, as well as the location of living heritage and archaeological sites. The locations of cultural sites were recorded by GPS. Tracks from the cultural heritage survey were also collected by GPS and represent the areas covered by the ERM survey (Figure 2-1). Areas targeted for cultural heritage survey were based on the project design at the time. Some aspects of the project design have changed since completion of the baseline survey.

Eco Progresso's field methodology was focused on conducting in-depth village interviews and recording information related to living and intangible heritage.

Information concerning festivals, music, and other cultural aspects of the local populations were recorded in some detail.

Figure 2-1 shows the results of the ERM and Eco Progresso investigations. ERM visited each of the cultural sites identified in the 2014 Golder report, only 14 of which could be confirmed. Sites identified in the baseline survey that could not be confirmed may have been isolated ceramic fragments that were collected during the survey, which would remove all surface evidence. It is also possible that some of the unconfirmed sites were misidentified or were recorded as areas where the local population indicated they had seen ceramics in the past. Information provided in the baseline, written by Golder Associates in 2014, does not help to clarify this issue, as only coordinates were provided without site descriptions.

In addition to confirming 14 previously identified sites, ERM recorded five new sites in the Mine area. Five new sites were also recorded by ERM in the Port area, which was not visited during the Tropica baseline survey. Eco Progresso identified 46 separate living heritage sites. However, coordinates were not recorded for most sites. As a result, only 15 living heritage sites identified by Eco Progresso are included in this report. The location of these 15 sites is not precisely known, but they have been placed on the map shown in Figure 2-1 using location descriptions provided in the Eco Progresso report. Site IDs with an asterisk in this report are those sites recorded by Eco Progresso for which locational data is absent. Future efforts should target the remaining living heritage sites that could not be relocated.

Combining the confirmed previously recorded sites and the newly recorded sites, the survey catalogued a total of 39 cultural sites, including:

- 15 archaeological sites (Table 2-2);
- seven cemeteries (Table 2-3);
- 11 sacred sites (Table 2-4); and
- six mosques (Table 2-5).

Ten of the sites were assessed to be of high sensitivity, six of medium sensitivity, and 23 of low sensitivity (Table 2-1).

Table 2-1: Sensitivity Ratings for Sites Identified in the Mine and Port Areas

Project Area	Archaeological Sites			Cemeteries			Sacred Sites			Mosques		
	High	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low
Mine	-	3	8	2	-	5	2	1	6	6	-	-
Port	-	1	3	-	-	-	-	1	1	-	-	-
Combined	-	4	11	2	-	5	2	2	7	**6**	-	-

Figure 2-1: Map of ERM Cultural Heritage Survey Tracks and the Results of the Verification of Sites Recorded in the Previous Baseline

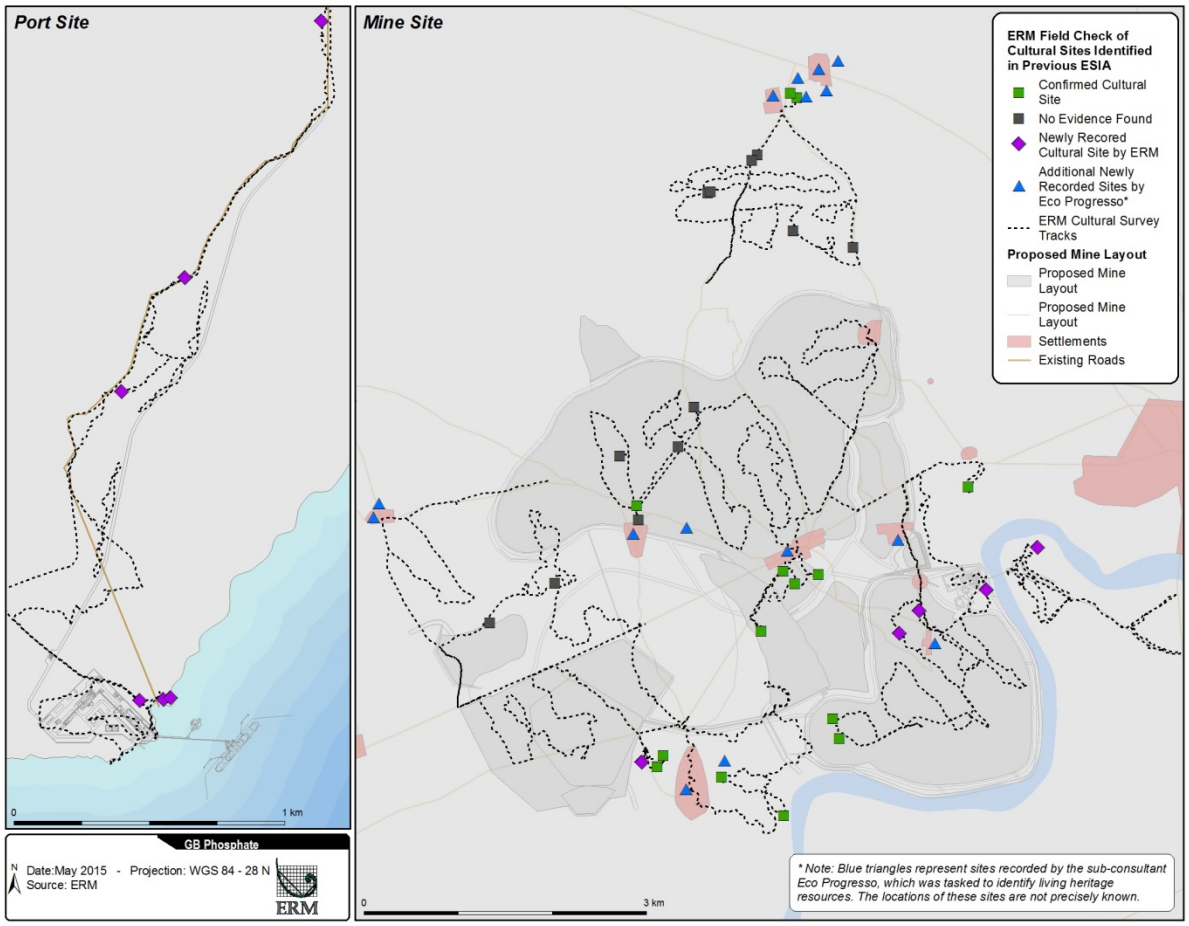
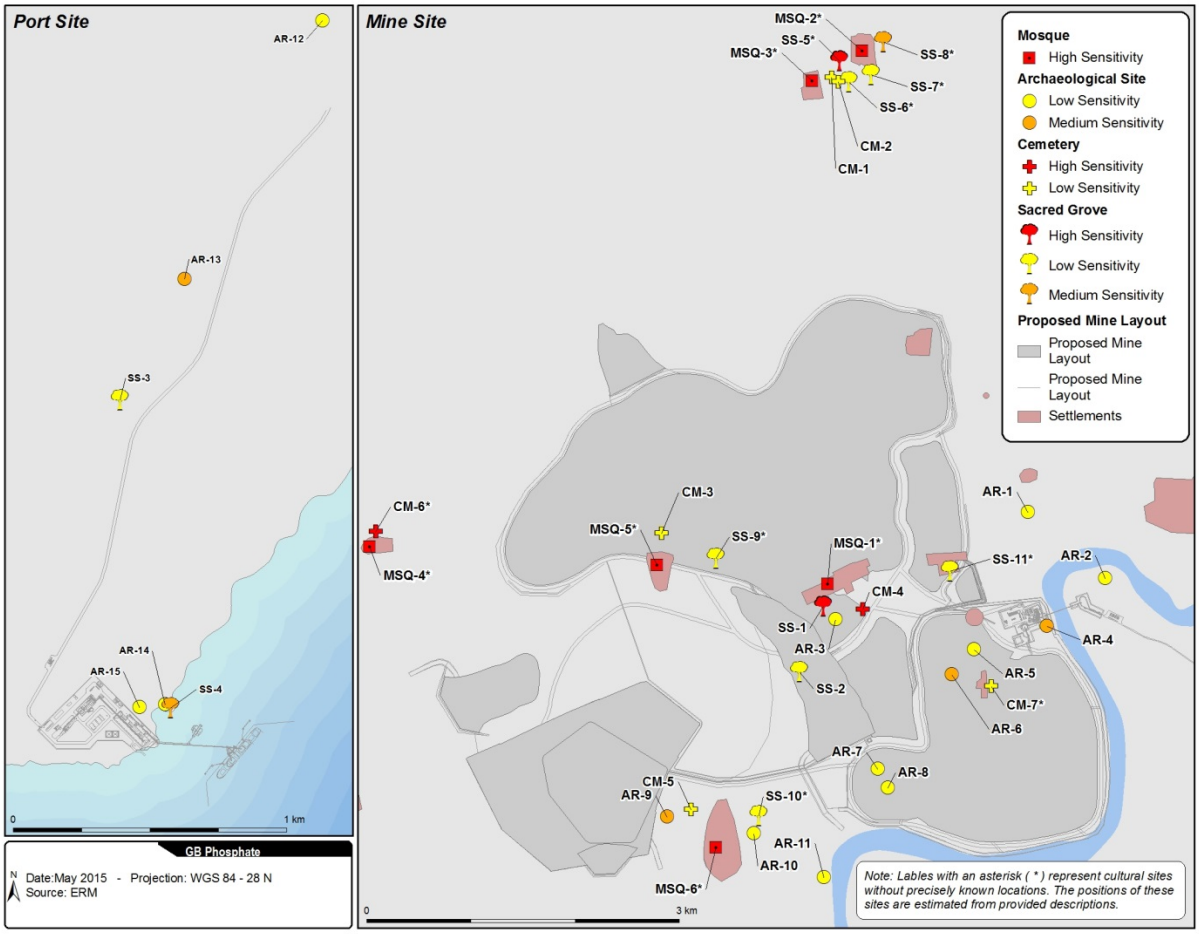


Figure 2-2: Map of the Sensitivity of Confirmed Cultural Heritage Sites



The ten high sensitivity cultural sites identified by the baseline effort include:

CM-4: Saliquinhe Ba Cemetery	SS-5*: Canico Tumane Sacred Grove
SS-1: Saliquinhe Ba Sacred Grove	CM-6*: Ufude Cemetery
MSQ-1*: Saliquinhe Ba Mosque	MSQ-4*: Ufude Mosque
MSQ-3*: Uriqui Mosque	MSQ-5*:Tambato Mosque
MSQ-2*: Canico Tumane Mosque	MSQ-6*: Canico Mosque

The sensitivity ratings for sites with an asterisk attached to the site ID were assessed by Eco Progresso. ERM assessed the sensitivity two sites without an asterisk. It is not clear if Eco Progresso used the same sensitivity rating system as ERM.

All high sensitivity sites are within the Mine area (Figure 2-2). The high significance of these sites relates to their regional importance. In the village of Saliquinhe Ba, for example, the cemetery (CM-4) contains the burial of a well-known imam who died in the early 20th century. His grave is visited by people from as far away as Guinea and Senegal during the annual festival of Gamou. The mosque at Saliquinhe Ba (MSQ-1*) dates to the

period of the well-known imam, and is the oldest mosque in the Mine area. The sacred grove at Saliquinhe Ba (SS-1) is also an important regional cultural landscape, where the Mandinga people from this part of Guinea-Bissau come to pray and sacrifice during times of hardship or celebration. The high sensitivity of the cemetery, mosque, and sacred forest at Saliquinhe Ba relates to the regional importance of this village as a cultural focal point.

The other seven high sensitivity sites were identified during the Eco Progresso survey, and represent living cultural resources that the local population identified as having high importance. Particular details concerning why the local population believe these sites are of high importance was not provided.

The baseline survey also identified the following five medium sensitivity cultural sites:

- AR-4: a dense scatter of archaeological ceramics dating to the 14th century AD, which likely represents an early Mandinga settlement;
- AR-6: a dense scatter of iron slag (the by-product of iron smelting), which likely dates to the 14th century AD and is potentially associated with the arrival of Mandinga iron smiths during the expansion of the Malian Empire;
- AR-9: an expansive and dense scatter of ceramics and pre-20th century glass shards, with evidence of settlement mounds and burial urns, which is a settlement site that likely dates to the mid to late colonial period;
- AR-13: a dense scatter of ceramics and pre-20th century glass shards, with evidence of settlement mounds, which is a settlement site that likely dates to the mid to late colonial period;
- SS-4: a sacred site located on rocky outcrop overlooking the ocean, which is used for prayer and sacrifice by the local Balande populations and is associated with a small ritual circle, animal bones, and broken glass bottles; and
- SS-8*: the sacred forest of Canico Tumane, known to the local villagers as *Kuiam Djalo*.

2.2.2 *Intangible Cultural Heritage*

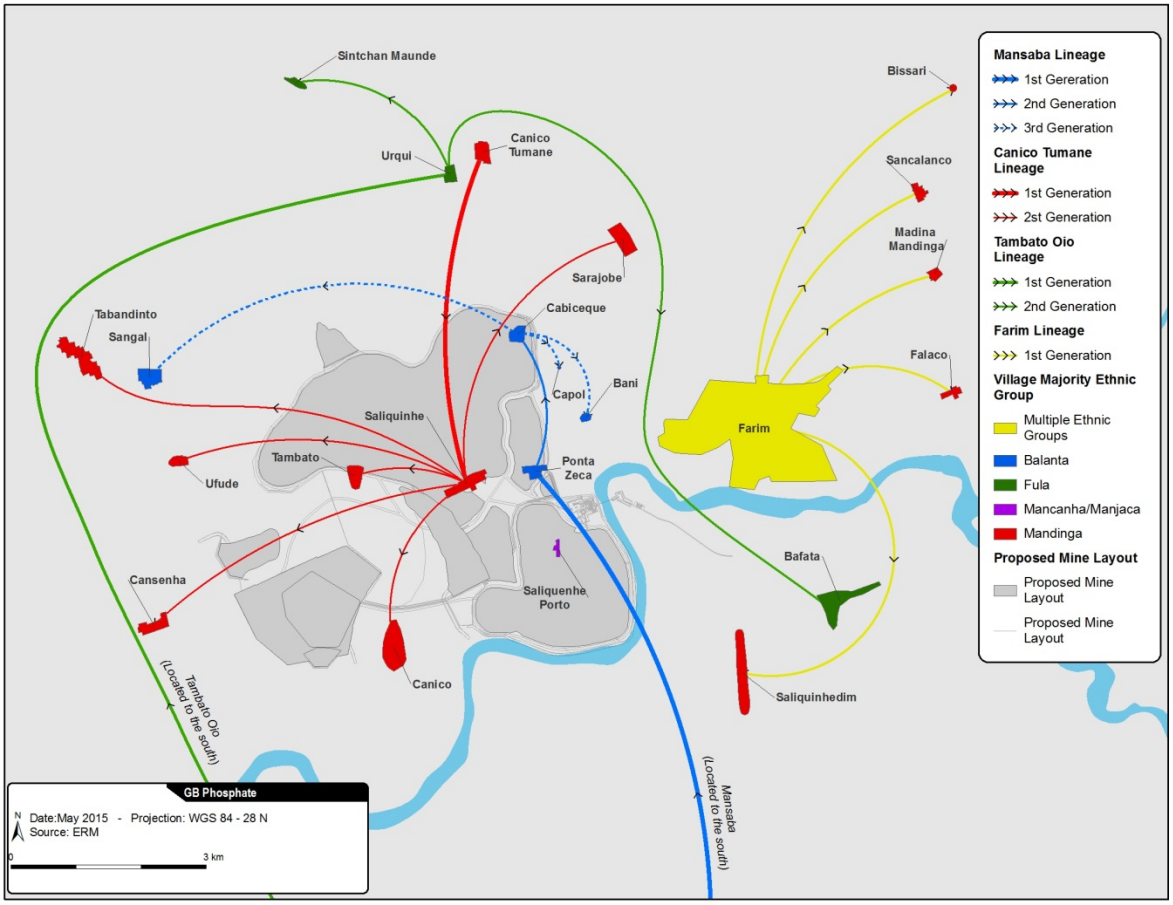
One of several types of intangible cultural heritage recorded during the baseline survey is village foundation lineages. West African village lineages are commonly preserved in oral histories and relate to the places from which the original founders of the villages came. There are a variety of factors for why a group might leave its ancestral village, including local inter-ethnic conflict, national political issues, fluctuation of resources, and natural disasters.

Figure 2-3 illustrates the village lineage history of the Mine area. It should be noted, however, that there is some degree of uncertainty in the data utilized to generate this map, as the oral histories often include different accounts. When this was the case, the most widely accepted accounts were utilized. A village lineage map was not generated for the Port Area, as there are only a few villages there, all of which are populated by the Balande ethnic group.

The village lineage histories are useful for identifying the oldest villages in the study area and to also better understand the settlement history of different ethnic groups. For example, the information suggests that the Balande ethnic group, which first migrated to the Mine area from Mansaba, was the first to arrive in the region, since it is the only group with three village generations. This supports the widely-held belief that the Balande arrived about four centuries before other ethnic groups, such as the Mandinga or Fula. The village lineages of these latter groups are only two village generations, suggesting a later arrival. Farim, founded by the Portuguese in 1641, only has one village generation that expands to the northeast of the town. The oldest Balande village in the mining area, according to these data, is Ponta Zeca. The oldest Mandinga village is Camico Tumane, whose original settlers likely came from either Senegal or Mali. The oldest Fula village is Urqui.

Information on village lineage can help identify which villages are perceived to be of higher or lesser cultural importance. For many villages in the study area, the founding clan draws its authority from events that may have occurred hundreds of years earlier. A village that has generated a large number of secondary villages in the past tends to be viewed as an important cultural centre. For example, while Canico Tumane may be the oldest Mandinga village, Saliquinhe Ba has generated the highest number of secondary Mandinga villages in the Mine area. As a result, Saliquinhe Ba is generally perceived by the local populations to be the Mandinga cultural centre in the Mine area. This observation is supported by the existence of a high sensitivity cemetery and sacred forest located at Saliquinhe Ba. Saliquinhe Ba was also the first village in the Mine area to build a mosque.

Figure 2-3: Map of Village Lineages



Another intangible cultural heritage resource recorded in the Mine area is the Kankourang, which is a secret society found across much of costal West Africa. It is most directly associated with the Mandinga ethnic group, although other ethnic groups participate in their own Kankourang societies. The role of the Kankourang largely revolves around conflict management. It includes ritual song and dance and the presentation of masked figures, which are typically only displayed in times of serious conflict, usually resulting from issues related to land rights or debts. By displaying masked figures and participating in ritual song and dance, the tensions between conflicting parties are reduced, allowing for subsequent conversations to be conducted and resolutions reached in a calmer manner. Aside from traditional Islamic beliefs and festivals, the Kankourang is probably the most important cultural tradition still in practice in the region.

Other types of intangible cultural heritage recorded in the project area include musical instruments and religious or community festivals. There are several types of musical instruments used by different ethnic groups in the study area, including: *bandjara* (large drums); *tam-tam* (small drums); whistles; guitars; *koras* (a small banjo-like instrument); gourds; flutes; and *balafons* (xylophone).

Figure 2-4: Select Photos of Musical Instruments Recorded During Survey

Image of a *bandjara,* a type of large drum made from a hollowed log

Image of a *balafom*, a type of African xylophone made from strips of wood and gourds.

There are four major festivals for Muslim communities in the study area that stand out as having high cultural value. These are Tabaski, Ramadan, New Year's Eve, and *Fanado* (a male circumcision ritual/rite of passage). The main festivals for Christian and Animists communities are Christmas, New Year's Day, and *Fanado*. The Balande ethnic group also has a series of unique festivals. *Kssunde*, which is a periodic feast only held when there is an abundant crop harvest, is the largest. The *Canta Po* is a music competition held between two different Balande families, which can last up to five days. Winners are chosen by the village audience.

During the baseline survey, cultural heritage specialists also recorded information about the perceptions of the local population on the potential influence the Project will have on cultural heritage. In general, the population has difficulty in processing the concept that one day some communities may have to leave their homes, cemeteries, and sacred sites. In general, many locals consider themselves to be following in the footsteps of their ancestors, and therefore believe their traditions and lifeways should be preserved for future generations. Aside from the desire to safeguard traditions and cultural landscapes, there is also concern amongst villagers within the study area that the removal of cemeteries, sacred sites, and mosques could anger their ancestors or resident spirits, which could cause illness or misfortune.

Table 2-2: Confirmed Archaeological Sites in the Mine and Port Areas

ID	Description	Sensitivity	Project Area	Size (m^2)	POINT X	POINT Y
AR-1	Very low sensitivity, possible not a site but just an isolated sherd.	Low	Mine Area	1	473600	1380297
AR-2	Low density ceramic scatter. One sherd looks like it came from a burial urn. Located on edge of mangrove. Indicative of subsurface remains. Possibly pre-colonial in date.	Low	Mine Area	1500	474340	1379665
AR-3	Low density ceramic scatted found near sacred site (SS-1). Probably associated with the sacred site. Not likely to be a settlement. Limited archaeological context.	Low	Mine Area	100	471752	1379267
AR-4	The ceramics here are fairly dense and cover a wide area. Located in a recently ploughed field. Site extents seem to taper off before reaching the tree line. The ceramics are of different size and function. Some diagnostic sherds. Likely dating to early medieval period.	Medium	Mine Area	3000	473777	1379206
AR-5	Very low sensitivity. Possible not a site but just an isolated sherd.	Low	Mine Area	1	473080	1378982
AR-6	High density scatter of iron slag. Indicates intensive local iron smelting activities. Probably not Iron Age, but more likely medieval in date. Important for regional and national history.	Medium	Mine Area	1000	472869	1378740
AR-7	Very low sensitivity, possible not a site but just an isolated sherd.	Low	Mine Area	1	472155	1377836
AR-8	Low to medium density ceramic scatter suggests a small settlement. Ceramics appear to be historic (recent) in date.	Low	Mine Area	100	472254	1377651
AR-9	Expansive, high density ceramic scatter. House mounds visible. The high density of ceramics suggests intensive domestic settlement. Presence of historic (pre-20th century) glass fragments mixed in with the ceramics suggests that this site dates to the middle-late colonial period.	Medium	Mine Area	9000	470135	1377373
AR-10	Probably modern ceramics associated with Canico village. Not a very sensitive site.	Low	Mine Area	250	470968	1377217
AR-11	Just a few isolated ceramic sherds. Not enough material present to indicate sub-surface remains. No diagnostic sherds found. Limited sensitivity.	Low	Mine Area	250	471640	1376791
AR-12	Very low sensitivity, possible not a site but just an isolated sherd.	Low	Port Area	1	453325	1322638
AR-13	Ceramics and glass suggests a site dating to the mid to late colonial period. Could be of some importance given the quality of the ceramics.	Medium	Port Area	500	452821	1321694
AR-14	Low density ceramic scatter. No other material. Ceramic found near sacred site. Probably associated with the site. Not likely to be a settlement. Limited archaeological context.	Low	Port Area	100	452750	1320137
AR-15	Low to medium density ceramic scatter. No other material. Ceramics suggest a small, perhaps seasonal, settlement. Surface finds likely date to the 20th century	Low	Port Area	250	452657	1320128

Table 2-3: Confirmed Cemeteries in the Mine Area

ID	Description	Sensitivity	Project Area	Size (m^2)	POINT X	POINT Y
CM -1	This is a Muslim cemetery that was used by the Fula people living in Urqui village. Not currently used for burials.	Low	Mine Area	100	471713	1384471
CM -2	This is a Muslim cemetery that is used by the Fula people living in Urqui village.	Low	Mine Area	250	471780	1384425
CM -3	This is a Muslim cemetery used by the Mandinga people of Tambato. The grave markers are simple wooden branches, stuck upright into the ground. There are about 50 grave markers here, but there are likely more graves that are unmarked.	Low	Mine Area	250	470081	1380097
CM -4	This is an old cemetery used by the Mandinga people of Saliquinhe Ba. It contains the remains of a well-known imam (Fode Biyaya), who was the first imam of the Saliquinhe Ba mosque. He died in the early 20th century. Pilgrims from Dakar, Bissau and Gambia come pray here during an annual ceremony called Gamou.	High	Mine Area	250	472011	1379366
CM -5	This is a Muslim cemetery for the Mandinga people living in Canico village.	Low	Mine Area	250	470363	1377444
CM -6*	Muslim Cemetery of Ufude	High	Mine Area	n/a	~467339	~1380112
CM -7*	Animist Cemetery of Saliquenhe Porto	Low	Mine Area	n/a	~473243	~1378629

Table 2-4: Confirmed Sacred Sites in the Mine and Port Areas

ID	Description	Sensitivity	Project Area	Size (m^2)	POINT X	POINT Y
SS-1	This is an important sacred forest. The surrounding population uses it and call it *Sousoutoto*. Ritual activities occur here during times of difficulty or celebration.	High	5000	Mine Area	471636	1379398
SS-2	Site where excision rituals take place. It is composed of two sacred trees. The first is called *Dialla*, the second is called *Santonwkoto*.	Low	500	Mine Area	471403	1378766
SS-3	Offering tree with a compartment carved into it. Bottles and other paraphernalia located inside compartment.	Low	100	Port Area	452586	1321251
SS-4	Ritual area on rocky outcrop overlooking the ocean. Site is used for prayer and sacrifice by the local Balande populations. Broken bottles and evidence of small fires were observed	Medium	100	Port Area	452770	1320126
SS-5*	Sacred Forest of Canico Tumane. The locals call it *N'ghansi-Colon*.	High	n/a	Mine Area	~471786	~1384631
SS-6*	Sacred Forest of Canico Tumane. The locals call it *Culumbato*.	Low	n/a	Mine Area	~471878	~1384429
SS-7*	Sacred Forest of Canico Tumane the locals call it *Fulamusso Djudje*.	Low	n/a	Mine Area	~472094	~1384496
SS-8*	Sacred Forest of Canico Tumane. The locals call it *Kuiam Djalo*.	Medium	n/a	Mine Area	~472213	~1384811
SS-9*	A place on the road between Tambato and Salquenhe Ba, where the shadow of a man sitting under a Bissilão tree can be seen in at dusk.	Low	n/a	Mine Area	~470607	~1379858
SS-10*	Sacred forest where deforestation is prohibited. The forest is believed to contain supernatural powers. The locals call it *Sitacum Sato*.	Low	n/a	Mine Area	~471013	~1377386
SS-11*	Sacred Tree of Ponta Zeca	Low	n/a	Mine Area	~472850	~1379730

Table 2-5: Confirmed Mosques in the Mine Area

ID	Description	Sensitivity	Project Area	Size (m^2)	POINT X	POINT Y
MSQ-1*	Mosque of Saliquinhe Ba	High	Mine Area	n/a	~471679	~1379613
MSQ-2*	Mosque of Canico Tumane	High	Mine Area	n/a	~472010	~1384724
MSQ-3*	Mosque of Urqui	High	Mine Area	n/a	~471525	~1384440
MSQ-4*	Mosqie of Ufude	High	Mine Area	n/a	~467283	~1379967
MSQ-5*	Mosque of Tambato	High	Mine Area	n/a	~470042	~1379792
MSQ-6*	Mosque of Canico-Lenque	High	Mine Area	n/a	~470604	~1377082

Republic of Guinea-Bissau
ECO PROGRESSO Office of Environmental and Social Impact Assessment Studies

GB MINERALS Ltd
FARIM PHOSPHATE PROJECT

STUDY ON CULTURAL INHERITANCE OF COMMUNITIES IN THE DIRECT AND ADJACENT AREAS OF PROJECT INTERVENTION

RESEARCH REPORT

Promoter:
GB Minerals Ltd. - Farim Phosphate Project

Consultant:
Pedro Quade, Anthropologist

Farim, June 2015

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1. INTRODUCTION

This research report was carried out by an anthropologist hired by the Office of Environmental and Social Impact Assessment Studies - ECO-PROGRESS. It focuses on cultural heritage in Farim, Guinea-Bissau and is part of several studies promoted by GB Minerals Ltd., in April and May 2015**,** particularly additional Environmental and Social studies to support the actions of this Project**.**

This work is part of international consulting aiming to Study Supplementary Environmental and Social Impact, with respect to national and international standards of financial institutions. According to Law No. 10/2010, in its Art. º. 13 point 4 - On Environmental and Social Assessments in Guinea-Bissau, the implication of a Local Office of Environmental and Social Impact Assessment is mandatory. It is in this context that the Office of Environmental and Social Impact Assessment Studies - ECO-PROGRESS, was asked to conduct studies on different thematic areas including archaeological and anthropological components, with the latter specialty included into this document. The results of the studies carried out by different teams of Guinean consultants, under GB Phosphate Minerals Ltd., (Company) should be integrated into the study documents simultaneously carried out in Farim by international consultants.

Given the very short time in which the work was prepared and elaborated, we do not pretend that the research results about cultural heritages reach the level of in-depth anthropological approach, but rather provides information about elements and ethnographic objects, with an ethnological approach to shine light on the degree of relationship and involvement of the society with the means and spaces that influence their material life; and on their daily beliefs and spirituality. With knowledge of this reality, the company and the promoters of phosphate exploration entities will be able to manage situations of cultural order in each step taken.

II. CONTEXT AND JUSTIFICATION

From the socio-cultural point of view, the Republic of Guinea-Bissau has a population of 1,548,159 inhabitants, with 792,300 women and 755,859 men, according to data from the INEC Census of 2009. Cultural diversity is very significant due to the high number of distinct ethnic groups in its continental and insular territory.

Currently the Farim Administrative Sector consists of 296 villages and features a diversity of ethnic groups from the urban center and its periphery to the most remote rural communities constituted by at least eight (8) ethnic groups, of which the Mandingo, Fulani, Balanta-Brassa and Balanta-Mane are the majority. The Sector has 48,264 inhabitants of which 23,141 are men and 25,123 are women (second local Census of 2014. ([1])

Given that future phosphate excavations will impact on economic, social, cultural areas and on the history and cultural heritage of the ancestors of local people, it is essential to do a study to identify these values; listen to popular perceptions on the existence of these values; the degree of involvement of residents with these tangible and intangible values; and also understand to what extent and with what proportions that actions will or will not affect communities, their cultural heritage, their balance and social cohesion in the medium and long term.

Thus, there is the urgent need to equip the Project and the country with a wide range of multi-sectoral and multidimensional background information data on issues and to make available the necessary knowledge for making decisions, corrective means and serve as guiding models before, during and after phosphate exploitation. This is what justifies an anthropological diagnosis of the cultural heritages of existing communities and perceptions of inhabitants regarding future incidences of phosphate exploration action on these heritages.

III. OBJECTIVES OF THE STUDY

General Objective

• The overall objective of advising on cultural heritage aims to contribute to a general analysis and additional assessment of the environmental and social impact, key depositary information with multi-sectoral and multi-dimensional issues that will permit the GB Mining Project, national entities and other actors involved, to have the necessary knowledge for decision making and advance directives, during and after the execution of phosphate exploration in Farim.

Specific Objective

• The specific objective is to carry out an intensive diagnosis of local actors, collecting relevant information on the material and immaterial sequels of cultural heritage of the local population and their correlation with phosphate exploration works;

III. METHODOLOGY USED

To collect information for the preparation of this document, the consultant used the following working methodology:

• Documentary Consultations (INEP, KAFO Headquarters in Bissau and Djalicunda, and others);

• Quick direct consultation made by the consultant, based on visits and interviews with representatives of the communities of Salquenhe Ba, Salquenhe Porto, Urqui, Canico-Lenque Curoto, Sandjal, Dugal, Tchúgue and neighborhoods of Nema, Morcunda and Gã-Sapo in Farim. During these visits, the consultant was accompanied by a guide, (resident of Farim) who is knowledgeable of the languages and cultures of the local populations. 17 groups of 68 individuals were directly approached by him, consisting of village chiefs, elderly men, women and youth.

• Consultation of other influential people and actors who have direct and indirect information on the Project;

• Consultation of representatives of State Administration Authorities in the Sector;

• Contacts with intellectuals knowledgeable on the history of the city and the historical and cultural heritage of the town of Farim.
• Parallel to data collection by the consultant, the work was also attended by three interviewers who had a questionnaire of nine (9) pages each filled out in 13 villages and three (3) neighborhoods for each restricted group of men, women and youth, totaling 33 forms.

Included in the total number interviewed by the consultant and the respondents through forms, the consultant also directly addressed 50 groups (17 + 33) corresponding to 200 individuals (68 + 132).

IV. SOCIO-CULTURAL REALITY

1. Historical and cultural reality of Farim

The Farim Administrative Sector is located in the northern part of the Oio Region, and borders with the neighboring Republic of Senegal to the north, and the town of Djalicunda in the southern part of the Farim River (which is an extension of the Cacheu River). Historically, Farim was originally occupied by an ethnic group called *banhuns*, ([3]) whose members emigrated over the centuries to the North-West of the country, due to inter-ethnic and religious conflicts. Farim and its surroundings areas were later absorbed by the ethnic groups of Islamic hegemony, particularly the Mandingo and Fulani, and additionally by the Balanta-Manes and Mansoncas through social acculturation of various kinds.

The first guests of the Mandingo ethnic group, that came to Farim in the seventeenth century, are designated as "Muros" and inhabited a place that would become known as Morcunda (one of the current six main districts) - meaning the neighborhood of "Muros". The phenomenon of Islamization of banhuns would become more pronounced over the first half of the 20th century (1940), a phase in which the dynamics of Muslim acculturation of the animists reached its highest level. ([4])

From a formal point of view of declared and recognized religions, the population of Farim and its surroundings consists of the following groups of which **most** are **Islamized:** Mandingo, Fulani, Balanta-Mane, Saracolés; while **Animists:** Mansoncas, Balanta-Brassa, a part of Balanta-Mane (that are not Islamized) and Manjacos, Mancanhas, Pepéis make up a small percentage. Christians are made up of Catholics and Protestants and occupy a lower percentage following the Animists.

However, *from a practical point of view,* most are still influenced strongly by Animism (i.e. traditional African beliefs). Other religions are recognized while recourse to the spiritual forces and souls of ancestors for the treatment of certain diseases; struggle against bad luck; spells; disaster and protection of families and villages; cultivation areas; and places of initiation (barracks used for initiation rituals) are still practiced. In short, Animism occupies a prominent place in the habits and practices of the day-to-day life of the locals, even when these practices are not always done openly during the day or night. They are justified by a simple rationale of *"respect for the tradition of our fore*

parents." The practice of Animistic belief is actually transverse to each ethnic group. It is very rare to see a community where there is no testimony to these beliefs.

As its characterization from the *point of view of social organization systems,* and power structures, the Mandingo and Fulani are part of the flexible vertical system of power characterized by the existence of a nobleman (ruler) with segmented authorities of village's chiefs *(alcálo or djarga)* in different zones surrounding its jurisdiction.

The socio-political and religious powers are separate. Although they have a system of social organization based on the Islamic religion, the basic criteria for choosing a ruler relies less on knowledge of Islam and more on the historical and patrilineal genealogy of kinship to the deceased ruler.

The main strengths of rulers at present resides in the place that traditionally is reserved by their communities because of their wisdom to ensure the reconciliation of family base evoking the Holy Qur'an and the sacred spiritual forces of the remaining Animist ancestry and the moral values of integration, social cohesion and peace.

Religious power has its own structures, from *Himames* and priests, through the *Naimo,* his advisers and spokesmen down to the messengers of mosques; the so-called *wadaniláh.*

2. Cultural and Ethnical Reality in the Phosphate Project Zones of Intervention

According to the traditional system in force today, the communities of the phosphate project intervention zone are an integral part **of** the **Canico jurisdiction,** consisting of about 30 villages (towns) scattered between the north, east, center and west of the town of Farim. The Canico jurisdiction has a ruler who resides in the Nema district of Farim. Despite the vastness of the territory, each of village chief exercises autonomy within its own village, supervised by the ruler. Both the ruler and the chiefs of villages, refer to the Sectorial and Regional State Administrative authorities for recourse on the issues that they fail to address, particularly issues related to security and crimes of blood and other economic conflicts.

The specific area of phosphate project intervention covers 13 villages: 11 in the West Farim Sector, namely: Canico Tumane, Urqui, Salquenhe Ba, Salquenhe Porto, Ufudi (Mandingo and Fulani), Tambato Mandinga, Sandjal 1 and 2, Canico-Lenque Coroto, Cabsseki Ponta, Demba Baio, Ceiro Delgada (Pã-Lamba) and two villages in the Mansoa Sector, particularly Dugal (on the main route between Mansoa-Nhacra) and Tchúgue (next to the Geba River). The latter two are where the phosphate transporters trucks will pass on their way to the Port of Bissau by sea. Because of their proximity to the route from the starting point to the Port of Farim, three (3) neighborhoods of Farim City were also included in the surveyed communities.

From the point of view of ethnic distribution, the same eight (8) major ethnic groups living in 293 villages of the Administrative Sector, described above, also live in these 13 villages (Mandingo, Fulani, Balanta-Brassa, Balanta-Manes, Manjacos, Mansoncas, Beafadas and Saracolés), in addition to a small core of Mancanhas.

VI. ACTIVITIES AND INSTRUMENTS

> *"While we cannot say that technology is the only determinant of cultural and social change, the truth is that human culture depends on its technological foundations. Human societies, even in its economic, political and intellectual aspects are dependent on their technological base ... "*([5])

The issue of expectations of the people over the fate of their agro-forestry and pastoral areas and their sacred places is intertwined with their expectations for their set habits, attitudes, practices and possible cultural shock. That is, the current internal social dynamics in the area and the dynamics that the exploitation of phosphate introduce into the location and the surroundings of Farim. The dimensions of cultural heritage is transversal and goes from the popular work-related knowledge, to festivities, to the ceremonial rites in cemeteries, to Animists shrines and sacred forests and instruments related to them. Harmonious systems that each ethnic group has and applies to maintain social stability, to the cultural habits of the population in the way each group deals with the land and ensuring the normal distribution of these lands between families and between neighboring villages.

Consequently, this research also includes, (although superficially), major artefacts produced and used by the communities, as a contribution to enrich the knowledge of a part of their cultural heritage; a stage where conservation and the balance between man, their instruments and their environment that will be substantially changed.

In the case of the communities covered by the Project in Farim and its surroundings (Dugal and Tchúgue), there is a diverse range of instruments used in productive activities and occasions of rituals, as well as in recreational events.

The types of working tools used in that area are directly dependent on the traditions of ethnic groups who use them and the context in which the social, technological and economic factors evolve in the country in general and communities in particular and the business sector.

1. Main activities

For men

In agriculture:

The social evolution of the different communities that cause social division of labor between men and women and between ethnic groups has decreased slightly in the agricultural field. For men, the activities practiced by most inhabitants (Muslims, Catholics and Animists) are as follows: cashew plantation, upland rice cultivation (Mpam-pam), peanuts, black corn, basil corn (*Catchupa),* sorghum, cassava, and sweet potatoes. The only exceptions are the Balanta-Brassa and Manjacos (Salquenhe Porto Village) who practice rice cultivation in mangrove fields.

2. Traditional instruments and other

Instruments used for upland agriculture:

The *"Drambo"* (in Mandingo) or *darambo* (in Balanta-Mane) or *"Fefe"* (in Fula) – is a kind of hoe that has a handle with a 45 degree curve and a terminal made of a plow blade - an antiquated instrument which is no longer used (for the past 50 years) due to its fragility in cutting roots in the ground. They are no longer available in the family stores. (There is a sample in Urque);

Bara (rake) is also one of the agricultural tools still used by the elders;
Short-handled hoe (currently used by all ethnicities) and ax;
Machete; "*cobadur*" (small manual digger) for weeding;
Knives and *n'ghoroto* (sickle) for harvesting cereals;
Animal drawn plow used for horses, donkeys or oxen are used in the fields of villages inhabited by Fulani - particularly in Urque, (seven [7] km from the border with Senegal, Ufude, Canico Tumane, Tambato and others).

Instruments used in mangrove field agriculture:

K'binde, long-handled plow (Balanta Brassa).

Tools and techniques used for fishing:

Men from nearby rivers settlements *(Salquenhe Ba, Salquenhe Porto, Canico Lenque Curoto, Tambato, Ufude and Sandjal)* practice artisanal fishing of casting nets *("felfelo");* traps *(cambua);* and fishing with fishing rods and hooks by the riverside. A few use paddle canoes and ever fewer use motor canoes. It is subsistence fishing.

Hunting tools:

Spears and arrows are no longer used, but machetes and 12 caliber weapons are. They used to use *long* guns years ago. A sample is available in Urque Village, belonging to the descendants of Aliu Djau, who died 80 years ago.

For women

For Muslim women (Mandinga, Balanta-Mane and Mansonca), the main activities that differ from those of men are in rice cultivation in wetlands (fields and swamps)*;* rudimentary fishing in lakes and streams; extraction of salt and palm oil; harvesting of wood; small domestic marketing of forestry and horticulture products. The rest of women in general (Muslim, Catholic, Animist) also participate in activities such as

the cultivation of peanuts, basil corn, sweet potatoes, harvesting cashew nuts, and charcoal exploration.

Instruments used in the low land field cultures:
While men are concerned with clearing rice fields on the plateau, women deal with low land rice fields (freshwater fields). They use *bara* (in Mandingo) or *barana* (in Fulani), which is a long handled hoe - and machetes.

The types of storage units "*bembas*" built in the form of giant pots (cylindrical or oval) on racks for bundles of cereals and shells after threshing.

Tools and techniques in fishing:

The women of the villages near the rivers *(Salquenhe Ba, Salquenhe Porto, Canico Lenque Curoto, Tambato, Ufude and Sandjal)* practice rudimentary fishing in "*cambuas"* (small traps used in water channels) in the streams and ponds, where women wade in the water to their waist and use *gourds* to empty the trap and catch the fish and transfer them to small baskets *(cufo)*. They also use round fishing nets *(nten)*.

Ceramic instruments associated with water and food: (locally manufactured baked clay):

Pots, kitchen pans (replaced by aluminum pans), large pots for bathroom water *(Fenke)*, steamers for "couscous" and rice), wooden spoons for cooking, gourd (all ethnicities), wood spoons, *f'tugul - testos* (Balanta-Brassa), clay jugs (increasingly substituted by kettles called *Salera)*.

Instruments used for salt extraction;
(In the settlements close to the rivers of Salquenhe Ba, Salquenhe Porto, Canico-Lenque Curoto, Tambato, Ufude and Sandjal).

Tancom (boiler made from a tank), *luntum* - barns made from mud mixed with rice straw or cous *(fonho), babato* - cylindrical and / or oval vessels made from mud mixed with rice straw to store salt and grain.

For palm oil extraction:
Tank halves, boilers, pounders, gourd shells and strainers.

Instruments used in music, parties and ceremonies:

For each festival and every ethnic group there are different instruments that go back to when ancestors founded the local communities, and in some cases, adapted to the social and cultural development of the times. There are *bandjara* (large drums); small drums;

whistles; guitars; koras "*droma"* (in Mandingo); gourds; flutes; *nhanhero* (Fulani); "balafons" (xylophone); *tam-tam* – (drums) *mbumbur* - bumbulum (Balanta Mane); typical three (3) string guitars *(Kssinti* or *singh,* or *Toka),* and *n'duk, tchegli* (cow horns).

The balafom is a type of African xylophone instrument made with art, skill and delicacy, made from strips of wood, bamboo and all sizes of gourds that give musical notes of all tones, resulting in unmistakable appreciable melody by the Balanta-Mane and certain Mandingo communities.

In wedding parties, *djiguidjo* (Balanta-Mane) are used or *CuMo* (a gourd in water in a bathtub). The *djiguidjo* used in Balanta Mane marriages symbolizes virginity of the bride.

Garments for youth are made from bags decorated with ornaments, small bells, coins and conch shells and whistles. N'*conossaba* – are made of short cloth for girls (Balanta Brassa). Other decorations are wrapped around the arms, wrists, head and ankles (Mandingo, Fulani and Balanta-Brassa) and turtle shells tied to their waist for dances *n'kúman* (Balanta Brassa).

In addition to traditional instruments, modern electric instruments are also used for music by young people.

Other instruments:
Pylons and pillar sticks; all sizes of household wooden benches made from palm tree branches; beehives made from wood, palm trunk and straw.

Party Costumes used in Final Passage Rites Ritual:
Locally made short multicolored ornaments and costumes, along with hats "*súmbia"* and *sakaró* (curve cane or stick made from mangrove) are used during the final passage ceremonies with ornaments that rattle – kinds of small bells to produce sounds), announcing their presence from long distances.

Sadjos, (ornaments made from to dry mango seeds) and gourds adorned with beads and cowries shells are placed on women's head during final passage rites and female fertility rituals.

VII. FESTIVALS AND EVENTS

In Islamic communities in Farim, at least four major events stand out that mobilize the inhabitants of each village for parties; (in their order of importance) are: Tabaski, Ramadan, New Year's Eve *(muscoto)* and Final Passage Rituals. In Christian and Animists communities in general (unconverted Balanta-Mane and Mansoncas, Balanta-Brassa, Manjacos and Mancanhas), the main festivals are: Christmas; New Year; and Final Passage Rituals ("kssunde" and "canta pó"). They all have direct or indirect relationship with the sacred.

Tabaski is the most important festival of the year. It happens two months and ten days after Ramadan. All who can afford to, kill sheep - symbolizing the desire of believers to strengthen their souls and guarantee salvation after death.

Ramadan - is considered one of the most prominent festivals of the year. It occurs after the fasting month when the first new moon appears. Traditionally, where the Muslim community is large and there is a "himami", confirmation is announced through the *tabbouleh* or *tamulde* (talking drum), by orders of the religious leader. However, in recent times, megaphones are used within the village and radio announcements for the whole Region and the country.

Since fasting takes place in a month of extensive and stringent restrictions during the day (i.e. abstinence from eating; drinking; sex; looking at the opposite sex naked; pronouncement of bad words; dancing; or listening to music); the main message conveyed during the Ramadan feast is that believers have an opportunity to manifest after the sacrifice of fasting and abstinence, fulfilling one of the five pillars of the Islamic Commandments, as well as for the consolidation of respect for religion.

Passage of Islamic Year - In the Islamic calendar, *Muscoto Karo* is the month of the passage of the New Year. The 10th day marks the end of the previous year and the beginning of the new one. For the Fulani and Mandingo communities with religious structures, the date is marked by reflection meetings among believers, to read the Koran and some passages of "Quitabu" holy book containing biographies and works of the Old Testament prophets whose messages are dedicated to each particular year. The aim is to make known to believers the messages for the coming year in order to be saved and serve as sources of reflection on its framework in social life over the next twelve months.

Christmas - Christian heritage is very rooted in the town of Farim and there are small groups of Catholic communities on the outskirts of Farim. In addition to numerous non-Islamized families from the town of Farim, some Animist and Christian families live in the villages of Salquenhe Porto, Demba Baio, Ufude, Sandjal, Dugal, Tchúgue and Farim neighborhoods celebrate the birthday of baby Jesus.

New Year (Western) - Initially practiced by Christian and Animist communities, is considered one of the biggest holidays celebrated by Catholic believers, Protestants and Muslims. The moments of passage into the New Year, transcends the boundaries between believers of different religions, (including Muslim), in the Farim Sector communities.

Boys Final Passage Rites (Fanado): The figure of ambivalent cultural survival

The Fanado (ritualized circumcision) does not happen every year. It depends on the amount of young people in the village who reach seven (7) to 15 years of age. Therefore, they may occur between five to seven years apart. There are male and female Fanados, with the latter being banned two years ago, following the dictates of the law passed by the Guinean Parliament. Since it doesn't happen every year, this event, as a rite of passage to the "adult" class, remains a time of great attraction for children and young people more willing to disclose their civic emancipation and for adults to promote and control the secrets of evocation and incarnation of the spiritual forces that are embodied in a man. It continues to be the source of reproduction and consolidation of the cultural patterns of fidelity to the collective secret, the sacred and respect for social norms of hierarchies between individuals. So it is characterized as a place of learning about the ways of good education *("cau di cunsi udjo"*- meaning the place to learn respect for and obey elders*).*

Kssunde - It's the biggest celebration of the Balanta-Brassa and lasts for two days. It is not seasonal. It happens only in years of higher abundance of agricultural crops, as a harvest feast. It serves to express their satisfaction with the success achieved in the production and the ability to receive many guests at once ([6]).

Canta Pó (or P'balak) - It is an enclosed competition that happens simultaneously between two groups or living compounds of the same village. It lasts for five days and is eliminatory (qualifiers) among the best songs and the artists who can mobilize greater number of supporters. Usually it happens in anticipation of a fanado ritual.

Broska – is a "Fun Dance" (Brassa Balanta), using a typical 3-5 string Viola.

The fanado (Animist) - is the third largest festival of the Balanta-Brassa. As characterized by communities of Farim, this Balanta rites of passage is also the source for replication and consolidation of the cultural patterns of fidelity to the collective secret, the sacred and respect for social norms of hierarchies between individuals. In non-Muslim communities, the fanado is held temporarily and at longer intervals than for Muslims (between 8-12 years).

The marriage of a girl and the sports championships were also identified as important celebrations occasions.

In non-Muslim communities, such as Balanta-Brassa, Balanta-Mane, Manjacos and other (Animists, Catholics and Protestants), the main celebrations are Christmas and the Passage of the Christian year.

d) ***Musical entertainment groups and dances*** - The *djidius* and dancing groups, called "*mandjuandades"* (depending on the ethnic group) are groups known for their musical entertainment capacity. Due to the nature of their specialty, many villages located in the Project intervention area have artists. There is a group in Sandal and Canico-Lenquere Curoto.

Its importance lies in the fact that, although they are autonomous, they carry a *cross-function* communication and artistic expression at various levels, to be present in both parties and diversions of its own initiative as largely in events for the whole society and social groups, requesting them (i.e. in Ramadan and Tabaski; at weddings; at the beginning and exit from fanados).

VIII. RELIGIOUS SPACES

1. The gift of respect for the sacred

Because the overwhelming majority of the population is Islamized, the main formally recognized consecrated religious spaces are represented by mosques, churches and cemeteries. In 12 villages of the Project intervention area, there are 20 Muslim Mosques and Chapels; four Catholic Churches and Chapels, Protestant and New Apostolic Churches.

The distribution of the respective sites by villages and other locations covered by anthropological work follows.

Mosques (Muslim):

- 9 Mosques and Muslim Chapels in the villages of Canico Tumane, Urqui, Salquenhe Ba, Ufudi, Tambato Mandinga, Sandjal 1, 2 and Sanjal Canico-Lenque Curoto and Dugal.
- 11 Mosques and Muslim Chapels in the neighborhoods of the town of Farim.

Churches:

- Catholic Churches: 2 in the city of Farim and village of Sandjal.
- New-Apostolic Church: 1 in the city of Farim.
- Protestant Church: 1 in the city of Farim.
- Universal Church of the Kingdom of God: 1 in Cassanova District.

2. Other sacred sites - the essence of religious syncretism

The cemeteries are considered sites of great cultural and religious value in all communities of different religions, because of belief in the existence of the soul after death and that the power of the souls of ancestors is still present in this world in the daily life of their descendants, able to intervene on their behalf or act in retaliation against those who are transgressors of the traditional rules of coexistence with the sacred. Therefore, for the Muslims, Catholics and Protestants, these places are objects of pilgrimages on the "night of the living dead"; "all saints day" (Christians) and Ramadan. For Animist residents in phosphate project intervention areas there are diverse forms of worship in the homes of relatives and near the graves. The Mancanhas, similar to Christians, have one day each year reserved to worship ancestors in cemeteries (Souls Day - *n'gúran*).

Identified cemeteries

Muslim cemeteries:

- 9 cemeteries in Villages of Canico Tumane, Urqui, Salquenhe Ba, Ufudi, Tambato Mandinga, Sandjal 1, 2 and Sanjal Canico-Lenque Curoto and Dugal.
- 4 cemeteries in the neighborhoods of the town of Farim.

Municipal Cemetery: 1 in the neighborhood of Nema (town of Farim)

Animists and mixed cemeteries: one in the Nema District (Mancanha), 1 in Salquenhe Porto (Manjacos), 1 in Cabsequi and 1 in Ponta Caeiro.

Individual Animist Graves : There are family graves in family living compounds of Balanta-Brassa in Salquenhe Porto, Demba Baio, Cabisseki, Dugal and Tchúgue. Please note that, in the tradition of the Balanta-Brassa ethnic group, the dead are not buried in the common cemetery, away from the housing, but in backyards, in side balconies and some in rooms of the house.

3. Religious syncretism

The presence of the sacred in informal dimensions, parallel to the formal religiosity

On the other hand, there are other sites where the presence of superhuman spirits is indicated, which are now formally recognized (groups of Animist; Christians; Mandingo Muslims; Balanta-Mane; and Beafadas), sometimes informally declared, i.e. – superficially (due to the shame of belonging to the universal religions - Christian and Muslim - and still going to Animist sites). These are the sacred forests and Animist sites called "boloba" and small shrines (*testos* and *firquidjas*). In concrete reality, due to inter-religious cohabitation quasi-religious syncretism, the informal life of individuals, there are almost no communities where there are no such sites both in homes and in the surrounding forests, considered as sites of existence of spirits or irans . Some are frequented as targets for cults and others just marked as prohibited and inviolable spaces.

Fanado Forrest - It is a place chosen by the community for the final passage initiation ritual - the Fanado. In the months that this ritual occurs, the local camp of the initiates (called the Fanado Barrack) is constructed. Depending on the circumstances, according to respondents, both Muslims and Animists, from Urqui (Fula) down to Tchúgue (Balanta-Brassa) is not mandatory that the fanado (*klushe*) be held in a sacred forest as such, permanently inhabited by a supernatural force (iran) therefore only becomes a sacralized space when men turn to sacred and attract him to the place in order to ensure vigilance against the evils of human and invisible spells. For Mandingos, in the area visited, this supernatural force is symbolized by his incarnation in one or more men who become, for

a time, in mythical figures designated as a *kankúram*. For Balanta-Brassa, although there may be some sacred forests, their Fanados are practices in any enclosed forest.

The *Kankuram* is thus a figure with ambiguous existence. It is a mythical figure due to its invisible spirit and supernatural powers. In the lives of Animistic people it is considered an *iran*, spirit of darkness, to which the living resort for protection, luck and successes in life or even to avenge themselves against a criminal.

On the other hand, the men responsible for fanados have to ensure that they have an enclosed youth camps (initiation huts) secured against the harmful effects of other evil spirits and human *sorcerers.* Thus they decide to summon their powers and incarnate them in a man. This individual or individuals wrap reddish tree barks from the fara tree, (e.g. the famous *kankúram* of Salquenhe ([7]), one of which was known by the name *fambondi*).

Thus, it is part of the cultural values of the intangible world and at the same time, the material world, present on the rites of passage occasions. It is a current event for Mandingos, which is one of the cultural heritages (one of the vestiges of Animism), deeply rooted in the everyday life of people living in this area and, therefore, makes the connection between the sacred practices of the present, represented by believers of Islam (the Mandingos, Balanta-Manes, Banhuns, Islamized Mansoncas), with the exception of Urque Village (Fulani), according to its inhabitants.

4. Description of some sacred sites

The sites where the presence of superhuman spirits are indicated in the sense of being the bearer of *numenoso* (holder of divinity or sacredness), referred to above, exist in most villages of the country, and specifically those in which the survey was conducted - whether formally recognized, or whether informal and quietly declared.

From an environmental point of view, these forests are among the best preserved areas because they are protected and provide the best shade and shelter conditions and sometimes are feared by the people. They serve as temporal boundaries for the spirits during the fanado period and during the years when there aren't any rituals. They are placed in the category of *malgós forestry* (sacred forest), a commendable concept to strengthen environmental protection mechanisms for endangered species. The main sites identified are:

Canico Tumane - There are 4 sites:
N'ghansi-colon Forest *(N'ghansi-cólonghato and N'ghansicólom Suto)* , *Culumbato* Forest , *Fulamusso Djudje* Forest and *Kuiam Djalo* Forest *(Information from Salum Sani, village chief; Mamadu Fode; Ture brothers and others).*

Urqui - There are no other sacred sites beyond the mosque and the cemetery *(Information from Francisco Adulai Emballo and elders*).

Salquenhe Ba - There is a forest spirit (*sussuto);* a small forest, 250 meters behind residences (Southern village) next to manogany trees and calabash trees, called

Filidje. Since the village is occupied by the Islamized Mandingo, no one currently formally and officially claims to be responsible for the rituals which are made in secret by private stakeholders from all backgrounds, in search of peace, protection against diseases in the living compounds; plenty of family farming and successes in business. The forest was never cleared inside because of the popular myth of its sacredness. (*Information from Seco Ture, Chief of village; Malam Tambadu - Dano- and elders*).

Tambato Mandinga (Brasso Tambato) - The following sacred sites are:

- Two sites on the river;
- One *Bertunta* site by the fields;
- A place on the road between Tambato and Salquenhe Ba, where from Monday to Friday, between 7:00 pm and 8:00 pm, usually gives physical signs of their presence (the figure of a man sitting under a Bissilão tree). ([8])
- The sea serpent (*iran*) in Sitandinto River (usually gives sounds like a horn);

There are also woods reserved for fanados - *Nhacadalo-stump* .
(Information from Malam Cisse, village chief).

Ufudi Village - in addition to the Mosque and cemetery, there are the following sites considered:

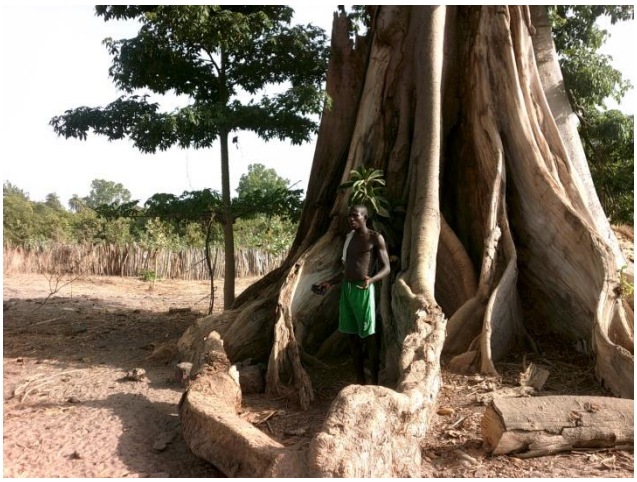
- The grave where a wise "Muro" was buried (in the Muslim cemetery). The site has become a place of pilgrimages of believers who go there to pray and ask for blessings and luck;
- *Bantanhel* Site , near the river, is a mysterious place inhabited by a spirit feared by the population.
- *Baracot* Forest (which also hosts fanados), is considered a sacred place *(Information from Aladje Darame).*

Sandjal 2 - While some residents being Islamized and other Christianized, the Balanta-Mane of Sandjal 1 and 2 recognize and assume the commitments of devotion to *irans,* the religious syncretism practices - symbiosis of animistic beliefs with Islam or Christianity .

- There are symbols of holy spirits in the homes (stones on the floor and *kdossan* - gourd shells (*calma),* hung at the entrance of each door). representing the House Iran ([9])
- There is also a site or baloba (sacred shrine) officially taken over by the community in the vicinity of living compounds, known as " *pass* ". It is located beneath the leafy canopy of a tree name *mandjandjam,* which produces bitter oil - *siti malgos* .
- There is also a fanado forest name *Cunte Quin-Kissangue* (Malila Forest) between 500 to 700 meters from the village, forbidden to be cleared, though not inhabited by spirits (*Information the village 2 chief).*

Sandjal 1 - There is a sacred place in the following:

- A place classified as "*pass"* (in the language Balanta-Mane), situated by the living compounds under a Poilão (a very large tree).



(*Myth: The Poilão tree did not exist until, according to the myth, after the burial of the elder Moro Mane, the current village chief's grandfather. This tree grew and leaned against the tomb of the late Muro. The wise elders advised residents that the tree was protected and people started to put under it the offerings of palm wine on Thursdays. So it became a balboa – a sacred shrine).*

- There is also a fanado forest 2 km from the village, forbidden to be cleared, although its degree of sacredness is not equivalent to a baloba (*Information from Village 1 chief).*

Canico-Lenque Curoto - As in villages inhabited by Mandingos, there are forests near this village recognized to be inhabited by powerful spirits, even though no one officially claims to be in charge of their rituals, unlike the Animist and relatively recent converts to Islam (Balanta-Mane). This is the case of *Saracunda-sutundim sebalo* forest (1 km from the Nascente do Sol) and *Sitacum Sato* forest (on the way to Tambato). They are considered sites where deforestation is prohibited; where the history of the distant past and the recent past reveals that there have been cases of retaliation against those who

would challenge their supernatural powers (*Information from Numo Dabo, 66 years old; Bacar Dabo, village chief; and Mamadou Dabo)* ([10]).

Salquenhe Port - There are 2 types of irans : small shrines made of *firquidjas* or stalls next to living compounds (home irans) and *irans* in the woods next to agricultural fields of each living compound (forest irans). According to residents' versions, the *Balanta-Brassa, Manjacos, Mansoncas* and *Mancanhas* Animists that emigrated there found no sacred forests inhabited by these spirits. So, over generations the elders took the "twins" of each home *iran* to the large trees found in the forests cleared for farming, in order to protect their crops. Today they have become authentic forest irans (at least for the four (4) ethnic groups mentioned above). Thus is it strongly advised that it must be dealt with respect and wisdom of the tradition of each ethnic group. The best known baloba in this village is located in the center of the old village of Salquenhe Porto (Ponta Zeca), under the *tumbum mangroves (* on the other side of the river, less than 1 km south of the current village) - *Information from Lalo Dafa, blind elder of 70 years of age. The village chief is Cletche Iemdi, 76 years of age.*

Demba Baio (Balanta Brassa) - There are also irans in each living compound as well as individual graves in the houses or beside them *(Information from Claudio Djata and others*).

Ponta Caeiro or Pã-Lamba (Balanta Brassa) - There is an *iran* called *Teck*. There are also *irans* in each living compound as well as individual graves in the houses or beside them *(Information from Domingos Costa, village chief; and youth Braima and Louis)*;

Cabssequi (Balanta-Brassa) - There is a forest with an *Iran* baloba (Mancanha) in the fields. There are also *Irans* in each living compound as well as individual graves in the houses or beside them *(Information from Bilama Quióde)*;

Dugal (Balanta-Brassa) – In addition to a Muslim Mosque and a Protestant Chapel, the following sacred places are:

- In each Balanta-Brassa living compound, there are small metal symbols in covered or uncovered stalls (*Iran firkidjas*);
- Outside of different living compounds, there are balobas in the following places: Baloba of *Atongba,* and baloba of *Biifa* (in the Poilão tre on the paved road), in the living compound of Aglaba; baloba of *Akdum;* baloba of *N 'fad* ; baloba of *Raga* ; and baloba *of Abagm* (the calabash tree on the left side

of the road on the way to Tchúgue) *(Information by Biefa Mbondi and Serifo Mane)* .

Tchúgue - As in most of the Balanta-Brassa villages, there are two types of *Irans*:

- The home Irans (in small stalls or *fikidjas*);
- The balobas themselves. The best known in Tchúgue is *baloba of the head of the port*, known for *Ule na Lang* (stone iran), exposed over the last boulder where the waves of the sea impinge.

Reportedly, the Port Baloba derives from the same House Iran that is in the living compound of *Tchúgue na Ksitch*, from where the final passage rituals are made in two steps: 1 at home and then at the port. Both sites serve to seek protection (surveillance) of villages, residents, farming activities, fishing and other *(Information from Ernesto Mario Jondi in the living compound of Tchúgue Kssintch)* ;

- Baloba of *Saié* (*Pó di cinza*);
- There are also sacred forests in *Tchúgue Knteda* : and the *Aquintchile, Thuggee kssitch* and *Flak-flete* (100 meters from the settlement), where they perform sacred ceremonies (*Information from Sana N 'dami and some youth of Tchúgue K'nteda).*

Nema - *Mussinhima-colom* water fountain*:* A water source near the field between the districts of Nema and Morcunda (Farim). It is a pilgrimage site for women (Christian-Animist and Muslim) in the dry season in search of maternal fertility *(information from M. Cisse, traditional ruler of Farim).*

Gã-Sapo - Baloba of *Farombal :* ([11]) Less than 500 meters South of Gã-Sapo Neighborhood, by the sea, on the right bank of the Farim River (by the Regional Administrative Headquarters), represents the spirit of mothers (of *Bambara* - fertility). It is considered an *Iran* that is procured by men and women from various parts of Farim and other regions in search of transcendental solutions. The sanctuary is located beneath a climbing fig tree by the river and on the base of the tree there is an inactive termite mound (*Bagabaga*), where the "priestess" sit and talk during the the ritual.

Before accompanying the stakeholders to *beautiful sea*, the "priestess" queries the Iran in its home (*baloba of farombal*), on the first road Gã-Sapo in Farim, where there is a *texto* (sacred pot) and a pot at the head of balobeira, Nha Rosita's bed. It is the starting point for the ceremonies, then they walk to the *seaside*. In fertility rituals, there are certain times when women go to the site and get naked for a while, then they cook and sprinkle or spray ([12]) brandy, palm wine and a handful of food and pieces of meat on the sanctuary and appeal for luck and good. Since this Iran is only for good, it is forbidden to go to appeal for the death or curse for someone *(Information from balobeira Rosa Brito Borges, and her assistant José Júlio Mendes Carvalho Tavares).*

Morcunda - There is a myth about the baobab tree in the neighborhood, and no one dares to cut it down, afraid that whoever (and their family) cuts it will be victimized by mysterious persecution. There is also a sacred site at the home of the head of fanado barrack *(Information from Aladje Lassana Baio).*

5. Other symbols of collective memory

Morcunda - Monument to the Martyrs of Terrorism - Massacre of November 1, 1965, symbolize the negative memory where the colonialist launched a grenade into the crowd during a Mandingo and Saracolés festival called *mandjuandadi* of *djidius*. The event not only resulted only in 20 deaths and many wounded from the grenade, but was also the starting point for a long night of fear in Farim, at the time. This is a tangled story woven by the colonial political police that served as the pretense for the persecution and mass arrests of 60 suspected anti-colonialists resistance supporters of the National Armed Struggle. Some were tortured to death in prisons of Farim and Bissau and others were incarcerated in the prisons of Galinha Islands and others in Tarrafal – during the time of Joaquim Silva Saraiva, Administrator *(Information from Carlos Malam Sani, last survivor of the attack)*;

Government Garden - Monument in honor of Titina Sila, heroine of the National Liberation Armed Struggle, killed while crossing of the Farim River in January 1973.

IX. EXPECTATIONS: THE UNKNOWN, MISTRUST, FEAR, ANGUISH AND THE IMPOTENCE OF THE LIVING

According to testimonies provided during anthropological research, faith in God, in the virtues and powers of the souls of ancestors and the supernatural forces that inhabit the villages and forests, are sacred values inherited over the centuries and are deeply rooted in the culture of these people and therefore are part of the behaviors, attitudes and practices in day-to-day life of local residents.

Hence, a part of the population, from the point of view of cultural and historical heritages, appear to have difficulties in digesting the information that one day they will have to leave their homes, villages, cemeteries and the land where they were born; where their fore parents and their parents were born and where they are today with their children. They consider themselves to be followers of memories and respectful to customs and traditions that were left to them by their ancestors.

1. Testimonials

In Salquenhe Ba, Urque, Sandajal, Canico-Lenque Curoto, Salquenhe Port and other village, there are common perceptions that the excavations and land removal of cemeteries and mosques are acts which violate against the honor and dignity of their ancestors and against God. Further, that the destruction of sacred sites will be highly dangerous acts, against the invisible powers, which are beyond the control of the will of the locals and may cause illness, misfortune and in their prognosis, even life - that someone may be called into question. Some extracts of the interviews are below.

2. *Waiting for clearer promises*

Among the elderly, women and young people of those villages, while there are those who are flexible, (as long as the comparative advantages may be favorable), most disagree with the idea of having to leave their villages. For them, if they have to do, the responsibility will be on the State, because the land belongs to the State. What frightens them is that they have had knowledge of this subject for over 20 years, but still do not have a clear solution. *"The solutions that have been presented so far are only promises and more mere promises. Here is where our fore parents were, and here is where we have land, plantations, bury our dead and here we know where to go by foot to seek solutions to life's and families' problems. We don't know where it is that we are supposed to move to and have no idea what will happen there. Therein lies the greatest doubt "*- opinion of the inhabitants of Sandjal 1 and 2, Urque, Canico-Lenque Curoto, Salquenhe Ba, Canico Tumane and others.

Youth and adults of Canico-Lenque Curoto ([13]) and Urque ([14]) have the following perception of the situation: *"Our properties were created during years and years of work, bit by bit, and we had no conflicts among us, because there was brotherhood and when a family doesn't have any space, another family gives them a piece of land. But if we have to go somewhere else, which is unknown to us, we'll have to start all over again under the orders of the land owners with no peace at hand on our land.... "*

An adult in Canico-Lenque Curoto was peremptory in using words: *"To be honest, whenever I hear the sound of a car, I raise my face to see; and when I realize that it is one of the phosphate project cars, I am startled. My heart beats fast, because for years I have been afraid. Fear of what awaits us ... I do not have much confidence in the promises. "* ([15])

"Before you destroy, you must first build and also compensate" (Bissunha and Luis of Ponta Caeiro). *"If what happens is unfavorable, then the courts will be able to solve the problems..."* (Demba Baio). *"The consequences on health and the forests will be difficult to calculate."* (Aladje Bay, Morcunda).

3. *Between a cemetery and a cashew plantation? Cede the one that is easier to recuperate.*

Under the insistence of the consultant for they themselves to suggest a solution, one of the residents Urque and another from Canico-Lenque Curoto ([16]) compared the embarrassment they would have if they have to choose between leaving the cemeteries or fruit properties, opined that: *"To destroy sacred sites of the forests is dangerous and we have an obligation to inform outsiders of this danger. But if they decide to destroy the forests it will be the responsibility of those who destroy it. As for the cemeteries? Actually, they are the homes of the dead and will be the destination for each of us tomorrow. But if the State decides to build another cemetery elsewhere, we will be sure of where we will be buried. What we do not know, or are not sure of is what the fate of our properties is. We have many questions, so if they ask us to choose between the two, we would let go of the cemetery, but not abandon our cashew plantations."*

4. ***Participatory solutions with the recourse to popular wisdom: the moratorium***

4.1 Cases of cemeteries abandoned against will

The research allowed us to hear more voices of popular wisdom from the mouths of the elders, who have a lot of experience in seeking internal solutions to problems facing the community imposed at certain times by political powers. According to the old octogenarian, Mamadou Cissé, 4th Ruler of Canico, residing in Nema, Farim, the first answer that either of them would give is that you should not dig cemeteries, rummaging through the bones of the deceased of loved because it would be gross disrespect for their memories and to the dignity of their survivors.

With this, he recited the history of moving the Nema District Cemetery during his father's reign, (Braima Cisse). The Farim Administrator forced them to transfer the burial acts to a graveyard further away from residences. The then ruler called several meetings with elders from other villages in its jurisdiction to help reflect and find a solution less daunting and less damaging to the feelings of the surviving families. After a few days passed, the administrator demand that his order should be enforced at all costs. So the elders proposed to the ruler that the best way to force the souls and spirits to leave the cemetery and to appease them, (so as to not have anger against their relatives), would be to turn the site into a stable for cattle herds. After that, the "whites" could begin construction of the neighborhood streets.

The ruler sent for the Urque Village chief and conveyed his desire to have the space used for his cows to graze and be sold to buyers. Both convinced Urque cattle owners to place their 200 heads of cows on the site. And so the moratorium on the use of space lasted two years, enough time for the adaptation of inhabitants to the new cemetery and the untying of transcendental alliances between them and the souls of those who had been buried in the first cemetery. To set an example, the family of the ruler transferred their living compound to the site and others also followed him later. Without any terrifying phenomena, the area transited smoothly to become an urbanized Farim neighborhood for the residents, with houses organized in blocks.

Another example was told by the elders of Salquenhe Ba, when, after giving their reticent opinion on a possible decision of the Government and the Project to abandon their village, and being asked by the consultant to suggest an internal alternative if they were to decide, they recalled the following: *"During the time of the National Liberation Armed Struggle, it was an obligation of everybody to leave the village because of the war. The first cemetery was abandoned and the site turned into bush. When the war ended eleven years later, the population returned and chose a new space for the cemetery. The old cemetery was abandoned peacefully because no one violated the graves of the deceased and for a long time, no one moved or shifted their bones. Only in recent years, due to popularity of cashew orchids, some people cleared, cultivated corn and planted cashew trees on that site (about 30 years later) ".*

"Changing without touching the bones of our great ancestors, is not the same as what will happen to us this time: forcing people to leave a village and then immediately begin

digging in the cemetery where some dead bodies of our relatives have yet to disintegrate within the earth. We have doubts about what will happen."

The story told by elder Mamadou Cissé and by elders of Salquenhe Ba, Salquenhe Porto and others of other villages where there are phosphate deposits, represent some of the advice that reveal popular *savoir faire*, as long as communities are involved and have their views taken into consideration, even in the case of a decision imposed from the top down that they don't agree with.

4.2 Hints from a traditional transfer method of an Iran to another territory: between certainty and ambiguity

For the Balanta-Brassa population, a decision to transfer a sacred site, with or without a baloba, must go through negotiations between men and the Iran but there is not always a guarantee that the negotiation and transfer are peaceful.

In the villages of Dugal and Tchúgue (towards the Geba River), there is a more skeptical perception than the ones of the Balanta-Brassa villages located in phosphate deposits zones in Farim, because they have never heard of a complete withdrawal of a baloba to another territory. What is known is that a family may decide to abandon a village to go to another and take an amulet (horn or harnesses portion of baloba symbolizing the transport part of the spiritual powers from Iran to the new living compound). But the baloba parent remains at the original location, especially if other family members remain there.

At the insistence of the consultant about how they would proceed in the event of the building of a road in the direction of a local baloba, the response of Mario Ernesto Jondi (41 years), from Gratnó N'tchoba Village, residing in the living compound of Thúgue *Ksitch* : *"You know, the Irans occupy a territory and dominate the space to the border with other irans. If the entire baloba is transferred, it is unknown if the iran will be peacefully accepted in the new territory that is already inhabited and controlled by other irans . There are also rivalries between them. They offer resistance when there are attempts to transfer them from the territory. So it is a very dangerous situation that is paid for with the blood of the person who makes such an act. This is what we know."*

However, in Salquenhe Porto, anthropological research detected a beam of light at the end of the tunnel for possible research methods to find less painful solutions to overcome the coping complication of the phenomena of popular mentality strongly rooted in archaic societies, submitted and dependent on the sacred.

For elder Lalo Dafa, her understanding is that irans have been around since the times of our foreparents, with a commitment to remain in these spaces, and are consequently very difficult to transfer from one territory to another. In the traditional method indicated by the elders, one should never take the initiative to kill an animal in a baloba to please and transfer an iran from one territory to another, without first having consulted the elders in the living compound or village. When, they agree among themselves, next they will consult secret societies, through *bota sorti* by *djambacós* (i.e. – consulting

soothsayers), *balobeiros* and Muros with transcendental powers. Only after one has made sure that the proposal would be accepted, then and only then should one advance to the questions about the terms of payment with animal blood, food and drinks. Sometimes they are accepted with a pig or two goats or a cow. It depends on each *iran*. If things are forced hastily without clarity to whether the response will be positive or negative, it may be a fatal risk; that the *Iran* turn against you, forcing you to pay for the mistake with your throat, i.e. death. *"Who will be responsible for the ceremonies costs in cases where requests to irans are accepted? And who will be responsible for human deaths, if the irans revolt against withdrawals not accepted by them?"* These are the questions that Lalo Dafa wanted to leave to the discretion of governmental authorities responsible for the decision to remove the people and their deities.

X. PERSPECTIVE OUTLOOK ON SOCIO-CULTURAL DYNAMICS AFTER RESETTLEMENT

1. *Phase of dreams*

In the opinion of some civil society activists in the Region ([18]), revelation of the Phosphate Project benefits has aroused curiosity and high expectations and has created enormous dreams among youth in the area.

With the promises made by the State Authorities and companies that have prospected there in the past, civil society representatives consider that the future phosphate exploration appears as a lifeline for young people, but they wonder: *"What are the comparative advantages of this Project, which will ensure populations' resettlement, adaptation, land tilling and use of natural resources in new areas and social and cultural balance of the different communities to be affected by the phenomenon "?*

2. *Limits of cultural resistance*

Progress versus deviations of moral values

The population living in the Project intervention zone are predominantly Muslim, usually recalcitrant to sudden changes from outside and tend to question rules of conduct, morality and religiosity.

At the level of youth, due to aridity of the climate and the high degree of drought in Northern Regions of the country, the search for economic and socio-cultural solutions for youth has led to seasonal migrations, after agricultural crops, to urban centers, or by temporary or permanent emigration of this layer abroad (Senegal and Gambia). At the beginning of phosphate exploration, it is anticipated that many of these young people will return to their villages of origin in search of new opportunities.

There is the concern that with new workers and different heterogeneous social levels and with different social and cultural habits, a new dynamics of social and labor relations will

gradually be created, with a new profile of the man and woman, each eager to have access to work and income, including rapid success and pleasures of life that young people are more susceptible to, with vulnerabilities. The new workers from different regions and different nationalities on the one hand, then the returnees of young former emigrants and permanent residents in the middle, will be facing an amalgam of systematic habits and customs in search of cohabitation, harmonies, balances and possible imbalances with trends of higher consumption of alcohol, sexual promiscuity, prostitution and delinquency.

3. Gender Consequences

The balance and social cohesion of peasant societies rely on the usual appeal to the parables of the myths and taboos closely linked to each geographic area inhabited by men; the use of intervention of the souls of ancestors and the surrounding medium of invisible spirits, helping to maintain balance between evil and good and hence maintaining the authority of heads of families, the living compounds, clan and community as a whole. However, the planned resettlement will be accompanied by different stages of disruption and restructuring of family tissue and balances and social cohesion of communities.

As is known, in the Mandingo communities in particular and rural communities in general, the social division of labor plays to the disadvantage of women, not only because of the overload of tasks to which they are subjected to in the struggle for safeguarding their marital duties and participation in all personal family and activities, as well as the subordinate position in which they are relegated.

In the past and present history of the country, during the times that families are faced with situations of social, economic and cultural crisis, women and young people are the primary and most affected social strata. Therefore, in situations where the comparative advantages of phosphate exploration and resettlement come to create imbalances in the resettled families, the woman's disadvantage trend will be more pronounced.

On this basis, KAFO Federation’s view is that it requires the involvement of social actors including civil society, government, popular grassroots organizations and traditional leaders of men, women and young people in their reflections and clear transparent negotiations and about the benefits, risks and future consequences. The approach of including social actors must also make sure that the nomination of officials nominated for the posts of administrative authorities of the Regional and Sectorial Government have technical skills, in order to enable them to exert their role of monitoring and supervision of the implementation of activities and take action with guidelines that favor the creation of a national economy but also to safeguard the interests of vulnerable populations. ([19])

XI. CONCLUSIONS

The specific phosphate deposits zone directly covers 13 villages in the Farim Sector: 11 to the West and Northwest Farim sector, which are Canico Tumane, Urqui, Salquenhe Ba,

Salquenhe Porto, Ufudi, Tambato Mandinga, Sandjal 1 and 2 , Canico-Lenque Curoto, Cabsseki Ponta, Demba Baio, Ponta Caeiro, and two villages in the Mansoa Sector - those of Dugal and Tchúgue.

The communities in this area of intervention are part of the Canico jurisdiction made up of about 30 villages scattered between the North, the East, the Centre and the West of the town of Farim.

The issue of expectations of the people over the fate of their agro-forestry and pastoral areas and their sacred places is intertwined with their expectations for their set habits, attitudes, practices and possible cultural shock. That is, the current internal social dynamics in the area and the dynamics that the exploitation of phosphate bring to the location and the surroundings of Farim. The dimensions of cultural heritage is transversal and goes from the popular work-related knowledge, to festivities, to the ceremonial rites in cemeteries, to Animists shrines (balobas) and sacred forests and instruments related to them. Harmonious systems that each ethnic group has and applies to maintain social stability, to the cultural habits of the population in the way each group deals with the land and ensuring the normal distribution of these lands between families and between neighboring villages.

Consequently, this research also includes, (although superficially), major artefacts produced and used by the communities, as a contribution to enrich the knowledge of a part of their cultural heritage, a phase where conservation and the balance between man, their instruments and their environment will be substantially changed.

The types of working tools used in that area are directly dependent on the traditions of ethnic groups who use them and the context in which the social, technological and economic factors evolve in the country in general and communities and the business sector in particular.

In Islamic communities in Farim, at least four major events stand out that mobilize the inhabitants of each village for festivities; (in their order of importance): Tabaski, Ramadan, New Year's Eve *(muscoto)* and Final Passage Rituals. In Christian and Animists communities in general (unconverted Balanta-Mane and Mansoncas, Balanta-Brassa, Manjacos and Mancanhas), the main festivals are: Christmas; New Years; and Final Passage Rituals ("kssunde" and "canta pó"). They all have direct or indirect relationship with the sacred.

Because the overwhelming majority of the populations are believers of different imported religions, the main consecrated religious spaces that are formally recognized are represented by Muslim Mosques, Christian Churches, Chapels and cemeteries.

The cemeteries are considered sites of great cultural and religious value in all communities of different religions, because the belief in the existence of the soul after death and the power of the souls of ancestors being present in this world; invisibly in the daily life of their descendants.

Therefore, for Muslims, Catholics and Protestants, cemeteries are the subject of pilgrimages on the "night of the living dead"; "all saints day" (Christians) and Ramadan. For Animist residents in phosphate project intervention areas, there are diverse forms of worship in the homes of relatives and near the graves in cemeteries.

> ***"IT IS EASIER TO DESTROY A VILLAGE THAN TO DESTROY A TRADITION"***
>
> Bambara proverb

On the other hand, there are other sites where the presence of superhuman spirits is indicated, which are now formally recognized, (groups of Animists; Christians; Mandingo Muslims; Balanta-Mane; and Beafadas), sometimes informally declared, i.e. – superficially (due to the shame of belonging to universal religions - Christian and Muslim - and still going to Animist sites). These are the sacred forests and Animist sites called "baloba" and small shrines (*testos* and *firquidjas*).

In concrete reality, due to inter-religious cohabitation (quasi-religious syncretism), in the informal life of individuals, there are almost no communities where there are no such sites (both in homes and in the surrounding forests), considered as sites of existence of spirits or irans. Some are frequented by cults and others just marked as prohibited and inviolable spaces.

It is the presence of the sacred in informal dimensions, parallel to the formal religiosity. From an environmental point of view, these forests are among the best preserved areas because they are protected and provide the best shade and shelter conditions and sometimes are feared by the people.

According to the testimonies provided during anthropological research, faith in God, in the virtues and powers of the souls of ancestors and the supernatural forces that inhabit the villages and forests, are sacred values inherited over the centuries and are deeply rooted in the culture of these people and therefore are part of the behaviors, attitudes and practices in day-to-day life of local residents.

This is why for the population, from the point of view of cultural and historical heritages, it costs them dearly to hear that one day they will have to leave their homes, the villages, cemeteries and the land where they and their fore parents were born and where they and their children consider themselves as followers of the values and memories that were left to them by their ancestors.

Among the elderly, women and young people of those villages, some are indifferent to the comparative advantages, if they are favorable. But most disagree with the idea of leaving the villages because they don't have confidence in the promises made. For them, if they have to leave, the responsibility will be on the State, because the land belongs to the State.

Revealing the entanglements that have to be suggested to them reflect on hypothetical options to choose between abandoning sacred places or fruit properties. Some have made

it clear that they are more confident that the State offers for new cemeteries will be less painful to lose sacred sites in the forests and the loss of fruit orchids that took a long time to be created by the peasants.

Anthropological research has allowed for the voices of popular wisdom to be heard from the elders, who have traditionally sought internal solutions when facing problems imposed on the community by political powers at certain times. The bottom line for them is for the political authorities to timely propose solutions and allow necessary time to participate in the application of methods that adapt to their realities and customs.

The stories told by elder ruler Mamadu Cissé of Farim and the elders of Salquenhe Ba about the abandonment of cemeteries, and the least painful methods of negotiation and balobas transfer from sacred sites to other territories (by Balanta-Brassa elders), represent some of the advice that they make available to the societies via popular *savoir faire* and manipulation (use) of the secrets of secret societies. They are beams of light at the end of the tunnel for possible methods in search for solutions, in order to peacefully cope with entanglement of the phenomena deeply rooted in the minds of the residents, submitted and dependent on sacredness.

XII. RECOMMENDATIONS

Whereas any political, administrative and technical decisions on issues that deal with survival, stability, balance and social cohesion of communities must go through the recognition of the rights, duties and feelings of people in areas covered by those decisions;

Given that rural communities who live in the Phosphate Project intervention zone, in their daily practices of productive, economic, social and religious life, are deeply rooted in beliefs about the existence of souls and spirits with supernatural powers;

It appears that the fundamental issue for residents of Farim is doubts about the political will of those in power to hear their proposed solutions, in a timely fashion, and to be informed on the forecasted planned schedule, to allow time for communities to apply methods that adapt to their realities and customs;

There is the absolute need to ensure that the project implementation and management process is done in a normal and uninterrupted situation, in an environment of perfect understanding, coexistence and harmony between the Government, the company and the inhabitants of the communities that will be subject to resettlement to new areas; for the sake of peace, regional and national stability, and for the sake of interests of all and interested parties;

We recommend the following:

a) <u>Useful preconditions for treating delicate cases:</u> That all those involved in the process, including representatives of the State and the company, strive to cultivate attitudes of understanding and respect for the traditions, using the socio-anthropological principle of

methodical abstraction to be able to coldly analyze the problems of the sacred and religious beliefs, knowing how to put yourself in the place of the "other" for better understanding. In the eyes of the peasants, it is essential that the promoters of controversial decisions are able to identify with the concerns of the victims; which will represent a step forward in the negotiation process;

b) Before the decision to start the Project's exploration, public consultations should be carried out in loco, directly in each community in order to listen to the people, reflect together with them and promote direct, clear and transparent negotiations about the benefits, risks and immediate and future consequences of abandonment of sacred sites and other tangible and intangible values of cultural heritage, suggesting to them to put forward proposals and counter-proposals of endogenous solutions to problems relating to resettlement and the transfer of these sacred sites in order to minimize or neutralize, from the very beginning, the obstacles, risks of profanity, fear, and psychological trauma and tendencies of resistance and subsequent conflicts;

c) Community involvement should not be understood to only mean visits to the field to transmit and clarify information on possible displacements of populations. Instead, it should mean open and constructive reflection on actions in the search for negotiated solutions between the parties, without rushing and risking putting the cart before the horse.

d) For a strategy to adapt to the levels of cultural understanding of cross-cultural phenomena, the action of promoters should take into account two levels of negotiations: on the one hand, negotiations between the promoters of phosphate exploration and the inhabitants of each village and on the other hand, negotiations between the communities, balobeiros and secret societies involving the transcendental forces that, in the view of popular believers, block the will of all to adhere to the process of them moving. That is, in the conception of Animistic beliefs, before residents move to another territory, first they must appease the wrath any eventual iran of the forces of divinity to accept the abandonment by its allied men in their moving locations or alternatively these irans will also accompany its allies in their move, in order to avoid religious desecration and feelings of offense, resentment, resistance and future revolts.

e) Quantify the costs of ritual processes (ceremonies) that may be needed in cases where negotiations with the secret societies for withdrawals are accepted, and co-share in the costs and possible compensation, ( ) always well prepared in public acts and inclusive, in the presence of representatives of the lineages of the villages founders and secret societies jurors (balobeiros, owners of Irans or owners of *calma* - the shell of the shrines).

f) As is known, the Mandingo communities in particular and rural communities in general, the social division of labor plays to the disadvantage of women. In the phosphate exploration phase, to reduce the negative effects of intervention that may create imbalances in families and consequent worsening social conditions of rural women, (still hostage to the double domination of man and cultural barriers of society), should act in the regulation and implementation of mechanisms of inclusion of parties, build alliances and ensure a transparent monitoring of the government and social players. In other words, all political and social actors, including central and regional government, civil society organizations, popular local membership organizations, women and the power of

traditional leaders should be involved in the process of following up and reviewing actions;

g) To guard against any breach of the commitments made by the Government and the company, a joint monitoring commission should be created. It should have members with technical profiles appointed by Sector and Regional Government, in order to follow-up and monitor the implementation of activities and intervene based on guidelines that favor the creation of the national economy as well safeguard the communities' interests.

h) Create mechanisms for control and correction any trends of cultural values deviation; prostitution, juvenile delinquency and criminal practices which go beyond the limits acceptable by the cultural standards of the Region and communities.

i) Recognizing that from an environmental point of view, the sacred forests or reserves are among the best preserved areas due to peasants habits, it is recommended that serious thought be given to the fate of these spaces, comparing the advantages between the existing deposits in local density and the ecological function that these forests grants for all the ecosystems in the Region.

June 2015 Pedro Quade
Anthropologist

End notes

[1] - Source: Farim Administrator
[2] - Calculation based on the average of four (4) per group.
[3] - Lemos Coelho travel records, in 1650 and 1660, showed awareness of the existence of Farim in 1641; the name coming from the name of its founder, *Farim Biai* , whose inhabitants, the banhuns, practiced palm wine quarrying.
[4] - Source: Papis Sadjo Ture, archivist, National Historic Centre.
[5] - Mesquitela Lima and others, in *Introduction to Cultural Anthropology*.
[6] - Similar to " *potlash "* of the Kwakiutl North American Indians
[7] – The folktale about at the height of the colonial authority, when one of the colonial administrators of Farim (Jaime S.), frontally doubted the powers of *kankuran*, but faced a demonstration of this, was dazzled by *flights* that scientific imagination struggles to explain and accept.
[8] - With the cross-checks, it should be noted that it is the same figure mentioned by the people of Salquenhe Ba, the *sussuto* designated *Filidje* .
[9] - On the wedding day, the bride and groom should take an oath by that stone along with a calma, that never the woman, no matter what the temptations are, will violate the principle of loyalty to her husband,
[10] – According to Mamadu S. Dabo, (66 years old), his grandfather, Braima Dabo, was injured and died for having breached the taboo of cutting down trees in that forest.
[11] - The *myth* of this Iran is that it defends the city of epidemic diseases and natural disasters and bombs during the anti-colonial war, with the result that there has never been a case of cholera in Farim city.
[12] – The act of putting drops on something, or sprinkle liquid on something, *dharma e uaga* in Creole.
[13] - Numo Dabo, (66 years of age).
[14] - Alfecen Balde, Umaru Sabali, Mamadu Sabali, Djibril Embalo Mama Sadjo Sabali.
[15] - Numo Dabo, (66 years of age).
[16] - Mamadou Dabo, (60 years of age).
[17] - Group interview: Seco Ture, (67 years of age), head of village; Malam Tambadu (Dano), (70 years of age); Djudju Ture, (85 years of age), former tailor; Sirem Camara 70; Mariama Ture (70 years years of age).
[18] - Sambu Seck, KAFO Federation.
[19] - Sambu Seck, KAFO Federation.
[20] - Analyze the alleged forms, consequences and questions presented by elder Lalo Dafa, of Salquenhe Porto.

MEMORANDUM

To:	Ms. Olga Kovalik	Date:	June 1, 2015
Copy To:		File No.:	NB301-520/2-A.01
From:	Richard Cook	Cont. No.:	NB15-00201
Re:	Farim Phosphate Project Supplementary Traffic Baseline Study - Product Transport Route and Port Components		

1 – INTRODUCTION

This technical memorandum presents the survey methodology and results of a traffic baseline study undertaken by GB Minerals Ltd. (GB Minerals) from April 23 - 25, 2015 in support of its Farim Phosphate Project (the Project).

The objective of this supplemental baseline traffic study, as part of the overall ESIA, is to complete the characterization of baseline traffic conditions along the product transport route and at the Ponta Chugue port site. The traffic survey established traffic levels for motorized, non-motorized, marine and pedestrian movement at four (4) locations between the mine and port site. Existing traffic will be taken into account when predicting what impacts are likely to occur as a result of the project and will enable road infrastructure and safety procedures to be developed, for all phases of the Project (construction, operation, and closure).

This study is supplementary in that it builds on previous traffic baseline work by Golder Associates (UK) Ltd. for the mine component of the Project (Golder, 2014). The previous baseline traffic study involved 3 days of traffic counts at seven stations (T1 - T7) in the vicinity of the mine site. Traffic along the road to the port site and traffic at Ponta Chugue was not included in the previous work.

Together, the two reports describe the traffic baseline conditions within the Project area, inclusive of the mine site, product transport route, port site and shipping route within River Geba (Figure 1).

2 – STUDY METHOD

2.1 APPLICABLE GUIDANCE

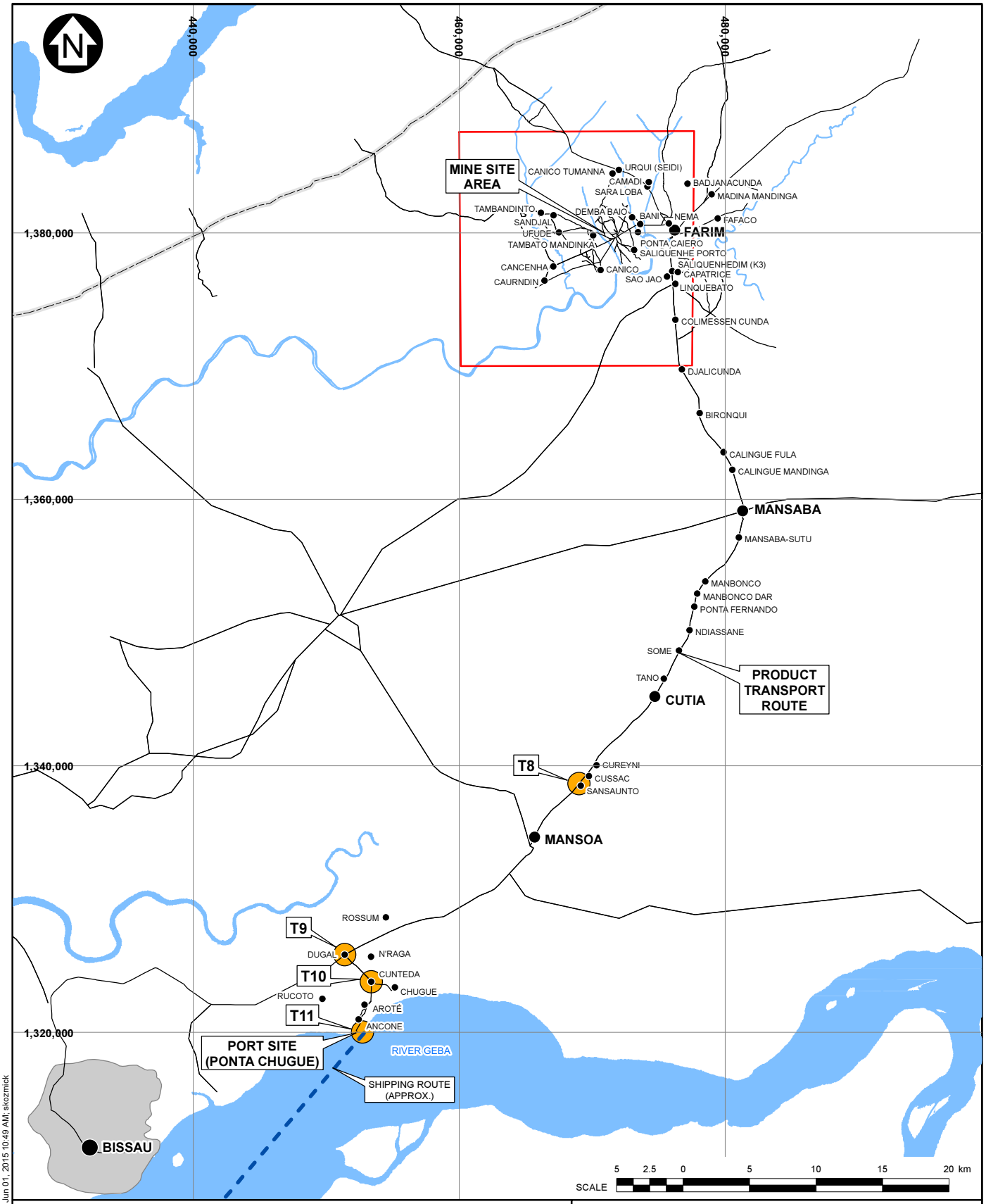
No national standards were identified for conducting traffic surveys in Guinea-Bissau. As such, the IFC's Performance Standards for Environmental and Social Sustainability were applied as guidance. (IFC, 2012a). IFC Guidance Note 4, G11, Community Health, Safety and Security highlights the private sector's responsibility to safeguard community residents and its workers in regard to traffic safety, particularly in situations where transportation infrastructure is poor or when the National regulatory environment is underdeveloped or poorly enforced (IFC, 2012b).

2.2 LIMITATIONS OF THIS STUDY

The traffic baseline results reflect traffic levels during the dry season. No events were identified that would limit or increase traffic rates within the area during the study. Road conditions are typically fair in the dry season. It is possible that traffic increases during harvests following the wet season.

2.3 METHODS USED FOR TRAFFIC COUNTING ASSESSMENT OF EXISTING TRAFFIC

For the purpose of this study, "traffic" includes pedestrians, bicycles, marine vehicles (canoes) and transport using animals such as horses and mules. This broader definition is especially relevant to the sparsely populated and rural context of the Project area.



LEGEND:

- VILLAGE
- TOWN
- CITY
- SUPPLEMENTAL TRAFFIC SURVEY LOCATION
- INTERNATIONAL BORDER
- EXISTING HIGHWAY
- WATER
- MINING LEASE BOUNDARY

NOTES:

1. COORDINATE GRID IS IN METRES.
   COORDINATE SYSTEM: BISSAU UTM ZONE 28N.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	01JUN'15	ISSUED WITH MEMO	MAS	SWK	RAC

GB MINERALS LTD.

FARIM PHOSPHATE PROJECT

SUPPLEMENTAL TRAFFIC SURVEY LOCATIONS

Knight Piésold CONSULTING

P/A NO. NB301-520/2

REF NO. NB15-00201

FIGURE 1

REV 0

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The 4 survey locations are described in Table 1.

Table 1 Traffic Survey Locations

ID	Survey Location	Description
T8	Sansaunto	The village of Sansaunto is located immediately north of Mansoa. Mansoa is one of the larger towns along the Product Transport Route. The route through Sansaunto is a high quality, paved highway.
T9	Dugal	On the Bissau-Farim paved highway and within the village of Dugal, at the turn-off to Chugue and the proposed port site (measuring north-south highway traffic only).
T10	Dugal to Chugue	On the unsurfaced road between Dugal and Chugue, just north of where the road branches to the proposed port site or village of Chugue.
T11	Ponta Chugue	At the port site location at Ponta Chugue on the River Geba. This location surveyed both land-based traffic and marine traffic on the River Geba.

The following transport options were included in the survey:

- Personal car
- Taxi car
- Passenger bus
- Single rear-axel pickup truck
- Double rear-axle truck
- Backhoe, bulldozer, tractor
- Motorcycle
- Bicycle
- Travel by animal and cart
- Pedestrian
- Marine vehicles (canoes)

The counts took place over a 12 hour period between 07:00 and 19:00 on each of the survey days, based on the sun rise and sunset times of 06:50 and 19:15 respectively. The Project`s transport of phosphate rock product from the mine to the port will occur during the same daylight period. Surveys were taken by local GB Minerals technicians, trained and overseen by a GB Minerals project manager, based on the study plan prepared by Knight Piésold and described in this report. The technicians used a tally system to record data on a survey sheet.

Each location was surveyed three times:

- Thursday April 23, 2015
- Friday April 24, 2015
- Saturday April 25, 2015

Surveys were taken on these days to account for weekly activities including:

- School days are Monday to Friday with morning classes taking place from 8:00 to 12:00 and afternoon classes from 15:00 to 18:00.
- On Fridays, Islamic prayer occurs in the afternoon, generally between 15:00 and 17:00. Before, during and after this period, local people are expected to travel between villages in the survey area and other locations.
- Friday is also the main market day; local people travel to surrounding larger villages to sell and buy goods. This usually occurs between 08:00 and 13:00.

- Fishermen from the Chugue area villages use the beach adjacent to the port site to access the River Geba. Fishing boats (large dugout canoes powered by outboards, sails or both) typically transit from this departure point at the beach to prime fishing areas near to the other side of the river. Convention has fishermen fishing the river only in front of their village boundaries. Therefore, boat traffic is typically from shore to opposite shore, as opposed to up/downstream on the river. Small numbers of people travel by foot (pedestrian traffic) from other villages remote from the sea to Ponta Chugue to buy fish and then sell it in their villages. The traffic survey captured both land-based and marine-based traffic.

3 – RESULTS AND DISCUSSION

3.1 ROAD CONDITIONS

In Guinea-Bissau, out of the 3,455 km of roadways, 965 km were paved as of 2002 (CIA, 2012). The Trans-West African Coastal Highway crosses Guinea-Bissau, connecting 12 West African coastal nations. Rivers are navigable for some distances; ports and terminals are established at Bissau, Buba, Cacheu and Farim (CIA, 2012).

Photos 1 to 8 in Appendix A illustrate the road condition and traffic types at the four traffic survey locations.

The section of the Bissau to Farim highway between Mansoa and Farim (approximately 51 km in length) was resurfaced between 2012 and 2013 and is in excellent condition (Figure 1; Photos 1 to 4 in Appendix A). Prior to this resurfacing, the travel time in the wet season from Bissau to Farim (a distance of approximately 100 km) was three and a half hours.

The section of the Bissau to Farim highway south of Mansoa is paved but older and showing some deterioration such as potholes and an eroding paved shoulder (see Photo 5 in Appendix A).

The section of the road from the main highway at Dugal to the port site is not surfaced (even with gravel) and the roadbed is narrow, with overhanging cashew trees and other vegetation at some locations (Photo 6 in Appendix A). The shoreline at the port site is shown in Photos 7 and 8.

3.2 ALL TRAFFIC

Total traffic counts by hour of the day at each of the four survey locations for the three observation days are shown in Table 2. In relation to traffic levels in the surveyed locations, the findings of the survey are described below:

- Friday was the busiest day at all survey locations (2,895 counts total at all 4 locations), followed by (2,304) Saturday and then Thursday (2,038). Traffic in all surveyed locations was approximately 40% higher on Friday than on Thursday and similar (2% higher) on Saturday compared to Thursday.
- The increase in traffic on Friday reflects that it is the main market day and Islamic holy day.
- The largest peaks in traffic occur in the early morning (07:00 - 08:00) for all 3 observation days.
- The highest traffic counts were at Dugal (T9), the most traffic survey location on the Bissau-Farim highway closest to Bissau (1,062, 1,549 and 1,151 for Thursday, Friday and Saturday, respectively).
- The next highest traffic counts were at Sansaunto (T8), the more northerly survey location on the Bissau-Farim Highway (623, 646 and 614 for Thursday, Friday and Saturday, respectively).
- The Dugal to Chugue survey location (T10) had the least traffic of the road survey locations (353, 700 and 539 for Thursday, Friday and Saturday, respectively).
- The Ponta Chugue port site location (T11) had the lowest counts and no vehicular traffic and mainly consisting of pedestrian and canoe traffic (73, 69 and 64 for Thursday, Friday and Saturday, respectively).

Table 2 Daily Total Traffic Counts

Time	T8	T9	T10	T11	Total
Thursday April 23, 2015					
7:00 - 8:00	119	85	73	10	277
8:00 - 9:00	64	117	16	0	197
9:00 - 10:00	50	83	0	7	133
10:00 - 11:00	39	67	2	2	108
11:00 - 12:00	33	85	89	6	207
12:00 - 13:00	59	112	39	21	210
13:00 - 14:00	54	116	35	0	205
14:00 - 15:00	44	82	8	0	134
15:00 - 16:00	37	64	6	15	107
16:00 - 17:00	37	79	11	9	127
17:00 - 18:00	43	89	42	3	174
18:00 - 19:00	44	83	32	0	159
Thursday Total	**623**	**1,062**	**353**	**73**	**2,038**
Friday April 24, 2015					
7:00 - 8:00	68	278	104	14	450
8:00 - 9:00	57	229	86	4	372
9:00 - 10:00	66	173	33	1	272
10:00 - 11:00	48	156	20	2	224
11:00 - 12:00	40	150	29	4	219
12:00 - 13:00	43	94	132	19	269
13:00 - 14:00	50	98	57	6	205
14:00 - 15:00	33	70	38	0	141
15:00 - 16:00	49	65	7	0	121
16:00 - 17:00	45	70	35	0	150
17:00 - 18:00	77	89	38	10	204
18:00 - 19:00	70	77	121	9	268
Friday Total	**646**	**1,549**	**700**	**69**	**2,895**
Saturday April 25, 2015					
7:00 - 8:00	74	117	65	10	256
8:00 – 9:00	62	135	47	2	244
9:00 - 10:00	42	113	55	2	210
10:00 - 11:00	55	107	38	5	200
11:00 - 12:00	41	96	48	0	185
12:00 - 13:00	19	93	46	6	158
13:00 - 14:00	64	94	50	7	208
14:00 - 15:00	36	75	25	17	136
15:00 - 16:00	33	66	40	4	139
16:00 - 17:00	53	93	80	2	226
17:00 - 18:00	80	91	23	3	194
18:00 - 19:00	55	71	22	6	148
Saturday Total	**614**	**1,151**	**539**	**64**	**2,304**
Total (All 3 Days)	1883	3762	1592	206	**7,237**

Trends in the traffic counts at each survey location are summarized below.

T8 - Sansaunto

This traffic count location is on the resurfaced section of the Bissau-Farim highway, at a village north of the larger town of Mansoa. Highlights in the data included:

- There was minimal deviation in traffic between Thursday, Friday and Saturday (max. 4%).
- The highest level of traffic in Sansaunto was Thursday morning, beginning at 07:00 and decreasing steadily until levelling out at noon.
- The village of Sansaunto had a moderate spike in traffic on Friday and Saturday after 17:00; which are likely due to travel home after work hours, the hours of Islamic prayer and market. This late afternoon spike in traffic did not happen on a regular weekday day (Thursday).

T9 - Dugal

This traffic count location is on the paved section of the Bissau-Farim highway at Dugal, where the Product Transport Route departs the main highway onto an unpaved road to the port site. Highlights in the data included:

- The highest traffic levels were observed at this traffic count location, with a total count of 6,373 over the 3 survey days. Traffic coming in and out of the village and internal traffic within Dugal were counted. A higher portion of this traffic is northbound during the survey period.
- The busiest period during the survey was Friday morning, beginning at 07:00 and decreasing steadily until levelling out at noon. Data showed that on Friday, traffic increased by 46% from Thursday, a regular week day. On Saturday, traffic only increased by 8% from Thursday.
- A minor decrease in traffic occurred during the time of Islamic prayer (15:00 to 17:00) on all 3 observation days.

T10 - Dugal to Chugue

This traffic count location is on the unsurfaced section of the access road into both Chugue village and the proposed port site. Highlights in the data included:

- The highest level of traffic was Friday at mid-day (11:00 to 14:00).
- On Fridays and Thursdays, the peaks in traffic were acute, and occurred in the early morning (07:00 - 08:00), mid-day (11:00- 14:00) and late afternoon (17:00 - 19:00).
- Data showed that on Friday, traffic increased by 98% from Thursday and increased by 53% from Thursday to Saturday.
- On Saturday, traffic behaved different from Thursday and Friday, with only one major spike in traffic occurring early in the afternoon (1:00 - 15:00).
- The count location showed a substantial decrease in traffic during the time of Islamic prayer (Friday 15:00 - 17:00).

T11 - Ponta Chugue - Marine Traffic on the River Geba

This traffic count location is at the port site. The lowest traffic levels were observed at this location; the location is removed from the primary traffic routes and the area is used for local agriculture and fishing. Highlights in the data included:

- Pedestrian traffic to the beach area next to the port site, and canoe use associated with fishing represented nearly all (>95%) of the total traffic.
- One bicycle was counted over the survey period, and no motorized vehicles were counted.
- Friday was the busiest of the 3 days, with 49 pedestrians and 20 canoes counted (69 total).

- Thursday was the next busiest, with 59 pedestrians and 13 canoes counted. The most active traffic period during the 3 day survey was on Thursday between 11:00 and 13:00, with 20 pedestrians and 6 canoes surveyed within 2 hours.
- Saturday traffic was similar to Thursday traffic, with 52 pedestrians and 12 canoes.
- On both Thursday and Friday, the peaks in traffic were acute in the early morning (07:00 - 09:00) and at mid-day (12:00 - 14:00).
- Ponta Chugue showed significant decreases in all traffic (marine and non-marine) during the hours of Islamic Prayer (Friday 15:00 - 17:00).
- Most marine traffic (canoes) at Ponta Chugue occurs mid-morning on a regular day (10:00 - 12:00). Friday had the most marine traffic of all surveyed days, and occurs between 11:00 - 14:00. Saturday, marine traffic was low until mid-afternoon, and was steady between 13:00 - 16:00.
- Pedestrian traffic reflected canoe traffic seen at the river access port. Most of this traffic is fishermen coming to fish from Chugue, but also people (usually women) from other communities, coming to buy fish from the fishermen to sell at market.

3.3 TIME OF DAY TRENDS

These results suggest that changes in traffic patterns on weekdays at high traffic areas are governed by market activity. At smaller villages near the port (T10 and T11), reductions in traffic flow were apparent during prayer times.

Table 2 shows results from the traffic surveys undertaken. Data shown includes all traffic counted, motorized and non-motorized. Figures 2 to 5 present total travel counts over three observation days at each survey location.

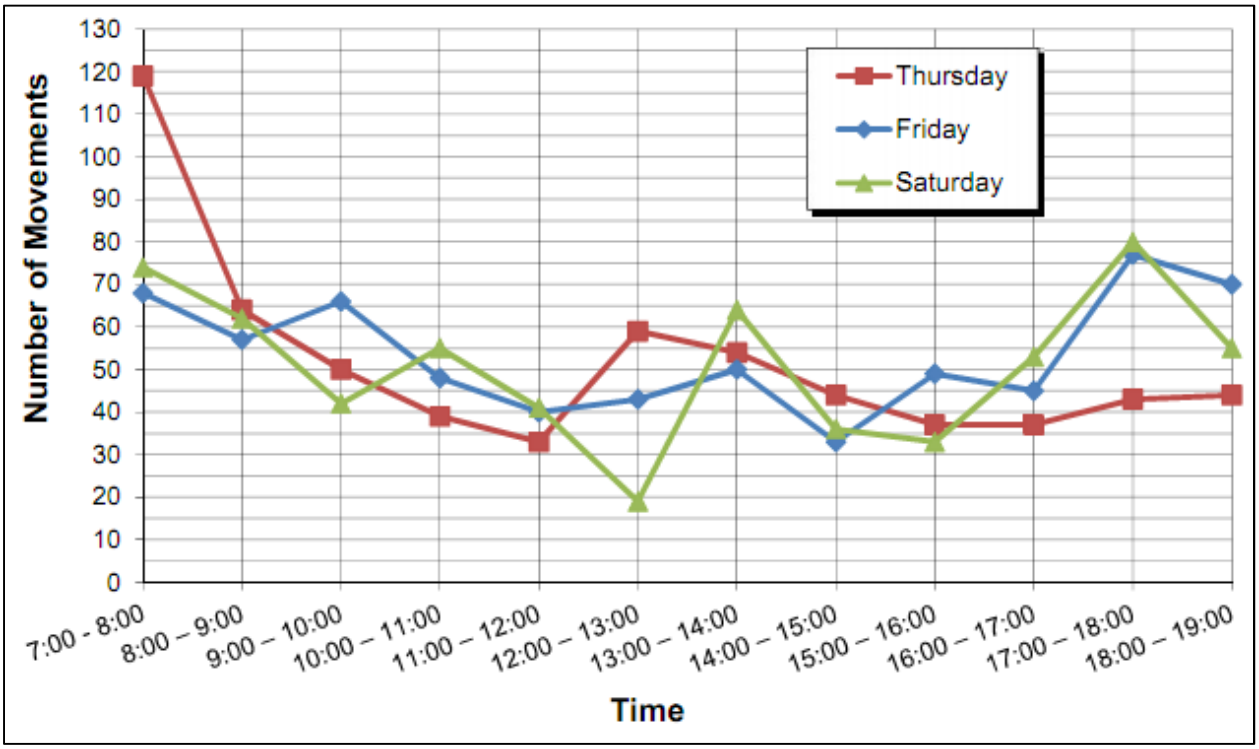

Figure 1 Survey Location T8 - Time of Day Traffic Count

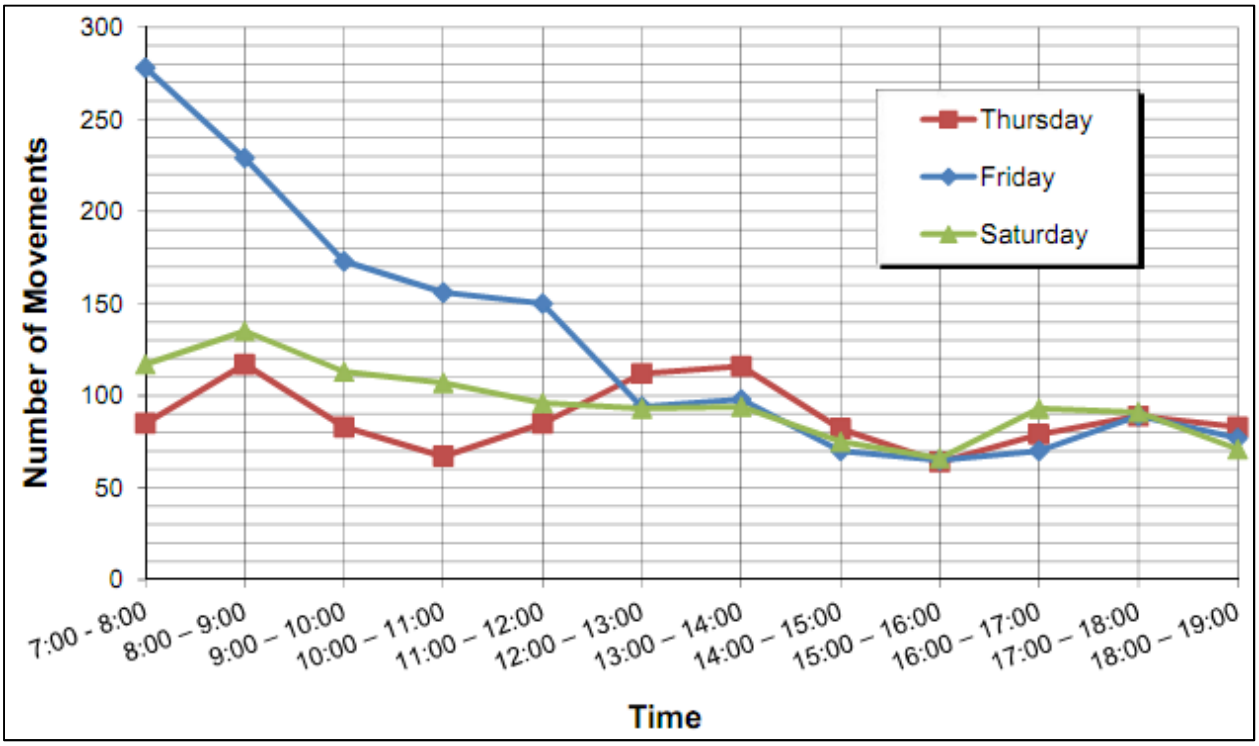

Figure 2 Survey Location T9 - Time of Day Traffic Count

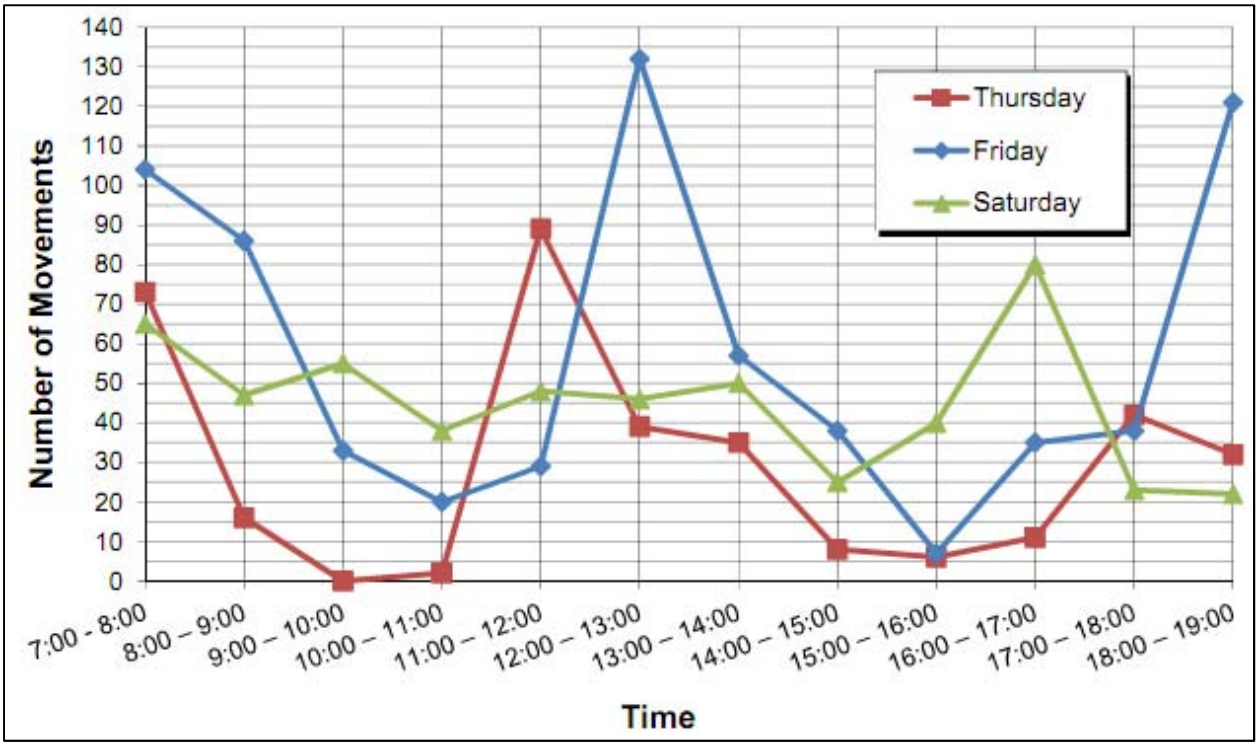

Figure 3 Survey Location T10 - Time of Day Traffic Count

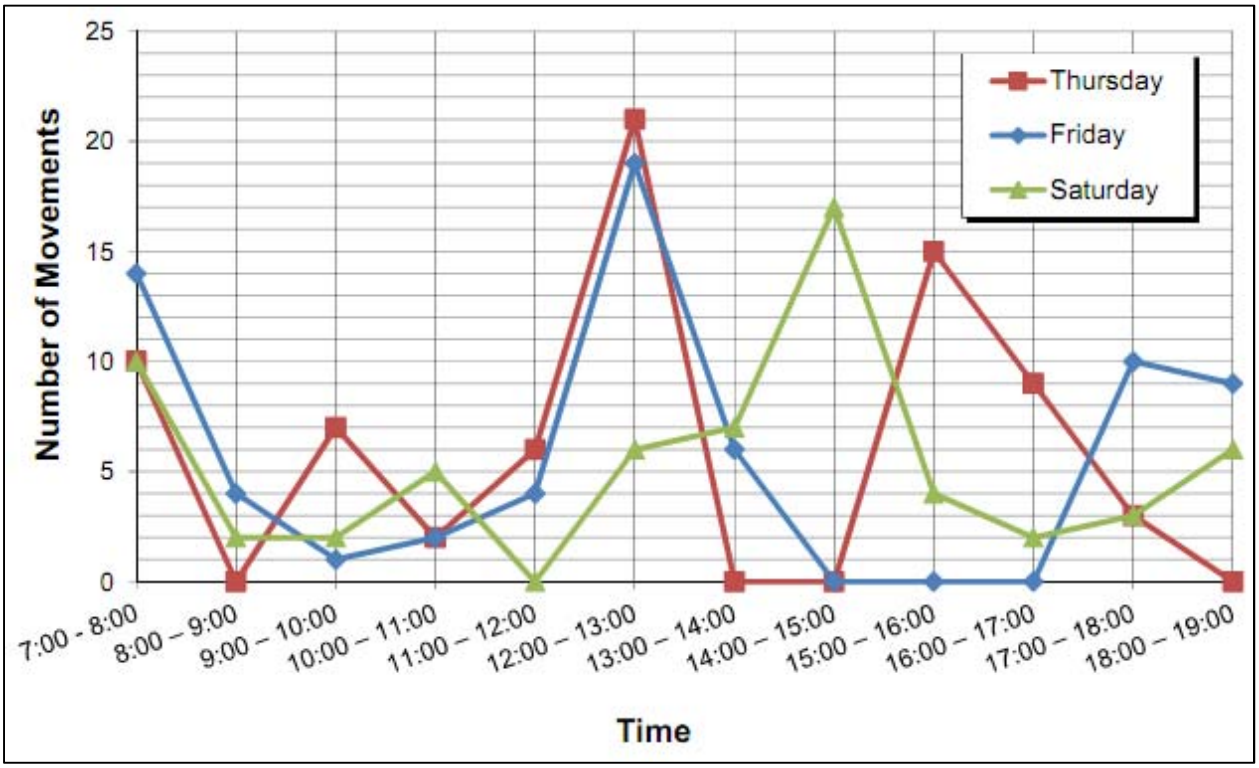

Figure 4 Survey Location T10 - Time of Day Traffic Count

3.4 TRAFFIC TYPE

In relation to the type of traffic observed in the study area, the findings of the survey are:

- Pedestrians make up approximately 32% of the total traffic at all stations, and 20% and 56% of total pedestrian traffic was observed at T9 and T10, respectively. Pedestrian traffic is the most common form of traffic overall.
- Pedestrian travel from all surveyed locations was observed to be highest on Friday (32%), and lowest on Thursday (31.6%). Pedestrians make up 85%, 78%, 23% and 13% of all the traffic at T11, T10, T8 and T9, respectively.
- Passenger buses make up approximately 22% of the total surveyed traffic, making them the most common form of motorized traffic and the second most common traffic type. Passenger bus traffic was highest on Thursday (24%), then Saturday (23%), and then Friday (20%). Passenger bus is the most common form of traffic in the village of Dugal (33%), followed by personal cars (18%) and taxis (17%).
- The village of Sansaunto (T8) was unique in that bicycles not pedestrians were the most common form of traffic, making up 30% of the total traffic observed.
- Personal cars were the third most common type of observed traffic overall, after passenger buses.
- Motorized vehicles of all types represent 46% and 85% of the traffic at surveyed locations T8 and T9, respectively.
- Travel by animal made up <1% of the total surveyed traffic.
- The lowest levels of traffic were from donkey and cart, double rear axle truck (1.2%) and canoe (1.0 %).
- The sum total of single and double rear-axel pickup truck at all survey locations on Thursday was 152. This is double Friday's values.
- At Ponta Chugue (T11), canoes were the only type of marine vessel that was recorded; no other marine vessels were noted.

Table 3 shows traffic volumes by type and location for the three observation days and is presented in Figure 6.

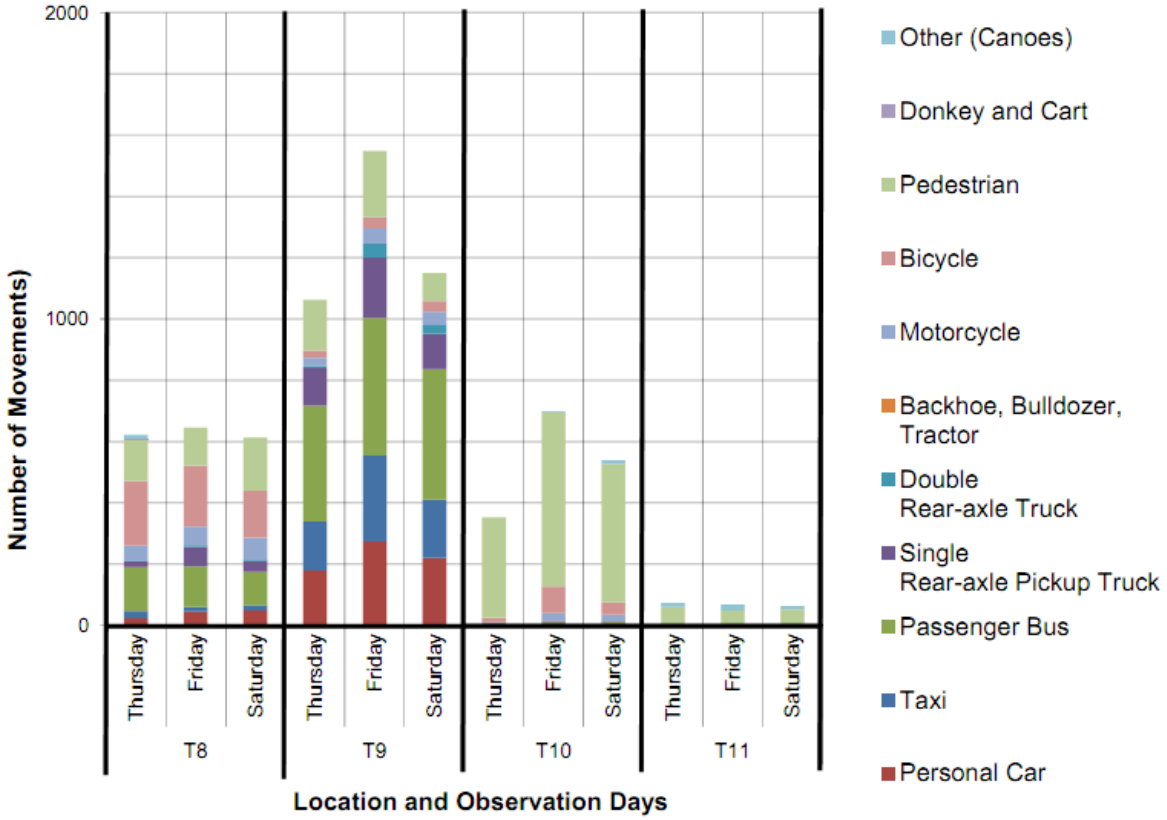

Figure 5 Traffic Volumes by Type and Location

4 – SUMMARY

The traffic count locations included a location on the newly surfaced highway north of Mansoa (T8); the older paved highway at Dugal (T9); the dirt access road to the port site (T10); and the port site location (T11).

Traffic at all of the survey locations is predominantly non-motorized, with most people travelling along the roads by foot. Very few people use personal vehicles in the area (and in the country), and as such, most of the motorized traffic is public bus.

Along the access road to the port, there appears to be even less use of motorized vehicles. At the port site, people access the river mainly by foot for fishing-related activities (fishing or buying fish). Private canoes dominate the water traffic.

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TABLE 3

GB MINERALS LTD.
FARIM PHOSPHATE PROJECT

SUPPLEMENTARY TRAFFIC BASELINE STUDY
TRAFFIC BY TYPE AND LOCATION FOR ALL SURVEYED DAYS

Print Jun/01/15 11:12:31

Survey Location	Date	Personal Car	Taxi	Passenger Bus	Single Rear-axle Pickup Truck	Double Rear-axle Truck	Backhoe, Bulldozer, Tractor	Motorcycle	Bicycle	Pedestrian	Donkey and Cart	Other	Percentage Change Between Thursday and Friday [%]	Percentage Change Between Thursday and Saturday [%]
T8	Thursday	24	24	142	20	3	0	48	209	136	2	15	4%	-1%
	Friday	45	15	133	64	5	0	61	199	124	0	0		
	Saturday	49	18	108	35	4	0	72	153	174	0	1		
T9	Thursday	179	160	379	122	7	0	27	23	165	0	0	46%	8%
	Friday	274	280	450	197	44	0	51	36	217	0	0		
	Saturday	220	191	425	115	29	0	44	35	92	0	0		
T10	Thursday	0	0	4	0	0	0	5	16	328	0	0	98%	53%
	Friday	3	1	8	4	0	0	24	87	569	0	4		
	Saturday	6	0	7	1	0	0	21	40	452	0	12		
T11	Thursday	0	0	0	0	0	0	0	1	59	0	13	-5%	-12%
	Friday	0	0	0	0	0	0	0	0	49	0	20		
	Saturday	0	0	0	0	0	0	0	0	52	0	12		
Total	Thursday	203	184	525	142	10	0	80	249	688	2	28	**40%**	**12%**
Total	Friday	322	296	591	265	49	0	136	322	959	0	24		
Total	Saturday	275	209	540	151	33	0	137	228	770	0	25		
Grand Total		800	689	1656	558	92	0	353	799	2417	2	77		

\\NB4\Project$\3\01\00520\02\A\Correspondence\NB15-00201 - Suppl Traffic Baseline\FINAL\[Table 3.xlsx]Table 3

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REV	DATE	DESCRIPTION	PREP'D	RVW'D

5 – REFERENCES

Central Intelligence Agency (CIA), 2012. *The World Factbook: Guinea Bissau: Roadways.* Retrieved from: https://www.cia.gov/library/publications/the-world-factbook/geos/pu.html

Golder Associates Ltd (Golder), 2014. *Farim Phosphate Mine, Guinea Bissau, Mine Component Environmental and Social Baseline Studies - Human and Social Elements.* Report No. 13514950200.550-3/B.0. Volume 3, pg. 290. February.

International Finance Corporation (IFC), 2012a. *Performance Standards and Guidance Notes - 2012 Edition.* Retrieved from: http://www1.ifc.org/wps/wcm/connect/115482804a0255db96fbffd1a5d13d27/PS_English_2012_Full-Document.pdf?MOD=AJPERES

International Finance Corporation (IFC), 2012b. *International Finance Corporation's Guidance Notes: Performance Standards on Environmental and Social Sustainability.* Retrieved from: http://www.ifc.org/wps/wcm/connect/e280ef804a0256609709ffd1a5d13d27/GN_English_2012_Full-Document.pdf?MOD=AJPERES. Accessed: 23 September 2012.

Prepared: _____
Meagan Shkwarek, EIT - Geological Engineering

Reviewed: _____
Richard Cook, P.Geo. (Ltd.) - Senior Environmental Scientist | Associate

Approval that this document adheres to Knight Piésold Quality Systems:

Attachments:
Appendix A Photographs

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CONSULTING

APPENDIX A

PHOTOGRAPHS

(Pages A-1 to A-4)

PHOTO 1 – A bus stop at Saliquenhedim, 3 km south of the ferry crossing at Farim. Newly surfaced section of the Bissau-Farim highway.

PHOTO 2 – Resurfaced section of the Bissau-Farim highway at Bironque.

PHOTO 3 – Bicycle traffic on a paved shoulder, on the newly surfaced section of highway, south of Mansaba.

PHOTO 4 – Pedestrian traffic on the highway within the central part of Mansoa.

PHOTO 5 – The older paved section of the Bissau-Farim highway, south of Mansoa and north of the port site turnoff at Dugal.

PHOTO 6 – The unpaved road into the port site, between Dugal and Cunteda.

PHOTO 7 – Typical canoes (beached at the Farim ferry crossing).

PHOTO 8 – Canoes beached at the Ponta Chugue port site.

Republic of Guinea-Bissau

ECO PROGRESSO Office of Environmental and Social Impact Assessment Studies

SOCIO-ECONOMIC ASSESSMENT REPORT ON ENVIRONMENTAL AND SOCIAL IMPACTS OF THE GB MINERALS LTD PHOSPHATE EXPLORATION INTERVENTION IN FARIM

MAY / 2015

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ANNEX 17

1. Introduction

Social economy has always been a major concern in Society serving as the main factor and guarantor of its survival, reproduction, and social regimes spatial distribution.

The country is experiencing an extreme social crisis, which translates into severe poverty for the vast majority of its population. Thus, the design and adoption of strategies to combat it become a pressing need to minimize the suffering that it entails. The best tool for this purpose is to strengthen the population's capacity to have access to income-generating activities.

To achieve the objectives mentioned above, it becomes imperative to conduct an examination and analysis of data relating to socio-economy in the GB Minerals Farim Phosphate Exploration Project direct intervention zone.

2. Demography

It is estimated that the population of the Oio Region, (where the Farim Sector is located), has **215,259 inhabitants,** of which **52%** are **female.** Approximately **85% of the population of Oio is rural, compared to 60% nationally.** The population of the Sector is very young, with **53%** under the age of 21 years **and 83%** of the population under the age of 40 years. The population of the Farim Sector lives predominantly in rural villages with each village having only one or two living compounds.

The area includes eight ethnic groups; **Mandingos (66% of the population); Mansonkas (17%); Fulani (7.6%); and Balantas (6%). Minority groups include Mandjakos, Pepel and Mancanhas.**

3. Farim

The Farim Sector is the second most populous of the Oio Region, with 48,264 inhabitants (42% of the population of Oio Region). The Region's population is relatively young, with over 50% under the age of 18 years.

While the town of Farim has a **population of 8,661 inhabitants,** the village population the rarely exceeds 500 people. The residential areas are dispersed in space. The houses are usually built by young people and are a single building with several rooms and **are mainly built out of clay (84%); 72% of the structures have four (4) to seven (7) divisions; and 19% of the homes have between eight (8) and 11 divisions.** About 80% of the houses have tin roofs and 15% have traditional thatched roofs.

As regards ownership, 25% of the families are the landowners; 11% have an occupation license; while more than half (55%) only have a traditional residence permit. The average family size is 10 and the area is predominantly inhabited by **Mandingos (40%);** followed by **Fulanis (27.6%) and Balantas (21.5%).**

4. Mobility

In Farim and the surrounding villages, there is considerable mobility, especially among the young adult population. Mobility is largely motivated by seeking employment in Bissau City (capitol), and neighboring countries **(ex. Senegal, The Gambia and Cape Verde)** and **Europe (Portugal and France).** The villages of Tambato, Canico, Tumana, Salikénié and the town of Farim are particularly **affected by immigration and emigration**.

5. Social organization

The habitats, (composed of several well-defined areas), are generally shared by several nuclear families related by kinship and a "chief" who is the father or grandfather common to them all. Families also share the land for agriculture.

Monogamy is more common than polygamy, (according to 51.8% of respondents). In general, the responsibility for domestic tasks falls on women and girls.

6. Decision-making

Decision-making takes place primarily through facilitated consensus by the heads of the village or village councils. When it is necessary to discuss any matter or make a decision, the

village chief (or the village council) convokes heads of families and representatives of youth and, in certain situations, representatives of women. Decisions are taken only after the issues are sufficiently discussed and each had the opportunity to express their opinion. The village chiefs are under the authority of the Farim Sector Administrator, to whom they report. The status of village chief is usually assigned to a person of the family who founded the village and is transmitted from generation to generation.

7. Methodology and Context Survey

7.1. Purpose / Context

GB Minerals Ltd is constituted by foreign capital, whose main objective is to explore, promote and support sustainable development of the Farim Community. Their actions are part of the promotion and protection of human rights; to create activities to support income generation; and support the promotion of children's education in the Project intervention area. Consequently, it needs to know the needs of the populations in the project intervention areas. To do so, we used many variables that facilitated conducting research to determine the real quantitative and qualitative needs, in order to:

- Guide our activities in the various areas where people's needs are felt at the highest level, thus facilitating the establishment of a list of the necessities of our beneficiary population;
- Facilitate the evaluation and monitoring of the results achieved on the ground, allowing the quantification of these results;
- Easily assess the impact of our intervention, restructure and further enhance the objectives pursued.

The main variables that constituted elements of our research included: **education; health; employment; land; income from various activities, especially raising cattle and agriculture;** the domestic capacity to cover basic needs, such as **housing or habitation; family goods;** and participation by individual members of the Farim community in the community as a whole were observed in reality. In short, everything about the conditions of socio-economic life in areas of direct or indirect intervention by the project, calls for a feasible local community development plan.

It is in this perspective that our survey fits in, giving condensed information in a document that reflects the conditions of socio-economic life of populations as much as possible in areas of project intervention.

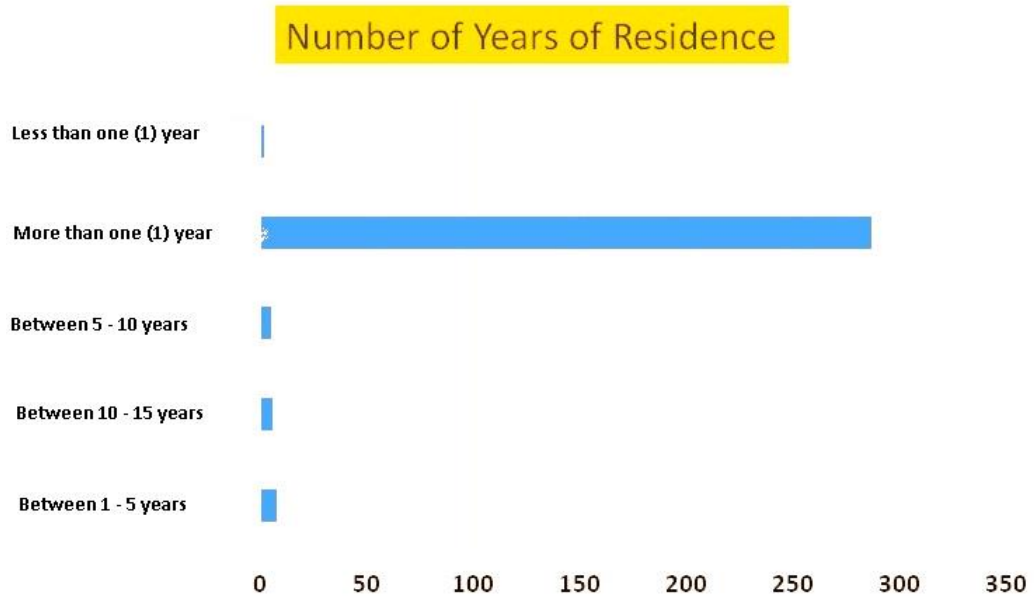
The sample size is summarized in the table below and takes into account the working conditions on the ground.

Table: 1 Number of cells / areas

Villages	Number of families surveyed
CAP SEQUE	8
CANICO TUMANA	29
CANICO LENQUE CUROTO	54
PONTA ZECA	11
SELQUENHE BA	73
SELQUENHE PORTO	
UFUDÉ	14
TAMBATO MANDINKA	
URQUI	21
TCHUGUÉ	24
AQUIMATCHA	1
D GAL	37
NFANDÉ	1
Grand Total	**297**

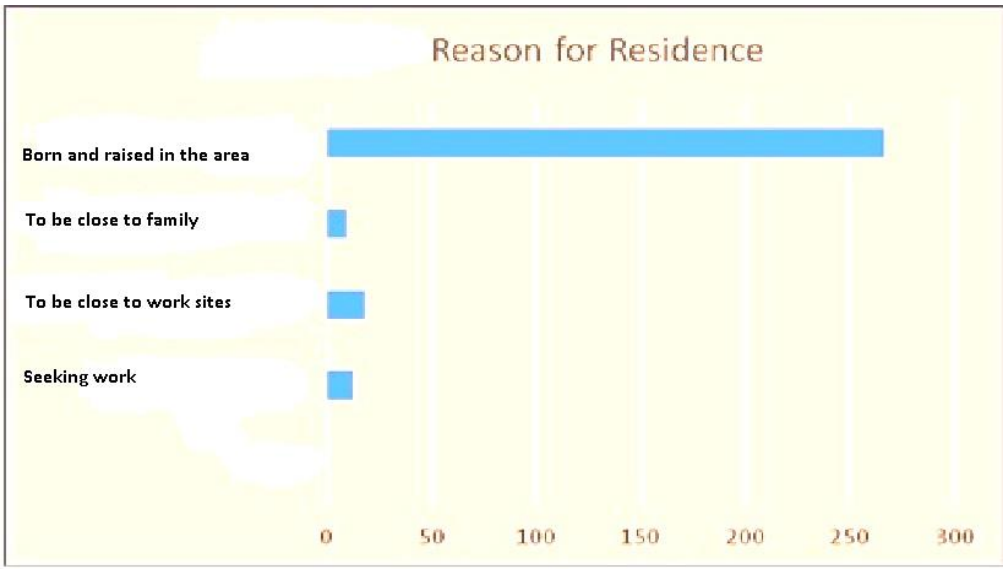
8. Residence Information

8.1. Number of years of family residence



The survey result show that the overwhelming majority of the families have been living in the villages, in the area of direct and indirect intervention of the project, for more than fifteen years, although there are some families who have resided in the localities from 5-10 years; and others from 10-15 years; and some who have resided there for more than one (1) year and from one (1) to five (5) years.

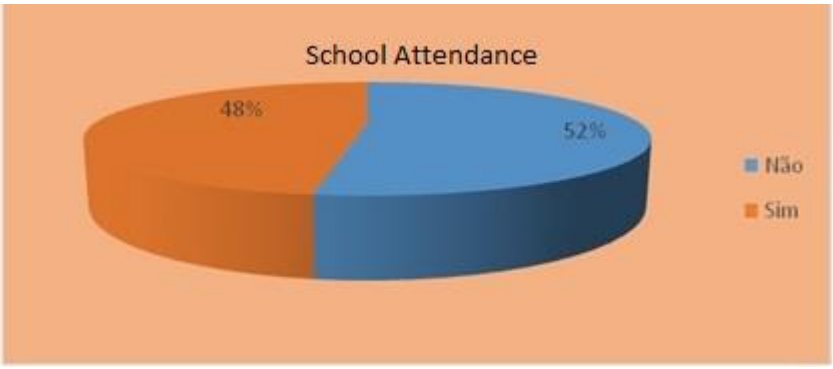
9. Reason for family residence in areas



Although there are families who reside in the area to be close to their family; to be close to where they work or seeking work; the investigation established that the reason that most families live there is because they were born and grew up in the same sites.

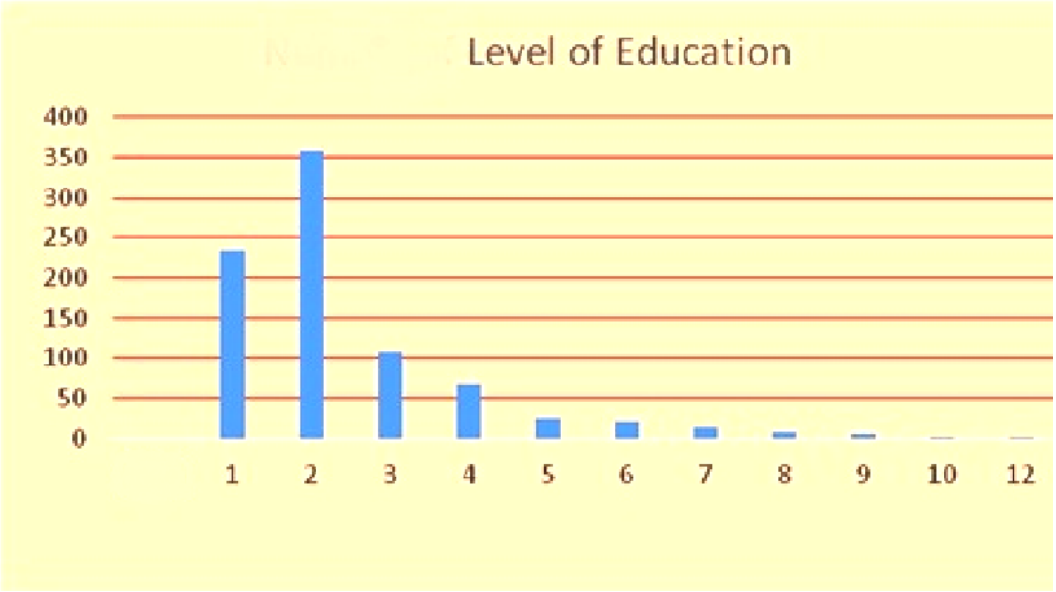
10. Education

10.1. Children attendance rates in school



In the area researched, there is a lack of schools. Where there are schools, they are mainly precarious temporary shelters. A lot of times, children do not attend school because the schools are far from their villages, which takes a long time to get to, thus many end up withdrawing or not even registering.

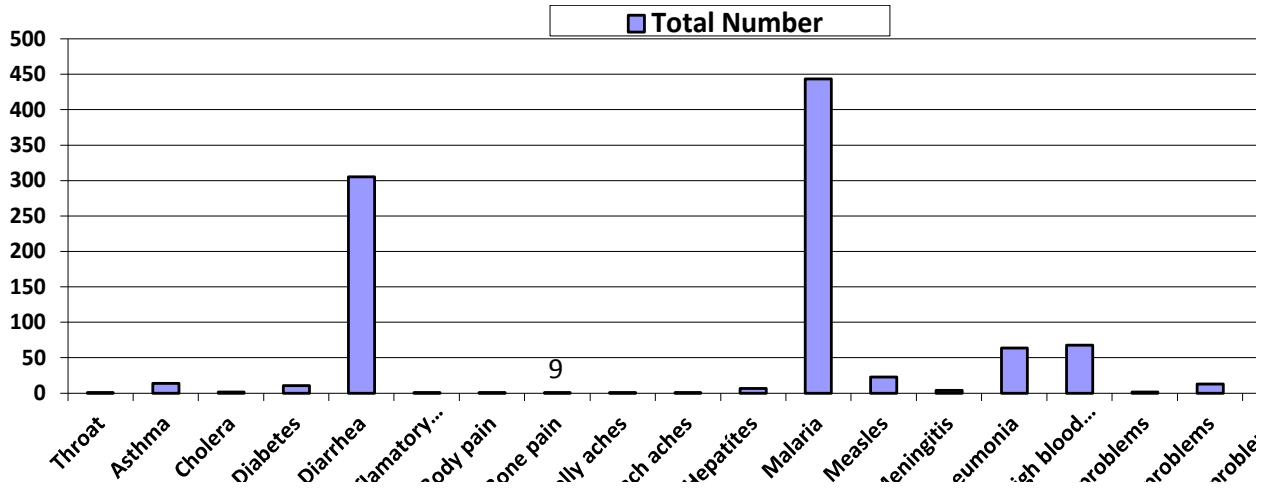
11. Level of education



In most of the villages and in the villages where they supposedly exists, the level of education goes only to 4th class – i.e. they are only elementary schools. Most of the people surveyed in the villages only concluded the 2nd class and high illiteracy rates still prevail.

12. Health

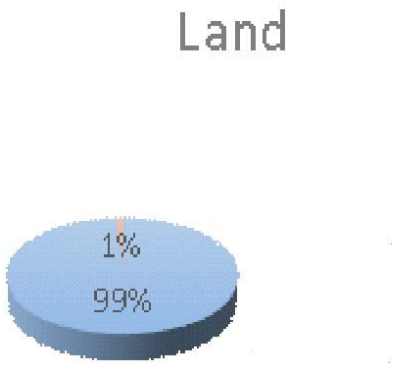
Frequency of illness on the population in the project intervention zone.



Throughout the area surveyed, as shown in the chart above, it was found that the most frequent diseases in the villages are: **malaria, diarrhea, tuberculosis, high blood pressure, heart problems; with malaria and diarrhea being the main ones.**

13. Property and land tenure

13.1. Land ownership



14. Land Access

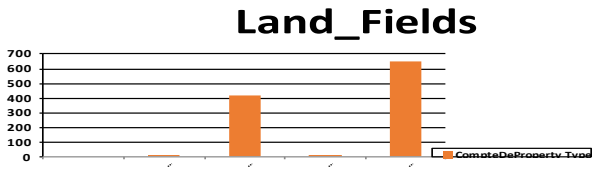
The Land Law (Law no. 5/98 of 23 April 2012) states that **Land is State property and heritage of the population.** However, **land is administered by the customary authorities, according to traditional law.** Thus, the law changed the basis of ownership by integrating customary practices of management in legal forms of ownership.

According to the traditional common system in rural areas, the "right of the conqueror" allows a person (a) clear lands that have never been occupied before and register with the village chief or (b) by assignment from the chief when the owner can clear the land.

Similarly, the owner can sell part of the land to third parties and declare the "transaction" to the village chief. On the other hand, in urban areas, such as Farim, granting land for residential purposes must be registered with the Administration in order for the transaction to be formally recognized.

As regards the use of land for farming, most of the families surveyed in this socio-economic study are actively farming land. Only a few are not owners of the land, while some have gained access to land by administrative and traditional means and explore other fields without

any previously recognized authorization. Almost all the families in the villages that are part of the project intervention zone declared that they own the land they cultivate, and are thus considered **as traditional occupants.**



Most families in the villages surveyed said that their land (agricultural fields) is their private property.

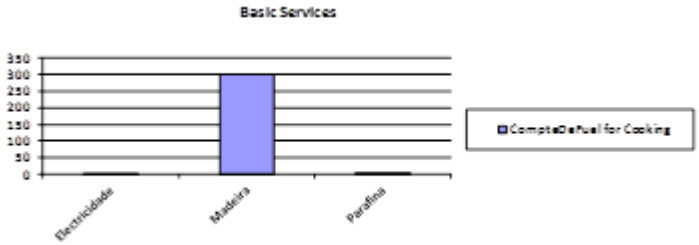
15. Poverty and access to Basic Services / Natural Resources

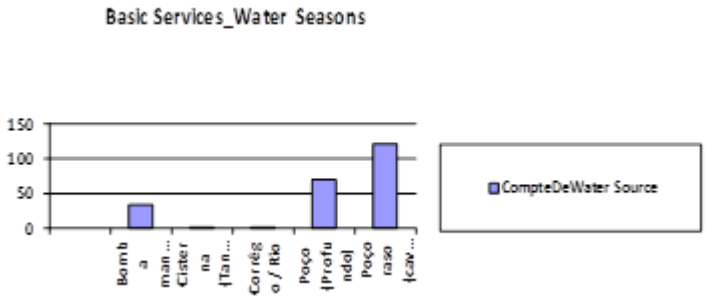
Poverty is a reality these communities where just getting enough to eat is still a major problem as reserves are depleted from around the beginning in August until November. However most of the families in the villages surveyed produce enough resources to ensure supplies throughout the entire year.

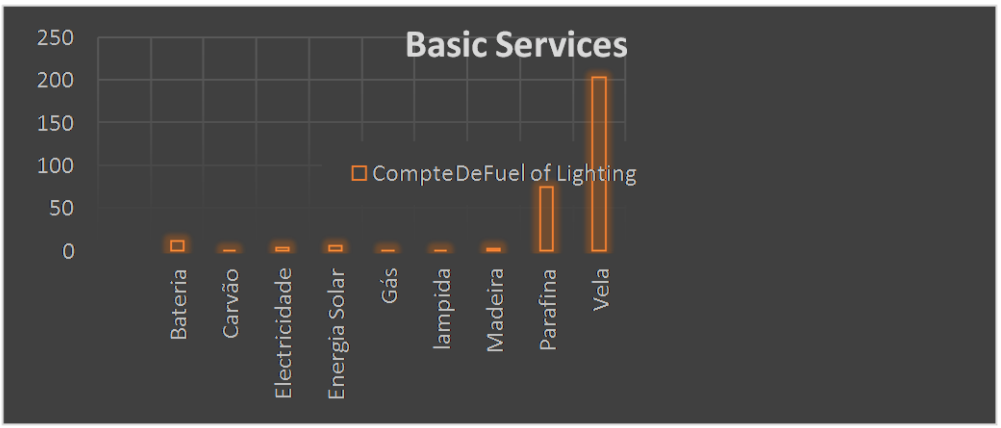
Access to basic social infrastructure is difficult for most people in these communities. Access to safe drinking water remains difficult. For example, despite the existence of some hand pumps in all villages, at less one of the villages visited only has one (1) hand pump, which is not enough to meet the needs of people, yet they continue to use traditional wells. Likewise, the school infrastructure is not sufficient in the project intervention area and the children of some villages are required to walk several kilometers to get to school.

Also, health facilities are very inadequate. Only the town of Farim has one hospital that serves all areas, but it is inadequate in terms of medicine supplies and giving primary health care to patients. The only ambulance available for hospital services is not adequate to guarantee proper evacuation of patients to Farim or Bissau. Most of the villages and the town of Farim use traditional wells and artesian wells operated by hand pumps for the production of drinking water for domestic purposes. There is no sewerage system in the area and domestic waste (**solid and liquid**) are disposed of without any control.

Non-timber forest products are used as food; building materials; and medicinal products (**pharmacopeia**). Timber is used as firewood and charcoal. The edible fruit (**baobab, palm fruit, etc**...) are collected in the dry season, as well as the fibers; leaves (**baobab leaf**); sap extracts (**palm wine**); and wood or woody material, (**90% of energy used for domestic needs**); **honey and various medicinal plants**. The products used and marketed include charcoal, the baoboa fruit, palm wine and fruits of the palm tree. The houses are built using materials collected directly from nearby natural products (ex., thatched, palm leaves and wooden stakes). All villages used fire wood to cook or prepare meals. The graphs below illustrate access to basic services and use of natural resources in all the villages surveyed.



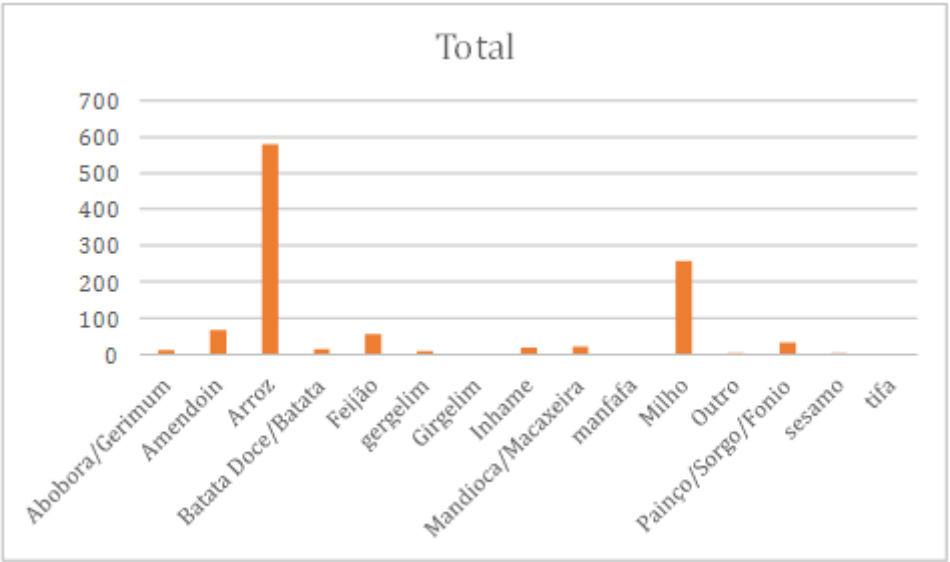




In all villages surveyed most use candles for lighting, while others also use lanterns, batteries, etc...

16. Agriculture and Livestock

In the area surveyed, corn, sorghum, rice and other cereals are grown for their own consumption. Rice is the most important crop grown by more than 51% of families. Next comes corn (maize). The proportion of families involved in the cultivation of other cultures (ex. beans, sweet potatoes, peanuts [ground-nuts], cassava, millet / sorghum and other cereals, pumpkin, etc.) is between 3% and 15%.



Almost 93% of surveyed households have livestock **(cattle, sheep and goats).** Production of **pigs is generally practiced by Balanta and Mandjoko women,** with an average of ten animals per household. Family ceremonies are the main opportunity to sell cattle, particularly goats, etc.

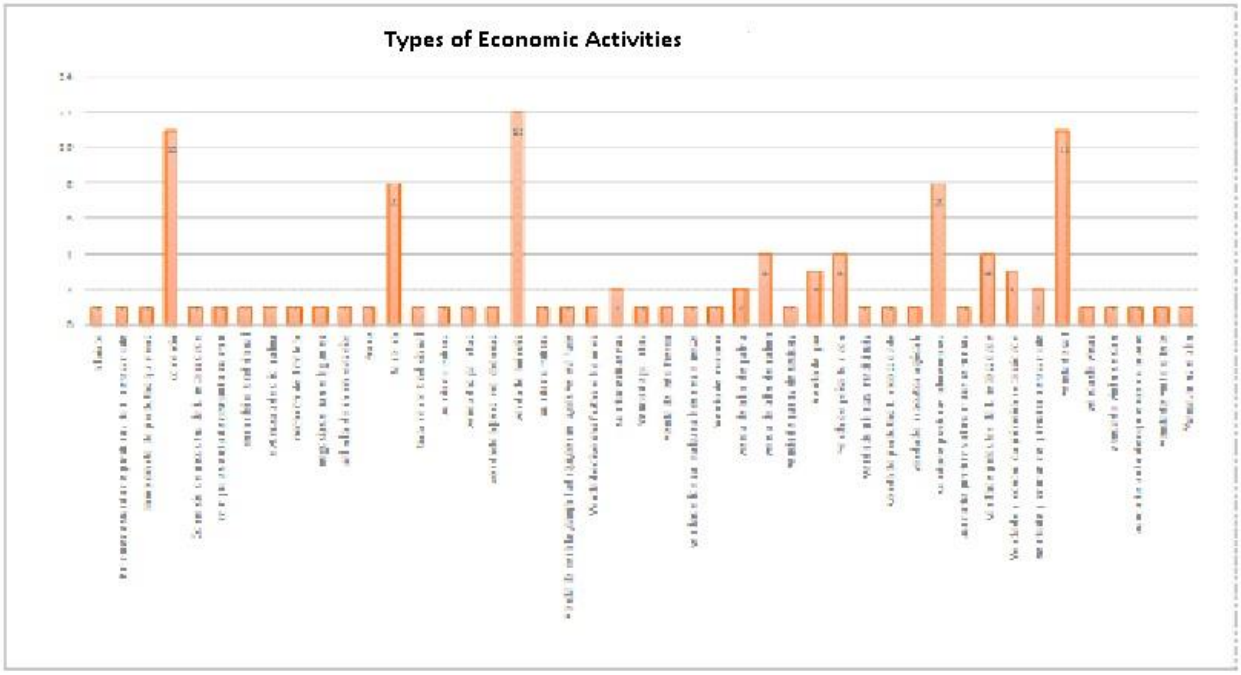
17. Food Security

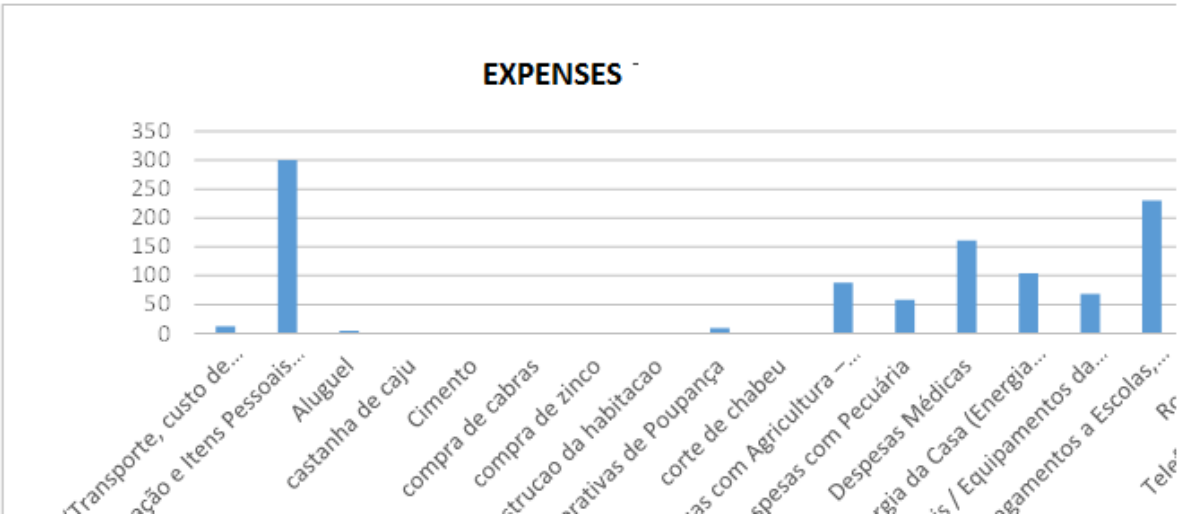
A deficit in food was reported by many families, despite the availability of arable land. The lack of food is due to the limited access to agricultural equipment and fertilizers, among other problems. Some of the products grown in the fields and private gardens are consumed by

their cultivators and the remaining is sold. Peanuts (groundnuts), cashew nuts, cassava and beans are high cash crops. The project intervention area is among the most important Regions for peanut production in the country and is sold mainly in Senegal, through a complex network of operators.

18. Economic Livelihood

The main economic activities generating income are: the sale of animals, salt, and small stores that sell basic necessities. These activities are more frequent during weekly open air markets **known as "Lumo"**.

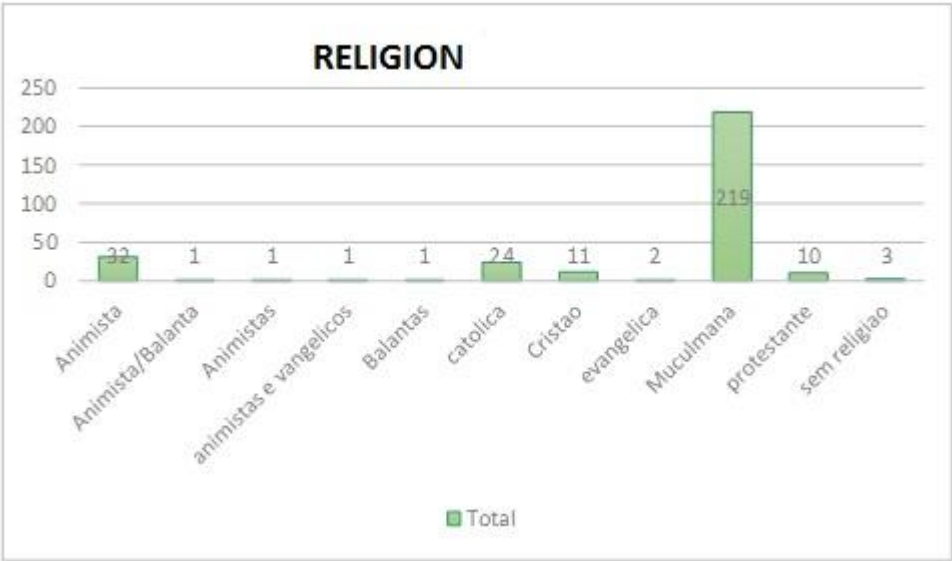




Based on the chart above, it appears that most expenses are spent on buying food; buying phone credits; buying clothes; paying children's school fees; medical expenses and other.

19. Religion and Cultural Heritage

Islam is the predominant religion (71%) in the area and is practiced by Mandingos and Fulani; while Christians **(Protestant and Evangelical Catholics) represent 25% of the population, and the animists (specifically the Balanta, Mancanhas, Mandjakos ethnic groups etc. ...) represent 4%.**



Baseline studies related to cultural heritage were conducted, which identified a total of 32 sites of cultural heritage. **(See EIAS, Table 4-6). These were subdivided into two groups:**

- **12 important cultural locations, including nine (9) cemeteries and three (3) places of ritual / prayers; and**
- **20 places that are archaeological remains.**

ANNEX

1

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07.05.2015 09:47

13.05.2015 09:59

13.05.2015 16:26

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SCIENCE INTEGRITY KNOWLEDGE

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE GB MINERALS LIMITED FARIM PHOSPHATE PROJECT, GUINEA-BISSAU

FINAL REPORT

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Prepared For: GB Minerals Ltd.
Suite 1500 – 701 West Georgia Street
Vancouver, BC V7Y1C6
Canada

6605 Hurontario Street, Suite 500 , Mississauga, Ontario ▪ L5T 0A3
Tel: 905-364-7800 ▪ Fax: 905-364-7816 ▪ www.intrinsik.com

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HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE GB MINERALS LIMITED FARIM PHOSPHATE PROJECT, GUINEA-BISSAU

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HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE GB MINERALS LIMITED FARIM PHOSPHATE PROJECT, GUINEA-BISSAU

1.0 INTRODUCTION

As part of the Environmental and Social Impact Assessment (ESIA) for the Farim Phosphate Project (hereafter referred to as the Project), Knight Piésold Limited (Knight Piésold) commissioned a Human Health and Ecological Risk Assessment (HHERA) on behalf of the GB Minerals Limited (the Proponent). The HHERA will address questions and considerations related to potential effects on human health and valued ecological components associated with possible releases of chemicals from the proposed operations of the Farim Mine, Transport Route, and Port facilities.

The HHERA follows standardized guidance and involved a review and evaluation of possible exposure pathways and risks associated with the proposed Project. The focus of the risk assessment (RA) was on the possible effect of emissions released from Project activities on air, soil, and agricultural crops in nearby areas used by residents for housing and farming.

The current HHERA consists of two main components: (1) an HHERA of the potential impacts from the operation of the Mine site, and (2) an HHERA of the potential impacts from the operation of the Port site. Within each of these separate HHERAs is a human health risk assessment (HHRA) component and an ecological risk assessment (ERA) component. Consideration of potential impacts along the transportation route is also provided.

Section 2 of this report provides a brief overview of RA methods utilized and the regulatory context under which the assessment was conducted. The Problem Formulation for the HHERA is provided in Section 3. Section 4 summarizes the exposure assessment portion of the HHERA, Section 5 the Hazard Assessment portion and Section 6 the Risk Characterization. Section 6.1 provides an overview of the Risk Characterization, Section 6.2 contains the HHERA results for the Mine Site, Section 6.3 evaluates the Port and Section 6.4 the Transportation Route. Section 7 evaluates the overall uncertainties associated with the HHERA of the Project. Section 8 provides overall conclusions of the HHERA with references being provided in Section 9. A series of appendices are included to provide detailed technical information regarding the assumptions, data and methods used in the HHERA.

2.0 METHODS

The current Human Health and Ecological Risk Assessment (HHERA) report consists of two individual components: (1) an HHERA of the potential impacts from the operation of the proposed Mine site (Section 3), and (2) an HHERA of the potential impacts from the operation of the proposed Port site (Section 4). In order to facilitate a simpler presentation of the individual component HHERAs, the current section was developed.

This section outlines the standardized RA methodology used to develop the individual HHERAs and to describe the considerations and assumptions made by the Study Team.

2.1 Risk Assessment Framework

An HHERA is a scientific study that evaluates the potential for the occurrence of adverse health effects from exposures of people and wildlife to Chemicals of Potential Concern (COPCs) present in surrounding environmental media (*e.g.*, air, soil, sediment, surface water, groundwater, food, *etc.*), under existing baseline and/or predicted exposure conditions. HHERA procedures are based on the fundamental dose-response principle of toxicology. The response of an individual receptor (human or ecological) to a chemical exposure increases in proportion to the chemical concentration in critical target tissues where adverse effects may occur. The concentrations of chemicals in the target tissues (the dose) are determined by the degree of exposure, which is proportional to the chemical concentrations in the environment where the receptor lives, works or visits.

All chemicals (anthropogenic and natural) have the potential to cause effects in people and the surrounding environment. However, it is the chemical concentration, the route and amount of exposure, and the inherent toxicity of the chemical that determines the level of effect and potential for adverse effects to an exposed receptor.

As illustrated in the diagram to the right, if a receptor is exposed to a hazardous chemical (*i.e.*, where the three circles overlap), the possibility of adverse health effects (risk) exists. The risk posed by a chemical is dependent on the presence of a receptor, the level of exposure to a chemical (which is related to its concentration in environmental media) and the chemical's inherent toxicity (*i.e.,* hazard).

The prediction of exposure to specific chemicals in the environment and the potential risks resulting from such exposures can be determined through the completion of a quantitative HHERA.

This HHERA was conducted in accordance with widely accepted risk assessment methods recommended by various regulatory agencies, including:

- Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0 (Health Canada, 2012);
- A Framework for Ecological Risk Assessment (General Guidance) (CCME, 1996);
- Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities (US EPA, 1999); and,
- The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (US EPA, 2005)

The prediction of an individual's exposure to specific chemicals in the environment and the potential risks resulting from such exposures can be determined through the completion of a quantitative HHERA. The current HHERA follows the standard HHERA framework (see Figure 2-1) that is composed of the following steps:

i) Problem formulation;
ii) Exposure assessment;
iii) Hazard assessment; and,
iv) Risk characterization.

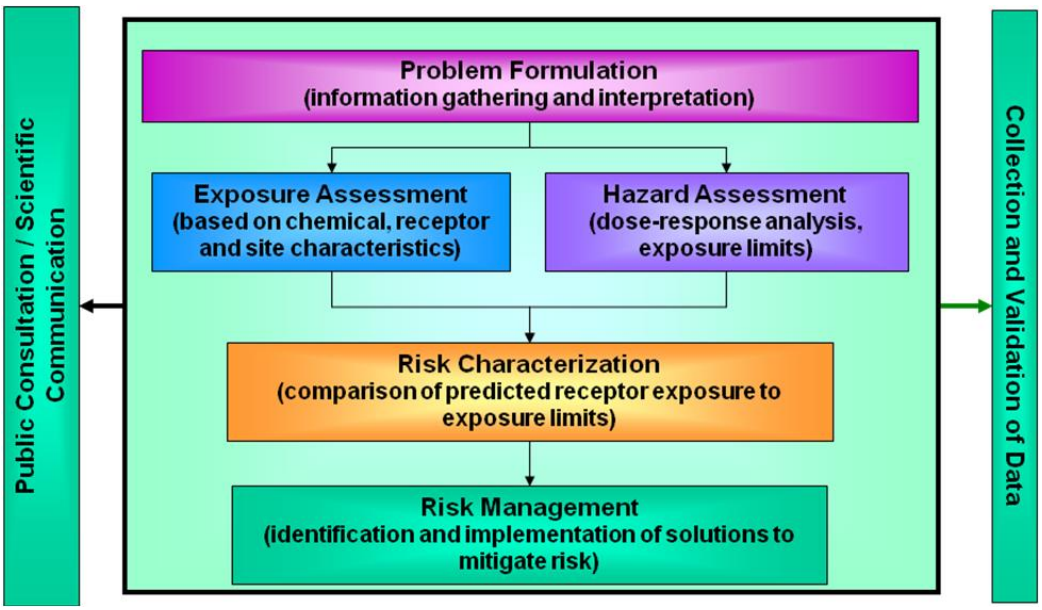


Figure 2-1 Overview of Standard HHERA Framework

Typically, where potential adverse impacts are predicted through risk characterization, an additional step providing risk management and recommendations for mitigation measures to address these concerns can be added, if necessary. This risk management step is an integral to the ESIA process, to ensure the mitigation of any predicted potential health risks in the surrounding community, should they be identified.

2.2 Regulatory Context

No applicable guidance was found to be available related to the assessment of human health and ecological risk assessment within Guinea-Bissau. In the absence of specific local guidance, guidance provided by international agencies and regulatory bodies were considered. Agencies such as the International Finance Corporation (IFC), the World Bank Group, the World Health Organization (WHO), U.S. Environmental Protection Agency (US EPA) and Health Canada were consulted. This HHERA was conducted in accordance with the following widely accepted risk assessment methods:

- Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0 (Health Canada, 2012);
- A Framework for Ecological Risk Assessment (General Guidance) (CCME, 1996);
- Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities (US EPA, 1999);
- The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (US EPA, 2005); and,
- The US EPA Risk Assessment Guidance for Superfund (RAGS) (US EPA, 1989; 1991; 2004; 2009)

3.0 PROBLEM FORMULATION

The problem formulation is an information gathering and interpretation stage that plans and focuses the study on critical areas of concern for the Project. The problem formulation defines the nature and scope of the work to be conducted, permits practical boundaries to be placed on the overall scope of work and ensures that the assessment is directed at the key areas and issues of concern. This step is critical to the success of the risk assessment as sound planning during the problem formulation reduces the need for significant modifications once the risk assessment has begun. The data gathered and evaluated in this step provides information into the physical layout and characteristics of the assessment area, possible exposure pathways, potential human and ecological receptors, COPC, and any other specific areas or issues of concern to be addressed.

The key tasks requiring evaluation within the problem formulation step included the following:

- A description of the regulatory context and project scope;
- Identification of the COPCs to be assessed within the HHERA based on existing data and predictions;
- Identification of receptors of concern, which included those persons with the greatest probability of exposure to COPCs from the Project and those that have the greatest sensitivity to these chemicals; and,
- Identification of exposure pathways and scenarios based on consideration of various factors that influence the means by which receptors come into contact with COPCs in environmental media including: chemical-specific parameters; characteristics of the site, such as physical geography, geology, and hydrogeology; as well as the physiology and behaviour patterns of receptors.

3.1 Project Description

The proposed Project is undergoing an Environmental and Social Impact Assessment (ESIA), as outlined in the description of the Project (Knight Piésold, 2015a). As described by Knight Piésold (2015a), the Project is proposed to include two open pit mines, offices, workshops, accommodation, storage areas, the process plant, power supply, and access and haul roads. At the Port Site, the Project is proposed to include storage sheds, product drying and handling facilities, the wharf and the ship-loading system.

The Project consists of the construction, operation, and closure of a proposed open pit mining operation to exploit the Farim phosphate orebody, a process plant at the Mine site to beneficiate the ore into a phosphate rock concentrate (product), and an associated port facility to export the product to customers (Knight Piésold, 2015a).

The Project is proposed to operate for a period of 26 years. Mining activities will remove overburden and will create waste rock, and therefore, the mine will have an overburden storage area. Haul roads will be built to connect the open pit to the phosphate processing facilities. A groundwater management system will be developed, to dewater the mine through the years of operations. Three phases of mining are conceptualized, which include:

- Years -2 to -1: Construction phase;
- Years 0 to 8: Operations phase (southern pit extraction);
- Year 8: Operations phase (simultaneous southern and northern pit extraction);

- Years 8 to 26: Operations phase (northern pit extraction); and,
- Years >26: Site closure (active and passive close)

The focus of the current HHERA is to evaluate the Operations phase of the proposed mine (Years 0 to 26) (see Figure 3-1).

3.2 Physical Setting

The proposed Mine site is west of Farim town, in Guinea-Bissau (Figure 3-2). The land near the Mine area is characterized as mostly savannah with distinct seasonal patterns (Golder, 2014). The climate is described as tropical and is generally hot and humid throughout the year. The wet season (June to October) is characterized by high amounts of rainfall, with a predominately southwesterly wind. The dry season (November to May) is characterized by a northeasterly wind, which introduces dry, dust-laden air (Golder, 2014).

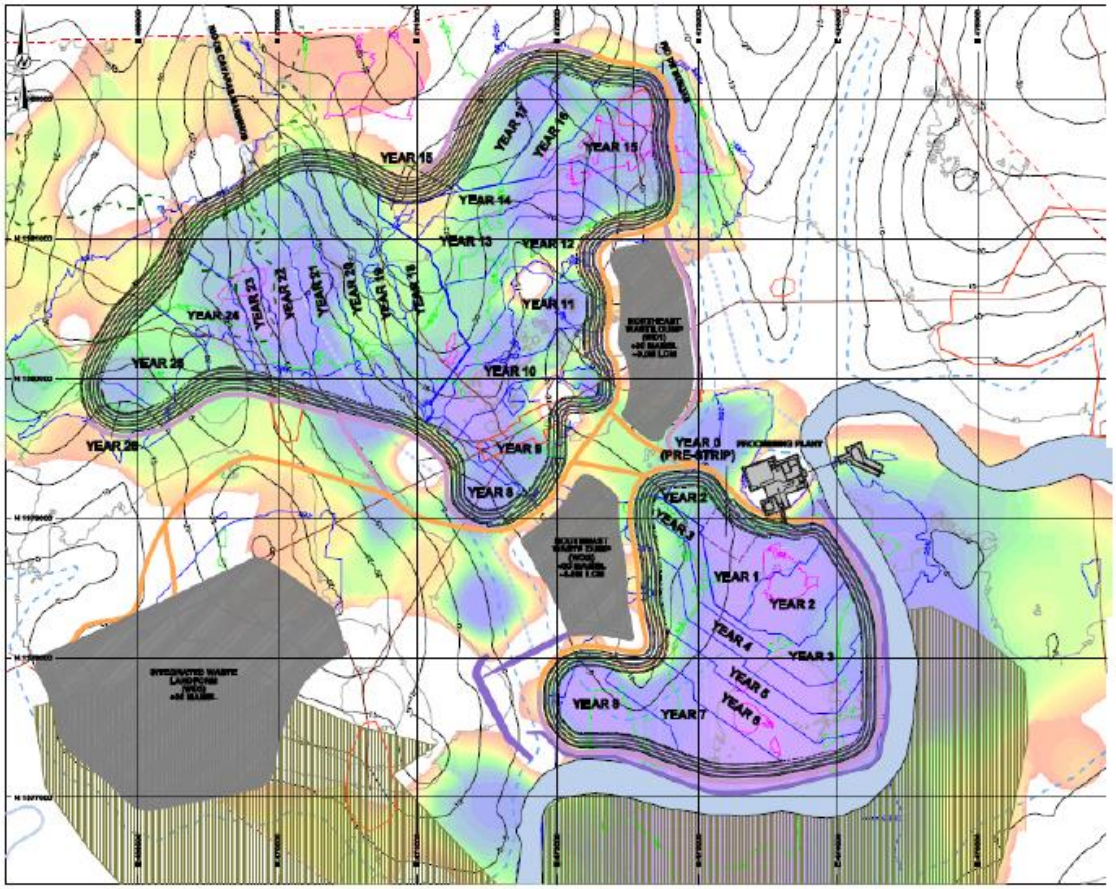
The topography in the area of the Project Mine is relatively flat between the Cacheu River (major river body located 4 km south of the Mine) and the northwestern edge of the Farim phosphate mine deposit (Golder, 2014). The elevation of between the Port and Mine varies between 5 m and 50 m. Farim town is located approximately 180 km upstream (east) on the Cacheu River from the Atlantic Ocean.

Smaller watercourses near the Project site are ephemeral, mirroring the dry and wet season rainfall patterns. Streams near the Project have mostly been modified to facilitate agricultural activities, such as the construction of rice paddies. Farim town and villages near the Mine site use traditional wells and hand pump-operated boreholes for domestic water supply.

Land use near the Mine site is dominated by subsistence agriculture, with income generation depending on cash crops and salt harvesting (Golder, 2014). Cash crops include peanuts, cassava, and beans. The area surrounding the Mine, Transport Route, and Port sites are largely residential and farming in nature.

The Port site is located in Ponta Chugue, in the mouth of the Geba River (Figure 3-3). The phosphate concentrate will be transported to the Port Site by trucks, which will unload the concentrate into the conveyor system. Concentrate storage facilities at the Port Site will include covered conveyors, roofed warehouses and stockpile encapsulation. Currently, the area around the Port site consists of rice paddies, mangroves, a fishing beach, cashew trees and residential areas.

The phosphate concentrate transport route between the Mine area and the Port Site was also considered.



NOTES:

1. SOURCE: GOLDER, IN LYCOPODIUM 2015.

Figure 3-1 Sequencing of Farim Phosphate Project Mining Activities (Knight Piésold, 2015a)

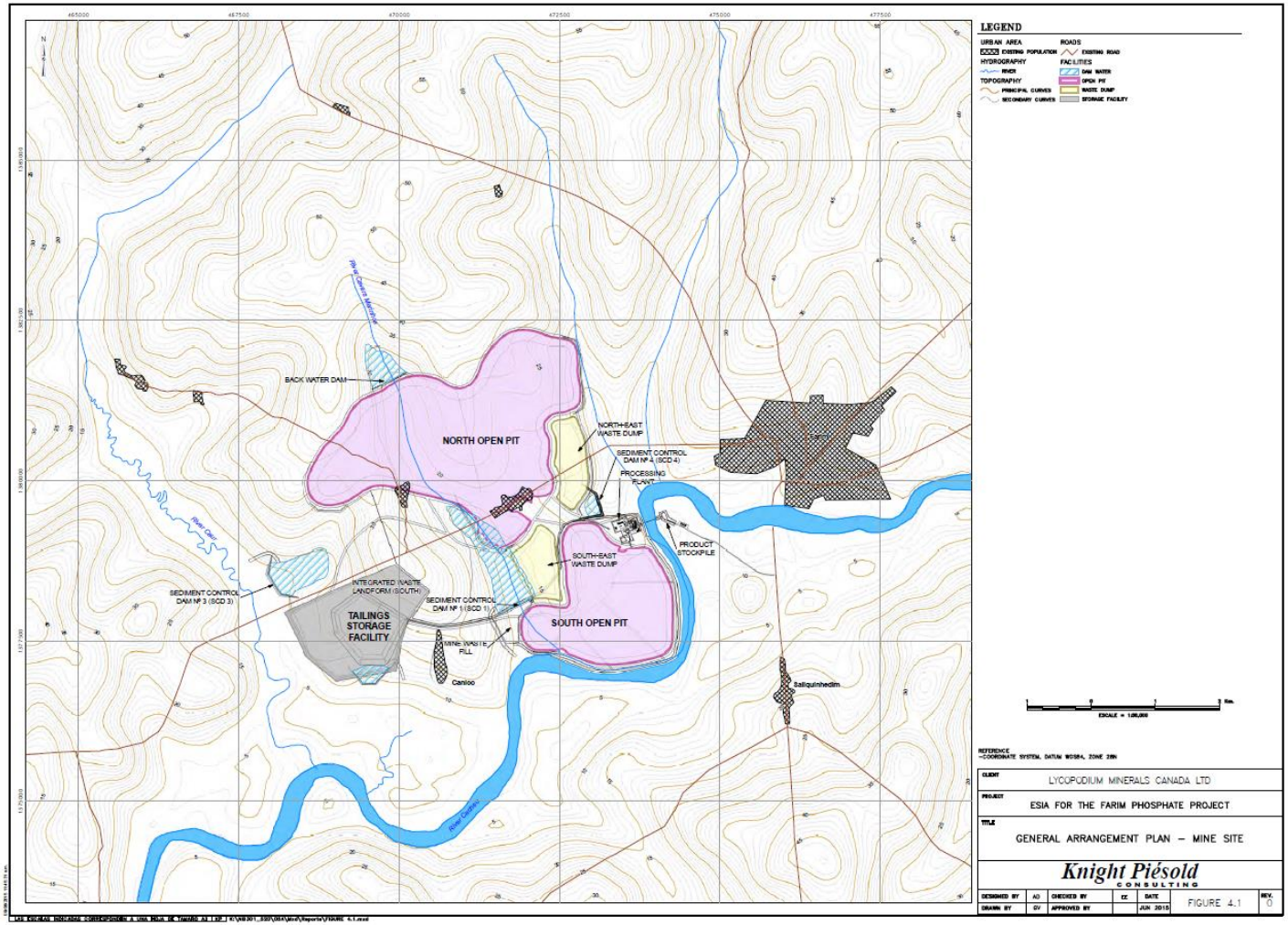


Figure 3-2 Project Areas-Mine Site (Knight Piésold, 2015b)

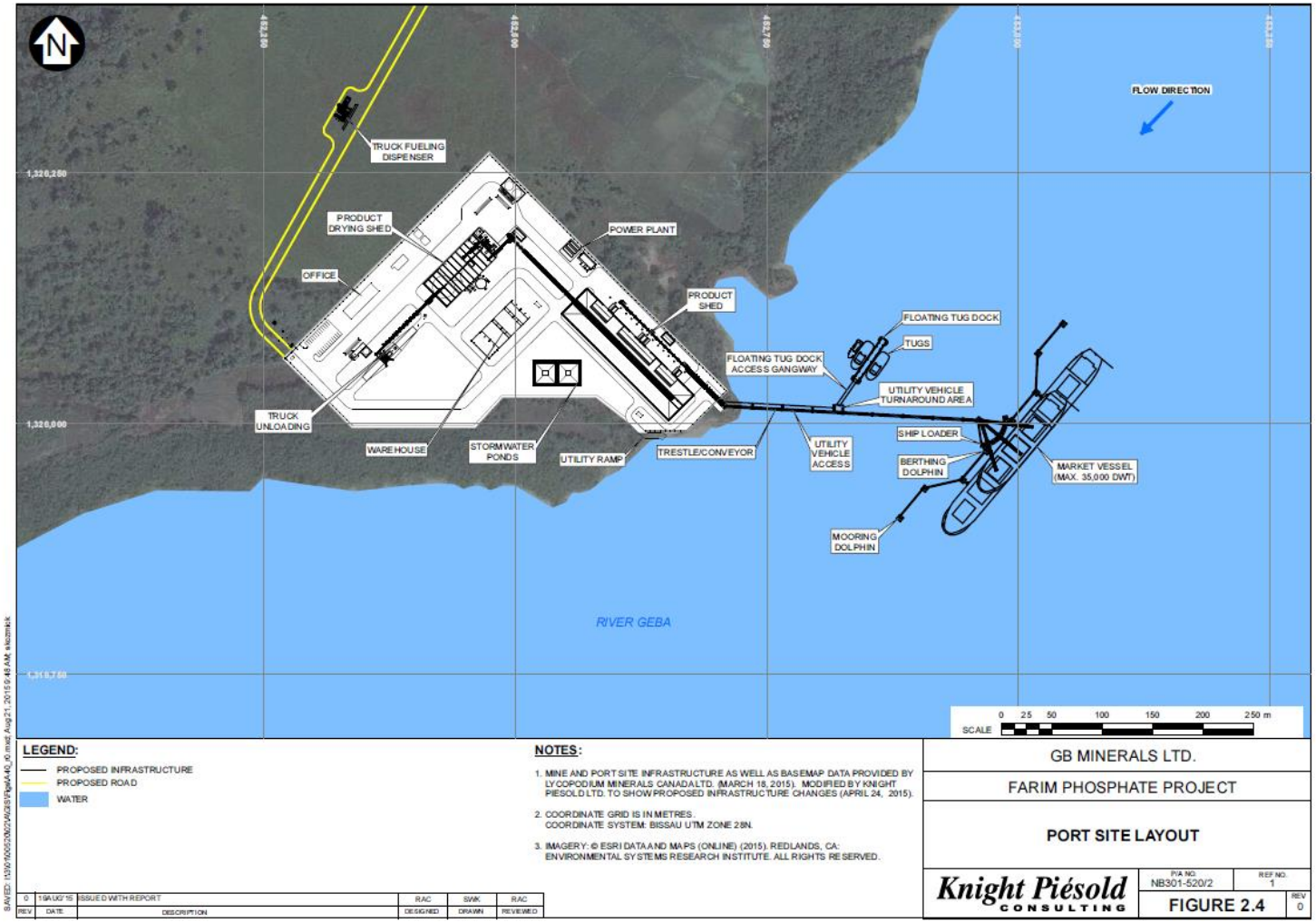


Figure 3-3 Project Areas-Port site (Knight Piésold, 2015a)

3.3 Risk Assessment Scenarios

The focus of the current HHERA was on the operations phase of the Project. When examining potential emissions from the three phases of a mine lifecycle (*i.e.,* construction, operations, decommissioning), typically, the operations phase represents the highest predicted emissions scenarios, and hence, all predictions presented in this report were related to this phase.

The following scenarios were assessed for the Project operations phase:

1) Baseline Scenario: For the air assessment, the baseline scenario was characterized by the absence of the Project based on ground level air monitoring conducted by Golder (2014). Based on available soil data, air concentrations of certain metals present assumed to be present in airborne dust were also evaluated.

   For the oral multi-pathway assessment, measured baseline data were available for soils, groundwater, and fish and hence, baseline conditions were characterized using these data.

   Project Alone Scenario: The potential increment provided by the Project operations was assessed separately. This increment was obtained using projected air emissions and air dispersion modelling for both air and multi-pathway assessments. With respect to temporal and spatial boundaries for the assessment, the proposed project will be mined for an operations period of 26 years.

2) Baseline + Project Scenario: For the air and oral multi-pathway assessments, baseline measured data were combined with the Project Alone scenario to provide the Baseline + Project scenario (over 26 years of operations).

3.4 Identification of COPCs

It is common practice when conducting a risk assessment to limit the number of compounds evaluated to those that, due to their environmental concentrations, distribution, or chemical and toxicological properties, have the greatest potential to contribute to increased human health and/or ecological risks. As a result, one of the first steps in the risk assessment process is to identify COPC emitted from the Project.

Chemicals of potential toxicological concern to human health and ecological receptors may be present in a multitude of environmental media. Through a detailed screening approach, the current risk assessment identified COPCs present in soil and air, and evaluated potential exposures to these chemicals in these media, as well as food items and groundwater.

COPCs in Soil

Possible COPCs in soils can be present currently in soils, as a result of baseline activities or natural enrichment, and can occur in the future as a result of mining activities. Future soils COPCs will predominantly be linked to dust deposition, and the possible accumulation of metals or other substances as a result of deposition. Metals in ore dusts present in air were assumed to deposit on soils, and hence accumulate in the soils.

COPCs in Air

Possible sources of dust and gases which may affect air quality include material handling, crushing of materials, bulldozing, grading of roads, hauling of materials on roads, movement of employee vehicles on the mine road, wind erosion of tailings and combustion of diesel by the various equipment operating at Mine and Port facilities.

Since fuel combustion and earthworks will produce dusts and gases, the air COPCs are largely focused on Criteria Air Contaminants (CACs), such as particulate matter (e.g., fine particulate matter, or $PM_{2.5}$, and the more coarse fraction, known as PM_{10}), as well as sulphur dioxide (SO_2), and nitrogen dioxide (NO_2) and carbon monoxide (CO). Metals will be adhered to these dusts, and therefore metals were also selected for assessment via the air pathway.

While diesel emissions from vehicles along the transport route are anticipated to be produced as a result of Mine and Port operations, based on direction from Knight Piésold (pers. comm.), volatile and semi-volatile organic compounds associated with this emission source were not included within the assessment. It is anticipated that vehicle emissions on the transport route will minor relative to the mining activities themselves.

COPCs in Food Items

Humans can be exposed to chemicals via the consumption of foods such as agricultural crops and fish. Agricultural crops could be exposed to mining emissions through both direct deposition of dusts onto vegetation (leaves and above ground plant parts), as well as uptake through soils which have received dust deposition. Since uptake is linked to dust deposition, the list of possible COPCs for crops is based on that for soils. Gases, such as SO_2, and NO_2 do not accumulate in vegetation, and hence do not require assessment relative to human health via the oral pathway.

COPCs in Drinking Water

Humans can be exposed to water *via* direct consumption, bathing and other household activities. Based on the brackish character of the nearest major surface water body, the Cacheu River, surface water was not assumed to be a source of drinking water. Analytical data from two groundwater sampling locations, as recommended by Knight Piésold (pers. comm.), were used to characterize baseline drinking water exposures to COPCs for humans.

Given that groundwater concentrations were not expected to change appreciably as a result of the Project (Knight Piésold, pers. comm.), measured drinking water concentrations were not used to represent Project-related exposures to drinking water.

3.4.1 COPC Screening

The HHERA COPC screenings consisted of three main components:

- **Baseline soil screening:** The maximum baseline surface soil concentration of chemicals collected in both the Mine and Port sites were compared to human health-based and ecological health-based guidelines. Chemicals exceeding the human or ecological health-based guidelines were carried forward for further evaluation. The COPC guideline screenings for human and ecological receptors are discussed in detail in Appendix A.

- **Oral toxic potency screening:** Screening based on the toxic potency of a chemical is a method to differentiate chemicals that have a high toxic potential and those that do not. A toxic potency screening was conducted separately for the Mine and Port sites for both the HHRA and ERA components. The Mine site toxic potency screening was based on the geochemistry of both the waste overburden and ore metal content, since these are the dominant forms of dust, based on the air dispersion analysis conducted. The Port toxic potency screening was based on the metal content of the product, since this would represent the dominant form of dust at the Port site. Chemicals which represented >99% of the cumulative toxic potency in the human screening and >95% cumulative toxic potency in the ecological screening were carried forward for assessment. The toxic potency screening are discussed in detail in Appendix A.

- **Bioaccumulation check:** Finally, a bioaccumulation check was completed where metals know to be bioaccumulative were also included for assessment. The bioaccumulation check is discussed in detail in Appendix A.

These screening steps were used to produce two separate COPC lists for the HHRA and ERA components of the HHERA.

3.4.2 Final HHRA COPC List

The final lists of COPCs are presented in Tables 3-1 and 3-2. Some COPCs were only assessed *via* the air inhalation route, as they do not appreciably accumulate in soils (COPCs for Inhalation Assessment Only; Table 3-1). These chemical parameters were selected for assessment in the HHRA as they are CACs. Other COPCs were assessed *via* both air and oral exposure pathways (COPCs for Inhalation and Multi-pathway Assessment; Table 3-2), due to their environmental fate characteristics which enable them to persist in area soils, and potentially accumulate in other media within the environment.

Table 3-1 Final List of COPCs for Inhalation Assessment Only

Chemical Parameter	*COPC Selection Criteria*
Carbon monoxide (CO)	Criteria air contaminant
Nitrogen dioxide (NO_2)	Criteria air contaminant
Respirable particulate matter ($PM_{2.5}$)	Criteria air contaminant
Inhalable particulate matter (PM_{10})	Criteria air contaminant
Sulphur dioxide (SO_2)	Criteria air contaminant

Table 3-2 Final List of COPCs for Inhalation and Multi-Pathway Assessment

Chemical	*Baseline Soil Screening*		*Oral Toxic Potency Screening*[a,b]			*Bioaccumulation Check*
			Mine		*Port*	
	Mine	*Port*	*Waste Overburden*	*Ore*	*Product*	
Aluminum	Yes	Yes	Yes	Yes	Yes	No
Antimony	No	No	No	Yes	Yes	No
Arsenic	Yes	Yes	Yes	Yes	Yes	No
Cadmium	No	Yes	No	No	Yes	Yes
Chromium	Yes	Yes	No	No	No	No
Cobalt	No	No	No	Yes	Yes	No
Iron	Yes	Yes	Yes	Yes	Yes	No
Lead	Yes	Yes	Yes	Yes	Yes	Yes
Lithium	Yes	Yes	Yes	No	No	No
Manganese	Yes	Yes	No	No	No	No
Nickel	Yes	Yes	No	No	Yes	Yes
Selenium	Yes	Yes	No	No	Yes	Yes
Thallium	No	No	Yes	Yes	Yes	Yes
Uranium	No	No	No	Yes	Yes	No
Vanadium	Yes	Yes	Yes	Yes	Yes	No
Zinc	No	No	No	No	No	Yes

Yes/No Chemical was (Yes) or was not (No) screened on as a COPC via the particular screening method listed.
[a] Toxic potency screening cut-off of 99% was used for HHRA
[b] Calcium screened on at both the Mine site for ore and Port site for product but was not carried forward for further assessment.

3.4.3 Final ERA COPC List

The final list of COPCs are presented in Tables 3-3 using the screening approach described previously.

Table 3-3 Final List of COPCs for Assessment in the ERA

Chemical	*Baseline Soil Screening*		*Oral Toxic Potency Screening*[a,b,c]			*Bioaccumulation Check*
			Mine		*Port*	
	Mine	*Port*	*Waste Overburden*	*Ore*	*Product*	
Aluminum	No	No	Yes	Yes	Yes	No
Arsenic	No	Yes	No	No	No	No
Beryllium	Yes	No	No	No	No	No
Cadmium	No	No	No	No	Yes	Yes
Chromium	No	Yes	No	Yes	Yes	No
Iron	No	No	Yes	Yes	Yes	No
Lead	No	No	No	No	No	Yes
Manganese	Yes	Yes	No	Yes	Yes	No
Nickel	No	No	No	No	Yes	Yes
Selenium	No	No	No	No	Yes	Yes

Table 3-3 Final List of COPCs for Assessment in the ERA

Chemical	Baseline Soil Screening		Oral Toxic Potency Screening[a,b,c]			Bioaccumulation Check
			Mine		Port	
	Mine	Port	Waste Overburden	Ore	Product	
Thallium	No	No	No	Yes	No	Yes
Uranium	No	Yes	No	Yes	Yes	No
Vanadium	No	No	No	No	Yes	No
Zinc	No	No	No	No	Yes	Yes

Yes/No Chemical was (Yes) or was not (No) screened on as a COPC via the particular screening method listed.
[a] Toxic potency screening cut-off of 95% was used for ERA
[b] Calcium screened on at both the Mine site for ore and Port site for product but was not carried forward for further assessment
[c] Sulphur screened on at the Mine site for ore but was not carried forward for further assessment

3.5 Determination of Media Concentrations

3.5.1 Estimation of Ambient Ground-Level Air Concentrations

To characterize air inhalation exposures, air dispersion modeling was undertaken to predict existing and future ground level air concentrations (Knight Piésold, 2015b). Assumptions used in the modeling study are explained in detail in Knight Piésold (2015b) and included an assessment of detailed emission inventories of Project-related COPC emissions, as well as emissions from existing domestic activities. The approach taken to estimate COPC concentrations in ambient air for the various scenarios being evaluated included the selection of receptor locations, the determination of baseline scenario exposures, the determination of project alone scenario exposures, and the determination of baseline plus project alone (*i.e.,* total project) scenario exposures.

3.5.1.1 Selection of Receptor Locations

Determining the spatial dispersion was performed by utilizing two nested grids with one at the Mine Site and at the Port Site. Another grid was configured for the transport route between the Mine and the Port. Receptor locations were assigned to areas where human populations are located, close to the projected facilities, and along the transport route between the mine and the port. Further details are provided by Knight Piésold (2015b).

Of the 70 original Mine, Transport Route, and Port receptor locations, a total of five receptor locations located near the Mine site were selected for evaluation in the Mine site RA. A total of two receptor locations near the Port site were selected for evaluation in the Port site RA. These receptor locations were selected based on their proximity to the proposed facilities and based on estimated Project emissions.

Selected Receptor Locations

The following receptor locations were selected for assessment in the HHRA (Name, Knight Piésold receptor identifier) (Figures 3-4 and 3-5):

Bani, R2: Located approximately 500 m east of the proposed North Pit waste disposal area and 800 m north of the proposed process plant. A total of 17 dwellings were identified by Golder

(2014) as being present at this village. This receptor location was identified as being the closest to the Mine operations.

Nema, R9: Located approximately 2 km east of the proposed North Pit waste disposal area and 1,500 m northeast of the proposed process plant. This receptor location was identified as being representative of the Army Base and Farim town urban area located east of the Mine operations.

Sandjal, R12: Located approximately 2 km northwest of the proposed North Pit. This receptor location, identified by Golder (2014) as having over 500 residents, was considered representative of areas located west of the Mine operations.

Sara Loba, R15: Located approximately 1.5 km northeast of the proposed North Pit. A major road connecting Farim town and Senegal is present within this settlement (Knight Piésold, 2015a). This receptor location was identified as being representative of areas located north of the Mine operations.

Tungina, R22: Located approximately 2.5 km south of the proposed South Pit. This receptor location was identified as being representative of areas located south of the Mine operations.

Village Chief, R69: Located approximately 250 m north of the proposed Port facility. This location is also in the immediate vicinity of the Product Transport Route connecting the Truck Load-Out facility (Mine site) and the Port site. This receptor location was identified as being representative of areas surrounding the Port operations.

Fishing Beach, R70: Located immediately adjacent (approximately 100 m) east to the proposed Port facility. This receptor location was identified as being representative of areas surrounding the Port operations.

3.5.1.2 Exposure Point Concentrations

Acute and chronic ground-level air contributions from the Mine site at each mine-related receptor location were predicted for the COPCs evaluated (*i.e.,* criteria air contaminants and metals) for each operational year scenario provided by Knight Piésold (2015b) (*i.e.,* Years 2, 8, 15 and 25).

Similarly, acute and chronic ground-level air contributions from the Port site at each port-related receptor location were predicted for the COPCs evaluated. However, unlike the Mine site, it was assumed that emissions from the Port operations would remain constant, such that COPC emissions would remain consistent throughout facility operation. As a result, acute and chronic ground-level air contributions from the Port were the same for all years evaluated (*i.e.,* Years 2, 8, 15 and 25).

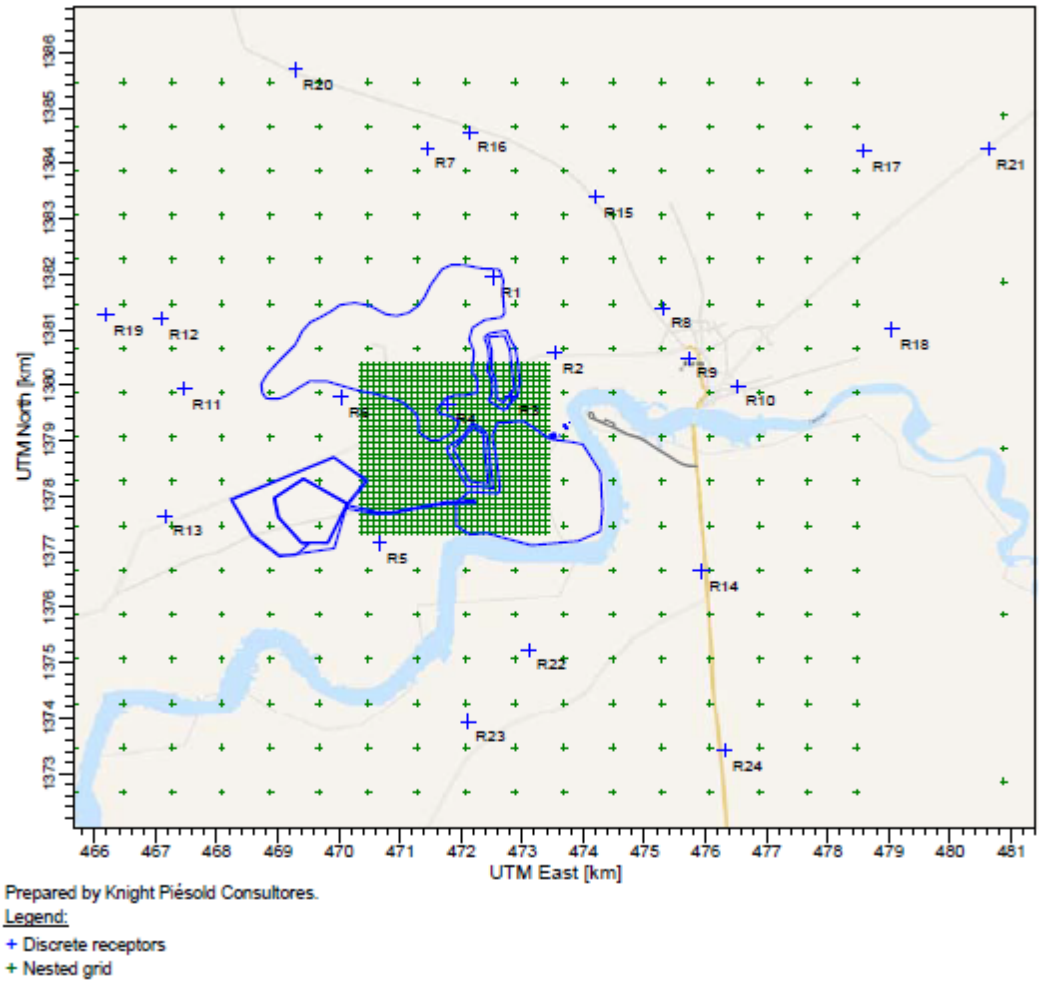
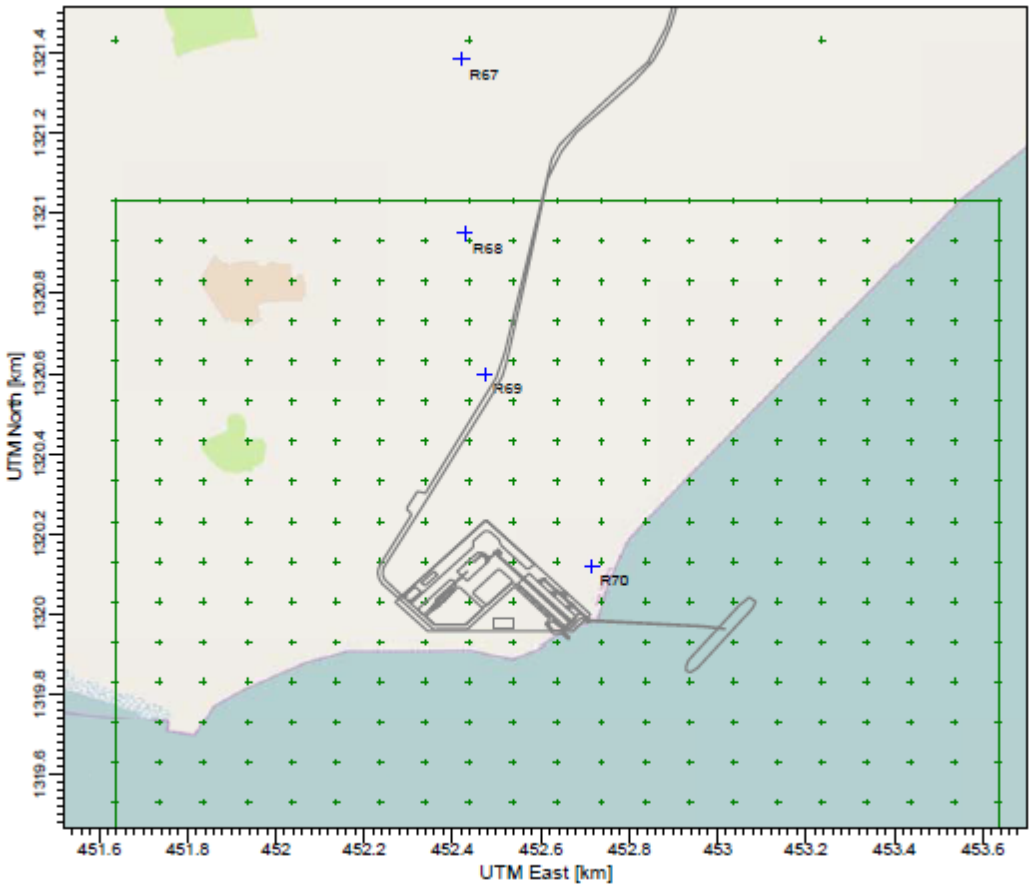


Figure 3-4 Receptor Locations for Evaluation in the Mine HHERA (Knight Piésold, 2015b)



Prepared by Knight Piésold Consultores.
Legend:
+ Discrete receptors
+ Nested grid

Figure 3-5 Receptor Locations for Evaluation in the Port HHERA (Knight Piésold, 2015b)

3.5.1.3 Determination of Baseline Scenario Exposures

Typically, ambient air monitoring data are used to characterize long-term baseline exposures (*i.e.,* in the absence of proposed operations). Background air quality levels were determined within the using the limited baseline study air quality data obtained by Golder (2014).

Air samples collected over eight months by Golder (2014) and analyzed for NO_x, NO_2, SO_2, and dust deposition were used to characterize baseline conditions for those analyzed parameters. The air samples were collected from eight monitoring stations in areas around the proposed Mine site. Concentrations collected from these eight monitoring locations were averaged to produce regional background concentrations for NO_x, NO_2, and SO_2.

In the absence of receptor location-specific sampling information, it was assumed that background levels of COPCs (*i.e.,* NO_x, NO_2, SO_2) obtained from the eight monitoring locations were representative of all of the receptor locations evaluated within the Mine and Port site RAs. The levels of the various CACs measured during the sampling period were utilized to determine exposure point concentrations within the Mine and Port RAs.

Additional air samples were collected from Station GB 4 Farim and were analyzed for PM_{10} and $PM_{2.5}$ over a total of five days in September of 2012 and 2013. These data were intended to characterize baseline conditions for these parameters. However, given the short duration of the background sampling for PM_{10} and $PM_{2.5}$, the Study Team determined that these data were inadequate to characterize baseline conditions. As a result, baseline conditions for PM_{10}, $PM_{2.5}$, and metals adsorbed to these airborne particles were not considered within the RA.

3.5.1.4 Determination of Project Alone Scenario Exposures

Air dispersion model predictions were conducted by Knight Piésold (2015b) using the CALPUFF model. Air concentrations for all CACs and dust deposition estimates were provided for all receptor locations. The dispersion model utilized topographical (*i.e.,* relief data), climate (*e.g.,* temperature, wind speed, precipitation, relative humidity), background air quality data, and projected land use information (*i.e.,* mine and transport activities). Further details are provided by Knight Piésold (2015b).

Metals present in air were estimated based on the predicted concentrations of PM_{10}. The breakdown of metals present in soil, specific to the Mine and Port sites, was applied to the PM_{10} concentrations under the assumption that PM_{10} had the same composition as the soil. These estimated air concentrations were utilized as exposure point concentrations for metals within the Mine and Port RAs.

3.5.1.5 Determination of Baseline + Project Scenario Exposures

Cumulative exposures to COPCs in air were evaluated by adding the baseline scenario exposures to the project alone scenario exposures. As indicated previously, in the absence of receptor location-specific baseline sampling information, the Baseline Plus Project Scenario exposures may not provide an accurate representation of future conditions, but do give context for the Project increment effect on air quality. Further, due to the limited availability of baseline

airborne particulate concentrations, cumulative exposures to PM_{10}, $PM_{2.5}$, and metals could not be predicted adequately.

3.5.1.6 Criteria Air Contaminants (CACs)

Acute ground-level air contributions from the Mine and Port sites were predicted for each of the criteria air contaminants for each receptor location and operational year scenario. Some of the CACs are not typically evaluated for certain exposure periods; therefore, only the following CACs were evaluated for the indicated exposure period:

- 1-hour acute concentrations were predicted for NO_2, SO_2, and CO;
- 8-hour acute concentration was predicted for CO; and,
- 24-hour acute concentrations were predicted for $PM_{2.5}$, $PM_{10,}$ and SO_2.

Acute ground-level air concentrations for each receptor location and operational year are provided in Appendix C.

Annual ground-level air contributions from the Mine and Port sites were predicted for each of the CACs for each receptor location and operational year scenario. Some of the CACs are not typically evaluated for certain exposure periods; therefore, only the following CACs were evaluated for a chronic exposure period (*i.e.,* annual):

- Annual average concentrations were predicted for $PM_{2.5}$, PM_{10}, SO_2, and NO_2.

Annual average ground-level air concentrations for each receptor location and operational year are provided in Appendix C.

3.5.1.7 Metals in Dust

The primary health concern related to metals are long-term and chronic in nature. As a result, the Air Quality assessment data provided for annual ground-level concentration for respirable dust (PM_{10}) was used to assess potential metal impacts. As described in Appendix A (Section 3.1 and 3.2), metallic fractions of the PM_{10} particles was determined based on geochemistry sources of PM_{10} emissions at the Mine and Port sites. At the Mine site the predominant geochemistry of PM_{10} (with the exception of road dusts) will be associated with waste overburden and ore. While road dusts related to limestone surfacing represented the largest source of PM_{10} emissions at the Mine site, geochemistry of these dusts were not used in the assessment. Limestone is comprised mainly of calcium carbonate which would be of low toxicity. Therefore to be conservative, the elemental breakdowns of ore and waste overburden were used to characterize PM_{10} at the Mine. Elemental composition data for 156 ore samples, 20 waste overburden samples (and duplicates) were used. Average metal concentrations in the ore and waste overburden samples were calculated by averaging the concentration of each metal in all the samples analyzed (chemicals that were not detected, were assumed to be present at their detection limit). The total average for each metal was summed and then a percentage of each metal in the entire sample was calculated. For the Port site, the main composition of dusts is expected to be related to the product. As such, the percent composition of each element in the product sample provided was determined and used to characterize PM_{10} at the Port. As there was only one product sample, there is uncertainty in this compositional breakdown. While analytical results were only available for one product sample, there were lab

results for 7 additional samples of product (which were split into two fractions) which were conducted for the metallurgical testing. These data were not used for PM_{10} characterization as detection limits for many of the metals were very high compared to those in the results of the product test. Nevertheless, several key metals are present in sufficient concentrations to validate the range of concentrations derived from the one result for the product.

Air contributions from the Mine and Port sites were predicted for each of the metals in dust for each receptor location and operational year scenario. Annual average ground-level air concentrations for each receptor location and operational year are provided in Appendix C.

3.5.2 Estimation of Environmental Media Concentrations

The objective of the multi-pathway assessment was to predict, using information from receptor and chemical characterization (Section 4.1), chronic exposures (expressed as µg chemical/kg body weight/day) to COPCs *via* the exposure pathways identified in the Problem Formulation (Section 3.4). This was accomplished using the maximum predicted annual ground-level air concentrations and deposition rates resulting from Mine and Port emissions alone (*i.e*., no background emission sources were considered) to predicted exposure point concentration in various environmental media.

The potential deposition of airborne particulate-bound contaminants from the atmosphere (originating from emissions from the Mine and Port) onto ground-level surfaces (such as soil, rice paddies, *etc*.) in the surrounding community is an important element of exposure. Deposition can be affected by a variety of different factors, the most important of which tend to be the characteristics of the atmosphere (*e.g.*, wind speed, temperature, atmospheric stability, *etc*.), the nature of the surface (*e.g.*, its surface roughness, porosity, *etc*.), and the properties of the depositing species (*e.g.*, reactivity, diameter and shape, solubility, *etc*.).

The geochemical breakdown of area soils and annual deposition rates resulting from Mine and Port emissions were used to predict EPCs in various environmental media. Chronic exposures to these media at the receptor locations were conservatively predicted under a residential exposure scenario regardless of current land use.

The methods, equations and assumptions used to predict concentrations in various environmental media were obtained from the US EPA (2005) and Health Canada (2012). Refer to Appendix D for details concerning the derivation of EPCs in various environmental media.

To characterize or estimate COPC concentrations in soil and other media, the following general approaches were used:

<u>Calculation of Baseline Scenario Exposures</u>: Concentration of COPCs (*i.e.,* metals) in soil, groundwater, fish, and agricultural crops were used to predict baseline scenario exposures to residential receptors. Media concentrations from the proposed Mine and Port sites were included where available and were used to characterize the baseline concentrations of COPCs in environmental media (e.g., soil and water) and biological media (e.g., fish).

When measured data were not available or analytical results were equivalent or below analytical method detection limits (MDLs), exposure models were used to predict environmental media concentrations (e.g., agricultural food items). Measured or predicted soil and agricultural crop

concentrations for all metals were provided for all receptor locations. Concentrations of metals in drinking water and in fish were only available for select metals.

Calculation of Project Alone Scenario Exposure: The multi-pathway exposure model was used to predict concentrations of soil, dust, and agricultural crop concentrations for all metals for each receptor location based on the projected Mine and Port operations. The COPC concentrations in groundwater not anticipated to change as a result of the Mine or Port operations and Project related impacts to fish tissue concentrations were not predicted.

Calculation of Baseline + Project Scenario Exposure: Cumulative exposures to COPCs in environmental media (other than air) were evaluated by adding the Baseline Scenario exposures to the Project Alone Scenario exposures.

Additional information on how exposure concentrations were determined for soil and other media are provided below.

3.5.2.1 Soil and Vegetation

Baseline Scenario: Soil samples collected from ore and waste overburden samples from the Farim Mine Project and analyzed for metals were used for estimating baseline exposures to soil and vegetation (See Appendix A). Most of the soil samples contained detectable concentrations of metals. In most instances, sufficient data (n ≥10) were available for the calculation of the 95 percent upper confidence limit of the mean (95UCLM). The use of the estimated 95UCLM takes into account the observed variability and uncertainty in the data; thereby providing a conservative estimate of the long term exposure point concentrations that are expected from harvesting foods and exposure to the local environment.

Guidance on preliminary quantitative risk assessment at federal contaminated sites (Health Canada, 2012) in Canada, generally recommends using maximum values to represent exposure point concentrations. However, the same reference also suggests using the arithmetic mean or 95UCLM for site specific assessments. The 95UCLM is judged to be a conservative metric for the HHRA based on the following:

Human receptors will not be chronically exposed to a 95UCLM or higher concentration. Instead, exposures are likely well represented in most situations by the average concentration due to spatial averaging that would occur through harvesting or foraging in different areas and at different times of the year or season.

Given data of sufficient quality, the use of the 95UCLM provides a reasonable and conservative estimate of chronic exposures (US EPA 1996, 2001).The use of the estimated 95UCLM in the HHRA takes into account the observed variability and uncertainty in the data; thereby providing a conservative estimate of the long term exposure concentrations.

If insufficient data were available to calculate a 95UCLM, maximum values were used and if the data were entirely non-detect or unavailable half of the highest reportable detection limit was used to estimate the maximum soil concentrations. Further details in regards to the measured soil and plant data and exposure point concentrations used in the HHRA are provided in Appendix D.

The agricultural crops considered in the HHRA included exposed aboveground produce (*e.g.,* manioc leaves), belowground produce (*e.g.,* manioc root), and protected aboveground produce (*e.g.,* rice). Under the Baseline scenario, COPC concentrations in soil were assumed to be taken up by these agricultural crops *via* root uptake.

Project Alone: To calculate Project Alone soil concentrations (which were then used to predict concentrations in other media), the estimated percentages of the COPCs on the ore and waste overburden were applied to a calculated annual total dust deposition rate predicted by Knight Piésold (2015b).

The Project Alone increment was calculated for each of the seven receptor locations based on 26 years of operation. Metals specific deposition rates at each of these receptor locations were then calculated by applying the baseline soil geochemistry composition.

These deposition rates were used in the multiple pathway exposure assessment are provided in Appendix C. Further details in regards to the baseline environmental and biological media available for the HHRA are described below and presented in Appendices A and D.

Soil concentrations were predicted for both soils at depth and surface soils assuming mixing depths of 20 cm and 2 cm, respectively as per US EPA (2005). To estimate exposure from dust and soil ingestion, estimated surface soil concentrations were used in the exposure models (top 2 cm). To predict vegetation concentrations, the predicted soil concentrations at depth were used (assuming a mixing depth of 20 cm). It is important to note that the loading into the top 2 and 20 cm of soil do not account for any soil erosion, surface runoff, or leaching or other natural processes which would be expected to occur and as such, would over estimate actual concentrations, and hence exposures.

Under the Project Alone scenario, COPC concentrations in soil were assumed to be taken up *via* root uptake by exposed aboveground produce, belowground produce, and protected aboveground produce. Additionally, atmospheric deposition of COPCs onto plant surfaces may also contribute to COPC concentrations in exposed aboveground produce.

Baseline + Project: To calculate Baseline + Project media concentrations, the increment from Project Alone was added to baseline conditions.

3.5.2.2 Fish

Measured fish concentrations for select metals were used for predicting dietary exposures in the HHRA for the Baseline assessment. Project related impacts to fish tissue concentrations were not predicted. Measured surface water concentrations were not used to estimate any wildlife exposures or tissue concentrations for the Project Alone assessment. Tissue exposure point concentrations for the Baseline assessment are presented in Appendix D.

3.5.2.3 Drinking water

A total of 43 groundwater water samples were collected from 23 monitoring wells around the proposed Farim Mine site from January 2012 to May 2015 by Golder (2014) and Knight Piésold (2015a) (See Appendix D). Analytical data from three samples taken from two locations (*i.e.,* KP-SGW-BH02, MW05A(S)), as recommended by Knight Piésold (pers. comm.), were used to

characterize baseline drinking water exposures for humans. Exposure point concentrations for each metal in groundwater is equal to the greater of the maximum detected concentration or half of the highest reportable detection limit from these three samples.

Given that groundwater concentrations were not expected to change appreciably as a result of the Project (Knight Piésold, pers. comm.), measured drinking water concentrations were not used to represent Project Alone exposures to drinking water. Further details in regards to the drinking water data and exposure point concentrations used in the HHRA are presented in Appendix D.

3.6 Identification of Human Receptors

A human receptor is a hypothetical person (*i.e*., an infant, toddler, child, teen, or adult) who may reside, spend leisure time and/or work in the area being investigated and is, or could potentially be, exposed to the chemicals identified as being of potential concern. General physical and behavioural characteristics specific to the receptor type (*e.g*., body weight, exposed surface areas, incidental soil ingestion rate, *etc*.) are used to approximate the amount of chemical exposure received by each receptor. The HHRA must be sufficiently comprehensive to ensure that those receptors with the greatest potential for exposure to COPCs, and those that have the greatest sensitivity, or potential for developing adverse effects from these exposures, are included. With this in mind, the selection of hypothetical receptors, with somewhat exaggerated life style habits (to ensure a conservative assessment), should be developed for consideration in the HHRA. Due to differences in physiological characteristics and activity patterns between children and adults, the exposures received by a child and an adult will be different. Consequently, the potential risks estimated for the same COPC will differ depending on the receptor chosen for evaluation.

With respect to the area potential affected by the Project, only off-site users have been considered in the HHRA. Exposures for mine workers will need to meet all relevant occupational health and safety requirements, and hence, should not be of concern and were not assessed further.

The area surrounding the Mine, Transport Route, and Port sites are largely residential and farming in nature. Therefore, the primary receptors were considered to be a residential and agricultural site users (at all life stages). To ensure a conservative assessment with respect to multi-pathway modelling, receptors were assumed to be in the area on a full-time basis (as residents).

For chemicals considered to be carcinogenic, it is common to assess exposure over a lifetime, as development of cancer associated with chemical exposure is a long-term process that may take many years to manifest. Health risks associated with exposure to carcinogenic compounds are usually expressed as an estimate of excess or Incremental Lifetime Cancer Risk (ILCR) for a population resulting from exposure to a particular source. Thus, risks associated with carcinogenic compounds were predicted using the average daily dose over a human receptor's entire life span (*e.g*., 49.5 years; CIA, 2013), or as preferred by Health Canada (2012), the duration of a specific life stage (*e.g*., 29.5-year adult life span).

In order to evaluate potential exposures, it is necessary to characterize the physiological and behavioural characteristics of each receptor group. Several published resources were considered in the selection of these parameters, including but not limited to:

- Federal Contaminated Sites Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment for Chemicals (PQRA). (Health Canada, 2012);
- Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc. (Richardson and O'Connor, 1997);

These sources have been used in numerous HHRAs that have been critically reviewed and accepted by regulatory agencies across Canada and the United States. Both the Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson and O'Connor, 1997) and Health Canada (2012) rely on data from published and reliable Canadian sources, such as Health Canada, Statistics Canada, and the Canadian Fitness and Lifestyles Research Institute. While there is an updated version of the Compendium of Canadian Exposure Factors (Richardson and Stantec, 2013), this version has not been used at this time, as no firm statement from Health Canada regarding the acceptance of revised parameter values has been issued to our knowledge.

3.7 Identification of Human Exposure Scenarios and Operable Pathways

Receptors can come into contact with chemicals in their environment in a variety of ways, depending on their daily activities and land use patterns. The means by which a person comes into contact with a chemical in an environmental medium are referred to as exposure pathways. The means by which a chemical enters the body from the environmental medium are referred to as exposure routes. There are three major exposure routes through which chemicals can enter the body which are inhalation; ingestion; and dermal absorption (*i.e.*, uptake through the skin).

Exposure pathways may require direct contact between receptors and the environmental media of concern (*e.g.*, incidental ingestion of soil), or may be indirect requiring the movement of the chemical from one environmental medium to another (*e.g.*, the deposition of dusts on soils, and uptake through vegetation).

For the residential/recreational site user, all life stages were initially considered, with the results being presented for the most sensitive receptor (i.e., the toddler; age 7 months to 4 years). The modelling assumed that the residential / recreational user could be present in the area 24 hours/day, 7 days/week, 52 weeks/year for their entire life span (Health Canada, 2012). This assumption overestimates potential exposures to recreational users as they are only in the area for a short period of the day and only on certain days of the year. Similarly, exposures to the residential receptor were overestimated as even full time residents would need to leave the area during some occasions (e.g., to go to town for supplies and other needs, visit friends, *etc.*).

The residential site user was assumed to be exposed to COPCs in soils *via* ingestion of soil, inhalation of soil/dust, and direct dermal contact with soil. In addition, exposures through ingestion of agricultural crops (such as manioc), fish, and water from area ground water, was also assumed to occur. The media–related exposure pathways that were considered for the assessment of human health are described below (Table 3-4), with specific receptor characteristics being presented in Section 4.1.

Table 3-4 Exposure Pathway Identification and Assumptions/Rationale for Selection of Open Exposure Pathways

Media Potentially Influenced by Project	*Open Pathway?*	*Specific Exposure Pathways*	*Comments*
Air	Yes	• Inhalation of outdoor air (dusts; gases; particulate)	Residential villages, farm lands, and fishing areas are in close proximity to the proposed Mine and Port sites.
Soil	Yes	• Ingestion of outdoor soil • Inhalation of outdoor soil • Dermal contact with outdoor soil	Same comment as above; Active use areas in close proximity to Mine and Port sites.
Surface water	No	• Ingestion and dermal contact with surface water	The Cacheu River, which is the nearest major surface water body is brackish in nature. As a result, it is not used as a water supply and unlikely to represent drinking water.
Groundwater	Yes	• Ingestion and dermal contact of groundwater	Groundwater is the major source of drinking water to the area. However, groundwater is not anticipated to change as a result of project activities. Therefore, exposure to groundwater was only evaluated in the Baseline assessment (and as a component for Baseline + Project)
Agricultural crops	Yes	• Ingestion of agricultural crops within the Project area • Ingestion of fish within the Project area	Agricultural crops could be influenced by Project activities through the deposition of dusts on area soils and vegetation. Metals could be taken up via the vegetation, which are consumed by residents. Three groups of agricultural crop were considered: exposed above ground produce (includes manioc leaf), below ground produce (includes manioc roots), and protected aboveground produce (includes rice). Fish in the area are consumed by local residents, but are not anticipated to change in the future, due to limited contributions to area rivers. Therefore, exposure to fish was only evaluated in the Baseline assessment (and as a component for Baseline + Project)

3.8 Human Health Secondary Chemical Screening for the Multi-Pathway Assessment

A total of 21 chemicals were retained as COPCs for the human health inhalation assessment (see Section 3.4.2). However, not all COPCs assessed via inhalation pathways were considered relevant to the multi-media assessment. Due to the physical-chemical properties of some COPC potentially emitted at the Mine and Port sites and the levels at which they are emitted from the sites, it was determined that they will not persist or accumulate in the environment.

For the purposes of the multi-media pathway assessment, five (5) criteria air contaminants, primarily gases or aerosols, were removed as potential COPCs due to their high volatility and associated lack of potential to persistent and/or accumulate following emission from the proposed facility:

- Sulphur dioxide (SO_2);
- Nitrogen dioxide (NO_2);
- Carbon monoxide (CO);
- Particulate matter (PM_{10}); and,
- Particulate matter ($PM_{2.5}$).

In the selection of COPCs for quantitative analysis in the multi-media assessment, a tiered chemical screening approach was applied. The first tier involved the chemical potency screening/selection process discussed in Section 3.4. For those COPCs identified through the potency screening process, modeled surface soil (i.e., top 2 cm) concentrations at the selected receptor locations were compared against regulatory criteria protective of human health (see Tables 3-5 through 3-11).

At the Mine site, aluminum and iron exceed human health soil quality guidelines for project plus baseline and as such warrant further study. At the Port site, aluminum, arsenic, cadmium, iron, lead and vanadium exceed human health soil quality guidelines for project plus baseline and as such warrant further study.

To ensure consistency, all chemicals carried forward into the multimedia assessment at either the Mine site or the Port sites were assessed at both sites. As such, the following chemicals of concern were assessed in the multimedia assessment:

- Aluminum;
- Arsenic;
- Cadmium;
- Iron;
- Lead; and,
- Vanadium.

Table 3-5 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Bani Receptor (R2) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME [d]	SA DEA [i]
Aluminum	9439	1433.5	10873	15.2%	32525	7800 [e]	
Antimony	<0.50[b]	0.038	0.54	7.6%	<0.51[b]	7.5 [f]	
Arsenic	1.34	0.30	1.65	22.6%	3.78	12	5.8
Cadmium	0.77	0.029	0.80	3.79%	0.40	1.4 / 14	7.5
Chromium[j]	20.81	6.89	27.70	33.1%	42.35	220 [h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	1.73	0.22	1.95	12.53%	4.32	22 [f]	300
Iron	8307	1127	9434	13.57%	19850	5500 [e]	
Lead	8.39	0.39	8.78	4.63%	21.52	140	20
Lithium	7.92	0.90	8.82	11.33%	40.98	16	
Manganese	104.27	8.13	112.41	7.80%	304.5	180[e, f]	740
Nickel	3.44	0.71	4.15	20.7%	11.8	330 [f]	91
Selenium	<2.0[b]	0.022	2.02	1.1%	<2.0[b]	80	
Thallium	<0.5[b]	0.043	0.54	8.6%	<0.50[b]	1 / 1.4	
Uranium	1.34	0.37	1.71	27.8%	4.68	23	
Vanadium	21.48	2.79	24.27	13.0%	47.88	39 [f]	150
Zinc	9.94	1.81	11.76	18.2%	31.13	5600 [f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 15

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-6 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Nema Receptor (R9) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME [d]	SA DEA [i]
Aluminum	9439	908	10348	9.6%	32525	7800 [e]	
Antimony	<0.50[b]	0.024	0.52	4.8%	<0.51[b]	7.5 [f]	
Arsenic	1.34	0.19	1.53	14.3%	3.78	12	5.8
Cadmium	0.77	0.018	0.79	2.40%	0.40	1.4 / 14	7.5
Chromium[j]	20.81	4.37	25.17	20.99%	42.35	220 [h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	1.73	0.14	1.87	7.94%	4.32	22 [f]	300
Iron	8307	714.2	9021	8.6%	19850	5500 [e]	
Lead	8.39	0.246	8.64	2.9%	21.52	140	20
Lithium	7.92	0.57	8.49	7.2%	40.98	16	
Manganese	104.27	5.15	109.42	4.9%	304.5	180[e, f]	740
Nickel	3.44	0.45	3.89	13.1%	11.8	330 [f]	91
Selenium	<2.0[b]	0.014	2.01	0.70%	<2.0[b]	80	
Thallium	<0.5[b]	0.027	0.53	5.4%	<0.50[b]	1 / 1.4	
Uranium	1.34	0.24	1.6	17.6%	4.68	23	
Vanadium	21.48	1.77	23.3	8.2%	47.88	39 [f]	150
Zinc	9.94	1.15	11.1	11.5%	31.13	5600 [f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-7 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Sandjal Receptor (R12) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME [d]	SA DEA [i]
Aluminum	9439	798	10238	8.5%	32525	7800 [e]	
Antimony	<0.50[b]	0.021	0.52	4.2%	<0.51[b]	7.5 [f]	
Arsenic	1.34	0.17	1.51	12.6%	3.78	12	5.8
Cadmium	0.77	0.016	0.79	2.1%	0.40	1.4 / 14	7.5
Chromium [j]	20.81	3.84	24.65	18.5%	42.35	220 [h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	1.73	0.12	1.85	7.0%	4.32	22 [f]	300
Iron	8307	628.0	8935	7.6%	19850	5500 [e]	
Lead	8.39	0.216	8.61	2.6%	21.52	140	20
Lithium	7.92	0.50	8.4	6.3%	40.98	16	
Manganese	104.27	4.53	108.8	4.3%	304.5	180[e, f]	740
Nickel	3.44	0.40	3.83	11.5%	11.8	330 [f]	91
Selenium	<2.0[b]	0.012	2.01	0.6%	<2.0[b]	80	
Thallium	<0.5[b]	0.024	0.52	4.8%	<0.50[b]	1 / 1.4	
Uranium	1.34	0.21	1.55	15.5%	4.68	23	
Vanadium	21.48	1.55	23.04	7.2%	47.88	39 [f]	150
Zinc	9.94	1.01	10.95	10.1%	31.13	5600 [f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table3-8 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Sara Loba Receptor (R15) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME [d]	SA DEA [i]
Aluminum	9439	966	10406	10.2%	32525	7800 [e]	
Antimony	<0.50[b]	0.026	0.53	5.2%	<0.51[b]	7.5 [f]	
Arsenic	1.34	0.20	1.55	15.2%	3.78	12	5.8
Cadmium	0.77	0.020	0.79	2.6%	0.40	1.4 / 14	7.5
Chromium [j]	20.81	4.65	25.5	22.3%	42.35	220 [h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	1.73	0.15	1.9	8.4%	4.32	22 [f]	300
Iron	8307	760	9067	9.1%	19850	5500 [e]	
Lead	8.39	0.262	8.65	3.1%	21.52	140	20
Lithium	7.92	0.61	8.53	7.6%	40.98	16	
Manganese	104.27	5.48	109.75	5.3%	304.5	180[e, i]	740
Nickel	3.44	0.48	3.91	14.0%	11.8	330 [f]	91
Selenium	<2.0[b]	0.015	2.01	0.75%	<2.0[b]	80	
Thallium	<0.5[b]	0.029	0.53	5.8%	<0.50[b]	1 / 1.4	
Uranium	1.34	0.251	1.59	18.7%	4.68	23	
Vanadium	21.48	1.88	23.4	8.8%	47.88	39 [f]	150
Zinc	9.94	1.22	11.2	12.3%	31.13	5600 [f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-9 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Tungina Receptor (R22) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME[d]	SA DEA[i]
Aluminum	9439	387	9827	4.1%	32525	7800[e]	
Antimony	<0.50[b]	0.010	0.51	2.0%	<0.51[b]	7.5[f]	
Arsenic	1.34	0.082	1.42	6.1%	3.78	12	5.8
Cadmium	0.77	0.0079	0.78	1.0%	0.40	1.4 / 14	7.5
Chromium[j]	20.81	1.86	22.67	9.0%	42.35	220[h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	1.73	0.059	1.79	3.4%	4.32	22[f]	300
Iron	8307	304	8611	3.7%	19850	5500[e]	
Lead	8.39	0.105	8.50	1.3%	21.52	140	20
Lithium	7.92	0.242	8.17	3.1%	40.98	16	
Manganese	104.27	2.20	106.5	2.1%	304.5	180[e, l]	740
Nickel	3.44	0.19	3.63	5.6%	11.8	330[f]	91
Selenium	<2.0[b]	0.0059	2.01	0.30%	<2.0[b]	80	
Thallium	<0.5[b]	0.012	0.51	2.4%	<0.50[b]	1 / 1.4	
Uranium	1.34	0.10	1.44	7.5%	4.68	23	
Vanadium	21.48	0.75	22.2	3.5%	47.88	39[f]	150
Zinc	9.94	0.49	10.4	4.9%	31.13	5600[f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

a Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

b All samples had non-detectable concentrations; number provided is the detection limit

c Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

d Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

e US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

f OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

g SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

h CCME guideline for total chromium (derived in 1997).

i Residential soil, non-diet

j Chromium was assumed to be present in the Cr^{+3} form

Table 3-10 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Port Village Receptor (R69) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME [d]	SA DEA [i]
Aluminum	37447	2.7	37450	0.0072%	80300	7800 [e]	
Antimony	<0.5[b]	0.0041	0.50	0.82%	<0.51[d]	7.5 [f]	
Arsenic	13.94	0.0024	13.94	0.017%	40.6	12	5.8
Cadmium	2.21	0.014	2.23	0.62%	5.69	1.4 / 14	7.5
Chromium[j]	114.91	0.30	115.21	0.26%	255.8	220 [h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	8.25	0.022	8.27	0.27%	12.73	22 [f]	300
Iron	60601	23.69	60624	0.039%	168800	5500 [e]	
Lead	24.01	0.0036	24.02	0.015%	39.69	140	20
Lithium	14.7	0.00	14.75	0.00%	45.52	16	
Manganese	112.43	0.41	112.84	0.37%	301.7	180[e, i]	740
Nickel	16.29	0.10	16.39	0.62%	33.06	330 [f]	91
Selenium	<2.0[b]	0.017	2.02	0.85%	<2.0[b]	80	
Thallium	<0.5[b]	0.0010	0.50	0.2%	<0.5[b]	1 / 1.4	
Uranium	5.14	0.16	5.30	3.1%	15.98	23	
Vanadium	94.04	0.21	94.24	0.22%	305.8	39 [f]	150
Zinc	38.82	0.33	39.16	0.85%	92.73	5600 [f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 15

NGA No guideline available

a Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

b All samples had non-detectable concentrations; number provided is the detection limit

c Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

d Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

e US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

f OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

g SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

h CCME guideline for total chromium (derived in 1997).

i Residential soil, non-diet

j Chromium was assumed to be present in the Cr^{+3} form

Table 3-11 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Port Fishing Beach Receptor (R70) Compared to Human Health Based Soil Quality Guidelines and 95th Percentile of Baseline

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Human Health Guideline (mg/kg)	
						CCME[d]	SA DEA[i]
Aluminum	37447	2.7	37450	0.0073%	80300	7800[e]	
Antimony	<0.5[b]	0.0042	0.50	0.84%	<0.51[d]	7.5[f]	
Arsenic	13.94	0.0024	13.94	0.017%	40.6	12	5.8
Cadmium	2.21	0.014	2.23	0.63%	5.69	1.4 / 14	7.5
Chromium[j]	114.91	0.31	115.2	0.27%	255.8	220[h]	46,000 Cr^{+3} / 6.5 Cr^{+6}
Cobalt	8.25	0.023	8.27	0.27%	12.73	22[f]	300
Iron	60601	24.151	60625	0.040%	168800	5500[e]	
Lead	24.01	0.0037	24.02	0.02%	39.69	140	20
Lithium	14.7	0.00	14.75	0.0%	45.52	16	
Manganese	112.43	0.42	112.85	0.37%	301.7	180[e, f]	740
Nickel	16.29	0.10	16.39	0.63%	33.06	330[f]	91
Selenium	<2.0[b]	0.018	2.02	0.90%	<2.0[b]	80	
Thallium	<0.5[b]	0.0010	0.50	0.20%	<0.5[b]	1 / 1.4	
Uranium	5.14	0.16	5.30	3.13%	15.98	23	
Vanadium	94.04	0.21	94.25	0.22%	305.8	39[f]	150
Zinc	38.82	0.34	39.16	0.87%	92.73	5600[f]	240

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 15

NGA No guideline available

a Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

b All samples had non-detectable concentrations; number provided is the detection limit

c Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

d Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

e US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

f OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

g SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

h CCME guideline for total chromium (derived in 1997).

i Residential soil, non-diet

j Chromium was assumed to be present in the Cr^{+3} form

3.9 Ecological Pathways and Receptors Selection and Secondary Chemical Screening for the Multimedia Assessment

Direct inhalation, incidental soil ingestion, food and water consumption, and dermal exposure were considered as potential pathways for ecological receptors.

To determine which chemicals are found in soil at concentrations that may result in adverse effects to ecological receptors, concentrations of contaminants were compared to criteria that are designed to be protective of terrestrial ecological receptors. These criteria consider effects to plants, soil organisms, birds, and mammals that may be exposed to impacted soils. Plants and soil organisms are primarily exposed to contaminants via direct contact with impacted soil. Wildlife may be exposed to chemicals in the environment via three distinct pathways: ingestion, inhalation, and dermal contact. Chemicals may be ingested through the consumption of impacted food and water, and by incidental ingestion of soil. Dermal exposure occurs when chemicals are absorbed through the skin as a result of direct contact with impacted soil. Dermal exposure is generally assumed to be negligible for birds and mammals. This is because feathers on birds and fur on mammals reduce dermal exposure by limiting the contact of skin with chemicals in soil (Sample *et al.*, 1997). Exposure may occur via inhalation if chemicals are volatile, or if they are components of fine particulate matter which may be re-suspended in ambient air. However, there is a paucity of available data describing the inhalation toxicity of chemicals to birds, and use of mammalian data is not possible due to the differences in avian and mammalian physiology. Inhalation toxicity data for mammalian wildlife are also limited for endpoints of interest in ERA (e.g., reproduction). Food and soil ingestion tend to be the most significant routes of exposure, contributing the greatest to overall risk. Therefore, only exposure via ingestion of food and soil was considered in this ERA. This approach is consistent with US EPA (1999) and Environment Canada (1994), which acknowledge that ingestion is the major pathway of concern for wildlife.

Given that the selected criteria are derived to be protective of the most significant source of exposure to environmental contaminants, those contaminants that are found in soil at concentrations that are below the criteria are not anticipated to represent a potential concern to ecological receptors.

The following tables present Baseline, Project Alone, and Baseline + Project scenario soil concentrations, percent increase in soil concentrations resulting from the projects contribution, and a comparison of these predicted soil concentration to area baseline soil levels and ecological health guidelines protective of ecological receptors, at each of the mine and port receptor locations.

At all receptor locations near the Mine site (Tables 3-11 through 3-15), Baseline + Project soil concentrations are less the selected ecological criteria with the following exception:

- Selenium's reported baseline value is a detection limit, which exceeds both the 95th percentile of baseline and ecological health based soil quality guidelines. However, given the small percent increase (<1.1%) related to the Project, it is unlikely selenium will cause any ecological effects.

Given that the selected criteria are derived to be protective of the most significant source of exposure to environmental contaminants, and that the percent change related to the Project for

selenium is small, none of the contaminants are anticipated to represent a potential concern to ecological receptors near the Mine site.

At all receptor locations Port (Tables 3-16 and 3-17), Baseline + Project soil concentrations are less the selected ecological criteria with the following exception:

- The projected soil concentrations for chromium exceed ecological health soil quality guidelines; however the predicted percent increase related to the Project is less than one percent, and well within the variation of baseline concentrations. As a result, it is unlikely chromium will cause any ecological effects.
- Selenium's reported baseline value is a detection limit, which exceeds both the 95th percentile of baseline and ecological health based soil quality guidelines. However, given the small percent increase (<1%) related to the Project, it is unlikely selenium will cause any ecological effects.

Given that the selected criteria are derived to be protective of the most significant source of exposure to environmental contaminants, and that the percent change related to the Project for selenium and chromium is small, none of the contaminants are anticipated to represent a potential concern to ecological receptors near the Port site.

Table 3-12 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Bani Receptor (R2) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	9439	1433	10873	15%	32525	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	1.34	0.30	1.65	23%	3.79	17	(CCME, 1997)
Beryllium	0.86	0.038	0.90	4.4%	4.53	4	(OMOE, 2011) [f]
Cadmium	0.77	0.029	0.80	3.8%	0.4	3.8 / 10	(CCME, 1999)
Chromium[i]	20.81	6.89	27.70	33%	42.4	64	(CCME, 1997) [g]
Iron	8307	1127	9434	14%	19850	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	8.39	0.39	8.78	4.6%	21.5	70 / 300	(CCME, 1999)
Manganese	104.27	8.13	112.41	7.8%	304.5	220	(U.S. EPA,2007b)
Nickel	3.44	0.71	4.15	21%	11.8	50	(CCME, 1999)
Selenium	<2.0[b]	0.022	2.22	1.1%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.50[b]	0.043	0.54	8.6%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	1.34	0.37	1.71	28%	4.68	33 / 500	(CCME, 2007)
Vanadium	21.48	2.79	24.27	13%	47.9	130	(CCME, 1997)
Zinc	9.94	1.81	11.76	18%	31.1	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-13 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Nema Receptor (R9) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	9439	908	10348	10%	32525	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	1.34	0.192	1.53	14.3%	3.79	17	(CCME, 1997)
Beryllium	0.86	0.024	0.89	2.8%	4.53	4	(OMOE, 2011) [f]
Cadmium	0.77	0.02	0.79	2.4%	0.4	3.8 / 10	(CCME, 1999)
Chromium[i]	20.81	4.37	25.17	21%	42.4	64	(CCME, 1997) [g]
Iron	8307	714	9021	8.6%	19850	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	8.39	0.25	8.64	2.9%	21.5	70 / 300	(CCME, 1999)
Manganese	104.27	5.15	109.4	4.9%	304.5	220	(U.S. EPA,2007b)
Nickel	3.44	0.45	3.89	13%	11.8	50	(CCME, 1999)
Selenium	<2.0[b]	0.014	2.01	0.7%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.50[b]	0.027	0.52	5.4%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	1.34	0.24	1.58	18%	4.68	33 / 500	(CCME, 2007)
Vanadium	21.48	1.77	23.25	8.2%	47.9	130	(CCME, 1997)
Zinc	9.94	1.15	11.09	12%	31.1	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-14 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Sandjal Receptor (R12) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	9439	798	10238	8.5%	32525	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	1.34	0.169	1.51	12.6%	3.79	17	(CCME, 1997)
Beryllium	0.86	0.021	0.88	2.5%	4.53	4	(OMOE, 2011) [f]
Cadmium	0.77	0.016	0.79	2.1%	0.4	3.8 / 10	(CCME, 1999)
Chromium[i]	20.81	3.84	24.65	18%	42.4	64	(CCME, 1997) [g]
Iron	8307	627.96	8934.90	7.6%	19850	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	8.39	0.22	8.61	2.6%	21.5	70 / 300	(CCME, 1999)
Manganese	104.27	4.53	108.8	4.3%	304.5	220	(U.S. EPA,2007b)
Nickel	3.44	0.40	3.83	12%	11.8	50	(CCME, 1999)
Selenium	<2.0[b]	0.012	2.01	0.6%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.50[b]	0.024	0.054	4.8%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	1.34	0.21	1.55	15%	4.68	33 / 500	(CCME, 2007)
Vanadium	21.48	1.55	23.04	7.2%	47.9	130	(CCME, 1997)
Zinc	9.94	1.01	10.95	10%	31.1	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-15 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Sara Loba Receptor (R15) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	9439	966	10406	10.2%	32525	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	1.34	0.204	1.55	15.2%	3.79	17	(CCME, 1997)
Beryllium	0.86	0.03	0.89	3.0%	4.53	4	(OMOE, 2011) [f]
Cadmium	0.77	0.02	0.8	2.6%	0.4	3.8 / 10	(CCME, 1999)
Chromium[i]	20.81	4.65	25.45	22%	42.4	64	(CCME, 1997) [g]
Iron	8307	760	9067	9.1%	19850	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	8.39	0.26	8.65	3.1%	21.5	70 / 300	(CCME, 1999)
Manganese	104.27	5.48	109.75	5.3%	304.5	220	(U.S. EPA,2007b)
Nickel	3.44	0.48	3.91	14%	11.8	50	(CCME, 1999)
Selenium	<2.0[b]	0.015	2.01	0.75%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.50[b]	0.029	0.53	5.8%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	1.34	0.25	1.59	19%	4.68	33 / 500	(CCME, 2007)
Vanadium	21.48	1.88	23.36	8.8%	47.9	130	(CCME, 1997)
Zinc	9.94	1.22	11.17	12%	31.1	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-16 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Mine Tungina Receptor (R22) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	9439	387	9827	4.1%	32525	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	1.34	0.08	1.42	6.1%	3.79	17	(CCME, 1997)
Beryllium	0.86	0.010	0.87	1.2%	4.53	4	(OMOE, 2011) [f]
Cadmium	0.77	0.0079	0.78	1.0%	0.4	3.8 / 10	(CCME, 1999)
Chromium[i]	20.81	1.86	22.67	9.0%	42.4	64	(CCME, 1997) [g]
Iron	8307	304	8611	3.7%	19850	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	8.39	0.10	8.50	1.3%	21.5	70 / 300	(CCME, 1999)
Manganese	104.27	2.20	106.47	2.1%	304.5	220	(U.S. EPA,2007b)
Nickel	3.44	0.19	3.63	5.6%	11.8	50	(CCME, 1999)
Selenium	<2.0[b]	0.006	2.01	0.3%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.50[b]	0.012	0.51	2.4%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	1.34	0.10	1.44	7.5%	4.68	33 / 500	(CCME, 2007)
Vanadium	21.48	0.75	22.24	3.5%	47.9	130	(CCME, 1997)
Zinc	9.94	0.49	10.43	4.9%	31.1	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-17 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Port Village Receptor (R69) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	37447	2.68	37450	0.01%	80300	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	13.94	0.0024	13.94	0.02%	40.6	17	(CCME, 1997)
Beryllium	1.40	0.0032	1.40	0.23%	3.78	4	(OMOE, 2011) [f]
Cadmium	2.21	0.014	2.23	0.62%	5.69	3.8 / 10	(CCME, 1999)
Chromium[i]	114.91	0.300	115.21	0.26%	255.8	64	(CCME, 1997) [g]
Iron	60601	23.691	60625	0.04%	168800	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	24.01	0.004	24.02	0.02%	39.69	70 / 300	(CCME, 1999)
Manganese	112.43	0.411	112.84	0.37%	301.7	220	(U.S. EPA,2007b)
Nickel	16.29	0.101	16.39	0.62%	33.06	50	(CCME, 1999)
Selenium	<2.0[b]	0.017	2.02	0.85%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.5[b]	0.001	0.5	0.20%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	5.14	0.158	5.30	3.07%	15.98	33 / 500	(CCME, 2007)
Vanadium	94.04	0.205	94.24	0.22%	305.8	130	(CCME, 1997)
Zinc	38.82	0.332	39.16	0.85%	92.73	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 15

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

Table 3-18 Predicted Future Surface Soil (0 to 2 cm) Concentrations (mg/kg) at Port Fishing Beach Receptor (R70) Compared to Ecological Health Based Soil Quality Guidelines and 95th Percentile of Baseline Soil

Analyte	Baseline[a]	Project	Baseline + Project	Percent Increase	95th Percentile of Baseline[c]	Ecological Health Guideline [d] (mg/kg) and Source	
Aluminum	37447	2.74	37450.20	0.01%	80300	pH<5.5[e]	(U.S. EPA, 2003a)
Arsenic	13.94	0.0024	13.94	0.02%	40.6	17	(CCME, 1997)
Beryllium	1.40	0.0032	1.40	0.23%	3.78	4	(OMOE, 2011) [f]
Cadmium	2.21	0.014	2.23	0.63%	5.69	3.8 / 10	(CCME, 1999)
Chromium[i]	114.91	0.306	115.22	0.27%	255.8	64	(CCME, 1997) [g]
Iron	60601	24.2	60625.3	0.04%	168800	pH 5 to 8 [h]	(U.S. EPA, 2003b)
Lead	24.01	0.0037	24.02	0.02%	39.69	70 / 300	(CCME, 1999)
Manganese	112.43	0.42	112.85	0.37%	301.7	220	(U.S. EPA,2007b)
Nickel	16.29	0.10	16.39	0.63%	33.06	50	(CCME, 1999)
Selenium	<2.0[b]	0.018	2.02	0.90%	<2.0[b]	1	(CCME, 2009)
Thallium	<0.5[b]	0.0010	0.5	0.20%	<0.5[b]	1 / 1.4	(CCME, 1999)
Uranium	5.14	0.16	5.30	3.13%	15.98	33 / 500	(CCME, 2007)
Vanadium	94.04	0.21	94.25	0.22%	305.8	130	(CCME, 1997)
Zinc	38.82	0.34	39.16	0.87%	92.73	200	(CCME, 1999)

Shaded grey cells indicate baseline plus project exceeds human health guidelines and/or 95th percentile.

N Number of Samples = 36

NGA No guideline available

[a] Baseline concentration is a 95UCLM unless otherwise noted are presented in Appendix A.

[b] All samples had non-detectable concentrations; number provided is the detection limit

[c] Unless otherwise noted, the 95th percentile of baseline value was calculated assuming non-detectable values (if/when they occurred) were equal to half the detection limit.

[d] Unless otherwise noted all guideline values are CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline.

[e] US EPA Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[f] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[g] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[h] CCME guideline for total chromium (derived in 1997).

[i] Residential soil, non-diet

[j] Chromium was assumed to be present in the Cr^{+3} form

4.0 EXPOSURE ASSESSMENT

The assessment of the potential for adverse effects from chemicals is based on the dose-response concept that is fundamental to the responses of biological systems to chemicals (Filov *et al.*, 1979; Amdur *et al.*, 1991). Since it is not usually practical to measure concentrations of chemicals at the actual site where the adverse response occurs within tissues and cells, exposures are estimated based on either the dose of the chemical that actually enters a receptor or more commonly, by the concentrations in various environmental media that act as pathways for exposure.

The primary objective of the exposure assessment is to predict, using a series of conservative assumptions, either the concentration of the COPCs (e.g., such as an air concentration of a substance, which is assumed to be an inhaled dose expressed in $\mu g/m^3$), or the rate of exposure (expressed in µg/kg body weight/day) of human receptors to COPCs through the exposure scenarios and pathways identified in the problem formulation.

The magnitude of exposure of human receptors to chemicals in the environment typically depends on the interactions of a number of parameters, including:

- The concentrations of chemicals in various environmental media (as determined by the quantities of chemicals entering the environment from various sources, their persistence, fate and behaviour in these media, and the normal ambient, or background concentrations that exist independent of a specific source);
- The physical-chemical characteristics of the chemicals of concern, which affect their environmental fate, transport, behaviour and persistence, and determine the degree or extent by which chemicals can be absorbed into the body;
- The influence of site-specific environmental characteristics, such as geology, soil type, topography, hydrology, hydrogeology, local meteorology and climatology, *etc*., on a chemical's fate, transport and behaviour within environmental media;
- The physiological and behavioural characteristics of the receptors (*e.g.,* respiration rate, soils/dusts intake rate, food ingestion rates, time spent at various activities and in different areas); and,
- The various exposure pathways for the transfer of the chemicals from the different environmental media to humans (*e.g.,* inhalation of indoor and outdoor air, soil particles and dusts; ingestion of food items, water, soils/dusts; skin penetration of various chemicals from dermal contact with soil/dust, water, sediments).

Exposure estimation in the multi-pathway assessment portion of the HHRA was conducted through the use of an integrated environmental risk assessment model developed by the Study Team. The model is spreadsheet based (Microsoft Excel™) but has a number of more advanced add-ons or features. Models of this type have been used on hundreds of peer-reviewed HHRAs in Canada, including those conducted for contaminated sites, landfills, smelters, refineries, incinerators, and a variety of other industrial facilities. The current model version incorporates the techniques and procedures for exposure modelling developed by various regulatory agencies and published scientific literature sources. Refer to Appendix E for a full description (*i.e.*, worked example) of the equations and parameters used in the HHERA.

It was conservatively assumed that human receptors located at the locations of interest were assumed to spend 100% of their time at the same location (*i.e.,* 24 hours/day, 7 days/week, 52 weeks/year). As a result, the predicted annual average air concentrations presented for the residential receptors were not adjusted. This approach is consistent with Health Canada (2012) guidance.

4.1 Human Receptor Characterization

As previously indicated in Section 2.2, human receptor parameters used in the exposure modelling were generally obtained from Health Canada (2012; 1994) and Richardson and O'Connor (1997) and are provided in Tables 4-1 and 4-2 for general physical characteristics and food consumption rates, respectively. Fish consumption rates were selected from Health Canada (2007), and were based on subsistence fisher data. The consumption rates for agricultural crops (*i.e.,* exposed aboveground produce, belowground produce, and protected aboveground produce) were assumed to be those for root vegetables and other vegetables recommended by Health Canada (2012).

Table 4-1 General Physical Characteristics Assumed for Receptors in the Multiple Pathway Exposure Assessment

Physical Characteristic	*Life Stage*[a]				
	Infant	*Toddler*	*Child*	*Adolescent*	*Adult*
Duration of Life Stage (years)	0.5	4.5	7	8	29.5[b]
Inhalation rate (m³/d)	2.2	8.3	14.5	15.6	16.6
Soil ingestion rate (g/d)	0.02	0.08	0.02	0.02	0.02
Water ingestion rate (L/d)	0.3	0.6	0.8	1.0	1.5
Body Weight (kg)	8.2	16.5	32.9	59.7	70.7
Lifetime Adjustment Factor	0.010	0.091	0.14	0.16	0.60
Arms and legs body surface area (cm^2)	1,460	2,580	4,550	7,200	8,220
Hand surface area (cm^2)	320	430	590	800	890
Total surface area (cm^2)	3,620	6,130	10,140	15,470	17,640
Soil adherence factor – hands only ($g/cm^2/d$)	0.0001	0.0001	0.0001	0.0001	0.0001
Soil adherence factor – other than hands ($g/cm^2/d$)	0.00001	0.00001	0.00001	0.00001	0.00001

[a] Parameters are from Health Canada (2012).
[b] Adult life stage is the average life span reported by CIA (2013) less the sum of the remaining life stage lengths from Health Canada (2012).
[c] Lifetime adjustment factor utilizes the length of the life stages reported by Health Canada (2012) and the average life span reported by CIA (2013).

Table 4-2 Food Consumption Rates (kg/d) Assumed for the Residential Group

Agricultural Crops	*Food Consumption Rate by Life Stage*[a]					*Comment*
	Infant	*Toddler*	*Child*	*Adolescent*	*Adult*	
Exposed Aboveground Produce	0	0.067	0.098	0.120	0.137	Other vegetables ingestion rate
Belowground Produce	0	0.105	0.161	0.227	0.188	Root vegetables ingestion rate
Protected Aboveground Produce	0	0.067	0.098	0.120	0.137	Other vegetables ingestion rate
Fish	0	0.020	0.033	0.040	0.040	Health Canada (2007)

[a] Parameters are from Health Canada (2012), unless otherwise indicated.

4.2 Exposure Estimates

Ground-level ambient air concentrations for each receptor location and operational year used in the air quality assessment are provided in Appendix C.

Exposure estimates for the multi-pathway assessment for each receptor location evaluated are provided in Appendix D.

5.0 HAZARD ASSESSMENT

5.1 Human Health Hazard Assessment

The hazard assessment involves identifying and understanding potential health outcomes that can result from exposure to each of the COPCs and the conditions under which the outcomes might be observed. The hazard, or toxicity, assessment methodology is based on the fundamental dose response principle. That is, the response of biological systems to chemical exposures increases in proportion to the concentration of a chemical in critical target tissues where adverse health outcomes may occur.

5.1.1 Dose-Response Approaches

Two basic and quite different chemical categories are commonly recognized by regulatory agencies, depending on the compound's mode of toxic action, and applied when estimating toxicological criteria for humans (FDA, 1982; US EPA, 1989). These are the *threshold approach* (or the no-observed-adverse-effect levels [NOAELs]/benchmark dose with extrapolation/uncertainty factor approach) typically used to evaluate non-carcinogens, and the *non-threshold approach* (or the mathematical model-unit risk estimation approach), typically used for carcinogenic compounds.

Threshold Response Chemicals: For most effects, it is thought that there is a dose-response threshold below which no adverse effects would be expected to occur. This relationship is true for all chemicals that do not cause cancer by altering genetic material. Thresholds are generally assumed for non-carcinogenic effects because, for these types of effects, it is generally believed that homeostatic, compensating, and adaptive mechanisms must be overcome before toxicity is manifested. A NOAEL can be identified for threshold chemicals, which is the dose or amount of the chemical that results in no observable response in the most sensitive test species and test endpoint. The application of uncertainty or safety factors to the NOAEL provides an added level of protection, allowing for derivation of a *toxicity reference value* (TRV) or exposure limit that is expected to be safe to sensitive individuals following exposure for a prescribed period of time. Exposure limits derived for threshold-response chemicals are called reference concentrations (RfC), reference doses (RfD), acceptable daily intakes (ADI), tolerable daily intakes (TDI) or permissible daily intakes (PDI) and are generally derived by regulatory agencies such as Health Canada and the US EPA. These values indicate doses of chemicals that individuals can be exposed to on a daily basis over an entire lifetime without appreciable risk of the occurrence of adverse health effects.

Non-threshold Response Chemicals: This means that any exposure greater than zero is assumed to have a non-zero probability of causing some type of response or damage. This relationship is typically used for chemicals that can cause cancer by damaging genetic material. Under a "non-threshold" assumption, any exposure has some potential to cause damage, so it is necessary to define an "acceptable" level of risk associated with these types of exposures.

The acceptable level of risk is an issue of policy rather than a scientific decision (CCME, 2006), and is set by regulatory agencies as opposed to risk assessors. Regulatory agencies have typically employed acceptable incremental lifetime cancer risk (ILCR) levels (*i.e.*, over and above baseline) between 1-in-100,000 and 1-in-1,000,000. An ILCR represents the incremental risk of an individual within a given population developing cancer over his or her lifetime due to

exposures from a specific carcinogenic compound. As a result, ILCRs generally consider risks related to a particular project (the Project Alone scenario, excluding any contribution from other background or pre-existing sources) in that the cancer risks are expressed on an incremental or additional basis as compared to cancer risks related to all sources. Health Canada has specified an ILCR of 1-in-100,000, which is considered "essentially negligible" (Health Canada, 2012). This ILCR was used for comparison in the current RA.

5.1.2 Exposure Limit Terminology

The terminology used to define threshold and non-threshold exposure limits differs according to the source/media and type of exposure and often varies between regulatory jurisdictions. The following terms are used to describe exposure limits in the current assessment.

Reference concentration (RfC): The US EPA defines a reference concentration as *"…an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."* It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. A reference concentration refers to the acceptable level of an airborne chemical for which the primary route of exposure is inhalation, and applies to either acute (*i.e.*, less than 24 hours) or chronic (*i.e.*, more than three months) exposure periods. The reference concentration is expressed as a concentration of the chemical in air (*i.e.,* micrograms per cubic metre, $\mu g/m^3$) and applies only to chemicals acting through a threshold mode of toxicological action.

Reference dose (RfD): The US EPA defines a reference dose as *"…an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime*". It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. The reference dose is most commonly expressed in terms of the total intake of the chemical per unit of body weight (*i.e.,* micrograms per kilogram of body weight per day, µg/kg bw/day) and applies only to chemicals acting through a threshold mode of toxicological action.

Inhalation unit risk (IUR): The US EPA defines a unit risk value as "*…the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/L in water, or 1 $\mu g/m^3$ in air".* The risks are referred to as "upper bound" because they are not likely to be underestimated and, in fact, may range from as low as zero to the upper bound value. A unit risk value of 3.0×10^{-5} per $\mu g/m^3$ would mean that under an upper worst-case estimate, three excess cancer cases would be expected to develop per one hundred thousand (100,000) people, if all 100,000 people were exposed every day for a lifetime to 1 µg of the chemical per m^3 of air.

Cancer slope factor (SF): The US EPA defines a cancer slope factor (SF) as *"…[a]n upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg-day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100.*"

5.1.3 Exposure Duration

The toxicity of a chemical has been observed to vary between acute (short term) and chronic (long term) exposure. Thus, it is important to differentiate TRVs based on duration of exposure.

The two TRV durations used in the current HHRA can be described as follows:

- ***Acute:*** the amount or dose of a chemical that can be tolerated without evidence of adverse health effects on a short term basis. These benchmarks are routinely applied to conditions in which exposures extend from minutes through several hours or several days only (ATSDR, 2006). For the current HHRA, risks were evaluated based upon 1-hour and 24-hour exposure periods, where a relevant acute TRV for that time period is available.
- ***Chronic:*** the amount of a chemical that is expected to be without effect, even when exposure occurs continuously or regularly over extended periods, possibly lasting for periods of at least a year, and possibly extending over an entire lifetime (ATSDR, 2006).

5.1.4 Summary of Toxicological Reference Values

Individuals with compromised health or within sensitive life stages (*e.g.*, pregnancy, newborn infants, children and elderly) were considered in the assessment by ensuring that the selected exposure limits were sufficiently stringent to protect such individuals under most exposure conditions. TRVs are presented for those substances that are related to the inhalation pathway only (such as CACs), as well as substances which may be inhaled directly on particulate matter and could potentially also be ingested as a result of deposition on soils (such as metals). Where the endpoints for a specific COPC differ between the inhalation and oral pathways, two separate TRVs were used in the assessment accordingly.

5.1.4.1 Inhalation TRVs - CACs

For CACs, which include CO, $PM_{2.5}$, PM_{10}, NO_2 and SO_2, these substances were only assessed via the inhalation pathways, as these substances do not appreciably contribute to exposure via other pathways. The ambient air guidelines selected for the assessment of risks are the current WHO air quality guidelines. These values were selected for compliance purposes with the International Finance Corporation Environmental, Health, and Safety Guidelines. In the absence of suitable WHO guidelines, those value from US EPA were selected.

Table 5-1 Toxicity Reference Values (µg/m3) Used in Assessment of Ambient Air for Criteria Air Contaminants

Criteria Air Contaminant	Duration	Guideline	Description of Guideline	Reference
1-Hour Acute Exposure Limits				
Carbon monoxide (CO)	1-Hour	30,000	1-Hour daily maximum concentration	WHO, 2000
Nitrogen dioxide (NO_2)	1-Hour	190	98th Percentile of 1-hour daily maximum concentrations over 3 years	US EPA, 2010
Particulate matter - PM_{10}	NA	-	-	-
Particulate matter - $PM_{2.5}$	NA	-	-	-
Sulphur dioxide (SO_2)	1-Hour	200	99th Percentile of 1-hour daily maximum concentrations over 3 years	US EPA, 2010

Table 5-1 Toxicity Reference Values (µg/m3) Used in Assessment of Ambient Air for Criteria Air Contaminants

Criteria Air Contaminant	Duration	Guideline	Description of Guideline	Reference
8 Hour and 24-Hour Acute Exposure Limits				
Carbon monoxide	8-Hour	10,000	8-Hour daily maximum concentration	WHO, 2000
Nitrogen dioxide (NO_2)	NA	-	-	-
Particulate matter - PM_{10}	24-Hour	50	99th Percentile of 24-hour averages	WHO, 2006
Particulate matter - $PM_{2.5}$	24-Hour	25	99th Percentile of 24-hour averages	WHO, 2006
Sulphur dioxide (SO_2)	24-Hour	20	24-Hour average	WHO, 2006
Chronic Duration (Annual Average) Exposure Limits				
Carbon monoxide	NA	-	-	-
Nitrogen dioxide (NO_2)	Annual	40	Annual average	US EPA, 2010
Particulate matter - PM_{10}	Annual	20	Annual average	WHO, 2006
Particulate matter - $PM_{2.5}$	Annual	10	Annual average	WHO, 2006
Sulphur dioxide (SO_2)	Annual	50	Annual average	WHO, 2000

NA Not assessed. A suitable guideline is not available from the World Health Organization (WHO, 2000; 2006) or US EPA (2010).

5.1.4.2 Inhalation and Oral TRVs – Metals

Metals are anticipated to be present on dusts released from mining activities (associated with PM_{10} and $PM_{2.5}$), and therefore, could be inhaled on airborne particulate matter, as well as ingested through incidental soil contact or through the consumption of vegetation.

Non-cancer and carcinogenic TRVs were identified from various regulatory agencies, such as Health Canada, US EPA, WHO, and the Dutch National Institute for Public Health and the Environment (RIVM).

The chronic non-carcinogenic and carcinogenic inhalation TRVs for each of the metal COPCs (where they were available), as well as the regulatory source for each TRV, are provided in Table 5-2. Carcinogenic inhalation TRVs were presented as Inhalation Unit Risk values (IURs).

Table 5-2 Toxicity Reference Values (µg/m^3) Used in Assessment of Ambient Air Exposures for Metals

COPC (Metal)	Chronic Inhalation Toxicity Reference Values			
	Non-Cancer (µg/m^3)	Reference	Cancer (µg/m^3)$^{-1}$	Reference
Aluminum	5	US EPA, 2006	NV	-
Antimony	0.2	US EPA IRIS, 1995	NV	-
Arsenic	0.015	Cal EPA, 2008	6.4×10^{-3}	Health Canada, 2010
Beryllium	0.007	Cal EPA, 2001	2.4×10^{-3}	US EPA IRIS, 1998
Cadmium	0.005	MOE, 2007	9.8×10^{-3}	Health Canada, 2010
Chromium (III)	0.041	TCEQ, 2009	NV	-
Cobalt	0.1	WHO, 2006	NV	-
Iron	5	TCEQ, 2014	NV	-
Lead	0.15	US EPA, 2008	NV	-
Lithium	NV	-	NV	-
Manganese	0.05	US EPA IRIS, 1993	NV	-
Nickel	0.0402	MOE, 2011	NV	-
Selenium	0.2	TCEQ, 2014	NV	-
Thallium	0.1	TCEQ, 2014	NV	-
Uranium	NV	-	NV	-
Vanadium	0.1	ATSDR, 2012	NV	-
Zinc	2	TCEQ, 2014	NV	-

NV No value. A suitable inhalation TRV was not identified for this chemical and endpoint.

The chronic non-carcinogenic and carcinogenic oral TRVs for each of the metal COPCs (where they were available), as well as the regulatory source for each TRV, are provided in Table 5-3. Carcinogenic oral TRVs are presented as Cancer Slope Factors (OSFs).

Table 5-3 Toxicity Reference Values (µg/kg/d) Used in Assessment of Multi-Pathway Exposures for Metals

COPC (Metal)	Chronic Oral Toxicity Reference Values			
	Non-Cancer (µg/kg/d)	Reference	Cancer $(\mu g/kg/d)^{-1}$	Reference
Aluminum	143[a]	WHO 2013, 2010a,b	NV	-
Antimony	0.4	US EPA IRIS, 1991	NV	-
Arsenic	0.3	US EPA IRIS, 1993	1.8×10^{-3}	Health Canada, 2010
Beryllium	2	US EPA IRIS, 1998	NV	-
Cadmium	1	Health Canada, 2010	NV	-
Chromium (III)	1,500	US EPA IRIS, 1998	NV	-
Cobalt	1.4	RIVM, 2001	NV	-
Iron	700	US EPA, 2006	NV	-
Lead	0.6[b]	JECFA, 2011	NV	-
Lithium	2	US EPA, 2008	NV	-
Manganese	140	US EPA IRIS, 1996	NV	-
Nickel	11	Health Canada, 2010	NV	-
Selenium	5.5	Health Canada, 2010	NV	-
Thallium	0.02[c]	US EPA, 2012	NV	-
Uranium	0.6	Health Canada, 2010	NV	-
Vanadium	2	RIVM, 2009	NV	-
Zinc	500	Health Canada, 2010	NV	-

NV No value. A suitable oral TRV was not identified for this chemical and endpoint.
[a] TRV selected is based on a provisional tolerable weekly intake of 1,000 µg/kg/d.
[b] TRV selected is a point of departure for loss of 1 IQ point in children exposed to lead.
[c] TRV selected is for thallium (I) sulfate.

6.0 RISK CHARACTERIZATION

The final step of a risk assessment is risk characterization. This involves the estimation, description, and evaluation of risk associated with exposure to COPCs by comparing the estimated exposure to the appropriate regulatory benchmark or TRV for a specific chemical or group of compounds.

6.1 Overview

Risk characterization involves the comparison of estimated exposures (identified in the exposure assessment) with regulatory benchmarks or TRVs (identified during the hazard/toxicity assessment) to identify potential human health risks. This comparison is typically expressed as a Concentration Ratio (CR) or Hazard Quotient (HQ) for non-carcinogenic chemicals and is calculated by dividing the predicted exposure by the regulatory benchmark/TRV. In the case of direct acting non-threshold carcinogenic chemicals, potential risks are expressed as incremental lifetime cancer risks (ILCRs), and represents the incremental risk of an individual within a given population developing cancer over his or her lifetime due to exposures from a specific carcinogenic chemical of concern.

Separate assessments were completed for short term (acute) and long term (chronic) durations because the health outcomes produced by some COPCs depend on the duration of exposure. It is important to distinguish between the health outcomes that might result from acute exposures *versus* effects that may occur following chronic exposures. In the chronic assessment, further distinction was made between inhalation alone (which included all emitted COPCs) and multiple pathway exposures (*i.e.*, inhalation, oral and dermal together) since the pathway of exposure could also influence the potential health outcomes associated with each of the COPCs.

In recognition of the influence of these exposure variables, risk estimates were segregated into:

- Acute inhalation (1-hour and 24-hour durations, or 8-hour durations in the case of carbon monoxide);
- Chronic inhalation (annual average durations); and,
- Chronic multi-media pathways (*i.e.,* oral and dermal exposures).

6.1.1 Concentration Ratios (CRs) and Hazard Quotients (HQs) for Non-Carcinogens

Concentration Ratios (CR)
CR values were used to evaluate the acute and chronic health risk from exposure to chemicals *via* inhalation. CR values were calculated by dividing the predicted ground-level air concentration (for 1-hour, 8-hour, 24-hour, or annual average exposure durations) by the appropriate toxicity reference value (*i.e.*, RfC), according to the following example equation:

$$CR_{duration} = \frac{[Air]_{duration}}{RfC_{duration}}$$

Where:

$CR_{duration}$	=	the duration-specific *CR* (unitless), calculated for acute and chronic durations, as appropriate
$[Air]_{duration}$	=	the predicted ground-level air concentration (µg/m^3) for the specific time duration
$RfC_{duration}$	=	the RfC (µg/m^3) for the specific time duration

For a COPC expected to be present in a single environmental media, such as the case with many gases which occur only or predominately in ambient air, a benchmark representing the entire exposure limit (*i.e.*, a CR value of 1.0) is considered appropriate. Therefore, a CR value of 1.0 (*i.e.*, 100% of the exposure limit) ws used as the CR benchmark in the inhalation assessment. Acute and chronic CR values less than the selected benchmark (*i.e.*, CR ≤1.0), indicate that predicted concentrations of COPC in air were considered negligible and that adverse health effects would not be expected to occur.

When predicted risks are greater than the inhalation benchmark level (*i.e.*, CR > 1.0), this indicates the potential for adverse health outcomes may exist. This outcome is referred to as an "exceedance" (*i.e.*, the predicted ground-level air concentration is greater than, or exceeds, the corresponding inhalation exposure limit for that averaging period). Re-evaluation of such CR estimates is important since both the exposure estimates and the toxicological criteria are based on a series of conservative assumptions, particularly when considering the maximum "worst-case" exposure scenarios.

In general, interpretation of the CR values proceeded as follows:

Key Indicator	**Human Receptors**
	For non-carcinogenic compounds
Negligible	CR≤1.0
Low and likely to be negligible	1.0<CR≤10
Potentially elevated	CR>10

Hazard Quotients (HQ)

Hazard Quotient (HQ) values were used to express risk resulting from chronic exposures to systemically acting, non-carcinogenic chemicals. This approach were used where the exposure to the chemical occurs through multiple pathways, and shows the additional risks related to the oral and dermal exposure pathways. HQ values were calculated by dividing the predicted exposure (*via* multiple pathways) by the appropriate toxicity reference value (RfD), according to the following example equation:

$$HQ = \frac{Exposure}{RfD}$$

Where:

HQ	=	the chronic Hazard Quotient (unitless), calculated for chronic exposures resulting from multiple pathways of exposure
Exposure	=	the chronic exposure estimate resulting from multiple pathways of exposure (µg/kg bodyweight/day
RfD	=	the chronic RfD (µg/kg bodyweight/day)

For chronic multi-media exposures, the CCME (2006) typically allocates 20% of the total exposure to any one environmental media during the derivation of its health-based soil quality criteria. This was based on the assumption that the source of exposure to a particular chemical may occur *via* five potential media: air, food, water, soil, and consumer products. This means that, in the absence of a multi-media assessment that takes into account multiple sources or media, the exposure limit should be apportioned for the single medium under consideration.

For the current assessment a benchmark of 0.2 was selected for the evaluation of the chronic multi-media assessment of the Mine or Port alone emissions since not all potential exposure sources were considered (*i.e.*, the contribution of background sources of these chemicals were not quantified in the multi-media assessment). HQ values that are less than 0.2 represent a situation in which Mine- or Port-related exposures (*e.g.*, facility and transport-related emissions) account for less than 20% of the oral exposure limit (*e.g.*, oral RfD) and as a result are considered negligible. No adverse health risks are expected to be associated with the estimated level of exposure. When predicted health risks resulting from Project alone emissions were greater than the benchmark level (*i.e.*, HQ > 0.2), this may indicate the potential for adverse health outcomes among the most sensitive members of the population and triggers an additional evaluation. Re-evaluation of such HQs is important since both the exposure estimates and the TRV are based on a series of conservative assumptions, particularly when considering the maximum “worst-case” exposure scenarios.

In general, interpretation of the HQ values proceeded as follows:

Key Indicator	**Human Receptors**
	For non-carcinogenic compounds
Negligible	HQ≤0.2
Low and likely to be negligible	0.2<HQ≤10
Potentially elevated	HQ>10

6.1.2 Incremental Lifetime Cancer Risks (ILCRs) for Carcinogens

ILCR estimates were used to evaluate the increased cancer risk resulting from a lifetime of exposure to non-threshold genotoxic carcinogenic chemicals. ILCR estimates provide the incremental lifetime cancer risk resulting from contributions from Project emissions to the surrounding community.

Direct Air Inhalation
For carcinogenic chemicals evaluated as part of the inhalation assessment, ILCR estimates resulting from direct air inhalation were calculated as follows:

$$ILCR = [Air]_{Mine/Port} \times IUR$$

Where:

ILCR	=	the incremental (or additional) lifetime cancer risk (unitless)
$[Air]_{Mine/Port}$	=	the predicted annual average ground-level air concentration (µg/m^3) for the specific chemical arising from Mine or Port emissions
IUR	=	the chemical-specific inhalation unit risk value (µg/m^3)$^{-1}$

Multi-Media Exposure
For carcinogenic chemicals evaluated as part of the multi-media assessment, ILCR estimates resulting from a lifetime of exposure through multiple pathways were calculated as follows:

$$ILCR = LADD \times CSF$$

Where:

ILCR	=	the incremental lifetime cancer risk (unitless)
LADD	=	the incremental Lifetime Average Daily Dose *via* multiple pathways resulting from facility emissions (µg/kg bodyweight/day)
CSF	=	the chemical-specific cancer slope factor (µg/kg bodyweight/day)$^{-1}$

The resulting estimated incremental lifetime cancer risk can be compared to an acceptable risk level of cancer to determine if predicted exposures pose an unacceptable health risk. Health Canada (2012) recommends the use of an acceptable ILCR of one-in-one hundred thousand (or 1-in-100,000). This risk level is considered negligible

In general, interpretation of the ILCR values proceeded as follows:

Key Indicator	**Human Receptors**
	For carcinogenic compounds
Negligible	No change from baseline or ILCR $\leq 1\times10^{-5}$
Low and likely to be negligible	$1\times10^{-5} < ILCR \leq 1\times10^{-4}$
Potentially elevated	$ILCR > 1\times10^{-4}$

6.2 Human Health Risk Assessment of Areas near the Farim Mine Site

6.2.1 Problem Formulation Summary

The approach taken to characterize and/or predict exposure, hazard and risk for receptors using the area of interest is presented under each of the possibly affected media sections below. Table 6-1 provides a high level summary of the approach, and the various types of information derived at the Problem Formulation stage.

Baseline soil, groundwater, and fish tissue data used in the assessment are provided in Appendix D. Predicted future air data are provided in Appendix C.

Table 6-1 Summary of Exposure, Hazard and Risk Characterization Approaches for Each Environmental Media Potentially Affected by Project Activities for the Mine Site

Media	*Exposure Assessment*			*Hazard Assessment*	*Risk Characterization*
	Baseline	*Project Alone*	*Baseline + Project*		
Air	Criteria Air Contaminants (CACs) were predicted using air dispersion modelling. For non-CACs, current ground level air concentrations were predicted using a ratio based on the relative contribution of ore and waste overburden soil to PM_{10} emissions (for metals).	CACs predicted using air dispersion modelling based on projected Project-sourced emissions. For non-CACs, future ground level air concentrations were predicted based on the relative contribution of ore and waste overburden soil to PM_{10} emissions for metals.	Cumulative concentrations of CACs from the measured Baseline and modelled Project Alone were combined. For non-CACs, cumulative ground level air concentrations were predicted based on the estimated metals compositions of measured and predicted PM_{10} emissions for the Baseline and Project Alone scenarios, respectively.	Human health-based ambient air quality guidelines, standards or reference air concentrations from regulatory agencies; health effects literature, as needed	Comparison of predicted ambient air concentrations to health-based ambient air concentrations, guidelines or standards, for each scenario (Baseline; Project Alone; Baseline + Project) Examination of potential incremental change as a result of the Project.
Soil	Surface soil sampling (156 samples) was conducted in Mine site area (Knight Piésold, 2015a). Exposure point concentrations were derived using the 95th percentile upper confidence limit mean (95UCLM) concentrations, maximum concentration if detectable concentrations were limited, or half of the maximum reportable detection limit in the absence of any detected concentrations.	Modelled approach, through the application of weighted deposition rates predicted as a result of project (Knight Piésold, 2015b) onto area soils, with an assumed mixing layer, for 26 years of operations. Ore and waste overburden geochemistry provided by Knight Piésold (2015b) was used to characterize potential metals in deposited dusts.	Assessment of predicted exposures to cumulative Baseline and Project Alone soil concentrations. The potential change in soils as a result of project activities was added to measured baseline.	Oral TRVs from appropriate regulatory agencies	Comparisons of exposures as a result of incidental ingestion of predicted Baseline, Project Alone, and Baseline + Project soils, as well as inclusion of other oral pathways (crops; water - see below) to regulatory oral TRVs. Examination of potential incremental change as a result of the Project.

Table 6-1 Summary of Exposure, Hazard and Risk Characterization Approaches for Each Environmental Media Potentially Affected by Project Activities for the Mine Site

Media	*Exposure Assessment*			*Hazard Assessment*	*Risk Characterization*
	Baseline	*Project Alone*	*Baseline + Project*		
Agricultural Foods	Modelled approach, through the application of measured baseline soil data provided by Knight Piésold (2015a)	Modelled approach, through the application of modelled deposition data for four representative project years provided by Knight Piésold (2015b), weighted over the 26 year operations period. Chemicals were assumed to be deposited onto area soils and vegetation directly for the projected 26 year operations phase. Uptake factors from literature were used to estimate potential uptake into crops by both soil pathway and direct deposition.	Assessment of predicted exposures to cumulative Baseline and Project Alone agricultural food concentrations. The potential change in food concentrations as a result of project activities was added to measured baseline.	Oral TRVs from appropriate regulatory agencies	Comparisons of exposures as a result of incidental ingestion of Baseline, Project Increment and Baseline + Project predicted future agricultural foods, in conjunction with other oral pathways (incidental soil ingestion; water) to regulatory oral TRVs. Examination of potential incremental change as a result of the Project.
Groundwater	Baseline metals data from area groundwater, which were assumed to be representative of current potable sources	No predicted change to water concentrations as a result of Project activities. This medium was not evaluated.	Only the Baseline contribution was considered.	Oral TRVs from appropriate regulatory agencies	Comparisons of exposures as a result of incidental ingestion of Baseline, Project Increment and Baseline + Project predicted future water, in conjunction with other oral pathways (incidental soil ingestion; crops) to regulatory oral TRVs.

6.2.2 Acute-Duration Air Quality Assessment

Concentration Ratio (CR) values were used to evaluate acute and chronic health risks resulting from exposures to COPCs *via* inhalation. CR values were calculated by dividing the predicted ground-level air concentration of a COPC (Section 3.5.1) by the appropriate health-based TRV (Section 5.1.4).

In general, a CR value less than or equal to one (CR value ≤1) represents a situation where the predicted ground-level air concentration at a specific receptor location is less than a corresponding health-based TRV. Considering the various assumptions used that attempt to over predict rather than under predict ground-level air concentrations and the typical uncertainty factors applied during the development of a health-based TRV, a CR value less than or equal to one (CR value ≤ 1) at the receptor location is a strong indicator of negligible health risks resulting from exposure to a particular COPC.

A CR value greater than one (CR value > 1) is indicative of a scenario whereby the predicted ground level air concentration is greater than the corresponding health-based TRV, suggesting that the potential for an adverse health effect may be present. The significance of the exceedance must be balanced against the degree of conservatism incorporated in the derivation of the TRVs as well as the predicted ground-level concentrations. Predicted CR values greater than 1 (CR>1.0) but less than or equal to 10 (CR≤10) represent health risks that are considered low and likely negligible, whereas health risks associated with CR values greater than 10 (CR>10) are considered potentially elevated.

Acute CR values are presented under existing baseline conditions, 'Project Alone', and 'Baseline + Project' scenarios for each COPC. CR values were presented for those COPC with a TRV data corresponding to the relevant exposure duration. Risk estimate tables for the five receptor locations near the Mine site are presented in Appendix C. The following sections evaluate risks to human health from COPCs in air for the Project Alone and Baseline + Project scenarios.

6.2.2.1 Project Alone Scenario

With the exception of NO_2, all 1-hour acute CR estimates for operational years 2, 8, 15, and 25 were less than a value of one (1.0) under the Project Alone scenario (Tables C-35 through C-38). This indicates that contributions from the Project (other than NO_2) are not expected to result in adverse acute inhalation health effects (*i.e.,* negligible risk).

For the Project Alone scenario, acute 1-hour CR estimates for NO_2 were greater than a value of one (CR > 1.0) at three separate locations (Year 2: R9; Year 8: R2; Year 15: R2 and R15). However, all of the CR estimates were less than 2.0, which indicates that the predicted health risks are low and likely to be negligible.

Additionally, the 1-hour risk estimates represent the maximum NO_2 concentrations and are likely not representative of the entire project duration. This is evidenced by the lack of consistent CR values above one (CR>1.0) at these locations for all operational year scenarios evaluated. However, it was not possible to further evaluate the frequency of these exceedances due to an absence of this information.

With the exception of PM_{10} and $PM_{2.5}$, all 8-hour and 24-hour acute CR estimates for operational years 2, 8, 15, and 25 were less than a value of one (1.0) under the Project Alone scenario (Tables C-39 through C-42). This indicates that contributions from the Project Alone (other than particulate matter) are not expected to result in adverse acute inhalation health effects (*i.e.,* negligible risk).

24-hour acute CR estimates for operational years 2, 8, 15, and 25 for $PM_{2.5}$ and/or PM_{10} were greater than a value of one but less than ten (1.0<CR<10) under the Project Alone scenario for at least three receptor locations per operational year evaluated (Year 2: R2, R9, and R22; Year 8: R2, R9, and R22; Year 15: R2, R9, R15, and R22; Year 25: R2, R9, R12, and R15). This indicates that contributions from the Project may result in adverse acute inhalation health effects associated with acute-duration particulate matter inhalation exposure but this risk is considered low and likely to be negligible.

The 24-hour risk estimates represent the maximum PM_{10} and $PM_{2.5}$ concentrations and are likely not representative of the entire project duration. This is evidenced by the lack of consistent CR risk estimates greater than one (CR>1.0) at these locations for all operational year scenarios evaluated. However, it was not possible to further evaluate the frequency of these exceedances due to an absence of this information.

While exposures to metals in air may occur over an acute-duration *via* exposure to particulate matter, only chronic-duration exposures (*i.e.,* annual average concentration) were considered in the air quality assessment for metals.

6.2.2.2 Baseline + Project Scenario

The Project + Baseline Scenario represents the cumulative risk estimates from COPCs in air from both baseline conditions and Project-related impacts to air quality.

With the exception of NO_2, all 1-hour acute CR estimates for operational years 2, 8, 15, and 25 were less than a value of one (1.0) under the Project Alone scenario (Tables C-52 through C-54). For the Baseline + Project scenario, acute 1-hour CR estimates were greater than a value of one but less than ten (1.0<CR<10) for NO_2 at three separate locations (Year 2: R9; Year 8: R2; Year 15: R2 and R15).

The NO_2 risk estimates (CRs) for Baseline + Project are consistent with those of the Project Alone Scenario, such that the proposed Project is likely the major contributor of NO_2 emissions at these locations. Based on the results of the current air quality assessment, consideration should be given to the mitigation and monitoring of NO_2 emissions from Mine operations.

Due to an absence of suitable acute-duration baseline data for particulate matter (PM_{10} and $PM_{2.5}$), it was not possible to calculate Project + Baseline scenario risks. As a result, it was also not possible to calculate risk estimates from metals in air for the acute-duration. This represents a significant uncertainty with respect to the overall impact that the Project will have on air quality. In order to reduce these uncertainties, it is highly recommended that baseline monitoring be conducted to better quantify particulate matter concentrations in the absence of the Project.

6.2.3 Chronic-Duration Air Quality Assessment

The potential for chronic adverse health effects resulting from long-term exposures (*via* inhalation) were evaluated at each of the receptor locations. Chronic non-carcinogenic CR values are presented under existing baseline conditions, 'Project Alone', and 'Baseline + Project' scenarios for each COPC. Chronic ILCR values are presented under the 'Project Alone' scenarios for carcinogenic metals. CR and ILCR values were presented for those COPCs with TRV data corresponding to the relevant exposure duration. Risk estimate tables for the five receptor locations are presented in Appendix C.

A non-cancer CR value less than or equal to one (CR ≤ 1.0) at the receptor location is a strong indicator of negligible health risks resulting from exposure to a particular COPC. Health risks associated with CR values greater than 1 (CR>1.0) but less than or equal to 10 (CR≤10) were considered low and likely to be negligible, whereas health risks associated with CR values greater than 10 (CR>10) were considered potentially elevated.

An ILCR value less than or equal to one-in-one hundred thousand (ILCR ≤ 1.0×10^{-5}) at a receptor location is a strong indicator risks resulting from exposure to a particular carcinogenic COPC would not be different from baseline. Health risks associated with ILCR values greater than one-in-one hundred thousand but less than or equal to one-in-ten thousand (1.0×10^{-5} ILCR≤1.0×10^{-4}) were considered low and likely negligible. Health risks associated with ILCR values greater than one-in-ten thousand (ILCR>1.0×10^{-4}) were considered potentially elevated.

6.2.3.1 Project Alone

With the exception of particulate matter, all annual average CR estimates for operational years 2, 8, 15, and 25 were less than a value of one (1.0) under the Project Alone scenario (Tables C-43 through C-46). This indicates that contributions from the Project (other than particulate matter) are not expected to result in adverse chronic inhalation health effects (*i.e.,* negligible risks).

As with the acute-duration risk estimates, chronic-duration (annual average) CR estimates for operational years 2 and 15 for $PM_{2.5}$ and/or PM_{10} were greater than a value of one but less than ten (1.0<CR<10) under the Project Alone scenario for at least two receptor locations (Year 2: R2 and R9; Year 15: R2, R9, and R15). This indicates that contributions from the Project may result in adverse chronic-inhalation health effects from exposure to particulate matter; however, the predicted health risks were considered low and likely to be negligible. The maximum annual average CRs for PM_{10} and $PM_{2.5}$ were 6.8 and 4.0, respectively (Year 15, R2).

Despite the occurrence of greater than negligible risk estimates, chronic-duration inhalation risks from particulate matter are highly dependent on where mining operations are taking place. This is evidenced by the absence of greater than negligible risk estimates (CR>1.0) for two of the operational year scenarios (Years 8 and 25).

Airborne concentrations of metals were estimated based on levels of PM_{10} in the air. Chronic-duration (annual average) CR estimates for operational years 2, 8, 15, and 25 were greater than a value of one but less than 10 (1.0<CR<10) under the Project Alone scenario for at least one metal (Tables C-47 through C-50).

Non-cancer risk estimates greater than one but less than ten (1.0<CR<10) from chronic-duration inhalation exposure were predicted for aluminum, arsenic, chromium (III), iron, and manganese. Cancer risks estimates from chronic-duration inhalation exposure for arsenic were predicted to be greater than 1-in-100,000 but less than 1-in-10,000 ($1.0x10^{-5}$<ILCR<$1.0x10^{-4}$). The health risk associated with the predicted CRs and ILCRs were considered low and likely to be negligible.

The predicted greater than negligible risks (CR>1.0, ILCR>$1.0x10^{-5}$) for metals were most prevalent at locations R2 and R9, with only three such predictions for R15 (Year 15: aluminum, arsenic, iron). No greater than negligible risks, under any operational year evaluated, were predicted for receptor locations R15 and R22.

6.2.3.1 Baseline + Project Scenario

The Baseline + Project Scenario represents the cumulative risk estimates from COPCs in air from both baseline conditions and Project-related impacts to air quality.

With the exception of particulate matter (PM_{10} and $PM_{2.5}$), all annual average CAC CR estimates for operational years 2, 8, 15, and 25 were less than a value of one (CR<1.0) under the Baseline + Project scenario (Tables C-59 through C-62) (*i.e.,* negligible risk).

For the Baseline + Project scenario, annual average CR estimates for PM_{10} and $PM_{2.5}$ were in excess of one but less than ten (1.0<CR<10) for all locations and operational years evaluated. The maximum predicted annual average CRs for PM_{10} and $PM_{2.5}$ were from receptor location R2 for operational Year 15 (PM_{10}: 6.8, $PM_{2.5}$: 4.0).

While the cumulative Baseline + Project scenario risk estimates for PM_{10} and $PM_{2.5}$ exceeded a CR of 1.0, with the exception of a single receptor location ($PM_{2.5}$: Year 15, R2), the overall contributions of particulate matter from Baseline conditions were greater than the Project Alone (Tables 6-2 and 6-3).

Table 6-2 Contribution of Cumulative Baseline + Project Annual Average PM_{10} Concentration Ratios from Project Alone for Receptor Locations near Mine Site

Receptor Location		Operational Year			
		Year 2	*Year 8*	*Year 15*	*Year 25*
R2	Bani	31%	18%	48%	21%
R9	Nema	29%	16%	26%	14%
R12	Sandjal	3%	1%	4%	6%
R15	Sara Loba	8%	4%	25%	11%
R22	Tungina	11%	9%	8%	5%

Table 6-3 Contribution of Cumulative Baseline + Project Annual Average $PM_{2.5}$ Concentration Ratios from Project Alone for Receptor Locations near Mine Site

Receptor Location		Operational Year			
		Year 2	*Year 8*	*Year 15*	*Year 25*
R2	Bani	49%	29%	66%	33%
R9	Nema	48%	24%	41%	21%
R12	Sandjal	5%	2%	8%	10%
R15	Sara Loba	15%	8%	41%	19%

Table 6-3	Contribution of Cumulative Baseline + Project Annual Average $PM_{2.5}$ Concentration Ratios from Project Alone for Receptor Locations near Mine Site				
Receptor Location		**Operational Year**			
		Year 2	***Year 8***	***Year 15***	***Year 25***
R22	Tungina	23%	15%	14%	8%

Despite the generally low contributions to risks from Project Alone (Tables 4-2 and 4-3), the cumulative Baseline + Project risk estimates (Tables C-59 through C-62) indicate health risks are in the low and likely to be negligible range. However, consideration should be given to the mitigation and monitoring of particulate matter emissions in the vicinity of the Mine site.

Due to an absence of suitable chronic-duration baseline data for particulate matter (PM_{10} and $PM_{2.5}$), it was not possible to calculate Project + Baseline scenario risks. As a result, it was also not possible to calculate risk estimates from metals in air for the chronic-duration. This represents a significant uncertainty with respect to the overall impact that the Project will have on air quality. In order to reduce these uncertainties, it is highly recommended that baseline monitoring be conducted to better quantify particulate matter concentrations in the absence of the Project.

6.2.4 Multi-Pathway Assessment

As demonstrated by the multi-pathway screening approach (Section 3.8 and Appendix A), not all COPC identified for evaluation *via* inhalation will persist and/or accumulate in the environment. The multi-pathway screening approach identified those COPC that have the potential to persist and/or accumulate in the environment, therefore, triggering a quantitative multi-pathway assessment.

The objective of the multi-pathway assessment was to predict human health risks resulting from chronic exposures to COPC *via* multiple exposure pathways and environmental media. Under the residential scenario, it was assumed that a family would live their entire lives without ever leaving the receptor location while being exposed to COPC through multiple exposure pathways, including:

- Incidental ingestion of soil and dust;
- Direct dermal contact with soil and dust;
- Inhalation and subsequent ingestion of course particulate matter;
- Ingestion of exposed aboveground, belowground, and protected aboveground agricultural crops; and,
- Ingestion of fish.

Human health risk estimates under existing baseline conditions, ‘Project Alone’, and ‘Baseline + Project’ scenarios at the five receptor locations are described below. Both non-cancer and carcinogenic risks (HQ values) are presented, where applicable. For the non-cancer risk estimates, results are presented for the highest predicted HQ of the five life stages. Cancer risk estimates (HQ values) are provided for the lifetime (or composite) receptor. Risk estimate tables for the five receptor locations are presented in Appendix D.

A non-carcinogenic HQ value less than or equal to 0.2 (HQ≤0.2) at the receptor location is a strong indicator of negligible health risks resulting from exposure to a particular COPC. Health risks associated with HQ values greater than 0.2 (HQ>0.2) but less than or equal to 10 (HQ≤10) were considered low and likely to be negligible, whereas health risks associated with HQ values greater than 10 (HQ>10) were considered potentially elevated.

An ILCR value less than or equal to one-in-one hundred thousand (ILCR ≤ 1.0×10^{-5}) at a receptor location is a strong indicator risks resulting from exposure to a particular carcinogenic COPC would not be different from baseline. Health risks associated with ILCR values greater than one-in-one hundred thousand but less than or equal to one-in-ten thousand (1.0×10^{-5} ≤ILCR≤1.0×10^{-4}) were considered low and likely negligible. Health risks associated with ILCR values greater than one-in-ten thousand (ILCR>1.0×10^{-4}) were considered potentially elevated.

6.2.4.1 Project Alone

The predicted non-carcinogenic HQ values for all COPCs at all five (5) receptor locations (*i.e.,* R2, R9, R12, R15, and R22) were less than a value of 0.2 under the Project Alone scenario (Tables D-22 through D-26). This indicates that contributions from the Project alone are not expected to result in adverse chronic non-carcinogenic health effects (*i.e.,* negligible risks).

The predicted carcinogenic ILCR values for arsenic at all five (5) receptor locations were less than a value of 1.0×10^{-5} under the Project Alone scenario (Tables D-22 through D-26). This indicates that contributions from the Project alone are not expected to result in adverse chronic carcinogenic health effects (*i.e.,* negligible risks).

6.2.4.1 Baseline + Project Scenario

The Baseline + Project Scenario represents the cumulative risk estimates from COPCs in multiple exposure pathways from both baseline conditions and Project-related impacts to environmental media.

The predicted non-carcinogenic HQ values for cadmium and vanadium at all five (5) receptor locations were less than a value of 0.2 under the Baseline + Project scenario (Tables D-22 through D-26). This indicates that cumulative contributions from baseline conditions and the Project are not expected to result in adverse chronic non-carcinogenic health effects (*i.e.,* negligible risks).

The predicted non-carcinogenic HQ values for aluminum, arsenic, iron, and lead at all five (5) receptor locations were above a value of 0.2 but less than a value of 10 under the Baseline + Project scenario (Tables D-22 through D-26). This indicates that contributions from baseline conditions and the Project are considered low and likely to be negligible. Furthermore, all Baseline + Project scenario HQ values were less than a value of 1.0 indicating that cumulative exposures were less than the selected regulatory benchmarks. It should be noted that the Project Alone non-carcinogenic HQ values for these four (4) COPCs were below a value of 0.2, and the elevated HQs under the Baseline + Project scenario are the result of elevated Baseline scenario HQ values.

There is no recommended or acceptable LCR benchmark associated with exposures to carcinogenic substances resulting from existing background or baseline conditions and,

therefore, the LCR estimates for ‘Baseline’ and ‘Baseline + Project’ scenarios are provided for reference only.

6.3 Human Health Risk Assessment of Areas near The Port Site

6.3.1 Problem Formulation Summary

The approach taken to characterize and/or predict exposure, hazard and risk for receptors using the area of interest is presented under each of the possibly affected media sections below. Table 6-4 provides a high level summary of the approach, and the various types of information derived at the Problem Formulation stage.

Table 6-4 Summary of Exposure, Hazard and Risk Characterization Approaches for Each Environmental Media Potentially Affected by Project Activities for the Port Site

Media	***Exposure Assessment***			***Hazard Assessment***	***Risk Characterization***
	Baseline	***Project Alone***	***Baseline + Project***		
Air	Criteria Air Contaminants (CACs) were predicted using air dispersion modelling. For non-CACs, current ground level air concentrations were predicted using phosphate rock concentrate geochemistry and estimated PM_{10} emissions.	CACs predicted using air dispersion modelling based on projected Project-sourced emissions. For non-CACs, future ground level air concentrations were predicted based on phosphate rock concentrate geochemistry and estimated PM_{10} emissions.	Cumulative concentrations of CACs from the measured Baseline and modelled Project Alone were combined. For non-CACs, cumulative ground level air concentrations were predicted based on the estimated metals compositions of predicted PM_{10} emissions for the Baseline and Project Alone scenarios, respectively.	Human health-based ambient air quality guidelines, standards or reference air concentrations from regulatory agencies; health effects literature, as needed	Comparison of predicted ambient air concentrations to health-based ambient air concentrations, guidelines or standards, for each scenario (Baseline; Project Alone; Baseline + Project) Examination of potential incremental change as a result of the Project.
Soil	Surface soil sampling (15 samples) was conducted in Port site area (Knight Piésold, 2015a). Exposure point concentrations were derived using the 95th percentile upper confidence limit mean (95UCLM) concentrations, maximum concentration if detectable concentrations were limited, or half of the maximum reportable detection limit in the absence of any detected concentrations.	Modelled approach, through the application of weighted deposition rates predicted as a result of project (Knight Piésold, 2015b) onto area soils, with an assumed mixing layer, for 26 years of operations. Phosphate rock concentrate geochemistry provided by Knight Piésold (2015b) was used to characterize potential metals in deposited dusts.	Assessment of predicted exposures to cumulative Baseline and Project Alone soil concentrations. The potential change in soils as a result of project activities was added to measured baseline.	Oral TRVs from appropriate regulatory agencies	Comparisons of exposures as a result of incidental ingestion of predicted Baseline, Project Alone, and Baseline + Project soils, as well as inclusion of other oral pathways (crops; water - see below) to regulatory oral TRVs. Examination of potential incremental change as a result of the Project.

Table 6-4 Summary of Exposure, Hazard and Risk Characterization Approaches for Each Environmental Media Potentially Affected by Project Activities for the Port Site

Media	*Exposure Assessment*			*Hazard Assessment*	*Risk Characterization*
	Baseline	*Project Alone*	*Baseline + Project*		
Agricultural Foods	Modelled approach, through the application of measured baseline soil data provided by Knight Piésold (2015a)	Modelled approach, through the application of modelled deposition data for four representative project years provided by Knight Piésold (2015b), weighted over the 26 year operations period. Chemicals were assumed to be deposited onto area soils and vegetation directly for the projected 26 year operations phase. Uptake factors from literature were used to estimate potential uptake into crops by both soil pathway and direct deposition.	Assessment of predicted exposures to cumulative Baseline and Project Alone agricultural food concentrations. The potential change in food concentrations as a result of project activities was added to measured baseline.	Oral TRVs from appropriate regulatory agencies	Comparisons of exposures as a result of incidental ingestion of Baseline, Project Increment and Baseline + Project predicted future agricultural foods, in conjunction with other oral pathways (incidental soil ingestion; water) to regulatory oral TRVs. Examination of potential incremental change as a result of the Project.
Groundwater	Baseline metals data from area groundwater, which were assumed to be representative of current potable sources	No predicted change to water concentrations as a result of Project activities. This medium was not evaluated.	Only the Baseline contribution was considered.	Oral TRVs from appropriate regulatory agencies	Comparisons of exposures as a result of incidental ingestion of Baseline, Project Increment and Baseline + Project predicted future water, in conjunction with other oral pathways (incidental soil ingestion; crops) to regulatory oral TRVs.

6.3.2 Acute-Duration Air Quality Assessment

Concentration Ratio (CR) values were used to evaluate acute and chronic health risks resulting from exposures to COPCs *via* inhalation. CR values were calculated by dividing the predicted ground-level air concentration of a COPC (Section 3.5.1) by the appropriate health-based TRV (Section 5.1.4).

In general, a CR value less than or equal to one (CR value ≤1) represents a situation where the predicted ground-level air concentration at a specific receptor location is less than a corresponding health-based TRV. Considering the various assumptions used that attempt to over predict rather than under predict ground-level air concentrations and the typical uncertainty factors applied during the development of a health-based TRV, a CR value less than or equal to one (CR value ≤ 1) at the receptor location is a strong indicator of negligible health risks resulting from exposure to a particular COPC.

A CR value greater than one (CR value > 1) is indicative of a scenario whereby the predicted ground level air concentration is greater than the corresponding health-based TRV, suggesting that the potential for an adverse health effect may be present. The significance of the exceedance must be balanced against the degree of conservatism incorporated in the derivation of the TRVs as well as the predicted ground-level concentrations. Predicted CR values greater than 1 (CR>1.0) but less than or equal to 10 (CR≤10) represent health risks that are considered low and likely negligible, whereas health risks associated with CR values greater than 10 (CR>10) are considered potentially elevated.

Acute CR values are presented under existing baseline conditions, 'Project Alone', and 'Baseline + Project' scenarios for each COPC. CR values were presented for those COPC with a TRV data corresponding to the relevant exposure duration. Risk estimate tables for the five receptor locations near the Mine site are presented in Appendix C. The following sections evaluate risks to human health from COPCs in air for the Project Alone and Baseline + Project scenarios.

6.3.2.1 Project Alone Scenario

With the exception of NO_2, all 1-hour acute CR estimates for all operational years were less than a value of one (1.0) under the Project Alone scenario (Table C-68). This indicates that contributions from the Project (other than NO_2) are not expected to result in adverse acute inhalation health effects for the 1-hour exposure duration.

For the Project Alone scenario, acute 1-hour CR estimates were greater than a value of one but less than ten (1.0<CR<10) for NO_2 at one location (*i.e.,* R70). Therefore, the health risk associated with this CR value is considered low and likely negligible.

The 1-hour risk estimates represent the maximum NO_2 concentrations and are likely not representative of the entire project duration. This is evidenced by the lack of consistent greater than negligible risks (CR>1.0) at these locations for all operational year scenarios evaluated. However, it was not possible to further evaluate the frequency of these exceedances due to an absence of this information.

With the exception of SO_2, all 8-hour and 24-hour acute CR estimates for all operational years were less than a value of one (1.0) under the Project Alone scenario (Table C-68). This indicates that contributions from the Project Alone (other than SO_2) are not expected to result in adverse acute inhalation health effects.

The 24-hour acute CR estimates for SO_2 for all operational years were marginally above a CR of 1.0 (*i.e.,* CR=1.1). As a result, the risk to human health was considered low and likely negligible. The 24-hour risk estimates represent the maximum SO_2 concentrations and are likely not representative of the entire project duration. This is evidenced by the lack of consistent greater than negligible risks (CR>1.0) at these locations for all operational year scenarios evaluated. However, it was not possible to further evaluate the frequency of these exceedances due to an absence of this information.

While exposures to metals in air may occur over an acute-duration *via* exposure to particulate matter, only chronic-duration exposures (*i.e.,* annual average concentration) were considered in the air quality assessment for metals. Given the relatively low concentrations of particulate matter predicted for the Port receptor locations, it is not anticipated that metals in air represent a significant health risk at these locations.

6.3.2.2 Project + Baseline Scenario

The Project + Baseline Scenario represents the cumulative risk estimates from COPCs in air from both baseline conditions and Project-related impacts to air quality.

With the exception of NO_2 and SO_2, all acute CR estimates for all operational years were less than a value of one (1.0) under the Project Alone scenario (Table C-68). For the Baseline + Project scenario, acute NO_2 1-hour CR estimates were greater than a value of one but less than ten (1.0<CR<10) at one location (R70). Similarly, acute 24-hour CR estimates were greater than a value of one but less than 10 (1.0<CR<10) for SO_2 at the same location (R70).

These NO_2 and SO_2 risk estimates (CRs) for Baseline + Project are consistent with those of the Project Alone Scenario, such that the proposed Project is likely the major contributor of NO_2 and SO_2 emissions at these locations. Therefore, based on the results of the current air quality assessment, consideration should be given to the mitigation and monitoring of NO_2 and SO_2 emissions from Port operations.

Due to an absence of suitable acute-duration baseline data for particulate matter (PM_{10} and $PM_{2.5}$), it was not possible to calculate Project + Baseline scenario risks. As a result, it was also not possible to calculate risk estimates from metals in air for the acute-duration. This represents a significant uncertainty with respect to the overall impact that the Project will have on air quality. In order to reduce these uncertainties, it is highly recommended that baseline monitoring be conducted to better quantify particulate matter concentrations in the absence of the Project.

6.3.3 Chronic-Duration Air Quality Assessment

The potential for chronic adverse health effects resulting from long-term exposures (*via* inhalation) were evaluated at each of the receptor locations. Chronic non-carcinogenic CR values are presented under existing baseline conditions, ‘Project Alone’, and ‘Baseline + Project’ scenarios for each COPC. Chronic ILCR values are presented under the ‘Project Alone’

scenarios for carcinogenic metals. CR and ILCR values were presented for those COPCs with TRV data corresponding to the relevant exposure duration. Risk estimate tables for the five receptor locations are presented in Appendix C.

A non-cancer CR value less than or equal to one (CR ≤ 1.0) at the receptor location is a strong indicator of negligible health risks resulting from exposure to a particular COPC. Health risks associated with CR values greater than 1 (CR>1.0) but less than or equal to 10 (CR≤10) were considered low and likely to be negligible, whereas health risks associated with CR values greater than 10 (CR>10) were considered potentially elevated.

An ILCR value less than or equal to one-in-one hundred thousand (ILCR ≤ 1.0×10^{-5}) at a receptor location is a strong indicator risks resulting from exposure to a particular carcinogenic COPC would not be different from baseline. Health risks associated with ILCR values greater than one-in-one hundred thousand but less than or equal to one-in-ten thousand (1.0×10^{-5} ILCR≤1.0×10^{-4}) were considered low and likely negligible. Health risks associated with ILCR values greater than one-in-ten thousand (CR>1.0×10^{-4}) were considered potentially elevated.

6.3.3.1.1 Project Alone

With the exception of NO_2, all annual average CR estimates for all operational years were less than a value of one (1.0) under the Project Alone scenario (Table C-68). This indicates that contributions from the Project (other than NO_2) are not expected to result in adverse chronic inhalation health effects (*i.e.,* negligible risks).

As with the acute-duration risk estimates, chronic-duration (annual average) CR estimates for all operational years for NO_2 were greater than a value of one but less than 10 (1.0<CR<10) under the Project Alone scenario for receptor location R70. The maximum annual average CR for NO_2 was 1.4.

Airborne concentrations of metals were estimated based on levels of PM_{10} in the air. Chronic-duration (annual average) CR estimates for all operational years were less than a value of one (1.0) under the Project Alone scenario for all metals (Table C-69). Annual average ILCRs for all operational years were less than one-in-one hundred thousand (ILCR<1.0×10^{-5}) for all metals. This indicates that risks from metals in air at receptor locations near the Port site are considered negligible. Due to a lack of a suitable TRVs uranium, risks from this chemical could not be determined.

6.3.3.1.2 Project + Baseline Scenario

The Project + Baseline Scenario represents the cumulative risk estimates from COPCs in air from both baseline conditions and Project-related impacts to air quality.

For the Baseline + Project scenario, annual average CR estimates for PM_{10} and $PM_{2.5}$ were in excess of one but less than ten (1.0<CR <10) for all locations and operational years evaluated. The maximum predicted annual average CRs for PM_{10} and $PM_{2.5}$ were from receptor location R70 (PM_{10}: 3.7; $PM_{2.5}$: 1.5).

While the cumulative Baseline + Project scenario risk estimates for PM_{10} and $PM_{2.5}$ exceeded a CR of 1.0, the overall contributions of particulate matter from baseline conditions were

significantly greater than the Project Alone (Table 6-5). Despite the generally low contributions to risks from Project Alone, the cumulative Baseline + Project risk estimates for particulate matter (Table C-69) are associated health risks that are low and likely to be negligible.

For the Baseline + Project scenario, annual average CR estimates for NO_2 were in excess of one but less than 10 (1.0<CR<10) for receptor location R70 for all operational years (CR=1.5). However, in contrast to the results for particulate matter, the overall contributions of NO_2 from Project Alone conditions were greater than baseline conditions (Table 6-5).

Table 6-5 Contribution of Cumulative Baseline + Project Annual Average Criteria Air Contaminant Concentration Ratios from Project Alone for Receptor Locations near Port Site

Receptor Location		All Operational Years		
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Nitrogen Dioxide (NO_2)*
R69	Village Chief	5%	7%	NA
R70	Fishing Village	4%	7%	93%

NA Not applicable. Predicted Baseline + Project CR was less than one (CR<1.0)

Therefore, based on the results of the air quality assessment, consideration should be given to the mitigation and monitoring of particulate matter and NO_2 emissions from Port operations.

Due to an absence of suitable chronic-duration baseline data for particulate matter (PM_{10} and $PM_{2.5}$), it was not possible to calculate Project + Baseline scenario risks. As a result, it was also not possible to calculate risk estimates from metals in air for the chronic-duration. This represents a significant uncertainty with respect to the overall impact that the Project will have on air quality. In order to reduce these uncertainties, it is highly recommended that baseline monitoring be conducted to better quantify particulate matter concentrations in the absence of the Project.

6.3.4 Multi-Pathway Assessment

As demonstrated by the multi-pathway screening approach (Section 3.8 and Appendix A), not all COPC identified for evaluation *via* inhalation will persist and/or accumulate in the environment. The multi-pathway screening approach identified those COPC that have the potential to persist and/or accumulate in the environment, therefore, triggering a quantitative multi-pathway assessment.

The objective of the multi-pathway assessment was to predict human health risks resulting from chronic exposures to COPC *via* multiple exposure pathways and environmental media. Under the residential scenario, it was assumed that a family would live their entire lives without ever leaving the receptor location while being exposed to COPC through multiple exposure pathways, including:

- Incidental ingestion of soil and dust;
- Direct dermal contact with soil and dust;
- Inhalation and subsequent ingestion of course particulate matter;

- Ingestion of exposed aboveground, belowground, and protected aboveground agricultural crops; and,
- Ingestion of fish.

Human health risk estimates under existing baseline conditions, 'Project Alone', and 'Baseline + Project' scenarios at the two (2) receptor locations are described below. Both non-cancer and carcinogenic risks (HQ values) are presented, where applicable. For the non-cancer risk estimates, results are presented for the highest predicted HQ of the five life stages. Cancer risk estimates (HQ values) are provided for the lifetime (or composite) receptor. Risk estimate tables for the five receptor locations are presented in Appendix D.

A non-carcinogenic HQ value less than or equal to 0.2 (HQ≤0.2) at the receptor location is a strong indicator of negligible health risks resulting from exposure to a particular COPC. Health risks associated with HQ values greater than 0.2 (HQ>0.2) but less than or equal to 10 (HQ≤10) were considered low and likely to be negligible, whereas health risks associated with HQ values greater than 10 (HQ>10) were considered potentially elevated.

An ILCR value less than or equal to one-in-one hundred thousand (ILCR ≤ 1.0×10^{-5}) at a receptor location is a strong indicator risks resulting from exposure to a particular carcinogenic COPC would not be different from baseline. Health risks associated with ILCR values greater than one-in-one hundred thousand but less than or equal to one-in-ten thousand (1.0×10^{-5} ≤ILCR≤1.0×10^{-4}) were considered low and likely negligible. Health risks associated with ILCR values greater than one-in-ten thousand (ILCR>1.0×10^{-4}) were considered potentially elevated.

6.3.4.1 Project Alone

The predicted non-carcinogenic HQ values for all COPCs at both receptor locations (*i.e.,* R69 and R70) were less than a value of 0.2 under the Project Alone scenario (Tables D-27 and D-28). This indicates that contributions from the Project alone are not expected to result in adverse chronic non-carcinogenic health effects (*i.e.,* negligible risks).

The predicted carcinogenic ILCR values for arsenic at both receptor locations were less than a value of 1.0×10^{-5} under the Project Alone scenario (Tables D-27 and D-28). This indicates that contributions from the Project alone are not expected to result in adverse chronic carcinogenic health effects (*i.e.,* negligible risks).

6.3.4.2 Baseline + Project Scenario

The Project + Baseline Scenario represents the cumulative risk estimates from COPCs in multiple exposure pathways from both baseline conditions and Project-related impacts to environmental media.

The predicted non-carcinogenic HQ values for all COPC at the two (2) Port receptor locations were above a value of 0.2 but less than a value of 10 under the Baseline + Project scenario (Tables D-27 and D-28). This indicates that contributions from baseline conditions and the Project are considered low and likely to be negligible. Furthermore, most Baseline + Project scenario HQ values were less than a value of 1.0 indicating that cumulative exposures were less than the selected regulatory benchmarks. Those that exceeded 1.0 (aluminum and lead)

only did so by marginal amounts. It should be noted that the Project Alone non-carcinogenic HQ values for all COPCs were below a value of 0.2, and the elevated HQs under the Baseline + Project scenario are the result of elevated Baseline scenario HQ values.

There is no recommended or acceptable LCR benchmark associated with exposures to carcinogenic substances resulting from existing background or baseline conditions and, therefore, the LCR estimates for 'Baseline' and 'Baseline + Project' scenarios are provided for reference only.

6.4 Human Health Risk Assessment of Areas along the Transport Route

Potential human health risks were not quantitatively assessed along the transportation route. Air quality receptor location along the transportation route indicated lower air quality impacts than at either the Mine or Port site receptor locations. As such, concerns related to the Project were adequately addressed through the Mine and Port site quantitative assessments.

7.0 DATA GAPS AND UNCERTAINTIES

In any detailed HHERA, the intention is to obtain the most accurate evaluation of risk based upon the available data and state of knowledge, without underestimating the potential health risks. With any such assessment, there are always a number of administrative and technical boundaries that limit the ability of the assessment to quantify risk with absolute certainty. The following section provides an overview of the key administrative and technical boundaries inherent within the current HHERA.

Quantitative HHERA involves assigning numerical values to input parameters in an appropriate exposure or risk model to obtain a quantitative estimate of risk. Numerical values are required for parameters describing chemical concentrations in environmental media, chemical fate and transport, exposure and toxic response. These values may be measured, assumed, prescribed, or based on published literature. Variability and uncertainty in the input parameters or risk model result in variability and uncertainty in the estimate of risk. The US EPA (2005) suggests that the risk characterization process maintain transparency, clarity, consistency, and reasonableness. The goal of risk characterization is to clearly communicate the key findings of the assessment and to provide a clear and balanced assessment of the strengths and limitations of the process. Risk characterization involves both scientific and policy based decision making, thereby resulting in a decision making process that blends both elements.

When assumptions are made during the risk assessment process, either because of data gaps or knowledge gaps, each can result in some degree of uncertainty in the overall conclusions. In order to understand the uncertainties within the HHERA and to ensure that the implications of these uncertainties are understood and addressed, it is important to document and characterize them. To ensure that the risk assessment does not underestimate the potential for the occurrence of adverse effects, it is necessary to make assumptions that are conservative (protective). In other words, assumptions should be made that tend to overestimate exposure, toxicity, and risk, rather than underestimate these parameters.

The following tables describe uncertainty within the HHERA, and discuss the potential impacts of these limitations on the conclusions drawn from the assessment. There were a number of instances where the data provided to the HHERA Study Team were deemed inadequate to evaluate exposures, and consequently risks, to human health and valued ecological components. Table 7-1 provides a summary of those data deemed inadequate and a discussion of the uncertainties associated with the data gaps they represent.

Given the tendency for the assumptions described below to overestimate both exposure and toxicity, it is likely that the risk characterization errs on the side of caution and over predicts risk. A summary of the conservative assumptions that were incorporated into the HHERA can be found in Table 7-2, arranged according to the steps of the risk assessment paradigm. Examination of the table shows that conservatism was introduced at virtually every step of the assessment, and extended to the problem formulation, exposure assessment, and toxicity assessment of the HHERA.

Table 7-1 Data Gaps Identified in the HHERA

Data Gap	*Discussion of Uncertainty*
While an evaluation of emissions to surface water was not completed as part of the HHERA, fish consumption was considered in the Baseline assessment. However, the fish tissue samples collected were not analyzed for all COPCs.	Exposures to metals in fish tissue could not be estimated for several COPCs. As a result, risks from those COPCs without analytical information could not be estimated.
Due to an absence of frequency data, that is predicted 1-hour and 24-hour concentrations over a duration of at least one year, the HHRA could only evaluate the maximum predicted concentrations.	Frequency analyses can be used to determine how often the exposure limits utilized within the assessment are predicted to be exceeded to provide a better understanding of the risk estimates. Based on these analyses, it can be determined if the predicted exceedances for these chemicals are representative of long-term conditions or if they are predicted to be highly intermittent in nature. The latter would represent a situation where a short-term exceedance of the exposure limit (*i.e.,* CR>1.0) would still be considered a negligible health risk to the general population.
Annual average concentrations for particulate matter (PM_{10} and $PM_{2.5}$) representative of Baseline conditions could not be calculated due to an inadequate availability of 24-hour concentrations.	Particulate matter measurements in air conducted to characterize Baseline conditions were only available for six (6) 24-hour periods. This amount of data was considered insufficient by the Study Team to represent annual average concentrations. As a result, exposures and risks from particulate matter and metals could not be estimated for the Baseline and Baseline + Project scenarios.
Baseline concentrations of carbon monoxide (CO) were not captured as part of the monitoring programs conducted.	Given the absence of baseline monitoring data for CO, exposures and risks to CO could not be estimated for the Baseline and Baseline + Project scenarios. However, based on the lack of existing combustion sources at each of the Project sites, baseline CO concentrations are expected to be low. Further, the predicted Project emissions of CO are expected to be low (Knight Piésold, 2015b)

Table 7-2 Major Assumptions and Associated Uncertainties Applied in the HHERA

Assumption	*Discussion of Uncertainty*
Problem Formulation	
Selection of COPCs was based only on criteria air contaminants and metals	These COPCs are considered to represent the primary substances that could be emitted from the Project. Other metals present in ore and waste overburden were cross checked to determine whether additional substances should be added to the assessment. These additional metals were present in concentrations that were extremely small, on a relative percentage basis, and were not considered to require further assessment.
Air quality assessment scenarios (operational Years 2, 8, 15, and 25) reflect realistic operating conditions of the Mine and Port sites	Careful consideration was given to the assessment scenarios evaluated in the HHRA, with reasonable worst-case operating conditions assumed for the air quality assessment, and ultimately the HHRA.
Only the Mine and Port site operational areas were quantitatively evaluated in the HHERA.	It was assumed that CAC and metals emissions from the Mine and Port site operations would exceed those of the Product Transport Route. As a result, exposures and risks from this aspect of the project were not quantitatively evaluated. Consideration should be given to the maintenance of transport vehicle emissions-reduction measures throughout the Mine, Transport, and Port phases of operations.

The receptor locations nearest to the Mine and Port sites would be most affected.	It was assumed that emissions from the Mine and Port sites would most likely impact those receptor locations nearest to those operations (R2 and R70, respectively). To capture potential impacts to receptors further away, receptor locations surrounding the Mine and Port sites, that is, in north-east-south-west headings, were also included in the assessment.
Carcinogenic PAHs and VOCs were not evaluated as part of the current assessment. It was assumed that exposures to these chemicals would be significantly less than those of CACs and metals.	Emissions data available from the US EPA indicates that several carcinogenic PAHs and several VOCs are emitted from diesel emission sources. The decision to exclude these chemical groups from the assessment will underestimate risk; however, given that relative abundance of these chemical groups are anticipated to be significantly less than those of CACs and metals, it is anticipated that the underestimated portion of risk will be low.
Measured fish concentrations for select metals were used for predicting dietary exposures in the HHRA for the Baseline assessment. However, project-related impacts to fish tissue concentrations were not predicted. Measured surface water concentrations were not used to estimate any wildlife exposures or tissue concentrations for the Project Alone assessment.	It is anticipated that emissions from Mine operations will result in the deposition and surface run-off of chemicals into nearby aquatic environments (*i.e.,* surface water, sediment). The presence of these chemical parameters in these media could result in bioaccumulation in fish tissue, which could be consumed by humans and wildlife. The decision to exclude this pathway from consideration in the risk assessment will likely underestimate chemical exposures and risks to human receptors. However, the level of exposure and risk that this potential pathway represents is uncertain.
Limited measured data were available to characterize environmental concentrations of hexavalent chromium. Exposures and risks from hexavalent chromium were not quantitatively assessed.	A total of six baseline soil samples from two locations were analyzed for hexavalent chromium. Hexavalent chromium was found to be present in each of the soil samples with a mean proportion of 3.4% total chromium. Due to the limited amount of data, it is highly uncertain if these data are representative of conditions throughout the Mine and Port sites. Additionally, speciated levels of chromium were not available for the other environmental media investigated (*i.e.,* fish and water). Due to these uncertainties, exposures and risks from hexavalent chromium were not quantitatively assessed in the HHERA and it was assumed that all chromium was in the trivalent form. While the exclusion of hexavalent chromium in the HHERA could represent an under-prediction of overall risk, it is anticipated that predicted risk levels for hexavalent chromium would be consistent with those of the other chemicals assessed (*i.e.,* negligible to low and likely to be negligible).
Exposure Assessment	
Ground-level air concentrations of COPCs related to emissions from various scenarios were estimated based on mathematical air dispersion models and meteorological data.	The HHERA relied on the results of air dispersion modelling conducted by Knight Piésold (2015b) to evaluate risks from direct inhalation exposure (human) and to evaluate future media concentrations and subsequent exposures and risks based on modelled particulate deposition. While the use of any modelling software comes with inherent uncertainties, particularly regarding the representative nature of the data inputted into the models, the approaches used by Knight Piésold remain among the best mechanisms to forecast future distributions of emissions. The air dispersion models used to provide data for the current assessment (*i.e.,* CALPUFF, CALMET) are approved by the US EPA for use on these types of emission studies.

Persons might be found in various areas in the vicinity of the Project not just at the seven receptor locations selected. Maximum 1-hour and 24-hour air concentrations predicted at each of the receptor locations were used to evaluate acute inhalation risks.	In reality, the frequency with which the maximum would occur at any one receptor location varies with respect to the COPCs and the receptor location. Individual exposure to 1-hour and 24-hour maximum ground-level air concentrations requires that a receptor (person) is present at the same time and duration of the maximum predicted air concentration at that particular receptor location. The selection of the receptor locations were intended to overstate the exposures that might actually be received. As a result, this assumption is conservative.
Predicted chronic exposures were based on the assumption that individuals would be exposed 24 hours per day, 365 days per year to the maximum predicted ground level air concentrations of the COPCs for the entire duration of their lives (i.e., 49.5 years).	The operational life of the Project is expected to be 26 years. However, It was conservatively assumed that people permanently reside at the evaluated receptor locations over a 49.5-year period.
North American human exposure parameters and characteristics were generally consistent with those of residents of the study area	The human exposure factors utilized within the HHRA were obtained from Health Canada (2012). These parameters are based on studies from the general population of Canada, with the exception of the lifespan used in the HHRA (49.5 years, specific to Guinea-Bissau). In the absence of exposure factor studies for the population of the study area, it is uncertain if the estimated chemical exposures are truly representative of those of the study area.
Residents were assumed to obtain 100% of their agricultural crop and fish exposures from local sources and drinking water from local groundwater sources.	The assumption that people obtain all of their food and water over their lifetime from the area likely contributes to the overstatement of the exposures that might be received by these people under actual circumstances.
COPCs in the soil were assumed to be 100% available for uptake into agricultural crops and people. COPCs in fish and agricultural crops were assumed to be 100% bioavailable to people.	There is plenty of scientific literature available to suggest that the availability of COPCs in the vicinity of mine sites for uptake into people, animals and vegetation is less than 100%. This is especially true of metals bound within the ore. The assumption of 100% used within the assessment will overestimate exposures.
Metals in dust for receptor locations near the Mine site were predicted based on total dustfall and relationship to ore and waste overburden for the Mine site.	This assumption is likely reasonable, but remains as an uncertainty in the assessment, since direct metals emission rates were not used. Also, metals in vehicular exhaust or from interior Mine site roads were not considered. This is likely a small contribution, relative to ore and waste overburden dusting sources, and hence, is unlikely to substantially impact overall risk estimates.
Metals in dust for receptor locations near the Port site were predicted based on total dustfall and relationship to concentrate product for the Mine site.	It was assumed that the major source of dust at the Port site is the concentrate product. It is uncertain if the transport of the product represents the major dust emissions source for the Port site area.
Half of the reportable laboratory method detection limits were used for COPCs where measured concentrations were below detection limits.	The HHERA conservatively used the half of the reportable detection limit when concentrations were not detected in environmental media (*e.g.,* baseline soil). It is likely that actual concentrations, in these cases, are lower than the assessed levels used in the HHERA.
Hazard Assessment	
TRVs were developed to be protective of sensitive and more susceptible individuals in the general population (e.g., infants and young children, the elderly, individuals with compromised health)	A considerable amount of conservatism is incorporated in the TRVs. TRVs are deliberately set to be protective of sensitive individuals. The use of uncertainty factors is already directed, in part, toward the protection of sensitive individuals.

For carcinogens, it was assumed that no repair of genetic lesions occurs, and therefore, no threshold can exist for chemicals that produce self-replicating lesions.	The existence of enzymes and biological pathways that routinely repair damage to genetic material (DNA) is well documented in the scientific literature. The potential adverse health outcomes arising from damage to DNA are usually observed only when the ability of these repair enzymes to "fix" the damage is blocked or exceeded.
Humans were assumed to be the most sensitive species with respect to toxic effects of COPC.	For obvious reasons, toxicity assays are not generally conducted on humans, so toxicological data from the most sensitive laboratory species were used in the estimation of toxicological criteria for humans, as appropriate. In some cases, however, human-specific data was available and was used in the Hazard Assessment.
Possible interactions of the COPCs released by the Project, which might lead to enhanced toxicity, were adequately addressed in the assessment.	Consistent with Health Canada (2012) guidance, potential health risks associated with the COPCs were considered to be additive if the exposure limit for the COPCs had the same toxicological endpoint. In some instances, it is possible that components of a mixture may have different mechanisms of effect, contributing some uncertainty in the predicted risk estimates for mixtures.
Risk Characterization	
The risk characterization errs on the side of caution and likely over predicts risk.	Overall, individual conservative assumptions made in the exposure and toxicity assessments likely contribute to an overestimation of the actual risks. This potential overestimation is further magnified by the compounding effects of multiple conservative assumptions that were applied throughout the exposure and risk characterization phases.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Summary of the HHERA

The proposed Project is undergoing an Environmental and Social Impact Assessment (ESIA), as outlined in the description of the Project (Knight Piésold, 2015a). The Project consists of the construction, operation, and closure of a proposed open pit mining operation to exploit the Farim phosphate orebody, a process plant at the Mine site to beneficiate the ore into a phosphate rock concentrate (product), an associated port facility to export the product to customers, and a highway built to transport the product to the port facility. The Project is proposed to operate for a period of 26 years (Knight Piésold, 2015a).

To ensure that the potential environmental effects from the Project were adequately assessed, exposure and risk estimates were developed for several different assessment scenarios through the use of a Human Health and Ecological Risk Assessment (HHERA). The HHERA follows standardized guidance and involved a review and evaluation of possible exposure pathways and risks associated with the proposed Project. The focus of the risk assessment (RA) was on the possible effect of emissions released from Project activities on air, soil, and agricultural crops in nearby areas used by residents for housing and farming.

The current HHERA consists of two main components: (1) an HHERA of the potential impacts from the operation of the Mine site, and (2) an HHERA of the potential impacts from the operation of the Port site. Within each of these separate HHERAs is a human health risk assessment (HHRA) component and an ecological risk assessment (ERA) component. Consideration of potential impacts along the transportation route (between the Mine and Port sites) is also provided.

The HHRA components (for the Mine and Port HHERAs) consisted of an inhalation assessment, which evaluated air exposures to chemicals, and a multi-pathway assessment, which evaluated dust deposition and subsequent exposures arising from the oral and dermal pathways associated with soils and local crops.

Using a detailed ecological risk-based screening approach, it was determined that an ERA component was not necessary for either the Mine or Port sites. For all receptor locations near the Mine and Port sites, predicted soil concentrations associated with the Baseline + Project Scenario were less the selected ecological criteria with three noted exceptions. Given that the selected criteria were derived to be protective of the most significant source of exposure to environmental contaminants, those chemicals that are found in soil at concentrations that are below the criteria are not anticipated to represent a potential concern to ecological receptors.

The predicted concentration of selenium at Mine-related receptor locations was greater than the selected criterion. Similarly, the predicted concentrations of chromium and selenium at Port-related receptor locations were greater than the selected criterion. However, the predicted concentrations of selenium (Mine and Port) and chromium (Port) were not markedly different than baseline levels; therefore, it was not anticipated that Project chemical emissions will result in any adverse ecological effects. As a result, a quantitative ERA was not necessary for either the Mine or Port sites.

Results of the Mine Site HHERA

The results of the Baseline + Project inhalation assessment indicate that some predicted short-term concentrations of NO_2 could result in adverse health effects at multiple receptor locations; however, the predicted levels of risk were considered to be low and likely to be negligible. An analysis of the project emissions indicated that contributions of NO_2 were predicted to be mainly attributable to the Project.

The results of the Baseline + Project inhalation assessment indicate that predicted long-term concentrations of particulate matter (PM_{10} and $PM_{2.5}$) could result in adverse health effects at multiple receptor locations; however, the predicted risk levels were considered to be low and likely to be negligible. An analysis of the project emissions indicate that contributions of particulate matter were predicted to be mainly attributable to baseline environmental conditions and not the Project.

Chronic-duration risks from airborne metals were evaluated based on predicted levels of PM_{10} in air. Risks of adverse health effects (both non-cancer and cancer) were predicted for a number of metals (*i.e.,* aluminum, arsenic, chromium (III), iron, and manganese) associated with particulate matter (*i.e.,* PM_{10} levels) for several receptor locations. However, these risks were considered to be low and likely to be negligible. Cumulative Baseline + Project Scenario exposures and risks could not be evaluated for airborne metals due to an absence of adequate baseline particulate matter concentration monitoring data.

Human receptors present near the Mine site may be subject to chemical exposures (*i.e.,* NO_2, PM_{10}, $PM_{2.5}$, aluminum, arsenic, chromium (III), iron, and manganese) *via* ambient air inhalation that may result in adverse health effects; however, the maximum levels of risk predicted were considered to be low and likely to be negligible. The predicted risks do not indicate that an adverse health will occur but rather that additional investigation and mitigation may be required.

For the multi-pathway assessment, risks from oral/dermal exposures *via* multiple pathways (*i.e.*, soil, dust, agricultural crops, fish, and groundwater) indicate that there is the potential that the deposition of chemicals from operations at the Mine site (*i.e.,* aluminum, arsenic, iron, and lead) could contribute to the development of adverse health effects in nearby residents. However, the predicted risk levels were considered low and likely to be negligible. The predicted risks do not indicate that an adverse health effect will occur but rather that additional investigation and mitigation may be required.

At all receptor locations near the Mine site, predicted soil concentrations associated with the Baseline + Project Scenario were less the selected ecological criteria, with the exception of selenium. However, the predicted concentration of selenium was not markedly different than baseline levels, such that it is not anticipated that Project-related chemical emissions will have any adverse ecological effects.

Results of the Port Site HHERA

The results of the Baseline + Project inhalation assessment indicate that some predicted short-term concentrations of NO_2 and SO_2 could result in adverse health effects at one receptor location; however, the predicted levels of risk were considered to be low and likely to be

negligible. An analysis of the project emissions indicate that contributions of NO_2 and SO_2 were predicted to be mainly attributable to the Project.

Similar to the results of the short-term assessment, the predicted long-term concentrations of NO_2 could result in adverse health effects at one receptor location. The predicted levels of risk were considered to be low and likely to be negligible. An analysis of the project emissions indicate that contributions of NO_2 were predicted to be mainly attributable to the Project.

The results of the Baseline + Project inhalation assessment indicate that predicted long-term concentrations of particulate matter (PM_{10} and $PM_{2.5}$) could result in adverse health effects at both Port receptor locations; however, the predicted risk levels were considered to be low and likely to be negligible. An analysis of the project emissions indicate that contributions of particulate matter were predicted to be mainly attributable to baseline environmental conditions and not the Project.

Chronic-duration risks from airborne metals were evaluated based on predicted levels of PM_{10} in the air. Predicted risks of adverse health effects (both non-cancer and cancer) were considered negligible. Baseline + Project cumulative exposures and risks could not be evaluated for airborne metals due to an absence of particulate matter monitoring.

For the multi-pathway assessment, risks from exposures *via* multiple pathways (*i.e.*, soil, dust, agricultural crops, fish, and groundwater) indicate that there is the potential that the deposition of chemicals from operations at the Port site (*i.e.,* aluminum and lead) could contribute to the development of adverse health effects in residents. However, the predicted risk levels were considered low and likely to be negligible.

At all receptor locations near the Port site, predicted soil concentrations associated with the Baseline + Project Scenario were less the selected ecological criteria, with the exception of chromium and selenium. However, the predicted concentrations of chromium and selenium were not markedly different than baseline levels, such that it is not anticipated that Project-related chemical emissions will have any adverse ecological effects.

Recommendations

In conclusion, the results of the HHERA indicate that some of the predicted emissions from the Mine and Port operations could potentially result in adverse health effects to residents of the surrounding communities. However, the level of risks predicted for these chemicals were, at worst, considered low and likely to negligible. Furthermore, the highly conservative exposure assumptions and the conservatisms used to derive the toxicity reference values utilized within the current assessment are not likely representative of the general population. Therefore, it is not anticipated that the emissions from the Mine and Port operations represent a significant health risk to the general population in the Mine and Port site areas.

However, based on the results of the Mine and Port Site HHERAs, consideration should be given to the monitoring of NO_2, SO_2, PM_{10}, and $PM_{2.5}$ levels during the operational phases of the Mine and Port sites in order to better evaluate risks associated with ground-level ambient air and multi-pathway oral/dermal exposures. If monitoring indicates elevated levels, that is, the measured concentrations are greater than the exposure limits utilized in the assessment (Table

8-1), then mitigation to minimize chemical releases from the Mine and Port sites should be considered.

Table 8-1 Toxicity Reference Values (µg/m^3) Used in Assessment of Ambient Air

Criteria Air Contaminant	Duration	Guideline	Description of Guideline	Reference
1-Hour Acute Exposure Limits				
Nitrogen dioxide (NO_2)	1-Hour	190	98th Percentile of 1-hour daily maximum concentrations over 3 years	US EPA, 2010
24-Hour Acute Exposure Limits				
Particulate matter - PM_{10}	24-Hour	50	99th Percentile of 24-hour averages	WHO, 2006
Particulate matter - $PM_{2.5}$	24-Hour	25	99th Percentile of 24-hour averages	WHO, 2006
Sulphur dioxide (SO_2)	24-Hour	20	24-Hour average	WHO, 2006
Chronic Duration (Annual Average) Exposure Limits				
Nitrogen dioxide (NO_2)	Annual	40	Annual average	US EPA, 2010
Particulate matter - PM_{10}	Annual	20	Annual average	WHO, 2006
Particulate matter - $PM_{2.5}$	Annual	10	Annual average	WHO, 2006
Sulphur dioxide (SO_2)	Annual	50	Annual average	WHO, 2000

Cumulative chemical exposures and risk associated with the Baseline + Project Scenario could not be evaluated for airborne metals due to an absence of adequate particulate matter baseline monitoring. It is anticipated that a reduction of particulate matter will minimize the human health risks associated with airborne metals and subsequent deposition and uptake.

9.0 REFERENCES

References are subdivided into general references (Section 9.1) and references related to the human exposure limits (Section 9.2). The human exposure limit references are further subdivided into chemical types and are ordered alphabetically.

9.1 General References

Amdur, M.O., Doull, J., and Klassen, C.D. (Eds.). 1991. Casarett and Doull's Toxicology: The Basic Science of Poisons. 4th Edition. Pergamon Press Ltd., New York, NY.

ATSDR. 2006. Minimal Risk Levels for Hazardous Substances (MRLs). US Department of Health and Human Services, Public Health Service. Agency for Toxic Substances and Disease Registry (ATSDR). Atlanta, Georgia. December 2006.

CCME. 1996. A Framework for Ecological Risk Assessment: General Guidance. Canadian Council of Ministers of the Environment, National Contaminated Sites Remediation Program, Ottawa, ON.

CCME. 2006. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. Canadian Council for Ministers of the Environment. ISBN – 10 1-896997-45-7 PDF.

CIA. 2013. The World Factbook 2013-14. Central Intelligence Agency. Available at: https://www.cia.gov/library/publications/the-world-factbook/index.html

Environment Canada. 1994. A Framework for Ecological Risk Assessment at Contaminated Sites in Canada: Review and Recommendations. Scientific Series No. 199. Environment Canada, Ecosystem Conservation Directorate, Evaluation and Interpretation Branch, Ottawa, ON. ISBN 0-662-22156-7.

Health Canada. 1994. Human Health Risk Assessment for Priority Substances. Canadian Environmental Protection Act: Priority Substances List Assessment Report No. 41. Ottawa, ON: Health Canada. PSL-41E EN40-215/41E.

Health Canada. 2007. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch. Ottawa, ON: Health Canada. ISBN: 978-0-662-47023-6

Health Canada. 2012. Federal Contaminated Site Risk Assessment in Canada (FCSAP). Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Contaminated Sites Program. Version 2.0. September 2010, Revised in 2012.

FDA. 1982. Toxicological Principles for the Safety Assessment of Direct Food Additives and Color Additives Used in Food. (US) Food and Drug Administration, Bureau of Foods, Washington, DC.

Filov, V., Golubev, A., Liublina, E., and Tolokontsev, N. 1979. Quantitative Toxicology: Selected Topics. John Wiley and Sons, New York, NY.

Golder. 2014. Farim Phosphate Project, Guinea Bissau, Mine Component Environmental and Social Impact Assessment. March 2014. Prepared for GB Minerals Ltd., Vancouver, Canada. Prepared by Golder Associates (UK) Ltd.

Knight Piésold. 2015a. GB Minerals Ltd. - Farim Phosphate Project – Environmental and Social Impact Assessment, Draft. August 19, 2015. Prepared for GB Minerals Ltd., North Bay, Canada. Prepared by: Knight Piésold Ltd.

Knight Piésold. 2015b. Air Dispersion Modeling, Final Report. Lycopodium Minerals Canada Ltd. – Environmental and Social Impact Assessment for the Farim Phosphate Project. August 2015. Prepared for Lycopodium Minerals Canada Ltd., Mississauga, Canada. Prepared by: Knight Piésold Consultores S.A.

Richardson and O'Connor, 1997 Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc.

Richardson, G.M. and Stantec Consulting Ltd. 2013. Canadian Exposure Factors Handbook. Toxicology Centre, University of Saskatchewan, SK Canada. Available at: www.usask.ca/toxicology.

Sample, B.E., Aplin, M.S., Efroymson, R.A., Suter II, G.W., and Welsh, C.J.E. 1997. Methods and tools for estimation of the exposure of terrestrial wildlife to contaminants. ORNL/TM-13391. Oak Ridge National Laboratory, Oak Ridge, TN.

US EPA. 1989. Risk Assessment Guidance for Superfund. US Environmental Protection Agency, Washington, DC.

US EPA. 1991. Risk Assessment Guidance for Superfund. Part B, Development of Risk-based Preliminary Remediation Goals, Interim. US Environmental Protection Agency, Washington, DC. December 1991

US EPA. 1996. Soil Screening Guidance: User's Guide. Second Edition. Office of Emergency and Remedial Response. EPA/540/R 96/018.

US EPA. 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Available at: http://www.epa.gov/combustion/ecorisk.htm

US EPA. 2001. Risk Assessment Guidance for Superfund: Volume III Part A, Process for Conducting Probabilistic Risk Assessment. Office of Emergency and Remedial Response. EPA 540 R 02 002 OSWER 9285.7 45 PB2002 963302.

US EPA. 2004. Risk Assessment Guidance for Superfund. Part E, Supplemental Guidance for Dermal Risk Assessment, Final. US Environmental Protection Agency, Washington, DC. August 2004.

US EPA. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Final. United States Environmental Protection Agency Region 6. Multimedia Planning and Permitting Division. Center for Combustion Science and Engineering.

Office of Solid Waste. EPA530-R-05-006. OSW. United States Environmental Protection Agency Office of Solid Waste.

US EPA. 2009. Risk Assessment Guidance for Superfund. Part F, Supplemental Guidance for Inhalation Risk Assessment, Final. US Environmental Protection Agency, Washington, DC. January 2009.

9.2 Human Exposure Limit References

9.2.1 Criteria Air Contaminant (CACs)

Carbon Monoxide

WHO. 2000. Air Quality Guidelines for Europe – Second Edition. World Health Organization. WHO Regional Office for Europe, Copenhagen, Denmark, 2000

Nitrogen Dioxide (NO_2)

US EPA. 2010. 40 CFR Parts 50 and 58, Code of the Federal Register. Primary National Ambient Air Quality Standard for Nitrogen Dioxide: Final Rule. US Environmental Protection Agency. February 9, 2010.

Particulate Matter (PM_{10})

WHO. 2006. Air Quality Guidelines: Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulphur dioxide. ISBN 92 890 2192 6. World Health Organization

Particulate Matter ($PM_{2.5}$)

WHO. 2006. Air Quality Guidelines: Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulphur dioxide. ISBN 92 890 2192 6. World Health Organization

Sulphur Dioxide (SO_2)

US EPA. 2010. 40 CFR Parts 50, 53, and 58, Code of the Federal Register. Primary National Ambient Air Quality Standard for Sulfur Dioxide: Final Rule. US Environmental Protection Agency. June 22, 2010.

WHO. 2000. Air Quality Guidelines for Europe – Second Edition. World Health Organization. WHO Regional Office for Europe, Copenhagen, Denmark, 2000

9.2.2 Metals

Aluminum

US EPA. 2006. Provisional Peer Reviewed Toxicity Values for Aluminum (CASRN 7429-90-5). Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development, United States Environmental Protection Agency. Available at: http://hhpprtv.ornl.gov/issue_papers/Aluminum.pdf

WHO. 2010a. Aluminum in Drinking Water. Background Document for Development of WHO Guidelines for Drinking-Water Quality. World Health Organization.

WHO. 2010b. Aluminum Summary Statement. World Health Organization. Available at: http://www.who.int/water_sanitation_health/dwq/chemicals/aluminium_summary_statement.doc

WHO. 2013. World Health Organization. WHO/HSE/WSH/10.01/13. Available at: http://www.who.int/water_sanitation_health/publications/aluminium.pdf

Antimony

US EPA IRIS. 1991. Antimony (CASRN 7440-36-0). Agency Integrated Risk Information System Database. US Environmental Protection Agency. Available at: http://www.epa.gov/ncea/iris/subst/0006.htm.

US EPA IRIS. 1995. Antimony Trioxide (CASRN 1309-64-4). Integrated Risk Information System. US Environmental Protection Agency. Available at http://www.epa.gov/ncea/iris/subst/0676.htm.

Arsenic

Cal EPA. 2008. Technical Support Document for the Derivation of Noncancer Reference Exposure Levels, Appendix D. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Branch. Available at: http://www.oehha.ca.gov/air/hot_spots/2008/AppendixD1_final.pdf.

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0

US EPA IRIS. 1993. Chronic Health Hazard Assessments for Noncarcinogenic Effects: Arsenic, inorganic (CASRN 7440-38-2). US Environmental Protection Agency Integrated Risk Information System. Office of Research and Development, National Center for Environmental Assessment, Washington, DC. Available at: http://www.epa.gov/iris/subst/0278.htm.

Beryllium

Cal EPA. 2001. Chronic Toxicity Summary – Beryllium and beryllium compounds. Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III: The Determination of Chronic Reference Exposure Levels. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section. December, 2001. Available at: http://www.oehha.ca.gov/air/hot_spots/2008/AppendixD3_final.pdf#page=35.

US EPA IRIS. 1998. Beryllium and Compounds (CASRN 7440-41-7). Carcinogenicity Assessment of Lifetime Exposure. US Environmental Protection Agency Integrated Risk Information System Available at: http://www.epa.gov/iris/subst/0012.htm

Cadmium

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0

MOE. 2007. Ontario Air Standards for Cadmium and Cadmium Compounds. Standards Development Branch, Ontario Ministry of the Environment. Available at: http://www.ontla.on.ca/library/repository/mon/20000/277806.pdf

Chromium (III)

TCEQ. 2009 Chromium. All Compounds Except Hexavalent Chromium. CAS Registry Trivalent Chromium 16065-83-1. Texas Commission on Environmental Quality. Final October, 2009. Available at: http://www.tceq.state.tx.us/assets/public/implementation/tox/dsd/final/october09/chromium3_16065-83-1.pdf

US EPA IRIS. 1998. Chromium (III), insoluble salts (CASRN 16065-83-1), Chronic Health Hazard Assessments for Noncarcinogenic Effectst. US Environmental Protection Agency Integrated Risk Information System. Available at: http://www.epa.gov/iris/subst/0028.htm

Cobalt

RIVM. 2001. Re-evaluation of human-toxicology maximum permissible risk levels. RIVM Report 711701 025. Rijksinsitituut Voor Volksgezondheid en Milieu, National Institute of Public Health and the Environment. Published as: Baars *et al*., 2001.

WHO. 2006. Cobalt and Inorganic Cobalt Compounds. Concise International Chemical Assessment Document 69; World Health Organization.

Iron

TCEQ. 2014. TCEQ Interoffice Memorandum Effects Screening Levels. Toxicology Division, Office of Executive Director, Texas Commission on Environmental Quality. March, 2014.

US EPA. 2006. Provisional Peer Reviewed Toxicity Values for Iron (CASRN 7439-89-6) and Compounds. Derivation of Subchronic and Chronic Oral RfDs. US Environmental Protection Agency. Available at: http://hhpprtv.ornl.gov/quickview/pprtv.php

Lead

JECFA. 2011. Safety evaluation of certain food additives and contaminants / prepared by the seventy-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO food additives series: 64. World Health Organization.

US EPA. 2008. Code of the Federal Register. Environmental Protection Agency. 40 CFR Parts 50, 51, 53 and 58. Primary National Ambient Air Quality Standards for Lead: Final Rule. US Environmental Protection Agency.

Lithium

US EPA. 2008. Provisional Peer Reviewed Toxicity Values for Lithium (CASRN 7439-93-2). Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development, US Environmental Protection Agency, Cincinnati, OH. http://hhpprtv.ornl.gov/quickview/pprtv.php

Manganese

US EPA IRIS. 1993. Manganese (CASRN 7439-96-5), Inhalation RfC Assessment. US Environmental Protection Agency Integrated Risk Information System. Available at: http://www.epa.gov/ncea/iris/subst/0373.htm

US EPA IRIS. 1996. Manganese (CASRN 7439-96-5), Oral RfD Assessment. US Environmental Protection Agency Integrated Risk Information System. Available at: http://www.epa.gov/ncea/iris/subst/0373.htm

Nickel

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0

MOE. 2011. Ontario Air Standards for Nickel and Nickel Compounds. Standards Development Branch. Ontario Ministry of the Environment, June 2011. 186 p.

Selenium

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0

TCEQ. 2014. TCEQ Interoffice Memorandum Effects Screening Levels. Toxicology Division, Office of Executive Director, Texas Commission on Environmental Quality. March, 2014.

Thallium

TCEQ. 2014. TCEQ Interoffice Memorandum Effects Screening Levels. Toxicology Division, Office of Executive Director, Texas Commission on Environmental Quality. March, 2014.

US EPA. 2012. Provisional Peer-Reviewed Toxicity Values for Thallium and Compounds. Final. Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development, US Environmental Protection Agency, Cincinnati, OH. Available at: http://hhpprtv.ornl.gov/quickview/pprtv.php

Uranium

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0

Vanadium

ATSDR. 2012. Toxicological Profile for Vanadium. Agency for Toxic Substances and Disease Registry, US Public Health Service, Department of Health and Human Services, Atlanta, GA. September 2012.

RIVM. 2009. Re-evaluation of some human toxicological Maximum Permissible Risk levels earlier evaluated in the period 1991-2001. Dutch National Institute of Public Health and the Environment (Rijksinstituut Voor Volksgezondheid En Milieu). RIVM report 711701092/2009. Available at: http://www.rivm.nl/bibliotheek/rapporten/711701092.pdf

Zinc

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0

TCEQ. 2014. TCEQ Interoffice Memorandum Effects Screening Levels. Toxicology Division, Office of Executive Director, Texas Commission on Environmental Quality. March, 2014.

APPENDIX A

HHRA AND ERA COPC SCREENING FOR THE MINE AND PORT SITES

APPENDIX A: HHRA AND ERA COPC SCREENING FOR THE MINE AND PORT SITES

A-1.0 INTRODUCTION

This appendix describes the approach used to screen the chemicals of potential concern (COPCs) in the human and ecological risk assessments for the Farim Mine and Port sites.

The HHRA and ERA COPC screenings consisted of three main components:

- **Baseline soil screening (Section A-2.0):** The maximum baseline surface soil concentration of chemicals collected in both the Mine and Port sites were compared to human health-based and ecological health-based guidelines. Chemicals exceeding the human or ecological health-based guidelines were carried forward for further evaluation. The COPC guideline screenings for human and ecological receptors are discussed in Section A-2.1 and A-2.2, respectively.

- **Oral toxic potency screening (Section A-3.0):** Screening based on the toxic potency of a chemical is a method to differentiate chemicals that have a high toxic potential and those that do not. A toxic potency screening was conducted separately for the Mine and Port sites for both the HHRA and ERA. The Mine site toxic potency screening was based on the geochemistry of both the waste overburden and ore metal content, since these are the dominant forms of dust, based on the air dispersion analysis conducted. The Port toxic potency screening was based on the metal content of the product, since this would represent the dominant form of dust at the Port site. Chemicals which represented >99% of the cumulative toxic potency in the human screening and >95% cumulative toxic potency in the ecological screening were carried forward for assessment. Sections A-3.1 and A-3.2, respectively discuss the toxic potency screenings for the Mine and Port.

- **Bioaccumulation check (Section A-4.0):** Finally, a bioaccumulation check was completed where metals know to be bioaccumulative were also included for assessment. The bioaccumulation check is discussed in Section A-4.0.

A-2.0 BASELINE SOIL SCREENING

The maximum baseline soil concentration of each metal from the Mine site data set and Port site data set were compared to human health-based and ecological health-based soil quality guidelines. While both human receptors and wildlife can move about a site, the maximum baseline soil concentrations at both sites were used as a conservative basis of comparison.

No Guinea Bissau specific guidelines were identified in the literature reviewed. The only African soil quality guidelines which were identified were South African Department of Environmental Affairs (SA DEA, 2014) soil screening values which were reported to be "protective of both human health and eco-toxicological risk for multi-exposure pathways, inclusive of contaminant migration to the water resource", (SA DEA, 2014). These guidelines were considered applicable for human health and were used in the human soil screening. As the specific basis for each guideline was not available, the SA DEA (2014) guidelines were used in the HHRA screening in conjunction with other available guidelines, where available (i.e., the lower of the SA DEA guideline or the guideline from another jurisdiction was used in the screening). The SA DEA guidelines were not applied to the ecological screening for this project as the soil screening values did not appear to be protective of terrestrial ecological receptors, but rather were derived in consideration of aquatic ecosystems (SA DEA, 2010).

Where available, human health-based (SQGHH) and ecological health-based (SQGE) CCME (Canadian Council of Ministers of the Environment; 2015; on-line) soil quality guidelines, were preferentially used for comparison purposes. CCME guidelines derived for both residential / parkland and agricultural land use, were used where available. While the CCME guidelines were derived for Canadian soils and are not specifically applicable to Guinea Bissau soils, they are scientifically based, peer reviewed guidelines that are protective of human and ecological health and are considered appropriate for use in the COCP screening in the absence of local guidelines.

For the HHRA, where no CCME SQGHH was identified, an Ontario Ministry of the Environment (OMOE, 2011) soil screening standard (S1; soil contact guideline) was selected for comparison purposes. Where no CCME or OMOE guideline was identified, the United States Environmental Protection Agency (US EPA) Regional Screening Levels (RSL) for residential soil were used.

For the ERA, CCME guidelines were also preferentially used for screening, with CCME SQGE being selected for comparison purposes where available. If no CCME SQGE was available, the U.S. EPA Ecological Soil Screening Levels (Eco SSLs) were used. If no CCME SQGE or U.S. EPA ecological health-based soil quality guideline was identified, the Ontario Ministry of the Environment (OMOE, 2011) soil component value for either mammal / bird and plant / soil organism (which ever was lower) were used.

Results of the HHRA and ERA soil guideline screenings are respectively provided in Sections A-2.1 and A-2.2.

A-2.1 HHRA Soil Guideline Screening Results

Results of the soil screening for the HHRA are provided in Tables A-1 and A-2, for the Mine and Port sites, respectively. Maximum soil concentrations of aluminum, arsenic, chromium, iron, lead, lithium, manganese and vanadium exceeded the soil quality guidelines at both the Mine and Port sites, while cadmium was only exceeded at the Port site. No guidelines were available for bismuth, calcium, magnesium, potassium, phosphorus, silicon and sodium. Calcium, magnesium, potassium, phosphorus and sodium were not carried forward for further

assessment given the lack of guidelines and that these chemicals are essential nutrients in humans (U.S. EPA, 2014) and would not be likely to result in adverse health effects.

Although the proposed mine is a phosphate mine, phosphorus analytical data were not available in various media (e.g., mine soils, Table A-1; and waste or overburden samples, Tables A-6 and A-7 in Section 3.0). Given phosphorus is an essential nutrient (U.S. EPA, 2014) and is of low toxicity (tolerable upper intake level of 42,000 µg/kg/day; IOM, 2011); phosphorus was not carried forward for assessment in the HHRA.

While no human health-based soil quality guideline was available for bismuth, this element is considered relative non-toxic likely due to its low solubility and low absorption (DiPalma, 2001). Bismuth-containing compounds have been used to treat gastrointestinal issues in humans for many years (Reynolds et al., 2012). Given this, bismuth was not considered further in the assessment.

Similarly, no guideline was available for silicon. Silicon is the second most abundant element in the earth's crust at approximately 27.7% (NAS, 2005). It is considered relatively non-toxic with no significant acute toxicity being reported in animals given doses up to 3000 mg/kg/bw per day. Only minor toxic effects (e.g., kidney stones in ruminants) were reported following extremely high chronic exposures of silicon in animals (NAS, 2005). Given the low reported toxicity of silicon, it was not carried forward for further assessment.

While the maximum copper baseline soil concentration at the Mine site of 16.5 mg/kg was below the CCME soil quality guideline of 1100 mg/kg, it slightly exceeded the South African (SA DEA, 2014) guideline of 16 mg/kg (See Table A-1). Copper concentrations at the Port site were below both the CCME and SA DEA guidelines. Given the slight exceedance (only 1 of 36 samples from the Mine site, and no exceedances in the 15 Port site copper samples), and that the average baseline soil copper concentration at the Mine site was 5.3 mg/kg; copper was not carried forward for further assessment as a result of guideline screening in the HHRA.

Based on results of the baseline soil screening, the following chemicals were carried forward as COPCs for the HHRA of the Port and Mine sites:

- Aluminum
- Arsenic
- Cadmium (exceeded guideline in Port area only)
- Chromium
- Iron
- Lead
- Lithium
- Manganese
- Vanadium

Table A-1 Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Mine Study Area to Human Health-Based Soil Quality Guidelines (mg/kg)		
Analyte	***Maximum Soil Concentration (mg/kg dw)a***	***Guideline (mg/kg)***
Aluminum (Al)	34,100	7800 (U.S. EPA, 2015a) c
Antimony (Sb)	<0.51	7.5 (OMOE, 2011) d
Arsenic (As)	7.13	12 (CCME, 1997) b / 5.8 (SA DEA, 2014) e
Barium (Ba)	73	6800 (CCME, 2013)
Beryllium (Be)	6.13	38 (OMOE, 2011) d
Bismuth (Bi)	1.3	NGA
Boron (Bo)	2.7	4300 (OMOE, 2011) d,f
Cadmium (Cd)	0.77	1.4 / 14 (CCME, 1999) b / 7.5 (SA DEA, 2014) e
Calcium (Ca)	3,830	NGA
Chromium (Cr)	46	220 (CCME, 1999)b, g /46,000 Cr+3 / 6.5 Cr+6 (SA DEA, 2014) e
Cobalt (Co)	6.7	22 (OMOE, 2011) d / 300 (SA DEA, 2014) e
Copper (Cu)	16.5	1100 (CCME, 1999) b / 16 (SA DEA, 2014) e
Iron (Fe)	34,000	5500 (U.S. EPA, 2013) c
Lead (Pb)	29.6	140 (CCME, 1999) b / 20 (SA DEA, 2014) e
Lithium (Li)	44.1	16 (U.S. EPA, 2015a) e
Magnesium	2000	NGA
Manganese (Mn)	325	180 (U.S., EPA, 2015a) c,h / 740 (SA DEA, 2014) e
Mercury (Hg)	<0.2	6.6 (CCME, 1999)b / 0.93 (SA DEA, 2014) e
Molybdenum (Mo)	1.29	110 (OMOE, 2011) d
Nickel (Ni)	14.9	330 (OMOE, 2011) d / 91 (SA DEA, 2014) e
Phosphorus	NDA	NGA
Potassium	2,320	NGA
Selenium (Se)	<2	80 (CCME, 2009) b
Silicon	278	NGA
Silver (Ag)	<0.5	77 (OMOE, 2011) d
Sodium (Na)	8,360	NGA
Strontium (Sr)	174	4700 (U.S. EPA, 2015a) c
Thallium (Tl)	<0.5	1 / 1.4 (CCME, 1999) b
Tin (Sn)	6.9	50 (CCME, 1991) i
Titanium (Ti)	242	30,000 j
Uranium (U)	6.17	23 (CCME, 2007) b
Vanadium (V)	50.4	39 (OMOE, 2011) d / 150 (SA DEA, 2014) e
Zinc (Zn)	39.2	5600 (OMOE, 2011) d / 240 (SA DEA, 2014) e

Notes:

< = less than the reportable detection limit; value provided is the detection limit; NDA = no data available (phosphorus data were provided for the mine site); NGA = no guideline available

N (number of samples) = 36

Shaded cell indicates maximum concentration exceeds soil quality guideline.

[a] Data from Knight Piésold, 2015a

[b] CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use unless otherwise stated. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline. The year in which the CCME guideline was derived is presented in brackets.

Table A-1	Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Mine Study Area to Human Health-Based Soil Quality Guidelines (mg/kg)	
Analyte	***Maximum Soil Concentration (mg/kg dw)a***	***Guideline (mg/kg)***

c U.S. EPA (2015a) Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.
d OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2011). Standard provided is the S1 (soil contact) guideline.
e SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za
f Total boron
g CCME guideline for total chromium (derived in 1997).
h Residential soil, non-diet
I CCME (1991) guideline; basis of guideline not provided.
j No soil quality guideline was identified in the literature reviewed for titanium. A value of 30,000 mg/kg was used for comparison purposes given evaluations of titanium dioxide by JECFA, SCF, and EFSA have each concluded that there are no safety concerns associated with the use of titanium dioxide as a food additive at levels ranging up to 3% (or 30,000 mg/kg; US EPA, 2005).

Table A-2	Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Port Study Area to Human Health-Based Soil Quality Guidelines (mg/kg)	
Analyte	***Maximum Soil Concentration (mg/kg dw)a***	***Guideline (mg/kg)***
Aluminum (Al)	83,100	7800 (U.S. EPA, 2015a) c
Antimony (Sb)	<0.51	7.5 (OMOE, 2011) d
Arsenic (As)	44.8	12 (CCME, 1997) b / 5.8 (SA DEA, 2014) e
Barium (Ba)	113	6800 (CCME, 2013) b
Beryllium (Be)	3.98	38 (OMOE, 2011) d
Bismuth (Bi)	6	NGA
Boron (Bo)	26	4300 (OMOE, 2011) d,f
Cadmium (Cd)	5.96	1.4 / 14 (CCME, 1999) b / 7.5 (SA DEA, 2014) e
Calcium (Ca)	3,830	NGA
Chromium (Cr)	302	220 (CCME, 1999)b,g / 46,000 Cr+3 / 6.5 Cr+6 (SA DEA, 2014) e
Cobalt (Co)	12.8	22 (OMOE, 2011) d / 300 (SA DEA, 2014) e
Copper (Cu)	11.6	1100 (CCME, 1999) b / 16 (SA DEA, 2014) e
Iron (Fe)	187,000	5500 (U.S. EPA, 2015a) c
Lead (Pb)	46.2	140 (CCME, 1999) b / 20 (SA DEA, 2014) e
Lithium (Li)	46.5	16 (U.S. EPA, 2015a) e
Magnesium	6,670	NGA
Manganese (Mn)	322	180 (U.S., EPA, 2015a) c,h / 740 (SA DEA, 2014) e
Mercury (Hg)	0.29	6.6 (CCME, 1999) b / 0.93 (SA DEA, 2014) e
Molybdenum (Mo)	6.44	110 (OMOE, 2011) d
Nickel (Ni)	33.9	330 (OMOE, 2011) d / 91 (SA DEA, 2014) e
Phosphorus	860	NGA
Potassium	4,830	NGA
Selenium (Se)	<2	80 (CCME, 2009) b
Silicon	238	NGA
Silver (Ag)	<0.5	77 (OMOE, 2011) d
Sodium (Na)	17,900	NGA
Strontium (Sr)	80.5	4700 (U.S. EPA, 2015a) c
Thallium (Tl)	<0.5	1 / 1.4 (CCME, 1999) b
Tin (Sn)	7.6	50 (CCME, 1991) i
Titanium (Ti)	297	30,000 j
Uranium (U)	18.5	23 (CCME, 2007) b
Vanadium (V)	352	39 (OMOE, 2011) d / 150 (SA DEA, 2014) e
Zinc (Zn)	153	5600 (OMOE, 2011) d / 240 (SA DEA, 2014) e

Notes:
< = less than the reportable detection limit; value provided is the detection limit; NGA = no guideline available
Shaded cell indicates maximum concentration exceeds soil quality guideline.
N (number of samples) = 15

Table A-2 Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Port Study Area to Human Health-Based Soil Quality Guidelines (mg/kg)

Analyte	*Maximum Soil Concentration (mg/kg dw)a*	*Guideline (mg/kg)*

[a] Data from Knight Piésold, 2015a

[b] CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) human health-based soil quality guidelines for residential / parkland and agricultural land use unless otherwise stated. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline. The year in which the CCME guideline was derived is presented in brackets.

[c] U.S. EPA (2015a) Regional Screening Value (RSL) for residential soil based on a hazard quotient (HQ) of 0.1.

[d] OMOE (Ontario Ministry of the Environment) soil screening standards from their generic site condition standards (SCS) document (OMOE, 2012). Standard provided is the S1 (soil contact) guideline.

[e] SA DEA (2014); South Africa Department of Environmental Affairs. Soil Screening Values for Metals and Organics. SSV1 – All land uses protective of the water resource. www.gpwonline.ca.za

[f] Total boron

[g] CCME guideline for total chromium (derived in 1997).

[h] Residential soil, non-diet

[I] CCME (1991) guideline; basis of guideline not provided.

[j] No soil quality guideline was identified in the literature reviewed for titanium. A value of 30,000 mg/kg was used for comparison purposes given evaluations of titanium dioxide by JECFA, SCF, and EFSA have each concluded that there are no safety concerns associated with the use of titanium dioxide as a food additive at levels ranging up to 3% (or 30,000 mg/kg; US EPA, 2005).

A-2.2 Ecological Soil Guideline Screening Results

Results of the soil screening for the ERA are provided in Tables A-3 and A-4, for the Mine and Port sites, respectively. At the Mine site the maximum concentrations of beryllium and manganese exceeded guidelines, while at the Port site arsenic, chromium, manganese and vanadium exceeded guidelines. No guidelines were available for bismuth, boron, calcium, lithium, magnesium, potassium, phosphorus, silicon, sodium, strontium, tin and titanium. Calcium, magnesium, potassium, phosphorus and sodium were not carried forward for further assessment given the lack of guidelines and that these chemicals are essential nutrients in animals (NAS, 2005) and would not be likely to result in adverse health effects. While no guidelines were available for bismuth, lithium, strontium, tin and titanium, these elements were evaluated further in the oral toxic potency screening (Section A-3.1). Boron and silicon were not analyzed in ore, waste overburden or product sample and as such could not be considered further in the oral toxic potency screening. However, these elements are considered relatively non-toxic (See Section A-2.1) and as such, were not considered further.

Selenium was not detected (detection limit of 2 mg/kg) in the Port (N=15) or Mine (N=36) site soil samples; however the CCME ecological health-based soil quality guideline, 1 mg/kg, is lower than the detection limit. Selenium was not analyzed in the ore samples, and not detected in the waste overburden samples (detection limit of 0.7 mg/kg) with the exception of two samples (detected at 0.10 mg/kg and 0.80 mg/kg; Table A-7). Selenium was detected in the one product sample at 11 mg/kg (Table A-12). Given the detectable concentrations of selenium in waste over burden and product, and given the lack of selenium data in the ore, selenium was carried forward for further assessment based on the guideline screen.

Based on results of the baseline soil screening, the following chemicals were carried forward as COPCs for the ERA of the Port and Mine sites:

- Arsenic
- Beryllium
- Chromium
- Manganese
- Selenium
- Vanadium

Table A-3 Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Mine Study Area Concentration to Ecological Health-Based Soil Quality Guidelines (mg/kg)

Analyte	*Maximum Soil Concentration (mg/kg)*[a]	*Guideline (mg/kg)*
Aluminum (Al)	34,100	pH<5.5 [c] (U.S. EPA, 2003a)
Antimony (Sb)	<0.51	20 (OMOE, 2011) [d]
Arsenic (As)	7.13	17 (CCME, 1997) [b]
Barium (Ba)	73	390 (OMOE, 2011) [d]
Beryllium (Be)	6.13	4 (OMOE, 2011) [d]
Bismuth (Bi)	1.3	NGA
Boron (B)	2.7	NGA
Cadmium (Cd)	0.77	3.8 / 10 (CCME, 1999) [b]
Calcium (Ca)	3,830	NGA
Chromium (Cr)	46	64 (CCME, 1997) [b, e]
Cobalt (Co)	6.7	40 (OMOE, 2011) [d]
Copper (Cu)	16.5	63 (CCME, 1999) [b]
Iron (Fe)	34,000	pH 5 - 8 (U.S. EPA, 2003b) [f]
Lead (Pb)	29.6	70 / 300 (CCME, 1999) [b]
Lithium (Li)	44.1	NGA
Magnesium (Mg)	2,000	NGA
Manganese (Mn)	325	220 (U.S. EPA, 2007) [g]
Mercury (Hg)	<0.2	12 (CCME, 1999) [b]
Molybdenum (Mo)	1.29	6.9 (OMOE, 2011) [d]
Nickel (Ni)	14.9	50 (CCME, 1999) [b]
Phosphorus (P)	NDA	NGA
Potassium (K)	2,320	NGA
Selenium (Se)	<2	1 (CCME, 2009) [b]
Silicon (Si)	278	NGA
Silver (Ag)	<0.5	20 (OMOE, 2011) [d]
Sodium (Na)	8,360	NGA
Strontium (Sr)	174	NGA
Thallium (Tl)	<0.5	1 / 1.4 (CCME, 1999) [b]
Tin (Sn)	6.9	NGA
Titanium (Ti)	242	NGA
Uranium (U)	6.17	33 / 500 (CCME, 2007) [b]
Vanadium (V)	50.4	130 (CCME, 1997) [b]
Zinc (Zn)	39.2	200 (CCME, 1999) [b]

< = less than the reportable detection limit; value provided is the detection limit; NDA = no data available (no phosphorus data were provided for the mine site); NGA = no guideline available

N (number of samples) = 36

Shaded cell indicates maximum concentration exceeds soil quality guideline.

[a] Data from Knight Piésold, 2015a

[b] CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) ecological health-based soil quality guidelines for residential / parkland and agricultural land use (agricultural guidelines are applicable to wildlands) unless otherwise stated. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline. The year in which the CCME guideline was derived is presented in brackets.

[c] U.S. EPA (2003a); for soils with pH <5.5 Al should be retained as a COC. The pH of 8 soil samples analyzed ranged from 5.1 to 5.9 with an average pH of 5.6.

[d] OMOE (Ontario Ministry of the Environment; 2011) soil component value. Value presented is lower of the mammal / bird and plant / soil organism soil component value.

[e] CCME Guideline for total chromium (derived in 1997).

[f] U.S. EPA (2003b); for soils with pH between 5 and 8, iron is considered non-toxic. The pH of 8 soil samples analyzed ranged from 5.1 to 5.9 with an average pH of 5.6 and thus fall into this range.

[g] US EPA (2007) Ecological Soil Screening Level (Eco SSL) for manganese. Value provided is the lower of the plant, soil invertebrate and wildlife guidelines.

Table A-4 Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Port Study Area Concentration to Ecological Health-Based Soil Quality Guidelines (mg/kg)

Analyte	*Maximum Soil Concentration (mg/kg)*[a]	*Guideline (mg/kg)*
Aluminum (Al)	83,100	pH<5.5 [c] (U.S. EPA, 2003a)
Antimony (Sb)	<0.51	20 (OMOE, 2011) [d]
Arsenic (As)	44.8	17 (CCME, 1997) [b]
Barium (Ba)	113	390 (OMOE, 2011) [d]
Beryllium (Be)	3.98	4 (OMOE, 2011) [d]
Bismuth (Bi)	6	NGA
Boron (B)	26	NGA
Cadmium (Cd)	5.96	3.8 / 10 (CCME, 1999) [b]
Calcium (Ca)	3,830	NGA
Chromium (Cr)	302	64 (CCME, 1997) [b, e]
Cobalt (Co)	12.8	40 (OMOE, 2011) [d]
Copper (Cu)	11.6	63 (CCME, 1999) [b]
Iron (Fe)	187,000	pH 5 - 8 (U.S. EPA, 2003b) [f]
Lead (Pb)	46.2	70 / 300 (CCME, 1999) [b]
Lithium (Li)	46.5	NGA
Magnesium (Mg)	6,670	NGA
Manganese (Mn)	322	220 (U.S. EPA, 2007) [g]
Mercury (Hg)	0.29	12 (CCME, 1999) [b]
Molybdenum (Mo)	6.44	6.9 (OMOE, 2011) [d]
Nickel (Ni)	33.9	50 (CCME, 1999) [b]
Phosphorus (P)	860	NGA
Potassium (K)	4,830	NGA
Selenium (Se)	<2	1 (CCME, 2009) [b]
Silicon (Si)	238	NGA
Silver (Ag)	<0.5	20 (OMOE, 2011) [d]
Sodium (Na)	17,900	NGA
Strontium (Sr)	80.5	NGA
Thallium (Tl)	<0.5	1 / 1.4 (CCME, 1999) [b]
Tin (Sn)	7.6	NGA
Titanium (Ti)	297	NGA
Uranium (U)	18.5	33 / 500 (CCME, 2007) [b]
Vanadium (V)	352	130 (CCME, 1997) [b]
Zinc (Zn)	153	200 (CCME, 1999) [b]

Table A-4	Comparison of Maximum Measured Baseline Surface Soil (0 to 5 cm) within the Port Study Area Concentration to Ecological Health-Based Soil Quality Guidelines (mg/kg)	
Analyte	***Maximum Soil Concentration (mg/kg)[a]***	***Guideline (mg/kg)***

Notes:

< = less than the reportable detection limit; value provided is the detection limit; NGA = no guideline available

N (number of samples) = 15

Shaded cell indicates maximum concentration exceeds soil quality guideline.

[a] Data from Knight Piésold, 2015a

[b] CCME (2015 on-line; http://ceqg-rcqe.ccme.ca/) ecological health-based soil quality guidelines for residential / parkland and agricultural land use (agricultural guidelines are applicable to wildlands) unless otherwise stated. Where agricultural and residential / parkland are different, the agricultural guideline is presented first followed by the residential / parkland guideline. The year in which the CCME guideline was derived is presented in brackets.

[c] U.S. EPA (2003a); for soils with pH <5.5 Al should be retained as a COC. The pH of 8 soil samples analyzed ranged from 5.1 to 5.9 with an average pH of 5.6. Delays in sample shipment from Guinea-Bissau resulted in holding times for pH being exceeded. Nevertheless, these pH values were used for assessment purposes due to lack of other data.

[d] OMOE (Ontario Ministry of the Environment; 2011) soil component values. Value provided is lower of the mammal / bird and plant / soil organism soil component value.

[e] CCME Guideline for total chromium (derived in 1997).

[f] U.S. EPA (2003b); for soils with pH between 5 and 8, iron is considered non-toxic. The pH of 8 soil samples analyzed ranged from 5.1 to 5.9 with an average pH of 5.6 and thus fall into this range. Delays in sample shipment from Guinea-Bissau resulted in holding times for pH being exceeded. Nevertheless, these pH values were used for assessment purposes due to lack of other data.

[g] US EPA (2007) Ecological Soil Screening Level (Eco SSL) for manganese. Value provided is the lower of the plant, soil invertebrate and wildlife guidelines.

A-3.0 ORAL TOXIC POTENCY SCREENING

A chemical screening process, referred to as toxic potency screening, was conducted to identify metals of potential concern for the HHRA and ERA. Separate toxic potency screens were conducted for the Port and Mine sites for both the HHRA and ERA.

Toxic potency screening is essentially a relative ranking system for chemicals that ranks chemicals based on the combination of toxic potency and an indicator of exposure potential, which can be emission rates, percent chemical composition of raw materials, environmental media concentrations *etc.* It is based on a screening procedure developed by the U.S. EPA (1989) and used by other regulatory agencies to determine COPCs in environmental impact statements (e.g., Alberta Health and Wellness, 2011).

The toxic potency of a chemical is the dose or quantity of that chemical which is necessary to produce adverse health effects (*i.e.*, toxic effects). For example, the toxic potency of chemical A would be greater than that of chemical B if toxic effects are produced at a lower concentration of chemical A than chemical B. It is important to consider the toxic potency of chemicals when selecting the chemicals of concern for a risk assessment, as chemicals present at low concentrations with a high toxic potency may pose a greater risk potential to human receptors than chemicals which are present at higher concentrations, but with a lower toxic potency.

Elemental composition data for 156 ore samples, 20 waste overburden samples (and duplicates) (Tables 1 to 3; Knight Piésold, 2015b) were used to conduct the toxic potency screening for the Mine site and one product sample was used for the Port site as these are the dominant geochemistry sources for dust and particulate emissions expected at these locations (based on PM10; See Sections A-3.1 and A-3.2).

Average percent metal composition of the dominant geochemistry sources for PM_{10} emissions at the Mine site (i.e., ore and waste over burden) and Port sites (i.e., product) were determined (See Sections A-3.1 and A-3.2). For the HHRA oral toxic potency screening, the average percent metal composition data for the dominant geochemistry were compared to regulatory oral toxicity reference values (TRVs) developed for human receptors (*e.g.*, Health Canada, U.S. Environmental Protection Agency, World Health Organization). TRVs are doses of chemicals that individuals can be exposed to on a daily basis without developing adverse health effects, or where the risk of incurring adverse health effects is considered to be at an acceptable level. Human TRVs are selected based on the most sensitive endpoints in individuals (*i.e.*, cancer, neurological effects, reproductive effects, *etc*.). In a toxic potency screen, human health TRVs are typically expressed as either reference doses (RfD) (used for non-carcinogens), or risk-specific doses (RsD), where the risk of incurring adverse carcinogenic health effects is considered to be at a predefined acceptable level (the RsD is typically only used for carcinogens). RsDs are calculated by dividing the acceptable risk level (*e.g.*, 1 in 100,000 to 1 in 1,000,000) by the cancer slope factor. A risk level of 1 in 100,000 (i.e., one additional cancer per 100,000 people) was selected based on a variety of guidance documents (i.e., WHO, 2000; 2009; Health Canada, 2010a).

For the ERA there are a limited number of published toxicity reference values for relevant ecological receptors. As such, in the ERA toxic potency screening, soil quality guidelines and maximum tolerable levels were used for comparison purposes.

In the toxic potency screening, the elemental weight percent values of each element (based on the dominant geochemistry of PM_{10}) were divided by the corresponding TRV, guideline or tolerable level for that element to yield a value that represents the individual toxic potency of

that element. It must be recognized that this value is simply an expression of relative toxic potency that relates the amount of chemical present in the concentrate to its exposure limit. Thus, the units do not need to cancel out. Individual toxic potency for each chemical parameter was then expressed as a per cent of the total summed toxic potency of all chemical parameters considered. Following this, the chemicals were ranked in descending order of contribution to total toxic potency. Cumulative toxic potency was then calculated by adding the per cent individual toxic potency of the chemical with the highest individual toxic potency to that of the chemical with the next highest individual toxic potency, until the cut-off value for cumulative toxic potency was reached (99% in this case for HHRA and 95% for ERA). The choice of cut-off for the cumulative toxic potency is an arbitrary decision. In many HHRAs and ERAs, cutoff values of 99% or 95% are used. There is no regulatory guidance on this issue; rather, professional judgment is important in defining a reasonable and protective cutoff value. For the current toxic potency screen, 99% cumulative toxic potency was considered a reasonable and conservative cutoff value, as it is very unlikely that chemicals contributing less than 1% of the cumulative toxic potency would not pose a risk in the HHRA. For the ERA a value of 95% was used as the focus of an ERA is generally on population level effects, rather than on individual effects which are the focus of a HHRA.

In the human toxic potency screening calcium, magnesium, phosphorus and potassium were not included as these elements are considered essential (U.S. EPA, 2014).

Results of the HHRA and ERA oral toxic potency screenings for the Mine and Port sites are provided in Sections A-3.1 and A-3.2, respectively.

A-3.1 Oral Toxic Potency Screening for the Mine Site

The dominant geochemistry sources of PM_{10} emissions at the Mine site were determined by Knight Piésold. At the Mine site the predominant geochemistry of PM_{10} (with the exception of road dusts) will be associated with waste overburden and ore (See Table A-5). While road dusts related to limestone surfacing represented the largest source of PM_{10} emissions at the Mine site, geochemistry of these dusts were not used in the assessment. Limestone is comprised mainly of calcium carbonate which would be of low toxicity. Therefore to be conservative, the elemental breakdowns of ore and waste overburden (provided by Lycopodium Tables 1 and 3) were used in the toxic potency screening for the mine.

Elemental composition data for 156 ore samples, 20 waste overburden samples (and duplicates) (Tables 1 to 3; Knight Piésold, 2015b) were used to conduct the toxic potency screening of the Mine site. Average metal concentrations in the ore and waste overburden samples were calculated by averaging the concentration of each metal in all the samples analyzed (chemicals that were not detected, were assumed to be present at their detection limit) (See Tables A-6 and A-7). The total average (in mg/kg) for each metal was summed and then a percentage of each metal in the entire sample was calculated.

Table A-5 Mine Emissions By Source Type for Various Years of Operation					
Scenario	***Source***	***Type of Source***	***PM_{10} emissions(g/s)***	***Dominant Geochemistry***	***Sum of PM_{10} Emissions by Source Type (g/s)***
Year 2	Generator 1	Point	0.0604	Diesel	Sum diesel = 0.1208
	Generator 2	Point	0.0604	Diesel	
	ROM Stockpile	Areal	0.2385	Ore	Sum ore = 1.062
	ROM bin grizzly / ROM belt feeder	Areal	0.0029	Ore	
	Coarse ore stockpile	Areal	0.0007	Ore	
	Reject screen 1 and 2	Volume	0.0599	Ore	
	Concentrate filter discharge conveyor	Volume	0.0002	Ore	
	Concentrate pipe conveyor feed bin	Volume	0.0003	Ore	
	South Open Pit	Volume	1.5196	Ore and Waste overburden [1]	
	Truck loading facility	Volume	0.0015	Product	Sum product = 0.00150
	South Open Pit - NEWD	Lineal	0.3568	Road: limestone surfacing	Sum road = 3.740
	South Open Pit - ROM Stockpile	Lineal	0.1363	Road: limestone surfacing	
	ROM Stockpile - ROM bin grizzly	Lineal	0.0445	Road: limestone surfacing	
	South Open Pit - IWL	Lineal	3.2021	Road: limestone trucked from a quarry	
	Tailing Storage Facility	Areal	0.1494	Tailings	Sum tailings = 0.1494
	South Open Pit - South Open Pit	Lineal	0.2647	Waste overburden [2]	Sum WO = 1.987
	Integrated Waste Landform (IWL)	Areal	0.7101	Waste overburden	
	South-East Waste Dump	Areal	0.0071	Waste overburden	
	North-East Waste Dump	Areal	0.2448	Waste overburden	
	Total Year 2		**7.0599**		
Year 15	Generator 1	Point	0.0604	Diesel	Sum diesel = 0.1208
	Generator 2	Point	0.0604	Diesel	
	ROM Stockpile	Areal	0.2385	Ore	Sum ore = 1.254
	ROM bin grizzly / ROM belt feeder	Areal	0.0029	Ore	
	Coarse ore stockpile	Areal	0.0007	Ore	
	Reject screen 1 and 2	Volume	0.0599	Ore	
	North Open Pit	Areal	1.9038	Ore and Waste overburden [1]	
	Truck loading facility	Volume	0.0015	Product	Sum product = 0.0020
	Concentrate filter discharge conveyor	Volume	0.0002	Product	
	Concentrate pipe conveyor feed bin	Volume	0.0003	Product	

Table A-5 Mine Emissions By Source Type for Various Years of Operation

Scenario	*Source*	*Type of Source*	*PM_{10} emissions(g/s)*	*Dominant Geochemistry*	*Sum of PM_{10} Emissions by Source Type (g/s)*
	North Open Pit - ROM Stockpile	Lineal	0.3665	Road: limestone surfacing	Sum road = 5.207
	North Open Pit - IWL	Lineal	4.6536	Road: limestone surfacing	
	North Open Pit - SPS	Lineal	0.1229	Road: limestone surfacing	
	North Open Pit - NPS	Lineal	0.0199	Road: limestone surfacing	
	ROM Stockpile - ROM bin grizzly	Lineal	0.0445	Road: limestone trucked from a quarry	
	Tailing Storage Facility	Areal	0.6834	Tailings	Sum tailings = 0.6834
	North Open Pit - North Open Pit	Lineal	0.3306	Waste overburden [2]	Sum WO = 2.723
	Integrated Waste Landform (IWL)	Areal	1.0077	Waste overburden	
	South Pit SOS	Volume	0.1753	Waste overburden	
	North Pit SOS	Volume	0.2576	Waste overburden	
	Total Year 15		**9.9904**		

Notes:
Data provided in e-mail from A. Delgado (Knight Piesold) to C. Moore (Intrinsik) dated July 13, 2015.
WO = waste overburden
1. When dominant geochemistry was listed as 2 different types for one source, each was assumed to represent half of the PM10 emissions indicated for that source.
2. Source type expected to be mainly truck haulage form the pit so dominant geochemistry is WO; however this will depend upon how the haulage road is built.

Table A-6 Metals Content of 156 Ore Samples

Parameter (in mg/kg)			Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Ni	Pb	S	Sb	Sr	Ti	Tl	U	V	Zn
Drillhole	Depth	Sample ID																										
SA 0	47.50	FASO 001	0.5	7,500	13	30	1.1	5	310,000	6.1	10	381	24	27,900	400	1,200	403	3	114	5	30,000	5	421	300	10	110	259	226
SA 0		FASO 002	0.5	12,200	19	30	0.8	2	256,000	4.7	6	219	15	30,700	1,400	12,300	1,045	4	114	3	34,900	5	552	600	10	120	196	129
SA 2	50.92	FASO 003	0.5	17,700	5	50	11.5	2	289,000	6	15	278	9	33,900	100	400	650	2	16	3	16,600	5	1,540	300	10	70	162	200
SA 2	52.65	FASO 004	0.5	13,700	9	40	6	5	288,000	4.2	15	220	15	40,700	700	800	946	1	21	5	16,400	5	318	600	10	80	183	130
SA 2	54.40	FASO 005	0.5	27,600	13	30	2.4	2	229,000	6.4	19	219	30	42,200	2,200	5,200	501	1	94	3	19,900	5	176	900	10	40	207	318
SA 3b	---	FASO 006	0.5	62,700	5	100	8.9	6	119,500	2.2	11	282	12	67,300	400	700	1,265	1	17	8	14,500	5	2,330	2,400	10	70	100	92
SA 3b	33.10	FASO 007	0.5	17,800	9	40	3.4	2	281,000	6.2	19	347	20	32,200	400	1,000	272	1	46	5	29,500	5	470	600	10	100	400	373
SA 3b	34.50	FASO 008	0.5	23,800	11	30	1.7	11	179,500	5.9	64	366	24	122,000	2,200	6,600	1,860	3	230	3	67,000	5	278	1,200	10	110	971	814
SA 3b	35.55	FASO 009	0.5	8,500	12	10	0.5	2	340,000	1.8	5	68	4	10,400	800	3,800	264	1	26	2	6,000	5	620	400	10	10	40	46
SB 3	---	FASO 010	0.5	30,800	18	40	3.9	2	241,000	4.8	9	359	22	18,300	400	1,000	155	1	55	4	14,200	5	794	400	10	100	404	166
SB 3	---	FASO 011	0.5	15,200	7	20	1.5	25	92,900	3.2	35	168	12	285,000	1,500	8,400	5,220	1	157	2	5,100	5	161	800	10	20	144	175
SB 3	30.16	FASO 012	0.5	10,400	14	10	0.5	2	335,000	1.6	2	78	4	6,200	1,200	4,900	101	1	17	2	100	5	874	500	10	20	36	38
SC 1	30.96	FASO 013	0.5	40,200	10	60	5.9	2	232,000	8.4	6	327	9	21,400	600	500	325	1	18	5	15,500	5	1,420	500	10	70	145	212
SC 1	32.10	FASO 014	0.5	5,400	12	30	1.7	2	318,000	5.9	2	346	8	17,100	100	200	163	1	17	4	18,000	5	397	200	10	90	201	195
SC 1	---	FASO 015	0.5	8,200	14	30	1.5	2	305,000	8.9	5	335	23	19,700	400	1,000	156	1	99	4	20,200	5	262	400	10	120	475	279
SC 1	---	FASO 016	0.5	2,000	5	10	0.5	2	352,000	1.4	1	77	5	7,500	200	1,700	324	1	17	2	8,000	5	224	100	10	20	56	37
SC 3b	41.20	FASO 017	0.5	19,900	18	40	3	2	257,000	6.8	19	262	21	21,600	700	500	465	3	68	2	14,800	6	549	300	10	80	235	445
SC 3b	42.35	FASO 018	0.5	8,900	17	20	1.6	2	319,000	6.9	14	294	17	18,700	300	800	188	2	75	5	20,500	5	263	300	10	110	266	289
SC 3b	43.50	FASO 019	0.5	11,300	7	20	1.4	2	309,000	6.1	12	345	16	14,000	600	1,300	151	2	77	4	12,200	5	328	500	10	110	257	273
FASO 020/12	---	FASO 020	0.5	10,700	5	10	0.5	2	342,000	1.8	2	88	6	6,300	1,200	5,000	101	1	20	3	100	5	886	500	10	20	38	44
SC 4b	41.00	FASO 021	0.5	43,700	9	190	2.2	2	11,100	0.6	11	120	3	12,900	1,100	400	79	1	24	7	8,400	5	1,830	3,200	10	10	62	87
SC 4b	42.00	FASO 022	0.5	38,800	15	170	7.3	2	38,900	0.8	9	526	4	11,700	300	100	281	1	10	11	7,100	5	5,470	2,200	10	80	184	114
SC 4b	---	FASO 023	0.5	39,900	13	60	4.9	2	188,000	5.6	33	292	12	18,900	600	300	301	1	39	4	11,000	5	2,070	600	10	70	157	384
SC 4b	39.90	FASO 024	0.5	17,900	10	40	2.4	2	249,000	5.7	18	247	9	14,700	300	300	258	1	25	4	10,100	5	1,160	300	10	80	144	351
SD 0b is b	41.50	FASO 025	0.5	8,500	5	30	1.3	3	306,000	12.2	17	331	46	43,100	500	1,900	1,050	1	179	2	16,600	5	376	400	10	120	517	291
SD 3	42.80	FASO 026	0.5	14,900	7	40	2.7	10	189,500	3.5	8	246	8	112,000	900	2,100	2,480	1	11	4	26,800	5	753	900	10	40	140	143
SD 3	---	FASO 027	0.5	9,400	8	20	1.3	3	319,000	4.4	7	405	40	28,300	300	900	563	1	20	4	22,000	5	304	400	10	130	380	199
SD 3	39.25	FASO 028	0.5	10,200	17	30	1.2	2	290,000	8.1	13	318	23	32,800	600	1,200	397	1	99	4	25,100	5	305	600	10	80	301	261
SD 3	40.40	FASO 029	0.5	11,700	6	30	1.1	16	151,000	3.7	8	216	15	185,000	900	5,700	4,100	1	96	4	42,900	5	213	800	10	50	193	115
SD 3	41.70	FASO 030	0.5	31,200	6	30	1.3	11	160,500	6.3	13	346	28	118,500	3,500	10,200	2,200	1	165	7	43,700	5	319	1,600	10	100	279	198
A1	42.50	FASO 031	0.5	10,000	13	50	2.5	2	256,000	5.3	32	316	21	30,500	400	900	268	1	150	3	30,800	9	1,200	500	10	70	225	519
A1	43.00	FASO 032	0.5	7,100	16	30	1	2	270,000	5.1	10	235	19	27,800	600	1,800	246	1	126	2	27,000	5	526	500	10	60	169	147
A1	43.55	FASO 033	0.5	2,600	10	10	0.5	2	343,000	2.5	1	84	6	9,500	200	2,500	174	1	20	2	11,000	5	356	100	10	30	55	45
A2	---	FASO 034	0.5	37,200	8	70	5	3	186,500	11.1	7	335	29	30,800	500	500	596	1	16	10	20,000	5	2,270	700	10	60	203	267
A2	---	FASO 035	0.5	15,900	13	50	2.3	2	231,000	7.4	5	313	23	17,800	600	500	287	1	14	4	14,000	5	882	300	10	40	216	376
A2	38.85	FASO 036	0.5	8,200	11	30	1.2	5	254,000	6.4	14	356	23	42,200	400	1,000	316	1	192	4	42,700	5	607	400	10	70	213	233
A2	40.50	FASO 037	0.5	5,800	15	20	0.6	3	312,000	2.2	5	73	11	20,700	400	2,600	370	1	31	6	12,000	5	591	300	10	30	61	80
A3	41.20	FASO 038	0.5	59,500	10	130	13.1	2	162,000	8.9	1	541	31	26,900	400	300	645	1	12	11	13,600	5	4,290	1,600	10	110	386	189
A3	42.50	FASO 039	0.5	10,800	11	40	3.2	2	297,000	8.6	9	360	27	15,700	200	200	214	1	18	5	16,000	5	700	400	10	70	282	362
A3	---	FASO 040	0.5	6,500	16	40	2.3	2	308,000	7.8	9	384	23	19,800	100	200	225	1	33	5	21,900	5	685	200	10	60	163	371
A3	40.00	FASO 041	0.5	5,300	7	40	2.4	2	295,000	5.3	25	322	31	35,300	200	300	237	2	177	2	41,300	5	417	300	10	60	258	212
A3	41.80	FASO 042	0.5	10,700	9	40	1.2	2	281,000	10.5	24	388	25	28,200	1,000	2,000	183	1	136	5	30,000	5	572	600	10	90	280	209
A3	43.00	FASO 043	0.5	7,800	16	30	1	2	289,000	9.3	19	384	30	36,300	800	2,300	737	1	118	2	21,900	5	507	400	10	110	261	316
A3	39.30	FASO 044	0.5	6,800	15	10	0.5	2	337,000	1.7	1	55	5	5,700	800	3,800	146	1	22	3	100	5	745	400	10	20	33	41

Table A-6 Metals Content of 156 Ore Samples

Parameter (in mg/kg)			Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Ni	Pb	S	Sb	Sr	Ti	Tl	U	V	Zn
Drillhole	Depth	Sample ID																										
FASO 045/14	40.40	FASO 045	0.5	5,500	5	30	1.6	2	307,000	5.8	1	336	8	16,900	200	200	165	1	18	4	18,100	5	390	200	10	80	197	192
A4	41.90	FASO 046	0.5	11,000	7	40	3.4	2	291,000	9.4	4	352	17	21,400	800	300	269	1	10	7	20,600	5	581	400	10	70	205	290
A4	---	FASO 047	0.5	4,000	11	30	1.6	2	323,000	6.6	1	396	12	14,500	100	200	155	1	8	4	16,000	5	378	200	10	70	203	281
A4	---	FASO 048	0.5	5,100	5	30	1.8	2	305,000	6.5	5	312	20	33,900	300	800	816	1	59	4	18,900	5	381	300	10	60	269	176
A4	39.45	FASO 049	0.5	7,900	9	30	1	2	300,000	7.5	14	373	22	16,600	700	1,900	223	1	146	5	16,600	5	563	400	10	100	274	172
A4	41.80	FASO 050	0.5	4,400	10	10	0.5	2	335,000	2.6	4	113	8	9,200	400	2,700	237	1	32	2	10,000	5	478	300	10	40	88	65
A5	43.00	FASO 051	0.5	21,000	16	60	3.4	4	211,000	5.1	5	304	17	35,200	1,300	1,100	419	1	22	6	22,600	5	714	600	10	50	195	250
A5	---	FASO 052	0.5	6,400	5	40	2.1	2	283,000	5.2	5	278	19	39,300	300	700	854	1	73	5	24,600	5	527	300	10	70	206	195
A5	---	FASO 053	0.5	9,400	11	40	2.3	2	231,000	5.7	8	247	16	36,700	500	1,200	788	1	92	5	25,500	5	816	400	10	80	184	154
A6	38.40	FASO 054	0.5	9,800	12	40	2.3	5	244,000	4.7	3	316	26	55,400	400	1,400	994	1	39	3	31,500	5	515	500	10	50	377	279
A6	40.40	FASO 055	0.5	7,400	8	40	1.5	4	269,000	7.1	11	348	20	46,500	400	1,500	1,105	1	103	5	25,100	5	469	400	10	80	350	284
A6	41.90	FASO 056	0.5	15,700	13	40	2	2	211,000	5.8	20	302	20	69,200	1,100	3,200	1,355	1	143	3	24,200	5	738	900	10	80	251	175
A6	---	FASO 057	0.5	4,500	5	20	0.6	2	327,000	2.8	5	99	5	18,500	300	2,400	517	1	33	2	8,000	5	339	300	10	30	79	73
A6	39.50	FASO 058	0.5	5,800	8	20	0.5	2	341,000	3.3	2	139	8	7,900	800	2,900	195	1	47	2	7,000	5	544	300	10	60	114	80
A7	41.10	FASO 059	0.5	60,600	14	100	7.6	2	212,000	8.5	7	383	29	17,400	100	800	158	1	26	4	19,200	5	5,050	300	10	60	284	212
A7	42.40	FASO 060	0.5	7,300	9	30	1.9	5	307,000	7.6	2	357	55	22,700	100	300	218	1	34	2	26,100	5	456	200	10	60	253	183
A7	39.80	FASO 061	0.5	7,100	14	40	1.7	3	287,000	7.1	47	315	28	47,700	400	1,300	928	1	530	5	21,000	5	509	300	10	80	248	306
A7	42.10	FASO 062	0.5	3,400	10	10	0.5	3	333,000	2.5	2	92	7	20,300	300	2,800	497	1	44	2	10,000	5	432	200	10	40	81	40
A7	40.50	FASO 063	0.5	4,800	13	10	0.5	2	346,000	1.3	2	40	3	4,900	600	3,500	189	1	20	2	100	5	572	300	10	20	29	27
A8	42.00	FASO 064	0.5	41,400	5	90	7.7	2	229,000	9.8	8	326	23	23,500	100	200	363	1	17	6	24,000	5	2,700	400	10	70	273	270
A8	43.40	FASO 065	0.5	12,500	11	40	2.8	2	294,000	9.5	12	346	21	31,300	200	500	698	1	56	5	20,600	5	894	200	10	70	196	278
A8	41.95	FASO 066	0.5	11,200	17	40	1.4	4	253,000	5.3	6	316	19	56,800	500	800	1,075	1	41	5	34,300	5	494	600	10	60	184	240
FASO 68/12	43.22	FASO 067	0.5	11,800	6	10	0.6	2	335,000	2.2	4	85	5	6,500	1,200	4,700	107	1	18	3	100	5	971	500	10	20	45	49
A9	44.02	FASO 068	0.5	62,000	5	70	6.8	2	196,500	15.1	18	342	36	24,700	200	400	257	1	29	2	27,700	5	3,060	500	10	60	315	449
A9	39.30	FASO 069	0.5	11,100	6	30	1.6	2	292,000	7	5	388	25	20,800	100	300	194	1	26	3	23,800	5	759	200	10	60	281	337
A9	41.00	FASO 070	0.5	9,400	8	30	1.4	3	262,000	8.4	10	384	25	38,800	600	1,300	523	1	136	6	37,000	5	558	400	10	90	247	166
A10	43.00	FASO 071	0.5	36,800	6	80	5.8	2	236,000	5	6	337	16	23,100	200	400	384	1	23	2,270	17,800	8	2,190	500	10	70	300	168
A10	---	FASO 072	0.5	8,900	7	30	1.1	3	216,000	6.5	17	321	41	109,500	700	3,100	2,180	1	188	6	37,200	5	486	400	10	80	298	193
A11	41.35	FASO 073	0.5	64,900	10	220	7.8	5	122,500	3.5	7	370	10	25,900	700	500	275	1	17	10	16,200	5	4,360	1,700	10	70	177	190
A11	43.20	FASO 074	0.5	6,300	14	30	2.3	2	311,000	7.5	9	353	37	17,600	100	300	171	1	65	6	18,600	5	359	200	10	60	232	338
A11	41.10	FASO 075	0.5	7,500	5	20	1.1	2	202,000	6.2	3	302	23	118,500	700	3,100	2,600	2	135	4	46,400	5	434	400	10	70	239	181
A12	42.50	FASO 076	0.5	61,500	9	190	18.7	6	106,500	3.7	4	622	14	18,600	200	300	178	1	8	7	16,900	5	7,070	1,100	10	130	146	160
A12	43.80	FASO 077	0.5	12,600	11	50	3.8	3	246,000	8.3	4	296	13	26,000	300	400	468	1	16	4	18,400	5	767	400	10	70	153	167
A12	39.15	FASO 078	0.5	6,500	11	30	2.7	2	298,000	7.5	3	341	32	26,000	200	500	436	1	40	4	20,500	5	361	300	10	70	315	232
B1	40.50	FASO 079	0.5	16,800	12	50	4.6	3	258,000	8.6	4	341	26	32,400	200	300	757	1	16	3	24,800	5	992	500	10	70	142	187
B1	42.00	FASO 080	0.5	14,600	17	40	1.7	3	240,000	5.9	8	302	15	36,300	1,100	700	333	1	54	6	25,000	5	314	700	10	40	176	244
B1	43.50	FASO 081	0.5	7,500	13	30	1.1	2	279,000	11	31	359	138	35,200	500	2,000	398	1	196	5	10,900	5	437	400	10	90	331	182
B1	---	FASO 082	0.5	7,700	7	10	0.5	2	335,000	1.4	1	56	4	4,300	800	4,400	87	1	18	2	100	5	896	400	10	10	28	42
B2	39.20	FASO 083	0.5	26,100	11	50	5.6	4	178,000	9.7	13	417	35	77,900	100	400	1,385	1	25	7	59,300	5	2,120	600	10	80	155	171
B2	40.80	FASO 084	0.5	5,300	5	30	1.6	5	248,000	6	13	322	22	69,000	300	1,800	1,160	1	130	5	21,500	5	370	200	10	60	265	183
B3	42.10	FASO 085	0.5	27,100	12	60	7.3	2	221,000	8.9	11	456	21	22,900	400	500	291	1	23	7	21,600	5	1,850	500	10	70	270	293
B3	39.35	FASO 086	0.5	5,200	5	30	2.3	2	298,000	5.6	6	333	19	35,800	100	500	409	1	81	2	32,800	5	477	200	10	50	206	178
B3	41.15	FASO 087	0.5	7,100	5	20	1.2	2	195,000	6	13	285	21	126,500	600	3,700	2,280	1	115	3	20,300	7	517	300	10	70	254	180
B4	---	FASO 088	0.5	16,700	16	60	5.3	2	279,000	8.5	2	350	16	21,300	200	300	234	1	9	3	18,800	5	1,650	300	10	70	236	235
B4	39.80	FASO 089	0.5	7,400	11	40	2.9	2	297,000	5.8	1	359	21	20,800	100	200	260	1	12	4	22,600	5	1,050	200	10	70	367	157

Table A-6 Metals Content of 156 Ore Samples

Parameter (in mg/kg)			Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Ni	Pb	S	Sb	Sr	Ti	Tl	U	V	Zn
Drillhole	Depth	Sample ID																										
B4	41.60	FASO 090	0.5	4,400	7	30	1.3	2	292,000	7	4	343	17	23,600	200	500	242	1	58	3	22,300	5	348	200	10	60	320	208
B4	40.00	FASO 091	0.5	6,600	8	20	0.9	4	233,000	9.5	12	291	28	66,300	700	2,500	1,310	1	118	3	24,200	5	420	300	10	80	232	181
Test	42.00	FASO 092	0.5	5,400	8	30	1.6	2	301,000	5.5	1	322	8	16,900	100	200	165	1	15	2	18,800	5	384	200	10	80	193	189
B5	---	FASO 093	0.5	24,200	10	60	5.7	4	253,000	9.2	2	293	21	15,500	100	200	213	1	15	3	16,900	5	1,410	400	10	70	263	213
B5	56.60	FASO 094	0.5	4,600	14	30	2	2	306,000	6.2	2	384	31	18,900	0.01	300	178	1	15	4	22,500	5	554	200	10	60	331	351
B5	58.15	FASO 095	0.5	6,200	15	30	1.5	3	264,000	7.9	18	304	30	33,800	400	1,400	465	1	178	4	33,100	5	593	300	10	80	240	219
B6	59.60	FASO 096	0.5	19,100	11	60	6.9	2	246,000	8.1	5	309	20	20,700	200	400	195	1	20	5	23,000	5	1,410	400	10	60	381	258
B6	50.12	FASO 097	0.5	6,600	10	30	1.6	6	261,000	6.3	3	338	20	38,000	300	1,000	625	1	42	5	24,200	5	466	300	10	60	413	361
B6	50.88	FASO 098	0.5	3,300	5	10	0.5	2	325,000	3.1	2	113	8	9,800	300	2,200	364	1	28	2	7,000	5	369	200	10	40	90	37
B7	51.95	FASO 099	0.5	6,500	20	30	2.2	2	251,000	5.9	35	298	14	33,500	200	600	266	1	352	3	36,000	12	394	400	10	50	625	237
B7	53.04	FASO 100	0.5	6,500	10	20	0.8	3	226,000	5.7	17	298	24	75,800	600	2,600	1,675	1	187	3	33,700	7	344	300	10	60	225	108
B8	53.70	FASO 101	0.5	31,900	15	100	5.8	2	131,500	5.8	18	203	12	18,500	400	300	190	1	52	5	18,900	9	1,850	1,400	10	30	439	262
B8	58.40	FASO 102	0.5	6,100	14	40	1.5	2	251,000	5.9	24	311	14	34,200	200	700	506	1	139	4	34,400	5	371	300	10	60	455	285
test	37.10	FASO 103	0.5	10,000	8	10	0.5	2	315,000	1.6	1	79	4	5,700	1,100	4,700	91	1	15	2	1,200	5	838	500	10	10	33	39
SB 2	38.10	FASO 104	3.4	46,100	23	100	9.8	2	174,000	5.2	19	226	12	34,100	1,100	600	296	6	48	6	25,200	5	2,550	1,100	10	50	132	235
SB 2	39.10	FASO 105	1.3	13,200	8	40	2.3	2	204,000	2.8	16	222	11	27,100	400	300	256	6	70	2	23,400	5	577	700	10	50	135	220
SB 2	33.05	FASO 106	1.3	10,800	7	30	1.8	2	286,000	5.7	19	312	31	47,400	700	2,000	1,130	5	134	5	16,400	5	368	500	10	120	398	331
SB -2	33.65	FASO 107	8.8	99,500	5	410	26.2	2	76,900	12.6	11	448	40	12,900	500	500	64	4	32	3	16,100	5	6,560	600	10	200	380	468
SB-2	35.00	FASO 108	1.7	14,500	11	60	5.1	2	314,000	11.2	31	323	31	15,600	200	400	279	6	88	3	16,700	5	923	200	10	100	260	498
SB-2	---	FASO 109	0.8	8,800	14	20	1.4	2	257,000	6.4	29	328	52	78,300	600	1,600	2,370	5	223	7	30,900	5	313	500	10	160	341	217
SB-2	52.15	FASO 110	0.9	12,200	12	30	1.1	3	210,000	2.4	4	190	23	157,000	1,000	2,200	5,320	4	60	5	14,900	5	365	700	10	60	137	122
SB-2	---	FASO 111	0.8	3,500	5	10	0.5	2	359,000	1.6	2	97	7	9,300	300	2,600	263	3	19	3	4,100	5	381	200	10	40	58	39
SB 1	53.60	FASO 112	0.9	10,400	15	30	2	2	287,000	4.7	11	340	25	44,200	300	700	446	4	78	3	48,000	5	474	500	10	100	402	134
SM-2	55.10	FASO 113	1	6,400	14	30	1.2	2	273,000	3.1	8	169	10	59,600	400	2,900	1,100	3	84	2	24,700	5	514	400	10	50	163	79
SM-2	53.67	FASO 114	1	2,700	10	10	0.6	2	350,000	1.4	1	88	9	12,800	300	2,300	290	4	22	2	15,800	5	483	200	10	30	40	25
SM-2	60.52	FASO 115	0.8	2,400	7	10	0.5	2	346,000	1.2	1	54	6	6,400	300	2,200	241	3	13	2	7,300	5	359	200	10	30	37	18
SM-3	48.00	FASO 116	0.8	38,600	13	60	1.9	2	163,000	10.9	9	387	29	39,500	1,900	2,100	385	4	23	10	29,800	5	359	2,500	10	190	289	274
SM-3	49.30	FASO 117	1.2	9,200	8	40	2	2	285,000	6	22	317	20	32,100	400	1,500	524	4	153	5	27,200	6	603	400	10	110	567	540
SM-3	54.18	FASO 118	0.8	5,800	9	20	0.5	2	312,000	2	6	104	8	37,100	500	1,900	172	3	77	2	43,500	5	369	300	10	30	218	77
SK-1	56.29	FASO 120	2.3	29,700	14	60	3.6	2	249,000	6.3	15	248	18	25,100	900	1,100	213	6	62	4	23,400	5	1,265	600	10	90	288	254
duplicate	57.77	FASO 121	2.2	27,800	15	60	3.5	2	249,000	6.3	16	244	18	23,300	700	1,000	206	5	61	3	21,800	5	1,265	600	10	90	287	243
SK-1	65.00	FASO 122	1.3	9,800	9	40	1.4	2	242,000	3.7	5	271	17	77,600	600	1,900	1,080	4	76	4	36,500	5	641	400	10	70	201	108
SK-1	66.42	FASO 123	1.1	3,000	8	10	0.5	2	320,000	1.8	1	105	7	33,300	200	2,000	595	4	19	3	32,100	5	395	100	10	40	89	33
SC-2	67.46	FASO 124	0.9	2,800	5	10	0.6	2	311,000	2.8	1	114	7	3,300	300	2,100	67	3	21	4	3,000	5	421	200	10	70	106	47
SC-3	66.63	FASO 125	1.6	6,700	5	40	0.8	2	307,000	4.2	1	138	16	10,300	700	3,500	118	5	66	2	10,300	5	704	400	10	90	124	91
SK 1b	55.23	FASO 126	0.9	10,300	8	40	1.6	2	290,000	4.7	41	249	14	20,300	500	600	453	8	107	2	17,600	5	320	500	10	90	237	444
SK 1b	32.29	FASO 127	1.1	25,000	10	60	1.1	2	165,000	2.3	30	261	22	71,100	2,800	5,600	1,730	8	139	6	52,000	5	387	1,200	10	70	253	296
SK 0	55.58	FASO 128	2.9	23,800	5	80	5.8	2	271,000	3.8	2	252	12	16,700	200	500	187	6	10	2	16,900	5	2,070	300	10	80	223	69
SK 0	46.74	FASO 129	1.2	11,200	6	40	2.2	2	272,000	4.8	3	267	17	15,600	200	400	324	7	10	5	12,200	5	491	600	10	90	287	145
SK 0	47.80	FASO 130	0.9	6,200	9	30	1.3	2	297,000	5.4	12	346	20	27,200	200	800	209	4	160	3	31,300	5	338	300	10	100	237	108
SK 0	33.58	FASO 131	1.1	9,400	12	30	1.1	2	225,000	5.9	7	286	24	63,200	600	1,300	366	6	137	8	77,900	5	396	700	10	120	254	135
SC 0	35.32	FASO 132	1.4	18,100	6	50	3.8	2	268,000	4.4	12	260	20	28,100	500	500	268	5	35	5	29,200	5	813	600	10	90	196	388
SC 0	36.27	FASO 133	1.1	9,700	6	30	1.5	2	270,000	24.6	49	356	60	27,600	500	1,400	154	5	319	4	32,700	6	465	500	10	120	461	488
SC 0	39.10	FASO 134	0.9	3,900	5	10	0.6	2	256,000	2.2	3	128	6	26,700	300	35,500	2,430	4	32	4	11,600	5	307	200	10	30	72	46
SC-1	38.24	FASO 135	2.3	22,500	12	80	3.1	2	182,000	6.4	6	213	13	28,500	600	800	307	5	26	4	24,900	5	1,640	700	10	80	187	158
SB-3	39.95	FASO 136	2	10,600	8	60	1.5	2	285,000	3.9	2	180	17	9,700	700	3,600	181	4	67	3	8,700	5	1,115	400	10	60	110	191

Table A-6 Metals Content of 156 Ore Samples

Parameter (in mg/kg)			Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Ni	Pb	S	Sb	Sr	Ti	Tl	U	V	Zn
Drillhole	**Depth**	**Sample ID**																										
SN-2	**49.22**	**FASO 137**	*0.5*	20,700	10	30	10.6	2	47,400	0.6	14	149	11	253,000	2,400	10,600	5,490	1	38	13	16,400	*5*	244	800	*10*	10	52	208
SB-3	**50.75**	**FASO 138**	*0.5*	3,900	*5*	90	0.5	*2*	327,000	4.4	3	138	13	4,700	400	3,500	210	1	53	3	4,100	*5*	515	200	*10*	50	83	92
MW 4	**57.50**	**FASO 139**	0.7	73,200	*5*	220	13.4	*2*	121,500	6.5	11	744	60	11,000	300	300	111	2	14	11	10,600	*5*	7,260	800	*10*	80	627	225
MW 4	**60.69**	**FASO 140**	*0.5*	14,300	10	50	3	*2*	295,000	14.3	32	263	28	19,400	300	800	205	2	75	4	20,000	*5*	840	300	*10*	100	478	492
SN 8	**62.14**	**FASO 142**	*0.5*	6,100	*5*	10	*0.5*	*2*	328,000	1.2	2	55	5	8,100	500	4,100	185	*1*	17	*2*	5,400	*5*	468	300	*10*	10	25	52
SN-3	**25.65**	**FASO 143**	*0.5*	33,500	9	70	6.7	*2*	235,000	5.1	12	318	17	25,000	200	600	125	2	41	4	28,100	*5*	1,365	500	*10*	90	430	169
SN-3	**26.13**	**FASO 144**	*0.5*	8,100	14	150	2.5	*2*	213,000	4.4	49	247	17	128,500	600	2,100	1,175	2	179	2	83,600	*5*	500	300	*10*	50	362	130
SL 8	**26.69**	**FASO 145**	0.6	5,000	*5*	110	1.8	*2*	246,000	8	12	287	26	84,300	300	4,400	721	*1*	65	2	6,400	*5*	433	300	*10*	90	225	173
SL 8b	**27.69**	**FASO 146**	30.8	7,000	10	70	2.5	*2*	276,000	26.5	11	311	25	45,900	200	1,300	458	2	50	4	13,100	*5*	396	400	*10*	70	174	313
SL 8b	**28.78**	**FASO 147**	3	6,800	6	20	1.9	*2*	235,000	8.3	17	291	37	110,000	400	3,600	1,155	1	67	3	9,200	*5*	304	400	*10*	110	269	361
SI 3	**---**	**FASO 149**	*0.5*	3,800	6	30	2.2	*2*	242,000	9.1	3	285	28	93,000	500	2,300	3,220	1	68	4	37,800	*5*	693	200	*10*	80	208	155
SI 3	**---**	**FASO 150**	*0.5*	3,700	5	30	1.1	*2*	265,000	9.5	2	320	22	62,800	400	1,200	2,870	*1*	31	3	26,300	7	643	200	*10*	50	173	155
SH 2	**---**	**FASO 151**	0.5	69,400	8	150	5.3	3	28,900		3	530	3	18,800	800	400	72	2	5	17	19,900	*5*	5,840	5,900	*10*	---	197	27
SH 2	**---**	**FASO 152**	*0.5*	3,500	7	30	1.5	*2*	287,000	12.8	4	368	30	44,200	400	1,600	835	*1*	55	2	16,400	*5*	606	200	*10*	80	271	198
SH 2	**---**	**FASO 153**	*0.5*	3,200	8	20	0.9	*2*	321,000	7.1	2	208	16	14,500	400	1,900	300	*1*	30	*2*	15,500	*5*	603	200	*10*	30	100	93
CEX 4 bis	**---**	**FASO 155**	*0.5*	57,400	18	130	5.7	*2*	25,200	0.6	16	448	8	30,800	1,300	900	561	3	14	17	13,600	*5*	4,760	3,300	*10*	---	75	87
CEX 4 bis	**---**	**FASO 156**	*0.5*	100,500	10	120	11.3	*2*	48,800	8	24	422	12	18,700	1,000	1,400	117	3	66	10	20,800	*5*	6,530	2,000	*10*	30	175	257
CEX 4 bis	**---**	**FASO 157**	*0.5*	61,000	12	50	6.1	*2*	183,000	14.6	40	206	12	20,500	800	3,800	118	2	103	5	17,200	*5*	2,920	1,000	*10*	30	182	667
CEX 4 bis	**---**	**FASO 158**	*0.5*	18,200	8	20	1.2	*2*	225,000	8.8	10	194	10	65,800	1,000	3,600	1,360	*1*	51	5	7,200	*5*	366	1,000	*10*	30	60	410
CEX 4 bis	**---**	**FASO 159**	*0.5*	25,700	5	30	1	*2*	149,000	4.1	11	251	10	56,900	1,600	14,100	887	*1*	80	4	4,900	*5*	361	1,700	*10*	10	94	199
duplicate	**---**	**FASO 160**	*0.5*	26,200	7	30	1.1	*2*	151,000	4.1	12	256	10	57,100	1,700	14,400	885	*1*	82	4	4,800	*5*	368	1,800	*10*	10	97	207
		Average (mg/kg)	0.93	17237.82	9.94	48.14	2.96	2.79	251737.82	6.11	11.32	280.53	19.74	38830.77	580.77	2185.90	692.71	1.94	69.83	18.87	21316.67	5.17	1055.10	595.51	10.00	68.38	227.06	211.76
		Sum of averages (mg/kg)	335228.53																									
		Percentages	0.0002788	5.142	0.00297	0.0144	0.0008831	0.0008318	75.09	0.001822	0.003377	0.08368	0.005888	11.58	0.1732	0.6521	0.2066	0.000577	0.02083	0.005630	6.359	0.001543	0.3147	0.1776	0.002983	0.02040	0.06773	0.06317

Note- Cells containing *italicized red* text represent non-detectable values; the value presented is the detection limit

Table A-7 Metals Content of Waste Overburden Samples

Parameter (mg/kg)		Hg	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Ni	Pb	Sb	Se	Sn	Sr	Ti	Tl	U	V	Y	Zn
Drillhole	Depth	10	15		55	625	30			12	240	380	190						200	210	530	15	100	900					250		720
BH-08 (North Pit)	0.0-12.45	*0.10*	0.23	38000	18	38	0.41	0.15	150	0.17	5	310	16	77000	470	6	280	200	3.2	13	15	0.90	*0.70*	1.7	14	4000	0.08	2.70	190	7	9
	12.45-24.45	*0.10*	0.28	69000	26	150	1.90	0.18	5200	0.28	29	210	12	120000	11000	25	5900	1000	2.3	48	15	*0.80*	*0.70*	1.7	150	4000	0.17	5.30	110	38	180
	24.45-27.45	*0.10*	0.36	110000	6.5	170	1.30	0.27	2100	0.20	7	190	13	30000	9500	44	4500	120	2.3	25	22	*0.80*	*0.70*	2.7	140	6100	0.28	2.60	92	17	62
	27.45-34.95	*0.10*	0.46	87000	13	150	1.10	0.48	1200	0.25	5	220	11	35000	6700	36	3000	77	1.8	19	19	*0.80*	*0.70*	2.4	120	5400	0.22	2.20	95	14	41
	34.95-54	*0.10*	0.39	73000	33	130	1.30	0.23	1600	0.23	14	220	12	66000	8100	49	3000	330	4.0	22	16	*0.80*	*0.70*	1.8	98	5500	0.24	2.20	100	30	51
BH-10 (North Pit)	0.0-6.45	*0.10*	0.28	78000	5.5	37	0.44	0.16	110	0.18	4	180	13	29000	1000	12	530	120	1.4	23	13	*0.80*	*0.70*	2.5	23	5800	0.10	1.90	74	14	16
	6.45-15.45	*0.10*	0.32	97000	16	150	1.10	0.25	330	0.16	4	180	11	55000	5700	12	1800	80	2.3	18	20	*0.80*	*0.70*	2.1	120	5800	0.20	2.80	140	28	39
	15.45-18.45	*0.10*	0.28	67000	15	170	2.50	0.16	690	0.18	12	230	11	38000	5200	15	1800	420	4.6	27	14	*0.80*	0.10	2.0	330	4000	0.15	5.20	77	35	82
	18.45-30.45	*0.10*	0.30	58000	34	130	1.00	0.19	550	0.15	5	210	10	64000	3900	17	1200	150	2.2	14	14	*0.80*	*0.70*	1.7	100	4600	0.14	2.90	110	14	37
	30.45-49.7	*0.10*	0.35	63000	9.9	130	4.00	0.30	8600	0.28	12	350	13	25000	5400	47	2100	330	1.3	21	12	*0.80*	*0.70*	1.6	1300	3900	0.14	29.00	82	87	70
	30.45-49.7	*0.10*	0.27	43000	8.7	83	1.90	0.11	5500	0.22	10	400	12	21000	3900	37	1700	340	1.3	17	9.2	*0.80*	*0.70*	1.2	520	3300	0.12	9.30	57	48	86
BH-20 (South Pit)	0.3-4.6	*0.10*	0.40	100000	5.6	110	1.10	0.22	510	0.23	7	170	15	23000	3400	79	2100	77	1.6	29	23	*0.80*	*0.70*	3.4	72	7700	0.25	3.10	79	14	25
	10-18	*0.10*	0.07	7000	0.6	18	0.16	*0.09*	420	0.10	3	460	6	12000	310	6	200	140	1.4	9	2.1	*0.80*	*0.70*	*0.5*	12	1200	*0.02*	0.66	9	7	5
	18-22	*0.10*	0.28	64000	12	97	1.20	0.16	780	0.19	9	250	10	49000	3900	37	2300	150	1.6	20	15	*0.80*	*0.70*	2.2	74	4700	0.16	3.00	83	20	44
	29-32	*0.10*	0.59	32000	1.5	63	0.90	*0.09*	580	0.13	10	300	9	22000	1500	37	920	140	5.0	14	10	*0.80*	*0.70*	1.0	110	2900	0.11	1.40	28	7	40
	35-40	*0.10*	0.55	10000	3.1	33	0.82	*0.09*	43000	0.69	4	340	8	16000	460	10	340	130	1.4	13	4.2	*0.80*	0.80	*0.5*	150	1200	0.07	14.00	28	39	26
BH-23 (South Pit)	0.33-3	*0.10*	0.32	81000	8.7	77	0.90	0.19	1600	0.19	5	170	16	83000	1900	23	2000	160	3.1	20	20	*0.80*	*0.70*	2.7	45	6400	0.18	4.70	130	16	20
	3-16.5	*0.10*	0.37	88000	15	120	0.93	0.22	780	0.21	5	180	13	69000	3400	21	1600	81	2.6	21	21	*0.80*	*0.70*	2.9	100	6400	0.20	3.20	130	14	24
	3-16.5	*0.10*	0.38	90000	11	130	0.82	0.22	360	0.18	4	190	11	45000	4600	20	2000	70	3.2	17	20	*0.80*	*0.70*	2.6	85	6200	0.20	2.40	140	13	25
	21-24.1	*0.10*	0.30	61000	11	120	0.75	0.17	750	0.16	3	230	9	17000	4600	17	1500	73	1.2	12	14	*0.80*	*0.70*	1.7	85	4800	0.17	1.80	71	11	23
	24.1-28.5	*0.10*	0.20	20000	4.9	55	0.32	*0.09*	300	0.13	2	600	9	13000	1800	12	800	82	13.0	12	6.5	*0.80*	*0.70*	1.1	36	2800	0.05	0.89	33	6	12
	28.5-33	*0.10*	0.31	53000	9.3	110	1.80	*0.09*	3300	0.43	17	290	9	81000	5500	47	3400	1200	2.3	27	14	*0.80*	*0.70*	1.9	110	4100	0.18	0.26	61	31	69
Average (mg/kg)		*0.10*	0.33	63136.36	12.20	103.23	1.21	0.19	3564.09	0.22	7.96	267.27	11.34	45000.00	4192.73	27.68	1953.18	248.64	2.87	20.04	14.50	0.80	0.68	1.90	172.45	4581.82	0.16	4.61	87.23	23.16	44.79
Sum of averages (mg/kg)		123481.75																													
Percentages		0.000081	0.00027	51.1301	0.0099	0.0836	0.0010	0.0002	2.8863	0.0002	0.0064	0.2164	0.0092	36.4426	3.3954	0.0224	1.5818	0.2014	0.0023	0.0162	0.0117	0.0007	0.0005	0.0015	0.1397	3.7105	0.0001	0.0037	0.0706	0.0188	0.0363

Note- Cells containing *italicized red* text represent non-detectable values; the value presented is the detection limit

Separate oral toxic potency screenings for the ore and waste overburden were conducted for the Mine site for both the HHRA and ERA. Results of the HHRA oral toxic potency screening are provided in Tables A-8 and A-9, while results of the ERA oral toxicity screening are provided in Tables A-10 and A-11. As human receptors could be exposed to emissions related to both the ore and waste overburden at the Mine site, chemicals which made up >99% of the total toxic potency from the ore and waste overburden toxic potency screenings were carried forward for further assessment.

Based on results of the HHRA oral toxic potency screening based on elemental content of the ore and waste over burden (Tables A-8 and A-9, respectively), the following chemicals made up >99% of the total toxic potency and were selected for further evaluation in the HHRA:

- Aluminum
- Antimony
- Arsenic
- Cobalt
- Iron
- Lead
- Lithium
- Thallium
- Uranium
- Vanadium

Based on results of the ERA oral toxic potency screening based on elemental content of the ore and waste over burden (Tables A-10 and A-11, respectively), the following chemicals made up >95% of the total toxic potency and were selected for further evaluation in the ERA:

- Aluminum
- Chromium
- Iron
- Manganese
- Thallium
- Uranium

Calcium and sulfur contributed to the cumulative toxic potency of 95% in the ERA (See Table A-10). These elements are essential nutrients in animals and are of low toxicity (maximum tolerable levels of 20,000 mg/kg for calcium and 5,000 mg/kg for sulfur; NAS, 2005; See Table A-10). The relative toxic potencies for calcium and sulfur are driven by these elements being present at such high concentrations in the ore (75% for calcium and 6.4% for sulfur). Given calcium and sulfur are essential elements; their uptake is expected to be regulated by the body. As such, calcium and sulfur were not carried forward for further assessment.

Table A-8 Oral Toxic Potency Screen of Metals Content of Ore for HHRA (Concentrations in 156 Ore Samples)

Parameter	*% Composition of Ore*	*Oral Exposure Limit (µg/kg/day)*	*Toxic Potency*[a]	*Relative Toxic Potency*	*Cumulative Toxic Potency*	*TRV Type*	*TRV Reference*
Arsenic	0.00297	0.0056	0.52961	64.48%	64.48%	RsD	Health Canada 2010b
Thallium	0.00298	0.02	0.14915	18.16%	82.64%	p-RfD	US EPA 2012
Aluminium	5.14211	143	0.03596	4.38%	87.02%	RfD	WHO 2013, 2010a,b
Uranium	0.02040	0.6	0.03400	4.14%	91.16%	RfD	Health Canada 2010b
Vanadium	0.06773	2	0.03387	4.12%	95.28%	RfD	RIVM 2009
Iron	11.58337	700	0.01655	2.01%	97.30%	p-RfD	US EPA, 2006
Lead	0.00563	0.6	0.00938	1.14%	98.44%	POD	JECFA 2011
Antimony	0.00154	0.4	0.00386	0.47%	98.91%	RfD	US EPA, 2015b
Cobalt	0.00338	1.4	0.00241	0.29%	99.20%	RfD	RIVM 2001
Nickel	0.02083	11	0.00189	0.23%	99.43%	RfD	Health Canada, 2010b
Cadmium	0.00182	1	0.00182	0.22%	99.65%	RfD	Health Canada, 2010b
Manganese	0.20664	140	0.00148	0.18%	99.83%	RfD	US EPA 2105b
Strontium	0.31474	600	0.00052	0.06%	99.90%	RfD	US EPA 2015b
Beryllium	0.00088	2	0.00044	0.05%	99.95%	RfD	US EPA 2015b
Zinc	0.06317	500	0.00013	0.02%	99.97%	RfD	Health Canada, 2010b
Barium	0.01436	200	0.00007	0.01%	99.97%	RfD	Health Canada, 2010b
Copper	0.00589	91	0.00006	0.01%	99.98%	RfD	Health Canada 2010b
Chromium	0.08368	1,500	0.00006	0.01%	99.99%	RfD	US EPA 2015b
Silver	0.00028	5	0.00006	0.01%	100.00%	RfD	US EPA 2015b
Molybdenum	0.00058	23	0.00003	0.00%	100.00%	RfD	Health Canada, 2010b
Titanium	0.17764	43,000	0.00000	0.00%	100.00%	Note [b]	US EPA 2005
Bismuth	0.00083	NA					
Potassium	0.17325	NA					
Sulfur	6.35885	NA					
		Totals	0.82135	100.00%			

Notes:

NA = no oral exposure limit available; RfD = reference dose; p-RfD = provisional reference dose; POD = point of departure

Shaded grey = chemicals carried forward for further assessment

[a] Toxic potency of each chemical was determined by dividing the composition of ore by the oral exposure limit.

[b] No oral RFD for titanium could be found in the literature reviewed. Evaluations of titanium dioxide by JECFA, SCF, and EFSA have each concluded that there are no safety concerns associated with the use of titanium dioxide as a food additive at levels ranging up to 3% (US EPA, 2005). This value (3% or 30,000,000 µg/kg was converted to a dose by dividing by a body weight of 70 kg).

Table A-9 Oral Toxic Potency Screen of Metals Content of Waste Overburden for HHRA (Concentrations in 22 Overburden Samples)

Parameter	*% Composition of Waste Overburden*	*Oral Exposure Limit (µg/kg/day)*	*Toxic Potency*[a]	*Relative Toxic Potency*	*Cumulative Toxic Potency*	*TRV Type*	*TRV Reference*
Arsenic	0.0099	0.0056	1.76363	77.92%	77.92%	RsD	Health Canada 2010b
Aluminium	51.1301	143	0.35755	15.80%	93.72%	RfD	WHO 2013, 2010a,b
Iron	36.4426	700	0.05206	2.30%	96.02%	p-RfD	US EPA, 2006
Vanadium	0.0706	2	0.03532	1.56%	97.58%	RfD	RIVM 2009
Lead	0.0117	0.6	0.01957	0.86%	98.45%	POD	JECFA 2011
Lithium	0.0224	2	0.01121	0.50%	98.94%	pRfD	US EPA 2008
Thallium	0.0001	0.02	0.00631	0.28%	99.22%	p-RfD	US EPA 2012
Uranium	0.0037	0.6	0.00623	0.28%	99.50%	RfD	Health Canada 2010b
Cobalt	0.0064	1.4	0.00461	0.20%	99.70%	RfD	RIVM 2001
Antimony	0.0007	0.4	0.00163	0.07%	99.77%	RfD	US EPA, 2015b
Nickel	0.0162	11	0.00148	0.07%	99.84%	RfD	Health Canada, 2010b
Manganese	0.2014	140	0.00144	0.06%	99.90%	RfD	US EPA 2015b
Beryllium	0.0010	2	0.00049	0.02%	99.92%	RfD	US EPA 2015b
Barium	0.0836	200	0.00042	0.02%	99.94%	RfD	Health Canada, 2010b
Mercury	0.0001	0.3	0.00027	0.01%	99.95%	RfD	Health Canada, 2010b
Strontium	0.1397	600	0.00023	0.01%	99.96%	RfD	US EPA 2015b
Cadmium	0.0002	1	0.00018	0.01%	99.97%	RfD	Health Canada, 2010b
Chromium	0.2164	1500	0.00014	0.01%	99.98%	RfD	US EPA 2015b
Molybdenum	0.0023	23	0.00010	0.00%	99.98%	RfD	Health Canada, 2010b
Copper	0.0092	91	0.00010	0.00%	99.99%	RfD	Health Canada 2010b
Selenium	0.0005	5.5	0.00010	0.00%	99.99%	RfD	Health Canada, 2010b
Titanium	3.7105	43000	0.00009	0.00%	99.99%	Note [b]	US EPA 2005
Zinc	0.0363	500	0.00007	0.00%	100.00%	RfD	Health Canada, 2010b
Silver	0.0003	5	0.00005	0.00%	100.00%	RfD	US EPA 2015b
Tin	0.0015	200	0.00001	0.00%	100.00%	RfD	RIVM 2009
Bismuth	0.0002	NA					
Yttrium	0.0188	NA					
		Totals	2.26329	100.00 %			

Notes:

NA = no oral exposure limit available; RfD = reference dose; UIL = upper intake level; p-RfD = provisional reference dose; POD = point of departure

Shaded grey = chemicals carried forward for further assessment

[a] Toxic potency of each chemical was determined by dividing the composition of waste overburden by the oral exposure limit.

[b] No oral RFD for titanium could be found in the literature reviewed. Evaluations of titanium dioxide by JECFA, SCF, and EFSA have each concluded that there are no safety concerns associated with the use of titanium dioxide as a food additive at levels ranging up to 3% (US EPA, 2005). This value (3% or 30,000,000 µg/kg was converted to a dose by dividing by a body weight of 70 kg).

Table A-10 Oral Toxic Potency Screen of Metals Content of Ore for ERA (Concentrations in 156 Ore Samples)

Parameter	*% Composition of Ore*	*SQG_E or MTL (mg/kg)*	*Toxic potency[a]*	*Relative Toxic Potency*	*Cumulative Toxic Potency*	*SQG_E or MTL*	*Reference*
Aluminum	5.14211	200	0.02571	40.93%	40.93%	MTL	NAS, 2005
Iron	11.58337	500	0.02317	36.88%	77.81%	MTL	NAS, 2005
Calcium	75.09439	20000	0.00375	5.98%	83.79%	MTL	NAS, 2005
Thallium	0.00298	1	0.00298	4.75%	88.54%	SQG_E	CCME, 2015 (1999) [b]
Chromium	0.08368	64	0.00131	2.08%	90.62%	SQG_E	CCME, 2015 (1997) [b, d]
Sulfur	6.35885	5000	0.00127	2.02%	92.65%	MTL	NAS, 2005
Manganese	0.20664	220	0.00094	1.50%	94.14%	SQG_E	U.S. EPA, 2007 [e]
Uranium	0.02040	33	0.00062	0.98%	95.12%	SQG_E	CCME, 2015 (2007)[b]
Vanadium	0.06773	130	0.00052	0.83%	95.95%	SQG_E	CCME, 2015 (1997) [b]
Cadmium	0.00182	3.8	0.00048	0.76%	96.72%	SQG_E	CCME, 2015 (1999) [b]
Nickel	0.02083	50	0.00042	0.66%	97.38%	SQG_E	CCME, 2015 (1999) [b]
Zinc	0.06317	200	0.00032	0.50%	97.88%	SQG_E	CCME, 2015 (1999) [b]
Strontium	0.31474	1000	0.00031	0.50%	98.38%	MTL	NAS, 2005
Beryllium	0.00088	4	0.00022	0.35%	98.74%	SQG_E	OMOE, 2011[c]
Arsenic	0.00297	17	0.00017	0.28%	99.01%	SQG_E	CCME, 2015 (1997) [b]
Magnesium	0.65206	5000	0.00013	0.21%	99.22%	MTL	NAS, 2005
Copper	0.00589	63	0.00009	0.15%	99.37%	SQG_E	CCME, 2015 (1999) [b]
Cobalt	0.00338	40	0.00008	0.13%	99.50%	SQG_E	OMOE, 2011[c]
Molybdenum	0.00058	6.9	0.00008	0.13%	99.64%	SQG_E	OMOE, 2011[c]
Lead	0.00563	70	0.00008	0.13%	99.77%	SQG_E	CCME, 2015 (1999) [b]
Antimony	0.00154	20	0.00008	0.12%	99.89%	SQG_E	OMOE, 2011[c]
Barium	0.01436	390	0.00004	0.06%	99.95%	SQG_E	OMOE, 2011[c]
Potassium	0.17325	10000	0.00002	0.03%	99.98%	MTL	NAS, 2005
Silver	0.00028	20	0.00001	0.02%	100.00%	SQG_E	OMOE, 2011[c]
Bismuth	0.00083	500	0.00000	0.00%	100.00%	MTL	NAS, 2005
Titanium	0.17764	NGA					
		Totals	0.06281	100.00%			

Notes:

NGA = No guideline or MTL available; SQG_E = Soil quality guideline for environmental health; MTL = maximum tolerable level. Maximum tolerable level from NAS, 2005 is based on MTL for rodents.

Shaded grey = chemicals carried forward for further assessment

[a] Toxic potency of each chemical was determined by dividing the composition of ore by the MTL or SQG_E

[b] The CCME (2015) ecological health-based soil quality guidelines were obtained on-line from the CCME website under soil quality guidelines, fact sheets which are provided for each individual chemical (2015 on-line; http://ceqg-rcqe.ccme.ca/). The year in bracket is the year the guideline was derived.

[c] OMOE (Ontario Ministry of the Environment; 2011) soil component values. Value provided is lower of the mammal / bird and plant / soil organism soil component value.

[d] CCME Guideline for total chromium (derived in 1997).

[e] US EPA (2007) Ecological Soil Screening Level (Eco SSL) for manganese. Value provided is the lower of the plant, soil invertebrate and wildlife guidelines.

Table A-11 Oral Toxic Potency Screen of Metals Content of Waste Overburden for ERA (Concentrations in 22 Overburden Samples)

Parameter	*% Composition of Ore*	*SQG_E or MTL (mg/kg)*	*Toxic Potency*[a]	*Relative Toxic Potency*	*Cumulative Toxic Potency*	*SQG_E or MTL*	*Reference*
Aluminum	51.1301	200	0.25565	75.53%	75.53%	MTL	NAS, 2005
Iron	36.4426	500	0.07289	21.53%	97.06%	MTL	NAS, 2005
Chromium	0.2164	64	0.00338	1.00%	98.06%	SQG_E	CCME, 2015 (1997) [b, d]
Manganese	0.2014	220	0.00092	0.27%	98.33%	SQG_E	U.S. EPA, 2007 [e]
Lithium	0.0224	25	0.00090	0.26%	98.60%	MTL	NAS, 2005
Arsenic	0.0099	17	0.00058	0.17%	98.77%	SQG_E	CCME, 2015 (1997) [b]
Selenium	0.0005	1	0.00055	0.16%	98.93%	MTL	CCME, 2015 (2009)[b]
Vanadium	0.0706	130	0.00054	0.16%	99.09%	SQG_E	CCME, 2015 (1997)[b]
Potassium	3.3954	10000	0.00034	0.10%	99.19%	MTL	NAS, 2005
Molybdenum	0.0023	6.9	0.00034	0.10%	99.29%	SQG_E	OMOE, 2011[c]
Nickel	0.0162	50	0.00032	0.10%	99.39%	SQG_E	CCME, 2015 (1999)[b]
Magnesium	1.5818	5000	0.00032	0.09%	99.48%	MTL	NAS, 2005
Beryllium	0.0010	4	0.00025	0.07%	99.55%	SQG_E	OMOE, 2011[c]
Barium	0.0836	390	0.00021	0.06%	99.62%	SQG_E	OMOE, 2011[c]
Zinc	0.0363	200	0.00018	0.05%	99.67%	SQG_E	CCME, 2015 (1999)[b]
Lead	0.0117	70	0.00017	0.05%	99.72%	SQG_E	CCME, 2015(1999) [b]
Cobalt	0.0064	40	0.00016	0.05%	99.77%	SQG_E	OMOE, 2011[c]
Copper	0.0092	63	0.00015	0.04%	99.81%	SQG_E	CCME, 2015 (1999) [b]
Calcium	2.8863	20000	0.00014	0.04%	99.85%	MTL	NAS, 2005
Strontium	0.1397	1000	0.00014	0.04%	99.89%	MTL	NAS, 2005
Thallium	0.0001	1	0.00013	0.04%	99.93%	MTL	CCME, 2015 (1999) [b]
Uranium	0.0037	33	0.00011	0.03%	99.97%	SQG_E	CCME, 2015 (2007) [b]
Cadmium	0.0002	3.8	0.00005	0.01%	99.98%	SQG_E	CCME, 2015 (1999) [b]
Antimony	0.0007	20	0.00003	0.01%	99.99%	SQG_E	OMOE, 2011[c]
Tin	0.0015	100	0.00002	0.00%	99.99%	MTL	NAS, 2005
Silver	0.0003	20	0.00001	0.00%	100.00%	SQG_E	OMOE, 2011[c]
Mercury	0.0001	12	0.00001	0.00%	100.00%	SQG_E	CCME, 2015 (1999) [b]
Bismuth	0.0002	500	0.00000	0.00%	100.00%	MTL	NAS, 2005
Titanium	3.7105	NGA					
Yttrium	0.0188	NGA					
		Totals	0.33848	100.00%			

Notes:

NGA = No guideline or MTL available; SQG_E = Soil quality guideline for environmental health; MTL = maximum tolerable level. Maximum tolerable level from NAS, 2005 is based on MTL for rodents.

Shaded grey= chemicals carried forward for further assessment

[a] Toxic potency of each chemical was determined by dividing the composition of ore by the MTL or SQG_E

[b] The CCME (2015) ecological health-based soil quality guidelines were obtained on-line from the CCME website under soil quality guidelines, fact sheets which are provided for each individual chemical (2015 on-line; http://ceqg-rcqe.ccme.ca/). The year in bracket is the year the guideline was derived.

[c] OMOE (Ontario Ministry of the Environment; 2011) soil component values. Value provided is lower of the mammal / bird and plant / soil organism soil component value.

[d] CCME Guideline for total chromium (derived in 1997).

[e] US EPA (2007) Ecological Soil Screening Level (Eco SSL) for manganese. Value provided is the lower of the plant, soil invertebrate and wildlife guidelines.

A-3.2 Oral Toxic Potency Screening for the Port Site

The approach to conduct the oral toxic potency screening for Port site was the same as the Mine site with one main exception. For the Port site, the main composition of dusts is expected to be related to the product, whereas at the Mine site ore and waste overburden are predicted to be the dominant geochemistry. As such, the percent composition of each element in the product sample provided by Knight Piésold (2015b; Table 2) was determined (See Table A-12) and used in the toxic potency screening of the Port. As there was only one product sample,

there is uncertainty in this compositional breakdown. While analytical results were only available for one product sample, there were lab results for 7 additional samples of product (which were split into two fractions) which were conducted for the metallurgical testing (Table A-13). These data were not used in the chemical screening as detection limits for many of the metals were very high compared to those in the results of the product test. Nevertheless, for several key metals, they show up in sufficient concentrations to show that the range of concentrations are a good check against the one result for the product.

Based on results of the HHRA oral toxic potency screening using the elemental content of the product (Table A-14), the following chemicals made up >99% of the total toxic potency and were selected for further evaluation in the HHRA:

- Aluminum
- Antimony
- Arsenic
- Cadmium
- Cobalt
- Iron
- Lead
- Nickel
- Selenium
- Thallium
- Uranium
- Vanadium

Table A-12 Metals Content of One Product Sample

Parameter (mg/kg)		Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Ni	Pb	Se	S	Sb	Sr	Ti	Tl	U	V	Zn
Phosphate Rock Product	2015 Product [1]	0.28	1,700	1.5	30	2	*0.09*	380,000	**8.7**	14	**190**	26	15,000	130	1,000	260	2.9	64	2.3	11	NDA	2.6	560	130	0.63	100	130	210
Sum (mg/kg)		399576																										
Percentages		0.00007	0.425	0.000375	0.00751	0.000501	0.000023	95.1	0.00218	0.00350	0.0476	0.00651	3.75	0.0325	0.250	0.0651	0.000726	0.0160	0.000576	0.00275		0.000651	0.140	0.0325	0.000158	0.0250	0.0325	0.0526

Notes:
Cells containing italicized red text represent non-detectable values; the value presented is the detection limit
1. From bench scale testing; single samples, hence results have uncertainty associated with them.

Table A-13a Laboratory Analytical Results for Seven Product Samples (Split into Two Fractions)

Sample ID	*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*MgO*	*CaO*	*Na_2O*	*K_2O*	*TiO_2*	*P_2O_5*	*MnO*	*Cr_2O_3*	*V_2O_5*	*LOI*	*Sum*	*Cl*	*Ag*	*As*	*Ba*	*Cd*	*Co*	*Cu*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	g/t	g/t	g/t	g/t	g/t	g/t	g/t
FT#1 1.18 +106 Conc	7.52	0.16	1.55	0.06	49.8	0.16	<0.01	<0.01	34.5	0.01	0.02	0.02	3.82	97.6	93	<2	<30	29.3	9	<20	22
FT#1 106 +20	4.27	0.87	2.91	0.52	49	0.18	0.03	0.05	33.4	0.03	0.04	0.04	5.22	96.5	96	<2	<30	31.4	10	<20	39.9
FT#2 1.18 +106 Conc	6.88	0.21	1.57	0.08	49.9	0.16	0.01	<0.01	34.5	0.02	0.02	0.02	3.85	97.2	85	<2	<30	28.2	9	<20	22
FT#2 106 +20	4.09	0.91	2.84	0.49	49.3	0.19	0.04	0.05	33.7	0.03	0.04	0.03	5.33	97.1	126	<2	<30	31.2	10	<20	39.8
FT#3 1.18 +106 Conc	6.74	0.21	1.68	0.1	49.8	0.16	0.01	0.02	34.6	0.02	0.02	0.02	3.92	97.3	89	<2	<30	27	10	<20	24.7
FT#3 106 +20	4.31	0.88	3.22	0.52	49	0.19	0.03	0.04	33.2	0.04	0.05	0.04	5.33	96.9	117	<2	<30	29.4	11	<20	40.7
FT#4 1.18 +106 Conc	6.48	0.21	1.53	0.07	50.2	0.16	0.01	<0.01	34.7	0.02	0.02	0.02	3.83	97.2	79	<2	<30	27.5	9	<20	20.6
FT#4 106+20	3.96	0.83	2.95	0.38	49.1	0.19	0.04	0.04	33.6	0.03	0.04	0.03	5.17	96.3	109	<2	<30	30.6	11	<20	37.8
FT#5 1.18 +106 Conc	2.71	0.23	1.59	0.07	52.1	0.17	0.01	<0.01	36.2	0.03	0.03	0.02	3.97	97.2	90	<2	<30	40.2	11	<20	19.9
FT#5 106+20	4.29	1	2.88	0.46	48.7	0.21	0.05	0.05	33.2	0.03	0.04	0.03	5.52	96.4	101	<2	<30	44.6	11	<20	39.2
FT#6 1.18 +106 Conc	4.12	0.19	1.58	0.06	51.5	0.17	<0.01	0.02	35.7	0.02	0.01	0.02	3.95	97.3	91	<2	<30	27.3	10	<20	19.8
FT#6 106+20	4.3	0.97	2.88	0.46	48.9	0.19	0.04	0.04	33.3	0.03	0.05	0.03	5.49	96.7	96	<2	<30	29.5	11	<20	39.1
FT#7 1.18 +106 Conc	1.45	0.23	1.61	0.07	52.7	0.19	0.02	0.01	36.7	0.02	0.03	0.02	4.06	97.1	100	<2	<30	32.4	11	<20	22
FT#7 106+20	4.27	0.95	3.14	0.41	48.8	0.21	0.06	0.04	33.5	0.03	0.04	0.04	5.58	97.1	---	<2	<30	29.6	11	<20	39.1

Notes:
g/t = mg/kg
Data provided to Intrinsik by Knight Piésold (from GB Minerals Ltd.).
Sample results for TOC leco; Acid Insol and CO_2 are not provided in the table as they are not relevant to the COPC screening

Table A-13b Laboratory Analytical Results for Seven Product Samples (Split into Two Fractions)

Sample ID	*Li*	*Mo*	*Ni*	*Pb*	*Sb*	*Se*	*Sn*	*Sr*	*Y*	*Zn*	*La*	*Ce*	*Pr*	*Nd*	*Eu*	*Tb*	*Dy*	*U*	*Th*	*Ga*	*Hg*	*F*
	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	%
FT#1 1.18 +106 Conc	<30	<8	60	<40	<20	<50	<40	501	257	252	140	127	21.6	92	4.5	3.3	22	100	6.9	0.5	<0.3	3.3
FT#1 106 +20	<30	<8	97	<40	<20	<50	<40	576	279	218	153	147	25.7	108	5.3	3.7	25	110	10.6	1.3	<0.3	3.29
FT#2 1.18 +106 Conc	<30	<8	62	<40	<20	<50	<40	509	257	193	136	125	22	91	4.5	3.3	22	99.5	6.7	0.6	<0.3	3.33
FT#2 106 +20	<30	<8	100	<40	<20	<50	<40	588	277	205	150	141	24.6	105	5.1	3.6	24	108	10.3	1.3	<0.3	3.28
FT#3 1.18 +106 Conc	<30	<8	53	<40	<20	<50	<40	486	249	195	143	129	22.4	93	4.6	3.3	22	103	7.1	0.6	<0.3	3.32
FT#3 106 +20	<30	<8	87	<40	<20	<50	<40	544	271	214	158	149	25.5	108	5.4	3.8	25	113	10.6	1.3	<0.3	3.29
FT#4 1.18 +106 Conc	<30	<8	46	<40	<20	<50	<40	492	248	205	142	135	22.3	94	4.6	3.4	22	104	6.8	0.6	<0.3	3.46
FT#4 106+20	<30	<8	78	<40	<20	<50	<40	550	264	207	153	143	24.8	106	5.3	3.8	24	110	10.3	1.2	<0.3	3.3
FT#5 1.18 +106 Conc	<30	<8	47	<40	<20	<50	<40	510	258	224	146	131	22.9	96	4.7	3.4	23	106	6.9	0.6	<0.3	3.54
FT#5 106+20	<30	<8	84	<40	<20	<50	<40	558	269	224	153	143	25.1	106	5.2	3.8	24	111	10.3	1.5	<0.3	3.28
FT#6 1.18 +106 Conc	<30	<8	47	<40	<20	<50	<40	504	256	195	152	134	22.9	97	4.8	3.4	23	106	7.1	0.6	<0.3	3.51
FT#6 106+20	<30	<8	89	<40	<20	<50	<40	552	270	211	161	159	26.4	111	5.3	3.8	24	112	12.4	1.4	<0.3	3.3
FT#7 1.18 +106 Conc	<30	<8	54	<40	<20	<50	<40	541	261	261	148	134	23.2	97	4.7	3.4	22	107	7	0.7	<0.3	3.49
FT#7 106+20	<30	<8	85	40	<20	<50	<40	554	264	229	154	143	25.1	105	5.2	3.7	24	111	10.1	1.4	<0.3	3.25

Notes:
g/t = mg/kg
Data provided to Intrinsik by Knight Piésold (from GB Minerals Ltd.).
Sample results for TOC leco; Acid Insol and CO_2 are not provided in the table as they are not relevant to the COPC screening

Table A-14 Oral Toxic Potency Screen of Metal Content of Product for HHRA (Concentration in 1 Product Sample)

Parameter	*% Composition of Product*	*Oral Exposure Limit (ug/kg/day)*	*Toxic Potency*[a]	*Relative Toxic Potency*	*Cumulative Toxic Potency*	*TRV Type*	*TRV Reference*
Arsenic	0.00038	0.0056	0.06704	44.19%	44.19%	RsD	Health Canada 2010b
Uranium	0.025	0.6	0.04171	27.50%	71.69%	RfD	Health Canada 2010b
Vanadium	0.0325	2	0.01627	10.72%	82.41%	RfD	RIVM 2009
Thallium	0.00016	0.02	0.00788	5.20%	87.61%	p-RfD	US EPA 2012
Iron	3.75	700	0.00536	3.54%	91.14%	p-RfD	US EPA 2006
Aluminium	0.425	143	0.00298	1.96%	93.10%	RfD	WHO 2013, 2010a,b
Cobalt	0.0035	1.4	0.00250	1.65%	94.75%	RfD	RIVM 2001
Cadmium	0.0022	1	0.00218	1.44%	96.19%	RfD	Health Canada, 2010b
Antimony	0.00065	0.4	0.00163	1.07%	97.26%	RfD	US EPA, 2015bb
Nickel	0.016	11	0.00146	0.96%	98.22%	RfD	Health Canada, 2010
Lead	0.00058	0.6	0.00096	0.63%	98.85%	POD	JECFA 2011
Selenium	0.0028	5.5	0.00050	0.33%	99.18%	RfD	Health Canada, 2010b
Manganese	0.0651	140	0.00046	0.31%	99.49%	RfD	US EPA 2015b
Beryllium	0.00050	2	0.00025	0.16%	99.65%	RfD	US EPA 2015b
Strontium	0.140	600	0.00023	0.15%	99.81%	RfD	US EPA 2015b
Zinc	0.0526	500	0.00011	0.07%	99.88%	RfD	Health Canada, 2010b
Copper	0.0065	91	0.00007	0.05%	99.92%	RfD	Health Canada 2010b
Barium	0.0075	200	0.00004	0.02%	99.95%	RfD	Health Canada 2010b
Chromium	0.048	1500	0.00003	0.02%	99.97%	RfD	US EPA 2015b
Molybdenum	0.00073	23	0.00003	0.02%	99.99%	RfD	Health Canada, 2010b
Silver	0.000070	5	0.00001	0.01%	100.00%	RfD	US EPA 2015b
Titanium	0.0325	43000	0.00000	0.00%	100.00%	Note [b]	US EPA 2005b
Bismuth	0.000023	NA					
		Totals	0.15170	100.00%			

Notes:

NA = no oral exposure limit available; RfD = reference dose; UIL = upper intake level; RfD = provisional reference dose; POD = point of departure

Shaded grey = chemicals carried forward for further assessment

[a] Toxic potency of each chemical was determined by dividing the percent composition of product by the oral exposure limit.

[b] No oral RFD for titanium could be found in the literature reviewed. Evaluations of titanium dioxide by JECFA, SCF, and EFSA have each concluded that there are no safety concerns associated with the use of titanium dioxide as a food additive at levels ranging up to 3% (US EPA, 2005). This value (3% or 30,000,000 µg/kg was converted to a dose by dividing by a body weight of 70 kg).

Based on results of the ERA oral toxic potency screening using the elemental content of the product (Tables A-15), the following chemicals made up >95% of the total toxic potency and were selected for further evaluation in the ERA:

- Aluminum
- Cadmium
- Chromium
- Iron
- Manganese
- Nickel
- Selenium
- Uranium
- Vanadium
- Zinc

Table A-15 Oral Toxic Potency Screen of Metals Content of Product for ERA (Concentrations in 1 Product Sample)

Parameter	*% Composition of Ore*	*SQG_E or MTL (mg/kg)*	*Toxic Potency[a]*	*Relative Toxic Potency*	*Cumulative Toxic Potency*	*SQG_E or MTL*	*Reference*
Iron	3.75	500	0.00751	35.41%	35.41%	MTL	NAS, 2005
Calcium	95.1	20000	0.00476	22.42%	57.83%	MTL	NAS, 2005
Selenium	0.0028	1	0.00275	12.98%	70.81%	MTL	CCME, 2015 (2009) [b]
Aluminum	0.425	200	0.00213	10.03%	80.85%	MTL	NAS, 2005
Uranium	0.025	33	0.00076	3.58%	84.42%	SQG_E	CCME, 201 (2007) [b]
Chromium	0.048	64	0.00074	3.50%	87.93%	SQG_E	CCME, 2015 (1997) [b, d]
Cadmium	0.0022	3.8	0.00057	2.70%	90.63%	SQG_E	CCME, 2015 (1999)[b]
Nickel	0.016	50	0.00032	1.51%	92.14%	SQG_E	CCME, 2015 (1999)[b]
Manganese	0.0651	220	0.00030	1.39%	93.53%	SQG_E	U.S. EPA, 2007 [e]
Zinc	0.0526	200	0.00026	1.24%	94.77%	SQG_E	CCME, 2015 (1999)[b]
Vanadium	0.0325	130	0.00025	1.18%	95.95%	SQG_E	CCME, 2015 (1999)[b]
Thallium	0.00016	1	0.00016	0.74%	96.70%	MTL	CCME, 2015 (1999)[b]
Strontium	0.140	1000	0.00014	0.66%	97.36%	MTL	NAS, 2005
Beryllium	0.00050	4	0.00013	0.59%	97.95%	SQG_E	OMOE, 2011[c]
Molybdenum	0.00073	6.9	0.00011	0.50%	98.44%	SQG_E	OMOE, 2011[c]
Copper	0.0065	63	0.00010	0.49%	98.93%	SQG_E	CCME, 2015 (1999)[b]
Cobalt	0.0035	40	0.00009	0.41%	99.34%	SQG_E	OMOE, 2011[c]
Magnesium	0.250	5000	0.00005	0.24%	99.58%	MTL	NAS, 2005
Antimony	0.00065	20	0.00003	0.15%	99.73%	SQG_E	OMOE, 2011[c]
Arsenic	0.00038	17	0.00002	0.10%	99.84%	SQG_E	CCME, 2015 (1997)[b]
Barium	0.0075	390	0.00002	0.09%	99.93%	SQG_E	OMOE, 2011[c]
Lead	0.00058	70	0.00001	0.04%	99.97%	SQG_E	CCME, 2015 (1999)[b]
Silver	0.000070	20	0.00000	0.02%	99.98%	SQG_E	OMOE, 2011[c]
Potassium	0.0325	10000	0.00000	0.02%	100.00%	MTL	NAS, 2005
Bismuth	0.000023	500	0.00000	0.00%	100.00%	MTL	NAS, 2005
Titanium	0.0325	NGA					
		Totals	0.02120	100.00%			

Notes:

NGA = No guideline or MTL available, SQG_E = Soil quality guideline for environmental health; MTL = maximum tolerable level. Maximum tolerable level from NAS, 2005 is based on MTL for rodents.

Shaded grey= chemicals carried forward for further assessment

[a] Toxic potency of each chemical was determined by dividing the composition of ore by the MTL or SQG_E

[b] The CCME (2015) ecological health-based soil quality guidelines were obtained on-line from the CCME website under soil quality guidelines, fact sheets which are provided for each individual chemical (2015 on-line; http://ceqg-rcqe.ccme.ca/). The year in bracket is the year the guideline was derived.

[c] OMOE (Ontario Ministry of the Environment; 2011) soil component value. Value presented is lower of the mammal / bird and plant / soil organism soil component value.

[d] CCME Guideline for total chromium (derived in 1997).

[e] US EPA (2007) Ecological Soil Screening Level (Eco SSL) for manganese. Value provided is the lower of the plant, soil invertebrate and wildlife guidelines.

A-4.0 BIOACCUMULATION CHECK

In addition to the guideline screening and toxic potency screening, chemicals which are considered to bioaccumulae or biomagnify were also included in the assessment.

Copper was reported to have little evidence of bioaccumulation and no evidence of biomagnification in the food chain (ATSDR, 2004), while cadmium was reported to bioaccumulates in all levels of the food chain but evidence of biomagnification were not conclusive (ATSDR, 2012). Selenium bioaccumulates in aquatic organisms and some terrestrial plants also take up selenium (ATSDR, 2003). The ATSDR (2005a) reported that in animals, nickel does not bioaccumulate to a great extent although there is evidence of uptake and accumulation in certain plants. Zinc was reported to moderately bioconcentrate in aquatic organisms, and concentrate in plants grown on contaminated soils, but it does not biomagnify through the terrestrial food chain (ATSDR, 2005b).

Thallium is thought to have the potential to bioaccumulate since it has been shown to bioconcentrate (ATSDR, 1992). Thallium has been reported to especially accumulate in plants of the family Brassicaceae (Babula and Zehnalek, 2008).

ICMM (2007) reported in their Metals Environmental Risk Assessment Guidance (MERAG) document that cadmium, methyl mercury and possibly lead are the only metals that have the potential to biomagnify in terrestrial organisms. Mercury has also been reported to have the potential to bioaccumulate in terrestrial food chains based on studies on mushrooms and earthworms (ATSDR, 1999). While mercury has the potential to bioaccumulate in terrestrial food chains, no data were available for mercury in the ore or in the product. In waste overburden samples, mercury was not detected (all samples <0.10 mg/kg; Table A-7). Mercury was not detected in the Mine soils (<0.2 mg/kg in 36 samples) and only detected in 1 of 15 samples of Port soils at a concentration just slightly above the detection limit (at 0.29 mg/kg). Given these considerations and lack of data, mercury was not evaluated in the assessment. However, mercury should be analyzed in environmental monitoring programs in the future to ensure levels do not become a concern.

Based on the information above, the following chemicals were selected as COPCs via the bioaccumulation check:

- Cadmium
- Lead
- Nickel
- Selenium
- Thallium
- Zinc

A-5.0 COPCS SELECTED FOR MINE AND PORT SITES FOR HHRA AND ERA

Table A-16 and A-17 provide a summary of the chemicals which screened on via either the baseline soil screening, oral toxic potency screening or bioaccumulation check for the Mine and Port sites for the HHRA or ERA. Given the similarity of lists for the Mine and Port site, the same COPCs were carried forward for modelling in the HHRA and ERA.

Table A-16 COPCs Carried Forward for Assessment in the HHRA

Chemical	*Baseline Soil Screening*		*Oral Toxic Potency Screening* [a]			*Bioaccumulation Check*
			Mine		*Port*	
	Mine	*Port*	*Waste Overburden*	*Ore*	*Product*	
Aluminum	yes	yes	yes	yes	yes	
Antimony				yes	yes	
Arsenic	yes	yes	yes	yes	yes	
Cadmium		yes			yes	yes
Chromium	yes	yes				
Cobalt				yes	yes	
Iron	yes	yes	yes	yes	yes	
Lead	yes	yes	yes	yes	yes	yes
Lithium	yes	yes	yes			
Manganese	yes	yes				
Nickel					yes	yes
Selenium					yes	yes
Thallium			yes	yes	yes	yes
Uranium				yes	yes	
Vanadium	yes	yes	yes	yes	yes	
Zinc						yes

Notes:
yes = chemical screened on as a COPC via the particular screening method listed
a. Toxic potency screening cut-off of 99% was used for HHRA

Table A-17 COPCs Carried Forward for Assessment in the ERA

Chemical	**Baseline Soil Screening**		**Oral Toxic Potency Screening** [a]			**Bioaccumulation Check**
			Mine		**Port**	
	Mine	**Port**	**Waste Overburden**	**Ore**	**Product**	
Aluminum			yes	yes	yes	
Arsenic		yes				
Beryllium	yes					
Cadmium					yes	yes
Chromium		yes		yes	yes	
Iron			yes	yes	yes	
Lead						yes
Manganese	yes	yes		yes	yes	
Nickel					yes	yes
Selenium	yes	yes			yes	yes
Thallium				yes		yes
Uranium				yes	yes	
Vanadium		yes			yes	
Zinc					yes	yes

Notes:
yes = chemical screened on as a COPC via the particular screening method listed
a. Toxic potency screening cut-off of 95% was used for ERA

A-6.0 REFERENCES

Alberta Health and Wellness. 2011. Guidance on Human Health Risk Assessment for Environmental Impact Assessment. Government of Alberta. August 2011. pg.21. http://www.health.alberta.ca/documents/Health-Risk-Enviro-Impact-Guide-2011.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2012. Toxicological Profile for Cadmium. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp5.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2005a. Toxicological Profile for Nickel. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp15.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2005b. Toxicological Profile for Zinc. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp60.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2004. Toxicological Profile for Copper. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp132.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2003. Toxicological Profile for Selenium. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp92.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 1999. Toxicological Profile for Mercury. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp46.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 1992. Toxicological Profile for Thallium. U.S. Department of Health and Human Services. http://www.atsdr.cdc.gov/toxprofiles/tp54.pdf

Babula, P., Zehnalek, J. 2008. Uncommon heavy metals, metalloids and their plant toxicity: a review. Environ Chem Lett (2008) 6:189–213. http://pages.towson.edu/racasey/602docs/Sb_literature/Environ%20Chem%20Lett%202008%20189-213.pdf

CCME. 2015. Canadian Environmental Quality Guidelines Summary Table. On-line. Canadian Council of Ministers of the Environment. http://www.ccme.ca/index.html

DiPalma, J.R. 2001. Bismuth Toxicity, Often Mild, Can Result in Severe Poisonings. Emergency Medicine News. Laboratory Rounds. Vol 23(3) p. 16 http://journals.lww.com/em-news/Fulltext/2001/04000/Bismuth_Toxicity,_Often_Mild,_Can_Result_in_Severe.12.aspx

Health Canada. 2010a. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRAChem). pg. 81 www.healthcanada.gc.ca

Health Canada. 2010b. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0 www.healthcanada.gc.ca

JECFA (Joint FAO / WHO Expert Committee on Food Additives). 2011. Safety evaluation of certain food additives and contaminants / prepared by the seventy-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO food additives series: 64. World Health Organization.

Knight Piésold. 2015a. Supplemental Terrestrial Soil Baseline Report – Farim Phosphate Project. Memo from R. Cook to O. Kovalik, July 13, 2015. File No. NB301-520/2-A.01

Knight Piésold. 2015b. Farim Phosphate Project – Screening of Metals Concentrations in Ore. Phosphate Rock and Waste Overburden for Future Assessment of Dusting and Water Quality Effects. Memo from D. Klodnicki to O. Kovalik, Juned 17, 2015. File No. NB301-520/2-A.01. Table 1 to 3 from Lycopodium Minerals Canada Ltd.

NAS (National Academy of Sciences). 2005. Mineral Tolerance of Animals, 2nd ed. Committee on Minerals and Toxic Substances in Diets and Water for Animals, Board of Agriculture and Natural Resources, Division on Earth and Life Sciences, National Research Council. The National Academies Press, Washington, D.C. URL: http://www.nap.edu/catalog/11309.html

OMOE (Ontario Ministry of the Environment). 2011. Rationale for the development of soil and groundwater standards for use at contaminates sites in Ontario. April 15, 2011. https://dr6j45jk9xcmk.cloudfront.net/documents/999/3-6-4-rationale-for-the-development-of-soil-and.pdf

ICMM. 2007. MERAG: Metals Environmental Risk Assessment Guidance. International Council on Mining and Metals. www.metalsriskassessment.org

IOM (Institute of Medicine). 2011. Dietary Reference Intakes (DRIs): Tolerable Upper Intake Levels, Elements. Food and Nutrition Board, Institute of Medicine, National Academies http://iom.nationalacademies.org/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/ULs%20for%20Vitamins%20and%20Elements.pdf

RAIS. 2015. The Risk Assessment Information System. Toxicity Profiles. Condensed Toxicity Summary for Lithium. http://rais.ornl.gov/tox/profiles/lith_c.html

Reynolds. P.T., Abalos, K.C., Hopp, J., Williams, M.E. 2012. Bismuth Toxicity: A Rare Cause of Neurologic Dysfunction. International Journal of Clinical Medicine, 2012, 3, 46-48 http://dx.doi.org/10.4236/ijcm.2012.31010. Published Online January 2012 http://www.SciRP.org/journal/ijcm

RIVM. 2001. Re-evaluation of human-toxicological maximum permissible risk levels. Dutch National Institute of Public Health and the Environment (Rijksinstituut Voor Volksgezondheid En Milieu). RIVM report 711701025. Available at: http://rivm.openrepository.com/rivm/bitstream/10029/9662/1/711701025.pdf

RIVM. 2009. Re-evaluation of some human toxicological Maximum Permissible Risk levels earlier evaluated in the period 1991-2001. Dutch National Institute of Public Health and

the Environment (Rijksinstituut Voor Volksgezondheid En Milieu). RIVM report 711701092/2009. Available at: http://www.rivm.nl/bibliotheek/rapporten/711701092.pdf

SA DEA (South Africa Department of Environmental Affairs). 2014. Government Notice. Staatskoerant, 2 May, 2014. National Environmental Management: Waste Act, 2008 (Act No. 59 OF 2008). National Norms and Standards for the Remediation of Contaminated Land and zSoil Quality. http://www.arc.agric.za/arc-iscw/Documents/Soil%20Remediation%20Workshop%20Files/Norms%20and%20Standards%20for%20Remediation%20of%20Contaminated%20Land%20and%20Soil%20Quality.pdf

SA DEA (South Africa Department of Environmental Affairs). 2010. Framework for the Management of Contaminated Land. May 2010. Department of Environmental Affairs Republic of South Africa. http://sawic.environment.gov.za/documents/562.pdf

U.S. EPA. 1989. Risk Assessment Guidance for Superfund. United States Environmental Protection Agency, Washington, DC. EPA/540/01. Pg. 5-23, 5-24. http://www.epa.gov/oswer/riskassessment/ragsa/pdf/rags_a.pdf

U.S. EPA. 2003a. Ecological Soil Screening Level for Aluminum: Interim Final. OSWER Directive 9285.7-60. United States Environmental Protection Agency. http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_aluminum.pdf

U.S. EPA. 2003b. Ecological Soil Screening Level for Iron. Interim Final. OSWER Directive OSWER Directive 9285.7-69. http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_iron.pdf

U.S. EPA. 2005. Inert Ingredient Tolerance Reassessment - Titanium Dioxide. Action Memorandum, June 28th, 2005. Office of Prevention, Pesticides and Toxic Substances. United States Environmental Protection Agency.

U.S. EPA. 2006. Provisional Peer Reviewed Toxicity Values for Iron (CASRN 7439-89-6) and Compounds. Derivation of Subchronic and Chronic Oral RfDs. United States Environmental Protection Agency. http://hhpprtv.ornl.gov/quickview/pprtv.php

U.S. EPA. 2007. Ecological Soil Screening Level for Manganese. Interim Final. OSWER Directive. OSWER Directive 9285.7-71. United States Environmental Protection Agency. http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_manganese.pdf

U.S. EPA. 2008. Provisional Peer Reviewed Toxicity Values for Lithium (CASRN 7439-93-2). Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. http://hhpprtv.ornl.gov/quickview/pprtv.php

U.S. EPA. 2012. Provisional Peer-Reviewed Toxicity Values for Thallium and Compounds. Final. Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development Cincinnati, OH. http://hhpprtv.ornl.gov/quickview/pprtv.php

U.S. EPA. 2014. Region 4 Human Health Risk Assessment Supplemental Guidance. January 2014 Draft Final. United States Environmental Protection Agency. Technical Services Section, Superfund Division. EPA Region 4.

http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/hhraguidedoc011014.pdf

U.S. EPA. 2015a. Regional Screening Levels (RSL). Residential soil table (TR-1E-6, HQ=0.1), June, 2015. United States Environmental Protection Agency Consolidated RSLs for U.S. EPA Regions 3, 6 and 9. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/ressoil_sl_table_run_JUNE2015.pdf

U.S. EPA. 2015b. IRIS (Integrated Risk Information System). On-Line. United States Environmental Protection Agency. http://www.epa.gov/iris/. Searched August, 2015.

WHO (World Health Organization). 2010a. Aluminum in Drinking Water. Background Document for Development of WHO Guidelines for Drinking-water Quality.

WHO (World Health Organization). 2010b. Aluminum Summary Statement. Available at: http://www.who.int/water_sanitation_health/dwq/chemicals/aluminium_summary_statement.doc

WHO (World Health Organization). 2013. WHO/HSE/WSH/10.01/13. Available at: http://www.who.int/water_sanitation_health/publications/aluminium.pdf

WHO. 2009. WHO Guidelines for Drinking-water Quality Policies and Procedures used in updating the WHO Guidelines for Drinking-water Quality. World Health Organization. http://apps.who.int/iris/bitstream/10665/70050/1/WHO_HSE_WSH_09.05_eng.pdf

WHO. 2000. Air quality guidelines for Europe; second edition. WHO regional publications. European series; No. 91. http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf

APPENDIX B

WORKED EXAMPLE FOR THE HUMAN HEALTH MULTIPLE PATHWAY EXPOSURE MODEL

APPENDIX B: WORKED EXAMPLE FOR THE HUMAN HEALTH MULTIPLE PATHWAY EXPOSURE MODEL

B-1.0 INTRODUCTION

The human health risk assessment (HHRA) focused on direct and indirect health risks associated with air emissions from the Farim Phosphate Project (the Project). The Project will emit chemicals of potential concern (COPCs) directly into air from various sources, thus people residing or working near the Project, as well as people visiting the area could be directly exposed to the COPCs via inhalation.

In addition to the primary pathways of exposure (e.g., inhalation), people that live or work in the area might be exposed to the COPCs via secondary exposure pathways. Some COPCs emitted to the atmosphere via air emissions may be deposited onto the soils and plants surrounding the Project area. Depending on the fate, transport and persistence of the COPCs in the environment, chemical deposition could affect the chemical concentrations in soils and foods (i.e., plants) derived from the local study area (LSA).

Health risks from the consumption of plants were characterized through a detailed multimedia exposure model used to predict long term exposures from non-volatile, persistent or bio-accumulative COPC. Chronic multiple pathway risks were estimated with oral COPC exposure limits considered protective of human health and sensitive individuals (e.g., children, elderly, and people with compromised health).

This appendix provides an example of the calculations used to estimate media concentrations and human exposures to the COPCs from chronic exposure to emissions resulting from the Project. Many of the methods, equations and assumptions used to predict concentrations in various environmental media were provided by the United States Environmental Protection Agency Office of Solid Waste (US EPA 2005) and Health Canada (2012).

B-1.1 Environmental Media Concentrations

In order to quantify potential human exposures (and associated potential health impacts) through multiple exposure pathways as a result of emissions from the Project, predicted chemical concentrations in various environmental media were required to estimate exposures and characterize risks. Chemical concentrations in the following media were estimated for the multiple pathway exposure model:

- Soil;
- Dust; and,
- Foods (exposed aboveground produce, belowground produce, and protected aboveground produce)

However, when available, measured chemical concentrations in soil were used to characterize baseline exposures. Measured chemical concentrations in groundwater and fish were also used to characterize baseline exposures.

This worked example is presented for a toddler resident exposed to arsenic in the Project Alone scenario. The results are presented for the toddler lifestage in this example, as toddlers typically represent the most sensitive life stage due to their exposure rates relative to body weight.

B-1.1.1 Chemical Deposition

Deposition rates were modelled by the Air Quality group and total deposition rates were provided for all receptor locations at operational year 2, 8, 15 and 25. The total deposition rate used for COPCs at each receptor location were estimated by calculating a weighted average of the total deposition rate at year 2, 8, 15, and 25 multiplied by the COPC-specific soil composition fraction. For the purposes of the worked example, the annual average total deposition rate for arsenic for the resident group at Receptor Location R2 is 3.62E-01 mg/m^2/yr under the Project Alone scenario.

B-1.2 Chemical Concentration in Soil

B-1.2.1 Predicted Chemical Concentration in Soil

Soil concentrations were estimated based on the chemical-specific deposition rates. Deposition to soil on a mass to mass basis was calculated using the following equation:

$$D_s = \frac{D_{tot}}{Z_s \times BD}$$

Where:

D_s = chemical-specific deposition (mg/kg/yr)
D_{tot} = chemical-specific deposition rate (mg/m^2/yr)
Z_s = soil mixing zone depth (m)
BD = soil bulk density (kg/m³)

For the current assessment, the bulk density was assumed to be 1,500 kg/m³, and soil concentrations were predicted for two mixing depths (*i.e.*, 2 cm and 20 cm) to calculate surface soil and soil concentrations, respectively.

Example 1 Deposition of arsenic to surface soil for prediction of human exposure

$$D_s = \frac{0.362}{0.02 \times 1{,}500}$$

$$D_s = 1.21E-02\ mg/kg/yr$$

Example 2 Deposition of arsenic to soil for prediction of human exposure

$$D_s = \frac{0.362}{0.2 \times 1{,}500}$$

$$D_s = 1.21E-03\ mg/kg/yr$$

B-1.2.2 Calculation of Soil Concentration

Soil concentrations were calculated on a mass per mass basis (mg/kg) based on the following equation:

$$C_s = \frac{D_s \times [1 - \exp(-kt \times tD)]}{kt}$$

Where:

C_s	=	average soil concentration over exposure duration (mg/kg soil)
D_s	=	deposition to surface soil or soil (mg of chemical/kg of soil/yr)
kt	=	chemical soil loss constant due to all processes (degradation or loss due to volatilization) (yrs^{-1})
tD	=	time period over which deposition occurs (yrs)

Atmospheric deposition was assumed to occur for 26 years (*i.e.,* operating lifetime of the project).

Example 3 Concentration of arsenic in surface soil for prediction of human exposure

$$C_s = \frac{1.21E-02 \times [1 - \exp(-2.53E-03 \times 26)]}{2.53E-03}$$

$$C_s = 3.03E-01\ mg/kg$$

Example 4 Concentration of arsenic in soil for prediction of human exposure

$$C_s = \frac{1.21E-03 \times [1 - \exp(-2.53E-03 \times 26)]}{2.53E-03}$$

$$C_s = 3.03E-02\ mg/kg$$

B-1.3 Chemical Concentrations in Dust

The chemical concentrations in dust were calculated using the measured and/or predicted soil concentration, as follows (Health Canada 2012):

$$C_{dust} = DL \times C_s \times CF$$

Where:

C_{dust}	=	chemical concentration in dust (µg/m³)
DL	=	dust level (kg/m³)
C_s	=	surface soil concentration from deposition over time (mg/kg)
CF	=	conversion factor from mg to µg (1,000 µg/mg)

A Health Canada (2012) recommended dust level of 250 µg/m³ (2.5E-07 kg/m³) was used to predict chemical concentrations in dust.

Example 5 Concentration of arsenic in dust for prediction of human exposure

$$C_{dust} = 2.5E-07 \times 3.03E-01 \times 1{,}000$$
$$C_{dust} = 7.58E-05 \mu g/m^3$$

B-1.4 Chemical Concentrations in Plants

The methodology used to estimate the contribution from each route of the chemical uptake in plants are described in the following sections. The following mechanisms were included when estimating the uptake of the chemicals into the tissue of plants.

- air to exposed aboveground produce (particle deposition to leaves or foliage)
- soil to exposed aboveground produce (root uptake)
- soil to belowground produce (root uptake)
- soil to protected aboveground produce (root uptake)

The worked example is provided for exposed aboveground produce.

B-1.4.1 Plant Concentration as a Result of Direct Deposition

The following equation was used to predict concentrations of exposed aboveground produce for consumption by human receptors as a result of deposition processes on a wet weight (WW) basis (US EPA 2005):

$$Pd = \frac{D_{tot} \times Rp \times \left[1.0 - \exp\left(-kp \times Tp\right)\right]}{Yp \times kp} \times \left(1 - WC\right)$$

Where:

Pd	=	exposed aboveground produce concentration as a result of direct deposition (mg/kg WW)
D_{tot}	=	deposition rate of COPC (mg/m²/yr)
Rp	=	intercept fraction of edible portions of plant (unitless)
kp	=	plant surface loss coefficient (yr^{-1})
Tp	=	length of plant exposure to deposition per harvest of the edible portion of the ith plant group (yr)
Yp	=	yield or productivity (kg DW/m²)
WC	=	plant water content (unitless)

The US EPA (2005) recommends the use of the default intercept fraction of edible portions of plant (*Rp*) value (unitless), because it represents the most current information available with respect to productivity and relative ingestion rates. A default *Rp* value of 0.39 was recommended for exposed aboveground produce.

The *kp* value is a measure of the amount of chemical lost as a result of removal by wind and water and growth dilution. The US EPA (2005) recommends a default *kp* value of 18 yr^{-1} for exposed aboveground produce, which corresponds to a 14-day half-life.

The US EPA (2005) recommends using a *Yp* value of 2.24 kg DW/m² for exposed aboveground produce and a *Tp* value of 0.16.

The water content for exposed aboveground produce was assumed to be 85% (US EPA 2005).

Example 6 Concentration of arsenic in exposed aboveground produce as a result of direct deposition for prediction of human exposure

$$Pd = \frac{0.362 \times 0.39 \times [1.0 - \exp(-18 \times 0.16)]}{2.24 \times 18} \times (1 - 0.85)$$
$$Pd = 4.95E-04\ mg/kg\ WW$$

B-1.4.2 Plant Concentration as a Result of Root Uptake

COPCs present in soil can be taken up into edible portions of plants. The US EPA (2005) provides an equation to predict COPC concentrations in exposed aboveground produce, belowground produce, and protected aboveground produce as a result of root uptake using soil concentrations and plant-to-soil bioconcentration factors (BCFs).

The following equation was used to predict the chemical concentration in exposed aboveground produce as a result of root uptake (US EPA 2005).

$$\Pr = C_s \times BCF \times (1 - WC)$$

Where:

Pr	=	chemical concentration in exposed aboveground produce as a result of root uptake (mg/kg WW)
C_s	=	chemical concentration in soil (mg/kg)
BCF	=	plant-soil bioconcentration factor for exposed aboveground produce (kg soil/kg plant DW)
WC	=	plant water content (unitless)

COPC-specific BCFs for exposed aboveground produce, belowground produce, and protected aboveground produce were provided by US EPA 2005. If a BCF value was not available, BCFs were obtained from Baes *et al.* (1984).

Example 7 Concentration of arsenic in exposed aboveground produce as a result of root uptake for the prediction of human exposure

$$\Pr = 3.03E-02 \times 6.33E-03 \times (1 - 0.85)$$
$$\Pr = 2.88E-05\ mg/kg\ WW$$

B-1.5 Total Chemical Concentration in Plants

The following equation was used to estimate the chemical concentration in exposed aboveground produce as a result of direct deposition and root uptake.

$$C_{plant} = (Pd + \Pr)$$

Where:

C_{plant} = total chemical concentration in exposed aboveground produce (mg/kg WW).
Pd = plant concentration as a result of direct deposition (mg/kg)
Pr = plant concentration as a result of root uptake (mg/kg)

Example 8 Concentration of arsenic in exposed aboveground produce as a result of direct deposition and root uptake for the prediction of human exposure

$$C_{plant} = (4.95E-04 + 2.88E-05)$$
$$C_{plant} = 5.24E-04\ mg/kg\ WW$$

B-1.6 Human Exposure Estimates

B-1.6.1 Incidental Ingestion of Soil

The following equation was used to estimate human exposure via incidental ingestion of soil. Soil ingestion rates and equations used to predict exposures were based on recommendations from Health Canada (2012).

$$EDI_{soil} = C_s \times SIR \times CF1 \times CF2$$

Where:

EDI_{soil} = estimated daily intake of chemical via ingestion of soil (µg/d)
C_s = chemical concentration in surface soil (mg/kg)
SIR = incidental soil ingestion rate (g/d)
CF1 = conversion factor from mg to µg (1,000 µg/mg)
CF2 = conversion factor from g to kg (0.001 kg/g)

Example 9 Estimated daily intake of arsenic by a toddler resident (Receptor Location R2) from incidental ingestion of soil

$$EDI_{soil} = 3.03E-01 \times 0.08 \times 1000 \times 0.001$$
$$EDI_{soil} = 2.43E-02 \mu g/d$$

B-1.6.2 Ingestion of Drinking Water

It was assumed that residents consumed groundwater. Water ingestion rates and equations used to predict exposures were based on recommendations from Health Canada (2012) and exposures were based on the following equation:

$$EDI_{water} = C_{dw} \times WIR \times CF$$

Where:

EDI_{water}= estimated daily intake of chemical via ingestion of water (µg/d)

C_{dw} = chemical concentration in groundwaterwater (mg/L)
WIR = water ingestion rate (L/d)
CF = conversion factor from mg to µg (1,000 µg/mg)

Since it is not anticipated that COPC concentrations in groundwater will change due to the Project activities, human receptors are not anticipated to be exposed to COPCs via groundwater ingestion under the Project Alone scenario.

B-1.6.3 Inhalation/Ingestion of Dust

The following equation was used to estimate human exposure via inhalation and subsequent ingestion of dust. Air inhalation rates and equations used to predict exposures were based on recommendations from Health Canada (2012).

$$EDI_{dust} = C_{dust} \times AIR$$

Where:

EDI_{dust} = estimated daily intake of chemical via inhalation of dust (µg/d)
C_{dust} = chemical concentration in dust (µg/m³)
AIR = air inhalation rate (m³/d)

Example 10 Estimated daily intake of arsenic by a toddler resident (Receptor Location R2) from inhalation of dust

$$EDI_{dust} = 7.58E-05 \times 8.3$$
$$EDI_{dust} = 6.29E-04\ \mu g/d$$

B-1.6.4 Dermal Exposure from Soil

Potential dermal exposure was estimated by applying soil loading rates to exposed skin, skin surface areas, and dermal absorption factors to measured or predicted soil concentrations. Dermal exposures were estimated separately for hands only and for surfaces other than hands (e.g., arms and legs).

Dermal Exposure to Hands

The following equation was used to estimate dermal exposure for hands only. Dermal exposures were based on recommendations from Health Canada (2010) or Ontario MOE (2011) and Health Canada (2012).

$$EDI_{dermal\_h} = C_s \times SAH \times SLH \times RAF_{dermal}$$

Where:

EDI_{dermal_h} = estimated daily intake of chemical from dermal contact of hands with soil (µg/d)
Cs = chemical concentration in surface soil (mg/kg)
SAH = skin surface area of hands (cm²)

SLH = soil loading rate to exposed skin on hands (g/cm²/event)
RAF_{dermal} = relative dermal absorption factor (%)

Example 11 Estimated daily intake of arsenic by a toddler resident (Receptor Location R2) from dermal exposure to hands

$$EDI_{dermal\_h} = 3.03E-01 \times 430 \times 1.0E-04 \times 0.03$$
$$EDI_{dermal\_h} = 3.91E-04\ \mu g/d$$

Dermal Exposure to Surfaces Other than Hands

The following equation was used to estimate dermal exposure for surfaces other than hands. Dermal exposures were based on recommendations from Health Canada (2010) or Ontario MOE (2011) and Health Canada (2012).

$$EDI_{dermal\_o} = C_s \times SAO \times SLO \times RAF_{dermal}$$

Where:

EDI_{dermal_o} = estimated daily intake of chemical from dermal contact of surfaces other than hands with soil (µg/d)
Cs = chemical concentration in surface soil (mg/kg)
SAO = skin surface area of upper and lower arms and legs (cm²)
SLO = soil loading rate to exposed skin on surfaces other than hands (g/cm²/event)
RAF_{dermal} = relative dermal absorption factor (%)

Example 12 Estimated daily intake of arsenic by a toddler resident (Receptor Location R2) from dermal exposure to surfaces other than hands

$$EDI_{dermal\_o} = 3.03E-01 \times 2580 \times 1.0E-05 \times 0.03$$
$$EDI_{dermal\_o} = 2.35E-04\ \mu g/d$$

B-1.6.5 Ingestion of Plants

The following equation was used to estimate human exposure via consumption of exposed aboveground produce. This equation was also used to estimate human exposure via consumption of belowground produce and protected aboveground produce. For exposed aboveground produce and protected aboveground produce, the Health Canada (2012) 'Other Vegetables' ingestion rate was used to predict exposures. For belowground produce, the Health Canada (2012) 'Root Vegetables' ingestion rate was used.

$$EDI_{EAGPlant} = Pb \times IR_{EAGPlant} \times Freq_{EAGPlant} \times ChemApport$$

Where:
$EDI_{EAG\ Plant}$ = estimated daily intake of chemical via consumption of exposed aboveground produce (µg/d)
Pb = chemical concentration in exposed aboveground produce (mg/kg WW)

$IR_{EAGPlant}$= exposed aboveground plant ingestion rate (g/d)
$Freq_{EAGPlant}$ = frequency of consumption per year (%)
ChemApport = chemical apportionment in food item

Example 13 Estimated daily intake of arsenic by a toddler resident (Receptor Location R2) from consumption of exposed aboveground produce

$$EDI_{EAGPlant} = 5.24E-04 \times 67 \times 1 \times 0.78$$
$$EDI_{EAGPlant} = 2.74E-02\ \mu g/d$$

B-1.6.6 Ingestion of Fish

Consumption rates and equations used to predict exposures were obtained from Health Canada (2007). The following equation was used to estimate human exposure via consumption of fish.

$$EDI_{fish} = C_{fish} \times IR_{fish} \times Freq_{fish} \times ChemApport$$

Where:

EDI_{animal}= estimated daily intake of chemical via consumption of fish (µg/d)
C_{animal} = chemical concentration in fish tissue (mg/kg WW)
IR_{animal} = fish ingestion rate (g/d)
$Freq_{animal}$= frequency of consumption per year (%)
ChemApport = chemical apportionment in food item

Project-related impacts to fish tissue concentrations were not predicted.

B-1.6.7 Total Human Exposure

Total exposure was calculated by summing the individual exposures from each medium (*i.e.*, soil, water, dust, and food intake) for all relevant exposure pathways on a per chemical and per life stage basis (Health Canada 2012):

$$EDI_{total} = EDI_{soil} + EDI_{water} + EDI_{dust} + EDI_{dermal\_h} + EDI_{dermal\_o} + EDI_{food}$$

Where:

EDI_{total} = total estimated daily intake of chemical via all routes (µg/d)
EDI_{soil} = estimated daily intake of chemical from incidental soil ingestion (µg/d)
EDI_{water}= estimated daily intake of chemical from ingestion of water (µg/d)
EDI_{dust} = estimated daily intake of chemical from dust inhalation (µg/d)
EDI_{dermal_h} = estimated daily intake of chemical from dermal contact of hands (µg/d)
EDI_{dermal_o} = estimated daily intake of chemical from dermal contact of surfaces other than hands (µg/d)
EDI_{food} = estimated daily intake of chemical from consumption of all food types (µg/d [sum of exposed aboveground produce, belowground produce, protected aboveground produce, and fish])

Example 14 Total estimated daily intake of arsenic for a toddler resident (Receptor Location R2) from all routes of exposure

$$EDI_{total} = 2.43E-02 + 0 + 6.29E-04 + 3.91E-04 + 2.35E-04 + 3.09E-02$$
$$EDI_{total} = 5.64E-02 \mu g/d$$

The total estimated daily intake was normalized to body weight as follows:

$$EDI_{total\_BW} = \frac{EDI_{total}}{BW}$$

Where:

EDI_{total_BW}= total estimated daily intake of chemical via all routes adjusted to body weight (µg/kg bw/d)
EDI_{total} = total estimated daily intake of chemical via all routes (µg/d)
BW = body weight (kg)

Example 15 Total estimated daily intake of arsenic for a toddler resident (Receptor Location R2) from all routes of exposure adjusted to body weight

$$EDI_{total\_BW} = \frac{5.64E-02}{16.5}$$
$$EDI_{total\_BW} = 3.42E-03 \mu g/kg\ bw/d$$

B-1.7 Human Risk Calculation

Hazard quotient (HQ) values for non–carcinogens and incremental lifetime cancer risks (ILCRs) for carcinogens were estimated using the following equations and the calculated exposure estimates.

B-1.7.1 Non-carcinogens

The following equation was used to calculate the hazard quotients for non–carcinogens (Health Canada 2012):

$$HQ_i = \frac{EDI_{total\_BW}}{RfD}$$

Where:

HQ_i = hazard quotient of chemical for the 'i' lifestage of the residents (unitless)
EDI_{total_BW}= total estimated daily intake of chemical via all routes adjusted to body weight for the 'i' lifestage (µg/kg bw/d)
RfD = chemical-specific reference dose (µg/kg bw/d)

The maximum HQ value of all the life stages (*i.e.*, infant, toddler, child, adolescent, and adult) was presented in the detailed HHRA report for non-carcinogens. The toddler lifestage had the highest HQ of all the life stages for arsenic.

Example 16 Hazard quotient for arsenic for the resident toddler life-stage in the Project Alone Scenario

$$HQ_i = \frac{3.42E-03}{0.3}$$
$$HQ_i = 1.1E-02$$

B-1.7.2 Carcinogens

The following equation was used to calculate the incremental lifetime cancer risks for carcinogens (Health Canada 2012):

$$ILCR = (EDI_{total\_BW-inf} x\, LAF_{-inf} + EDI_{total\_BW-tod} x\, LAF_{-tod} + EDI_{total\_BW-child} x\, LAF_{-child} + EDI_{total\_BW-adol} x\, LAF_{-adol} + EDI_{total\_BW-adult} x\, LAF_{-adult}) x SF$$

Where:

ILCR = ILCR of chemical for the sum of the lifestages of the residents (unitless)
EDI_{total_BW-i} = total estimated daily intake of chemical via all routes adjusted to body weight for the 'i' lifestage (µg/kg bw/d)
SF = chemical-specific slope factor (µg/kg bw/d)$^{-1}$
LAF-i = Lifetime adjustment factor for the 'i' lifestage for general population (yr-life stage/yr-total)

The ILCR value for carcinogens are based on predicted exposures of the composite (or lifetime) receptor.

Example 17 ILCR for arsenic for the resident in the Project Alone scenario

$$ILCR = (8.12E-04x1.01E-02 + 3.42E-03x9.09E-02 + 1.63E-03x1.41E-01 + 1.09E-03x1.62E-01 + 1.01E-03x5.96E-01)x1.8E-03$$

$$ILCR = 2.4E-06$$

B-2.0 REFERENCES

Baes III, C.F., Sharp, R.D., Sjoreen, A.L. and Shor, R.W. 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture. Research sponsored by the Office of Radiation Programs, US Environmental Agency under Interagency Agreement AD-89-F-2-A106. Prepared by the Oak Ridge National Laboratory. ORNL-5786.

Health Canada. 2007. Health Canada's revised assessment of mercury in fish enhances protection while reflecting advice in Canada's Food Guide. Available at: http://www.hc-sc.gc.ca/ahc-asc/media/advisories-avis/2007/2007_31_e.html

Health Canada 2010. Federal Contaminated Site Risk Assessment in Canada. PART II: Health Canada Toxicological Reference Values (TRVs) and Chemical-specific Factors, Version 2.0. Prepared by Contaminated Sites Division Safe Environments Directorate. September 2010.

Health Canada. 2012. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. Prepared by; Contaminated Sites Division, Safe Environments Directorate, Ottawa, ON.September 2010, revised 2012.

RAIS (Risk Assessment Information System). 2009. Chemical Specific Parameters. Available at: http://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chem_spef

Suter, GW, RA Efroymson, BE Sample and DS Jones. 2000. Ecological Risk Assessment for Contaminated Sites. Lewis Publishers, CRC Press LLC.

US EPA. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Final. US EPA Region VI. Multimedia Planning and Permitting Division. Center for Combustion Science and Engineering. Office of Solid Waste.

APPENDIX C

GROUND-LEVEL AIR EXPOSURE AND RISK ESTIMATES

APPENDIX C: GROUND-LEVEL AIR EXPOSURE AND RISK ESTIMATES

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C-1.0 INTRODUCTION

This appendix provides air exposure and risk estimate tables for receptor locations near the Farim Mine site and Port site for the Baseline, Project Alone, and Baseline + Project scenarios evaluated within the HHRA component of the HHERA.

Section 2 of the current appendix provides air exposure and risk estimate tables for receptor locations near the Farim Mine site, while Section 3 provides air exposure and risk estimate tables for receptor locations near the Port site.

C-2.0 RECEPTOR LOCATIONS NEAR THE MINE SITE

This section provides exposure and risk estimate tables for receptor locations near the Farim Mine site for the Baseline, Project Alone, and Baseline + Project scenarios for Project operational years 2, 8, 15, and 25.

C-2.1 Estimated Exposures for Baseline Scenario

This section provides exposure estimate tables for the Baseline Scenario.

C-2.1.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average exposure estimate tables for the criteria air contaminants (Tables C-1 through C-3).

Table C-1 Estimated Average Baseline 1-Hour Air Concentrations of Criteria Air Contaminants for Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	1.38E+00	3.76E+00	-
R9	Nema	NA	NA	1.38E+00	3.76E+00	-
R12	Sandjal	NA	NA	1.38E+00	3.76E+00	-
R15	Sara Loba	NA	NA	1.38E+00	3.76E+00	-
R22	Tungina	NA	NA	1.38E+00	3.76E+00	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
\- Baseline data were not available for this chemical parameter.

Table C-2 Estimated Average Baseline 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour [a]	*24-Hour* [a]	*24-Hour* [b]	*24-Hour*	*8-Hour*
R2	Bani	-	-	1.38E+00	NA	-
R9	Nema	-	-	1.38E+00	NA	-
R12	Sandjal	-	-	1.38E+00	NA	-
R15	Sara Loba	-	-	1.38E+00	NA	-
R22	Tungina	-	-	1.38E+00	NA	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
\- Baseline data were not available for this chemical parameter.

Table C-3 Estimated Baseline Annual Average Air Concentrations of Criteria Air Contaminants for Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual	*Annual*	*Annual*	*Annual*	*Annual*
R2	Bani	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA

Table C-3	Estimated Baseline Annual Average Air Concentrations of Criteria Air Contaminants for Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs) (µg/m³)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		Annual	***Annual***	***Annual***	***Annual***	***Annual***
R9	Nema	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA
R12	Sandjal	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA
R15	Sara Loba	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA
R22	Tungina	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

C-2.1.2 Metals

Exposures to metals were not determined due to the absence of adequate baseline PM_{10} data.

C-2.2 Estimated Exposures for Project Alone Scenario

This section provides exposure estimate tables for the Project Alone Scenario.

C-2.2.1 Criteria Air Contaminants

This section provides maximum 1-hour (Tables C-4 through C-7), maximum 8-hour, maximum 24-hour (Tables C-8 through C-11), and annual average (Tables C-12 through C-15) exposure estimate tables for the criteria air contaminants.

C-2.2.1.1 1-Hour Exposures

Table C-4	Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 2 Operations from Project Alone at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs) (µg/m³)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		1-Hour	***1-Hour***	***1-Hour*** [a]	***1-Hour*** [b]	***1-Hour***
R2	Bani	NA	NA	8.38E+00	5.32E+01	1.54E+03
R9	Nema	NA	NA	2.91E+01	3.42E+02	2.08E+03
R12	Sandjal	NA	NA	6.49E-01	3.31E+00	3.91E+02
R15	Sara Loba	NA	NA	1.55E+00	1.89E+01	7.80E+02
R22	Tungina	NA	NA	9.97E+00	4.64E+01	1.85E+03

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.

[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

Table C-5	Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 8 Operations from Project Alone at Receptor Locations near Mine Site				
Receptor Location	**Criteria Air Contaminants (CACs) (µg/m³)**				
	Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***

		1-Hour	1-Hour	1-Hour [a]	1-Hour [b]	1-Hour
R2	Bani	NA	NA	2.12E+01	2.47E+02	1.14E+03
R9	Nema	NA	NA	1.07E+01	1.28E+02	6.36E+02
R12	Sandjal	NA	NA	5.37E-01	2.64E+00	4.96E+02
R15	Sara Loba	NA	NA	4.58E+00	3.30E+01	4.97E+02
R22	Tungina	NA	NA	6.30E+00	5.47E+01	8.48E+02

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

Table C-6 Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		1-Hour	1-Hour	1-Hour [a]	1-Hour [b]	1-Hour
R2	Bani	NA	NA	2.96E+01	2.87E+02	1.58E+03
R9	Nema	NA	NA	9.67E+00	7.47E+01	1.23E+03
R12	Sandjal	NA	NA	6.83E-01	4.90E+00	7.75E+02
R15	Sara Loba	NA	NA	2.67E+01	3.18E+02	1.28E+03
R22	Tungina	NA	NA	1.15E+00	1.24E+01	4.37E+02

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

Table C-7 Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		1-Hour	1-Hour	1-Hour [a]	1-Hour [b]	1-Hour
R2	Bani	NA	NA	1.43E+01	1.50E+02	8.72E+02
R9	Nema	NA	NA	7.25E+00	5.79E+01	6.06E+02
R12	Sandjal	NA	NA	3.47E+00	1.17E+01	1.56E+03
R15	Sara Loba	NA	NA	1.00E+01	9.19E+01	1.02E+03
R22	Tungina	NA	NA	9.95E-01	9.41E+00	2.82E+02

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

C-2.2.1.2 8-Hour and 24-Hour Exposures

Table C-8 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 2 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location	Criteria Air Contaminants (CACs) (µg/m³)				
	Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)

		24-Hour [a]	24-Hour [a]	24-Hour [b]	24-Hour	8-Hour
R2	Bani	1.11E+02	4.35E+01	4.63E+00	NA	4.04E+02
R9	Nema	1.26E+02	4.97E+01	7.49E+00	NA	5.83E+02
R12	Sandjal	3.14E+01	1.18E+01	8.25E-01	NA	9.88E+01
R15	Sara Loba	4.04E+01	1.52E+01	1.70E+00	NA	1.98E+02
R22	Tungina	7.19E+01	2.93E+01	4.06E+00	NA	4.78E+02

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.
[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

Table C-9 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour [a]	24-Hour [a]	24-Hour [b]	24-Hour	8-Hour
R2	Bani	7.47E+01	2.64E+01	4.86E+00	NA	3.18E+02
R9	Nema	6.82E+01	2.35E+01	2.71E+00	NA	2.46E+02
R12	Sandjal	2.09E+01	7.53E+00	1.03E+00	NA	1.08E+02
R15	Sara Loba	3.24E+01	1.11E+01	1.72E+00	NA	1.32E+02
R22	Tungina	7.03E+01	2.64E+01	2.54E+00	NA	2.38E+02

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.
[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

Table C-10 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour [a]	24-Hour [a]	24-Hour [b]	24-Hour	8-Hour
R2	Bani	2.85E+02	1.16E+02	9.75E+00	NA	8.08E+02
R9	Nema	1.25E+02	4.84E+01	3.52E+00	NA	2.65E+02
R12	Sandjal	4.99E+01	1.89E+01	9.90E-01	NA	1.43E+02
R15	Sara Loba	1.23E+02	5.04E+01	7.23E+00	NA	4.03E+02
R22	Tungina	5.85E+01	2.25E+01	1.10E+00	NA	1.55E+02

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.
[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

Table C-11 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour [a]	24-Hour [a]	24-Hour [b]	24-Hour	8-Hour
R2	Bani	1.12E+02	4.01E+01	3.69E+00	NA	3.15E+02
R9	Nema	7.46E+01	2.48E+01	2.26E+00	NA	2.76E+02

Table C-11 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour [a]	*24-Hour* [a]	*24-Hour* [b]	*24-Hour*	*8-Hour*
R12	Sandjal	7.28E+01	2.60E+01	2.88E+00	NA	3.17E+02
R15	Sara Loba	6.64E+01	2.34E+01	2.82E+00	NA	2.40E+02
R22	Tungina	4.23E+01	1.59E+01	8.36E-01	NA	8.61E+01

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.

[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

C-2.2.1.3 Annual Exposures

Table C-12 Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 2 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual [a]	*Annual* [a]	*Annual* [a]	*Annual* [a]	*Annual*
R2	Bani	3.21E+01	1.22E+01	6.28E-01	1.07E+01	NA
R9	Nema	2.78E+01	1.15E+01	1.18E+00	2.08E+01	NA
R12	Sandjal	1.88E+00	7.42E-01	3.21E-02	5.69E-01	NA
R15	Sara Loba	6.12E+00	2.43E+00	1.26E-01	2.25E+00	NA
R22	Tungina	9.13E+00	3.92E+00	3.43E-01	5.80E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

Table C-13 Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual [a]	*Annual* [a]	*Annual* [a]	*Annual* [a]	*Annual*
R2	Bani	1.61E+01	5.60E+00	8.98E-01	1.56E+01	NA
R9	Nema	1.36E+01	4.53E+00	5.76E-01	1.00E+01	NA
R12	Sandjal	8.98E-01	3.36E-01	3.95E-02	6.86E-01	NA
R15	Sara Loba	3.30E+00	1.18E+00	1.63E-01	2.87E+00	NA
R22	Tungina	6.93E+00	2.57E+00	2.31E-01	3.82E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

Table C-14 Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual [a]	*Annual* [a]	*Annual* [a]	*Annual* [a]	*Annual*
R2	Bani	6.55E+01	2.63E+01	1.11E+00	3.35E+01	NA
R9	Nema	2.54E+01	9.57E+00	3.95E-01	1.23E+01	NA
R12	Sandjal	3.24E+00	1.24E+00	4.67E-02	1.40E+00	NA
R15	Sara Loba	2.36E+01	9.83E+00	1.22E+00	3.70E+01	NA
R22	Tungina	6.59E+00	2.34E+00	7.26E-02	2.25E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

Table C-15 Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual [a]	*Annual* [a]	*Annual* [a]	*Annual* [a]	*Annual*
R2	Bani	1.93E+01	6.93E+00	5.76E-01	1.79E+01	NA
R9	Nema	1.13E+01	3.68E+00	2.57E-01	8.39E+00	NA
R12	Sandjal	4.48E+00	1.61E+00	1.64E-01	4.98E+00	NA
R15	Sara Loba	8.92E+00	3.21E+00	3.34E-01	1.01E+01	NA
R22	Tungina	3.36E+00	1.17E+00	5.54E-02	1.81E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

C-2.2.2 Metals

This section provides exposure estimate tables for metals in air (Tables C-16 through C-19). Only chronic-duration (*i.e.,* annual exposures) were considered in the assessment.

C-2.2.2.1 Annual Exposures

Table C-16 Predicted Annual Average Air Concentrations of Metals for Year 2 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Fraction of Metal in Soil	Receptor Location				
		R2	R9	R12	R15	R22
		Bani	Nema	Sandjal	Sara Loba	Tungina
		Predicted Metals Concentrations in Air (µg/m^3)[b]				
Annual Average PM_{10}[a]	NA	3.21E+01	2.78E+01	1.88E+00	6.12E+00	9.13E+00
Aluminum	3.58E-01	1.15E+01	9.95E+00	6.73E-01	2.19E+00	3.27E+00
Antimony	9.49E-06	3.05E-04	2.64E-04	1.78E-05	5.81E-05	8.66E-05
Arsenic	7.57E-05	2.43E-03	2.11E-03	1.42E-04	4.63E-04	6.91E-04
Beryllium	9.48E-06	3.04E-04	2.64E-04	1.78E-05	5.80E-05	8.66E-05
Cadmium	7.29E-06	2.34E-04	2.03E-04	1.37E-05	4.46E-05	6.65E-05
Chromium (III)	1.72E-03	5.53E-02	4.79E-02	3.24E-03	1.05E-02	1.57E-02
Cobalt	5.43E-05	1.74E-03	1.51E-03	1.02E-04	3.32E-04	4.95E-04
Iron	2.82E-01	9.04E+00	7.83E+00	5.29E-01	1.72E+00	2.57E+00
Lead	9.70E-05	3.12E-03	2.70E-03	1.82E-04	5.94E-04	8.86E-04
Lithium	2.24E-04	7.20E-03	6.23E-03	4.21E-04	1.37E-03	2.05E-03
Manganese	2.03E-03	6.52E-02	5.65E-02	3.82E-03	1.24E-02	1.85E-02
Nickel	1.78E-04	5.70E-03	4.94E-03	3.34E-04	1.09E-03	1.62E-03
Selenium	5.48E-06	1.76E-04	1.52E-04	1.03E-05	3.36E-05	5.01E-05
Thallium	1.08E-05	3.46E-04	3.00E-04	2.03E-05	6.60E-05	9.85E-05
Uranium	9.29E-05	2.98E-03	2.58E-03	1.75E-04	5.69E-04	8.48E-04
Vanadium	6.97E-04	2.24E-02	1.94E-02	1.31E-03	4.26E-03	6.36E-03
Zinc	4.52E-04	1.45E-02	1.26E-02	8.50E-04	2.77E-03	4.13E-03

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the metals air quality assessment.

[a] The annual average concentrations presented for PM_{10} is a 3-year annual average.

[b] Predicted concentrations of metals in air are the product of the annual average PM_{10} concentration and the fraction of the metal in the PM10 source (*i.e.,* soil)

Table C-17 Predicted Annual Average Air Concentrations of Metals for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Fraction of Metal in Soil	Receptor Location				
		R2	R9	R12	R15	R22
		Bani	Nema	Sandjal	Sara Loba	Tungina
		Predicted Metals Concentrations in Air (µg/m^3)[b]				
Annual Average PM_{10}[a]	NA	1.61E+01	1.36E+01	8.98E-01	3.30E+00	6.93E+00
Aluminum	3.58E-01	5.78E+00	4.87E+00	3.21E-01	1.18E+00	2.48E+00
Antimony	9.49E-06	1.53E-04	1.29E-04	8.52E-06	3.13E-05	6.58E-05
Arsenic	7.57E-05	1.22E-03	1.03E-03	6.80E-05	2.50E-04	5.25E-04
Beryllium	9.48E-06	1.53E-04	1.29E-04	8.51E-06	3.13E-05	6.57E-05
Cadmium	7.29E-06	1.18E-04	9.91E-05	6.54E-06	2.40E-05	5.05E-05
Chromium (III)	1.72E-03	2.78E-02	2.34E-02	1.55E-03	5.68E-03	1.19E-02
Cobalt	5.43E-05	8.75E-04	7.38E-04	4.87E-05	1.79E-04	3.76E-04
Iron	2.82E-01	4.54E+00	3.83E+00	2.53E-01	9.29E-01	1.95E+00
Lead	9.70E-05	1.57E-03	1.32E-03	8.71E-05	3.20E-04	6.73E-04
Lithium	2.24E-04	3.62E-03	3.05E-03	2.01E-04	7.40E-04	1.55E-03
Manganese	2.03E-03	3.28E-02	2.76E-02	1.82E-03	6.70E-03	1.41E-02
Nickel	1.78E-04	2.87E-03	2.42E-03	1.59E-04	5.86E-04	1.23E-03

Table C-17 Predicted Annual Average Air Concentrations of Metals for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Fraction of Metal in Soil	Receptor Location				
		R2	R9	R12	R15	R22
		Bani	Nema	Sandjal	Sara Loba	Tungina
Selenium	5.48E-06	8.85E-05	7.46E-05	4.92E-06	1.81E-05	3.80E-05
Thallium	1.08E-05	1.74E-04	1.47E-04	9.68E-06	3.56E-05	7.47E-05
Uranium	9.29E-05	1.50E-03	1.26E-03	8.34E-05	3.07E-04	6.44E-04
Vanadium	6.97E-04	1.12E-02	9.48E-03	6.25E-04	2.30E-03	4.83E-03
Zinc	4.52E-04	7.30E-03	6.15E-03	4.06E-04	1.49E-03	3.14E-03

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the metals air quality assessment.

[a] The annual average concentrations presented for PM_{10} is a 3-year annual average.

[b] Predicted concentrations of metals in air are the product of the annual average PM_{10} concentration and the fraction of the metal in the PM10 source (*i.e.,* soil)

Table C-18 Predicted Annual Average Air Concentrations of Metals for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Fraction of Metal in Soil	Receptor Location				
		R2	R9	R12	R15	R22
		Bani	Nema	Sandjal	Sara Loba	Tungina
		Predicted Metals Concentrations in Air ($\mu g/m^3$)[b]				
Annual Average PM_{10}[a]	NA	6.55E+01	2.54E+01	3.24E+00	2.36E+01	6.59E+00
Aluminum	3.58E-01	2.34E+01	9.09E+00	1.16E+00	8.45E+00	2.36E+00
Antimony	9.49E-06	6.21E-04	2.41E-04	3.07E-05	2.24E-04	6.25E-05
Arsenic	7.57E-05	4.96E-03	1.92E-03	2.45E-04	1.79E-03	4.99E-04
Beryllium	9.48E-06	6.21E-04	2.41E-04	3.07E-05	2.24E-04	6.25E-05
Cadmium	7.29E-06	4.77E-04	1.85E-04	2.36E-05	1.72E-04	4.80E-05
Chromium (III)	1.72E-03	1.13E-01	4.37E-02	5.58E-03	4.06E-02	1.13E-02
Cobalt	5.43E-05	3.55E-03	1.38E-03	1.76E-04	1.28E-03	3.58E-04
Iron	2.82E-01	1.84E+01	7.15E+00	9.12E-01	6.64E+00	1.86E+00
Lead	9.70E-05	6.36E-03	2.47E-03	3.14E-04	2.29E-03	6.40E-04
Lithium	2.24E-04	1.47E-02	5.69E-03	7.26E-04	5.29E-03	1.48E-03
Manganese	2.03E-03	1.33E-01	5.16E-02	6.58E-03	4.79E-02	1.34E-02
Nickel	1.78E-04	1.16E-02	4.51E-03	5.76E-04	4.19E-03	1.17E-03
Selenium	5.48E-06	3.59E-04	1.39E-04	1.78E-05	1.29E-04	3.61E-05
Thallium	1.08E-05	7.06E-04	2.74E-04	3.49E-05	2.55E-04	7.11E-05
Uranium	9.29E-05	6.09E-03	2.36E-03	3.01E-04	2.19E-03	6.12E-04
Vanadium	6.97E-04	4.56E-02	1.77E-02	2.26E-03	1.64E-02	4.59E-03
Zinc	4.52E-04	2.96E-02	1.15E-02	1.47E-03	1.07E-02	2.98E-03

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the metals air quality assessment.

[a] The annual average concentrations presented for PM_{10} is a 3-year annual average.

[b] Predicted concentrations of metals in air are the product of the annual average PM_{10} concentration and the fraction of the metal in the PM10 source (*i.e.,* soil)

Table C-19 Predicted Annual Average Air Concentrations of Metals for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Fraction of Metal in Soil	Receptor Location				
		R2	R9	R12	R15	R22
		Bani	Nema	Sandjal	Sara Loba	Tungina
		Predicted Metals Concentrations in Air ($\mu g/m^3$)[b]				
Annual Average PM_{10}[a]	NA	1.93E+01	1.13E+01	4.48E+00	8.92E+00	3.36E+00
Aluminum	3.58E-01	6.91E+00	4.05E+00	1.60E+00	3.19E+00	1.20E+00
Antimony	9.49E-06	1.83E-04	1.07E-04	4.25E-05	8.46E-05	3.19E-05
Arsenic	7.57E-05	1.46E-03	8.56E-04	3.39E-04	6.75E-04	2.54E-04
Beryllium	9.48E-06	1.83E-04	1.07E-04	4.25E-05	8.46E-05	3.19E-05

Table C-19 Predicted Annual Average Air Concentrations of Metals for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Fraction of Metal in Soil	Receptor Location				
		R2	R9	R12	R15	R22
		Bani	Nema	Sandjal	Sara Loba	Tungina
Cadmium	7.29E-06	1.41E-04	8.23E-05	3.26E-05	6.50E-05	2.45E-05
Chromium (III)	1.72E-03	3.32E-02	1.95E-02	7.71E-03	1.54E-02	5.79E-03
Cobalt	5.43E-05	1.05E-03	6.13E-04	2.43E-04	4.84E-04	1.82E-04
Iron	2.82E-01	5.43E+00	3.18E+00	1.26E+00	2.51E+00	9.46E-01
Lead	9.70E-05	1.87E-03	1.10E-03	4.35E-04	8.66E-04	3.26E-04
Lithium	2.24E-04	4.33E-03	2.53E-03	1.00E-03	2.00E-03	7.53E-04
Manganese	2.03E-03	3.92E-02	2.30E-02	9.10E-03	1.81E-02	6.82E-03
Nickel	1.78E-04	3.43E-03	2.01E-03	7.96E-04	1.58E-03	5.97E-04
Selenium	5.48E-06	1.06E-04	6.20E-05	2.46E-05	4.89E-05	1.84E-05
Thallium	1.08E-05	2.08E-04	1.22E-04	4.83E-05	9.62E-05	3.62E-05
Uranium	9.29E-05	1.79E-03	1.05E-03	4.16E-04	8.29E-04	3.12E-04
Vanadium	6.97E-04	1.34E-02	7.87E-03	3.12E-03	6.21E-03	2.34E-03
Zinc	4.52E-04	8.73E-03	5.11E-03	2.03E-03	4.04E-03	1.52E-03

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the metals air quality assessment.

[a] The annual average concentrations presented for PM_{10} is a 3-year annual average.

[b] Predicted concentrations of metals in air are the product of the annual average PM_{10} concentration and the fraction of the metal in the PM10 source (*i.e.,* soil)

C-2.3 Estimated Exposures for Baseline + Project Scenario

This section provides exposure estimate tables for the Baseline + Project Scenario.

C-2.3.1 Criteria Air Contaminants

This section provides maximum 1-hour, maximum 8-hour, maximum 24-hour, and annual average exposure estimate tables for the criteria air contaminants (Tables C-20 through C-31).

C-2.3.1.1 1-Hour Exposures

Table C-20 Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 2 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour* [a]	*1-Hour* [b]	*1-Hour*
R2	Bani	NA	NA	9.75E+00	5.70E+01	-
R9	Nema	NA	NA	3.05E+01	3.45E+02	-
R12	Sandjal	NA	NA	2.03E+00	7.06E+00	-
R15	Sara Loba	NA	NA	2.92E+00	2.27E+01	-
R22	Tungina	NA	NA	1.13E+01	5.02E+01	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
\- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

Table C-21 Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour* [a]	*1-Hour* [b]	*1-Hour*
R2	Bani	NA	NA	2.26E+01	2.51E+02	-
R9	Nema	NA	NA	1.21E+01	1.32E+02	-
R12	Sandjal	NA	NA	1.91E+00	6.40E+00	-
R15	Sara Loba	NA	NA	5.96E+00	3.68E+01	-
R22	Tungina	NA	NA	7.68E+00	5.85E+01	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
\- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

Table C-22 Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location	Criteria Air Contaminants (CACs) (µg/m³)

		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		1-Hour	1-Hour	1-Hour [a]	1-Hour [b]	1-Hour
R2	Bani	NA	NA	3.10E+01	2.91E+02	-
R9	Nema	NA	NA	1.10E+01	7.84E+01	-
R12	Sandjal	NA	NA	2.06E+00	8.66E+00	-
R15	Sara Loba	NA	NA	2.81E+01	3.22E+02	-
R22	Tungina	NA	NA	2.53E+00	1.62E+01	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

Table C-23 Predicted Maximum 1-Hour Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		1-Hour	1-Hour	1-Hour [a]	1-Hour [b]	1-Hour
R2	Bani	NA	NA	1.56E+01	1.53E+02	-
R9	Nema	NA	NA	8.63E+00	6.17E+01	-
R12	Sandjal	NA	NA	4.85E+00	1.55E+01	-
R15	Sara Loba	NA	NA	1.14E+01	9.56E+01	-
R22	Tungina	NA	NA	2.37E+00	1.32E+01	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.
[a] The 1-hour concentrations of SO2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO2 presented are the 98th percentile values.

C-2.3.1.2 8-Hour and 24-Hour Exposures

Table C-24 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 2 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour [a]	24-Hour [a]	24-Hour [b]	24-Hour	8-Hour
R2	Bani	-	-	6.01E+00	NA	-
R9	Nema	-	-	8.87E+00	NA	-
R12	Sandjal	-	-	2.20E+00	NA	-
R15	Sara Loba	-	-	3.07E+00	NA	-
R22	Tungina	-	-	5.44E+00	NA	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.
[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.
[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

Table C-25 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour [a]	*24-Hour* [a]	*24-Hour* [b]	*24-Hour*	*8-Hour*
R2	Bani	-	-	6.24E+00	NA	-
R9	Nema	-	-	4.09E+00	NA	-
R12	Sandjal	-	-	2.40E+00	NA	-
R15	Sara Loba	-	-	3.10E+00	NA	-
R22	Tungina	-	-	3.92E+00	NA	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

\- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.

[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

Table C-26 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour [a]	*24-Hour* [a]	*24-Hour* [b]	*24-Hour*	*8-Hour*
R2	Bani	-	-	1.11E+01	NA	-
R9	Nema	-	-	4.90E+00	NA	-
R12	Sandjal	-	-	2.37E+00	NA	-
R15	Sara Loba	-	-	8.61E+00	NA	-
R22	Tungina	-	-	2.48E+00	NA	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

\- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.

[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

Table C-27 Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour [a]	*24-Hour* [a]	*24-Hour* [b]	*24-Hour*	*8-Hour*
R2	Bani	-	-	5.07E+00	NA	-
R9	Nema	-	-	3.64E+00	NA	-
R12	Sandjal	-	-	4.26E+00	NA	-
R15	Sara Loba	-	-	4.19E+00	NA	-
R22	Tungina	-	-	2.21E+00	NA	-

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

\- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

[a] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.

Table C-27	Predicted Maximum 8-Hour and 24-Hour Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site				
Receptor Location	**Criteria Air Contaminants (CACs) (µg/m³)**				
	Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
	24-Hour [a]	***24-Hour*** [a]	***24-Hour*** [b]	***24-Hour***	***8-Hour***

[b] The 24-hour concentrations of SO_2 presented are the 99th percentile values.

C-2.3.1.3 Annual Exposures

Table C-28	Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 2 Operations from Baseline + Project at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs) (µg/m³)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		Annual [a]	***Annual*** [a]	***Annual*** [a]	***Annual*** [a]	***Annual***
R2	Bani	1.02E+02	2.50E+01	2.01E+00	1.45E+01	NA
R9	Nema	9.70E+01	2.37E+01	2.56E+00	2.46E+01	NA
R12	Sandjal	7.31E+01	1.45E+01	1.41E+00	4.32E+00	NA
R15	Sara Loba	7.71E+01	1.61E+01	1.50E+00	6.01E+00	NA
R22	Tungina	7.95E+01	1.71E+01	1.72E+00	9.55E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

Table C-29	Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs) (µg/m³)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		Annual [a]	***Annual*** [a]	***Annual*** [a]	***Annual*** [a]	***Annual***
R2	Bani	8.80E+01	1.96E+01	2.28E+00	1.94E+01	NA
R9	Nema	8.64E+01	1.88E+01	1.95E+00	1.38E+01	NA
R12	Sandjal	7.22E+01	1.42E+01	1.42E+00	4.44E+00	NA
R15	Sara Loba	7.48E+01	1.51E+01	1.54E+00	6.62E+00	NA
R22	Tungina	7.95E+01	1.68E+01	1.61E+00	7.58E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

Table C-30	Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs) (µg/m³)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		Annual [a]	***Annual*** [a]	***Annual*** [a]	***Annual*** [a]	***Annual***
R2	Bani	1.37E+02	4.02E+01	2.49E+00	3.72E+01	NA
R9	Nema	9.67E+01	2.34E+01	1.77E+00	1.61E+01	NA

Table C-30 Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual [a]	*Annual* [a]	*Annual* [a]	*Annual* [a]	*Annual*
R12	Sandjal	7.45E+01	1.51E+01	1.42E+00	5.15E+00	NA
R15	Sara Loba	9.49E+01	2.37E+01	2.60E+00	4.08E+01	NA
R22	Tungina	7.79E+01	1.62E+01	1.45E+00	6.00E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

Table C-31 Predicted Annual Average Air Concentrations of Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs) (µg/m³)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual [a]	*Annual* [a]	*Annual* [a]	*Annual* [a]	*Annual*
R2	Bani	9.06E+01	2.08E+01	1.95E+00	2.16E+01	NA
R9	Nema	8.26E+01	1.75E+01	1.63E+00	1.21E+01	NA
R12	Sandjal	7.58E+01	1.55E+01	1.54E+00	8.73E+00	NA
R15	Sara Loba	8.02E+01	1.71E+01	1.71E+00	1.39E+01	NA
R22	Tungina	7.46E+01	1.50E+01	1.43E+00	5.57E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.

[a] The annual average concentrations presented for all CACs are 3-year averages.

C-2.3.2 Metals

Exposures to metals were not determined due to the absence of adequate baseline PM_{10} data.

C-2.4 Risk Estimates for Baseline Scenario

This section provides risk estimate tables for the Baseline Scenario.

C-2.4.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average risks estimate tables for the criteria air contaminants (Tables C-32 through C-34).

C-2.4.1.1 1-Hour Risks

Table C-32 Summary of Baseline 1-Hour Concentration Ratios for Criteria Air Contaminants for All Operational Years at Receptor Locations near Mine Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*

		1-Hour	1-Hour	1-Hour	1-Hour	1-Hour
R2	Bani	NA	NA	6.9E-03	2.0E-02	-
R9	Nema	NA	NA	6.9E-03	2.0E-02	-
R12	Sandjal	NA	NA	6.9E-03	2.0E-02	-
R15	Sara Loba	NA	NA	6.9E-03	2.0E-02	-
R22	Tungina	NA	NA	6.9E-03	2.0E-02	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-33 Summary of Baseline 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for All Operational Years at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour	24-Hour	24-Hour	24-Hour	8-Hour
R2	Bani	-	-	6.9E-02	NA	-
R9	Nema	-	-	6.9E-02	NA	-
R12	Sandjal	-	-	6.9E-02	NA	-
R15	Sara Loba	-	-	6.9E-02	NA	-
R22	Tungina	-	-	6.9E-02	NA	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-34 Summary of Baseline Annual Average Concentration Ratios for Criteria Air Contaminants for All Operational Years at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		Annual	Annual	Annual	Annual	Annual
R2	Bani	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA
R9	Nema	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA
R12	Sandjal	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA
R15	Sara Loba	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA
R22	Tungina	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

C-2.4.2 Metals

Risks from metals were not determined due to the absence of adequate baseline PM_{10} data.

C-2.5 Risk Estimates for Project Alone Scenario

This section provides risk estimate tables for the Project Alone Scenario.

C-2.5.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average risks estimate tables for the criteria air contaminants (Tables C-35 through C-46).

C-2.5.1.1 1-Hour Risks

Table C-35 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 2 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	4.2E-02	2.8E-01	5.1E-02
R9	Nema	NA	NA	1.5E-01	**1.8E+00**	6.9E-02
R12	Sandjal	NA	NA	3.2E-03	1.7E-02	1.3E-02
R15	Sara Loba	NA	NA	7.7E-03	1.0E-01	2.6E-02
R22	Tungina	NA	NA	5.0E-02	2.4E-01	6.2E-02

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-36 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	1.1E-01	**1.3E+00**	3.8E-02
R9	Nema	NA	NA	5.4E-02	6.7E-01	2.1E-02
R12	Sandjal	NA	NA	2.7E-03	1.4E-02	1.7E-02
R15	Sara Loba	NA	NA	2.3E-02	1.7E-01	1.7E-02
R22	Tungina	NA	NA	3.2E-02	2.9E-01	2.8E-02

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-37 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	1.5E-01	**1.5E+00**	5.3E-02
R9	Nema	NA	NA	4.8E-02	3.9E-01	4.1E-02
R12	Sandjal	NA	NA	3.4E-03	2.6E-02	2.6E-02
R15	Sara Loba	NA	NA	1.3E-01	**1.7E+00**	4.3E-02
R22	Tungina	NA	NA	5.8E-03	6.5E-02	1.5E-02

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-38 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*

		1-Hour	1-Hour	1-Hour	1-Hour	1-Hour
R2	Bani	NA	NA	7.1E-02	7.9E-01	2.9E-02
R9	Nema	NA	NA	3.6E-02	3.0E-01	2.0E-02
R12	Sandjal	NA	NA	1.7E-02	6.2E-02	5.2E-02
R15	Sara Loba	NA	NA	5.0E-02	4.8E-01	3.4E-02
R22	Tungina	NA	NA	5.0E-03	5.0E-02	9.4E-03

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter l.

C-2.5.1.2 8-Hour and 24-hour Risks

Table C-39 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 2 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour	24-Hour	24-Hour	24-Hour	8-Hour
R2	Bani	**2.2E+00**	**1.7E+00**	2.3E-01	NA	4.0E-02
R9	Nema	**2.5E+00**	**2.0E+00**	3.7E-01	NA	5.8E-02
R12	Sandjal	6.3E-01	4.7E-01	4.1E-02	NA	9.9E-03
R15	Sara Loba	8.1E-01	6.1E-01	8.5E-02	NA	2.0E-02
R22	Tungina	**1.4E+00**	**1.2E+00**	2.0E-01	NA	4.8E-02

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-40 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour	24-Hour	24-Hour	24-Hour	8-Hour
R2	Bani	**1.5E+00**	**1.1E+00**	2.4E-01	NA	3.2E-02
R9	Nema	**1.4E+00**	9.4E-01	1.4E-01	NA	2.5E-02
R12	Sandjal	4.2E-01	3.0E-01	5.1E-02	NA	1.1E-02
R15	Sara Loba	6.5E-01	4.5E-01	8.6E-02	NA	1.3E-02
R22	Tungina	**1.4E+00**	**1.1E+00**	1.3E-01	NA	2.4E-02

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-41 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		24-Hour	24-Hour	24-Hour	24-Hour	8-Hour
R2	Bani	**5.7E+00**	**4.6E+00**	4.9E-01	NA	8.1E-02
R9	Nema	**2.5E+00**	**1.9E+00**	1.8E-01	NA	2.6E-02
R12	Sandjal	1.0E+00	7.6E-01	4.9E-02	NA	1.4E-02
R15	Sara Loba	**2.5E+00**	**2.0E+00**	3.6E-01	NA	4.0E-02
R22	Tungina	**1.2E+00**	9.0E-01	5.5E-02	NA	1.6E-02

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-42	Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		24-Hour	***24-Hour***	***24-Hour***	***24-Hour***	***8-Hour***
R2	Bani	**2.2E+00**	**1.6E+00**	1.8E-01	NA	3.1E-02
R9	Nema	**1.5E+00**	9.9E-01	1.1E-01	NA	2.8E-02
R12	Sandjal	**1.5E+00**	1.0E+00	1.4E-01	NA	3.2E-02
R15	Sara Loba	**1.3E+00**	9.4E-01	1.4E-01	NA	2.4E-02
R22	Tungina	8.5E-01	6.4E-01	4.2E-02	NA	8.6E-03

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

C-2.5.1.3 Annual Risks

Table C-43	Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 2 Operations from Project Alone at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		Annual	***Annual***	***Annual***	***Annual***	***Annual***
R2	Bani	**1.6E+00**	**1.2E+00**	1.3E-02	2.7E-01	NA
R9	Nema	**1.4E+00**	**1.1E+00**	2.4E-02	5.2E-01	NA
R12	Sandjal	9.4E-02	7.4E-02	6.4E-04	1.4E-02	NA
R15	Sara Loba	3.1E-01	2.4E-01	2.5E-03	5.6E-02	NA
R22	Tungina	4.6E-01	3.9E-01	6.9E-03	1.4E-01	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-44	Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Project Alone at Receptor Locations near Mine Site					
Receptor Location		**Criteria Air Contaminants (CACs)**				
		Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
		Annual	***Annual***	***Annual***	***Annual***	***Annual***
R2	Bani	8.1E-01	5.6E-01	1.8E-02	3.9E-01	NA
R9	Nema	6.8E-01	4.5E-01	1.2E-02	2.5E-01	NA
R12	Sandjal	4.5E-02	3.4E-02	7.9E-04	1.7E-02	NA
R15	Sara Loba	1.6E-01	1.2E-01	3.3E-03	7.2E-02	NA
R22	Tungina	3.5E-01	2.6E-01	4.6E-03	9.6E-02	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-45	Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 15 Operations from Project Alone at Receptor Locations near Mine Site
Receptor Location	**Criteria Air Contaminants (CACs)**

		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		Annual	Annual	Annual	Annual	Annual
R2	Bani	**3.3E+00**	**2.6E+00**	2.2E-02	8.4E-01	NA
R9	Nema	**1.3E+00**	9.6E-01	7.9E-03	3.1E-01	NA
R12	Sandjal	1.6E-01	1.2E-01	9.3E-04	3.5E-02	NA
R15	Sara Loba	**1.2E+00**	9.8E-01	2.4E-02	9.3E-01	NA
R22	Tungina	3.3E-01	2.3E-01	1.5E-03	5.6E-02	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-46 Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 25 Operations from Project Alone at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
		Annual	Annual	Annual	Annual	Annual
R2	Bani	9.6E-01	6.9E-01	1.2E-02	4.5E-01	NA
R9	Nema	5.7E-01	3.7E-01	5.1E-03	2.1E-01	NA
R12	Sandjal	2.2E-01	1.6E-01	3.3E-03	1.2E-01	NA
R15	Sara Loba	4.5E-01	3.2E-01	6.7E-03	2.5E-01	NA
R22	Tungina	1.7E-01	1.2E-01	1.1E-03	4.5E-02	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

C-2.5.2 Metals

This section provides risk estimate tables for metals in air (Tables C-47 through C-50). Only chronic-duration (*i.e.,* annual exposures) were considered in the assessment.

C-2.5.2.1 Annual Risks

Table C-47 Summary of Risk Estimates for Metals for Year 2 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Receptor Location									
	R2		R9		R12		R15		R22	
	Bani		Nema		Sandjal		Sara Loba		Tungina	
	Risk Estimates									
	CR	ILCR	CR	ILCR	CR	ILCR	CR	ILCR	CR	ILCR
Aluminum	**2.3E+00**	NA	**2.0E+00**	NA	1.3E-01	NA	4.4E-01	NA	6.5E-01	NA
Antimony	1.5E-03	NA	1.3E-03	NA	8.9E-05	NA	2.9E-04	NA	4.3E-04	NA
Arsenic	1.6E-01	**1.6E-05**	1.4E-01	**1.3E-05**	9.5E-03	9.1E-07	3.1E-02	3.0E-06	4.6E-02	4.4E-06
Beryllium	4.3E-02	7.3E-07	3.8E-02	6.3E-07	2.5E-03	4.3E-08	8.3E-03	1.4E-07	1.2E-02	2.1E-07
Cadmium	4.7E-02	2.3E-06	4.1E-02	2.0E-06	2.7E-03	1.3E-07	8.9E-03	4.4E-07	1.3E-02	6.5E-07
Chromium (III)	**1.3E+00**	NA	**1.2E+00**	NA	7.9E-02	NA	2.6E-01	NA	3.8E-01	NA
Cobalt	1.7E-02	NA	1.5E-02	NA	1.0E-03	NA	3.3E-03	NA	5.0E-03	NA
Iron	**1.8E+00**	NA	**1.6E+00**	NA	1.1E-01	NA	3.4E-01	NA	5.1E-01	NA
Lead	2.1E-02	NA	1.8E-02	NA	1.2E-03	NA	4.0E-03	NA	5.9E-03	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	**1.3E+00**	NA	**1.1E+00**	NA	7.6E-02	NA	2.5E-01	NA	3.7E-01	NA
Nickel	1.4E-01	NA	1.2E-01	NA	8.3E-03	NA	2.7E-02	NA	4.0E-02	NA
Selenium	8.8E-04	NA	7.6E-04	NA	5.2E-05	NA	1.7E-04	NA	2.5E-04	NA
Thallium	3.5E-03	NA	3.0E-03	NA	2.0E-04	NA	6.6E-04	NA	9.8E-04	NA
Uranium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	2.2E-01	NA	1.9E-01	NA	1.3E-02	NA	4.3E-02	NA	6.4E-02	NA
Zinc	7.3E-03	NA	6.3E-03	NA	4.3E-04	NA	1.4E-03	NA	2.1E-03	NA

Bolded values highlighted in grey are in excess of a CR of 1.0 or an ILCR of 1.0E-05 (1-in-100,000 cancer risk level).
NA Not assessed. Indicates that an appropriate exposure limit was not available for this chemical parameter for this endpoint.

Table C-48 Summary of Risk Estimates for Metals for Year 8 Operations from Project Alone at Receptor Locations near Mine Site

COPC	Receptor Location

	R2		R9		R12		R15		R22	
	Bani		Nema		Sandjal		Sara Loba		Tungina	
	Risk Estimates									
	CR	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***
Aluminum	**1.2E+00**	NA	9.7E-01	NA	6.4E-02	NA	2.4E-01	NA	5.0E-01	NA
Antimony	7.7E-04	NA	6.5E-04	NA	4.3E-05	NA	1.6E-04	NA	3.3E-04	NA
Arsenic	8.1E-02	7.8E-06	6.9E-02	6.6E-06	4.5E-03	4.4E-07	1.7E-02	1.6E-06	3.5E-02	3.4E-06
Beryllium	2.2E-02	3.7E-07	1.8E-02	3.1E-07	1.2E-03	2.0E-08	4.5E-03	7.5E-08	9.4E-03	1.6E-07
Cadmium	2.4E-02	1.2E-06	2.0E-02	9.7E-07	1.3E-03	6.4E-08	4.8E-03	2.4E-07	1.0E-02	4.9E-07
Chromium (III)	6.8E-01	NA	5.7E-01	NA	3.8E-02	NA	1.4E-01	NA	2.9E-01	NA
Cobalt	8.8E-03	NA	7.4E-03	NA	4.9E-04	NA	1.8E-03	NA	3.8E-03	NA
Iron	9.1E-01	NA	7.7E-01	NA	5.1E-02	NA	1.9E-01	NA	3.9E-01	NA
Lead	1.0E-02	NA	8.8E-03	NA	5.8E-04	NA	2.1E-03	NA	4.5E-03	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	6.6E-01	NA	5.5E-01	NA	3.6E-02	NA	1.3E-01	NA	2.8E-01	NA
Nickel	7.1E-02	NA	6.0E-02	NA	4.0E-03	NA	1.5E-02	NA	3.1E-02	NA
Selenium	4.4E-04	NA	3.7E-04	NA	2.5E-05	NA	9.0E-05	NA	1.9E-04	NA
Thallium	1.7E-03	NA	1.5E-03	NA	9.7E-05	NA	3.6E-04	NA	7.5E-04	NA
Uranium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	1.1E-01	NA	9.5E-02	NA	6.3E-03	NA	2.3E-02	NA	4.8E-02	NA
Zinc	3.6E-03	NA	3.1E-03	NA	2.0E-04	NA	7.5E-04	NA	1.6E-03	NA

Bolded values highlighted in grey are in excess of a CR of 1.0 or an ILCR of 1.0E-05 (1-in-100,000 cancer risk level).
NA Not assessed. Indicates that an appropriate exposure limit was not available for this chemical parameter for this endpoint.

Table C-49 Summary of Risk Estimates for Metals for Year 15 Operations from Project Alone at Receptor Locations near Mine Site

COPC	***Receptor Location***									
	R2		R9		R12		R15		R22	
	Bani		Nema		Sandjal		Sara Loba		Tungina	
	Risk Estimates									
	CR	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***
Aluminum	**4.7E+00**	NA	**1.8E+00**	NA	2.3E-01	NA	**1.7E+00**	NA	4.7E-01	NA
Antimony	3.1E-03	NA	1.2E-03	NA	1.5E-04	NA	1.1E-03	NA	3.1E-04	NA
Arsenic	3.3E-01	**3.2E-05**	1.3E-01	**1.2E-05**	1.6E-02	1.6E-06	1.2E-01	**1.1E-05**	3.3E-02	3.2E-06
Beryllium	8.9E-02	1.5E-06	3.4E-02	5.8E-07	4.4E-03	7.4E-08	3.2E-02	5.4E-07	8.9E-03	1.5E-07
Cadmium	9.5E-02	4.7E-06	3.7E-02	1.8E-06	4.7E-03	2.3E-07	3.4E-02	1.7E-06	9.6E-03	4.7E-07
Chromium (III)	**2.8E+00**	NA	**1.1E+00**	NA	1.4E-01	NA	9.9E-01	NA	2.8E-01	NA
Cobalt	3.6E-02	NA	1.4E-02	NA	1.8E-03	NA	1.3E-02	NA	3.6E-03	NA
Iron	**3.7E+00**	NA	**1.4E+00**	NA	1.8E-01	NA	**1.3E+00**	NA	3.7E-01	NA
Lead	4.2E-02	NA	1.6E-02	NA	2.1E-03	NA	1.5E-02	NA	4.3E-03	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table C-49	Summary of Risk Estimates for Metals for Year 15 Operations from Project Alone at Receptor Locations near Mine Site									
COPC	Receptor Location									
	R2		R9		R12		R15		R22	
	Bani		Nema		Sandjal		Sara Loba		Tungina	
	Risk Estimates									
	CR	ILCR	CR	ILCR	CR	ILCR	CR	ILCR	CR	ILCR
Manganese	**2.7E+00**	NA	1.0E+00	NA	1.3E-01	NA	9.6E-01	NA	2.7E-01	NA
Nickel	2.9E-01	NA	1.1E-01	NA	1.4E-02	NA	1.0E-01	NA	2.9E-02	NA
Selenium	1.8E-03	NA	7.0E-04	NA	8.9E-05	NA	6.5E-04	NA	1.8E-04	NA
Thallium	7.1E-03	NA	2.7E-03	NA	3.5E-04	NA	2.5E-03	NA	7.1E-04	NA
Uranium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	4.6E-01	NA	1.8E-01	NA	2.3E-02	NA	1.6E-01	NA	4.6E-02	NA
Zinc	1.5E-02	NA	5.7E-03	NA	7.3E-04	NA	5.3E-03	NA	1.5E-03	NA

Bolded values highlighted in grey are in excess of a CR of 1.0 or an ILCR of 1.0E-05 (1-in-100,000 cancer risk level).
NA Not assessed. Indicates that an appropriate exposure limit was not available for this chemical parameter for this endpoint.

Table C-50	Summary of Risk Estimates for Metals for Year 25 Operations from Project Alone at Receptor Locations near Mine Site									
COPC	Receptor Location									
	R2		R9		R12		R15		R22	
	Bani		Nema		Sandjal		Sara Loba		Tungina	
	Risk Estimates									
	CR	ILCR	CR	ILCR	CR	ILCR	CR	ILCR	CR	ILCR
Aluminum	**1.4E+00**	NA	8.1E-01	NA	3.2E-01	NA	6.4E-01	NA	2.4E-01	NA
Antimony	9.2E-04	NA	5.4E-04	NA	2.1E-04	NA	4.2E-04	NA	1.6E-04	NA
Arsenic	9.7E-02	9.4E-06	5.7E-02	5.5E-06	2.3E-02	2.2E-06	4.5E-02	4.3E-06	1.7E-02	1.6E-06
Beryllium	2.6E-02	4.4E-07	1.5E-02	2.6E-07	6.1E-03	1.0E-07	1.2E-02	2.0E-07	4.6E-03	7.6E-08
Cadmium	2.8E-02	1.4E-06	1.6E-02	8.1E-07	6.5E-03	3.2E-07	1.3E-02	6.4E-07	4.9E-03	2.4E-07
Chromium (III)	8.1E-01	NA	4.7E-01	NA	1.9E-01	NA	3.7E-01	NA	1.4E-01	NA
Cobalt	1.0E-02	NA	6.1E-03	NA	2.4E-03	NA	4.8E-03	NA	1.8E-03	NA
Iron	**1.1E+00**	NA	6.4E-01	NA	2.5E-01	NA	5.0E-01	NA	1.9E-01	NA
Lead	1.2E-02	NA	7.3E-03	NA	2.9E-03	NA	5.8E-03	NA	2.2E-03	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	7.8E-01	NA	4.6E-01	NA	1.8E-01	NA	3.6E-01	NA	1.4E-01	NA
Nickel	8.5E-02	NA	5.0E-02	NA	2.0E-02	NA	3.9E-02	NA	1.5E-02	NA
Selenium	5.3E-04	NA	3.1E-04	NA	1.2E-04	NA	2.4E-04	NA	9.2E-05	NA
Thallium	2.1E-03	NA	1.2E-03	NA	4.8E-04	NA	9.6E-04	NA	3.6E-04	NA
Uranium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	1.3E-01	NA	7.9E-02	NA	3.1E-02	NA	6.2E-02	NA	2.3E-02	NA
Zinc	4.4E-03	NA	2.6E-03	NA	1.0E-03	NA	2.0E-03	NA	7.6E-04	NA

Table C-50	Summary of Risk Estimates for Metals for Year 25 Operations from Project Alone at Receptor Locations near Mine Site									
COPC	***Receptor Location***									
	R2		R9		R12		R15		R22	
	Bani		Nema		Sandjal		Sara Loba		Tungina	
	Risk Estimates									
	CR	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***	***CR***	***ILCR***

Bolded values highlighted in grey are in excess of a CR of 1.0 or an ILCR of 1.0E-05 (1-in-100,000 cancer risk level).
NA Not assessed. Indicates that an appropriate exposure limit was not available for this chemical parameter for this endpoint.

C-2.6 Risk Estimates for Baseline + Project Scenario

This section provides risk estimate tables for the Baseline + Project Scenario.

C-2.6.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average risks estimate tables for the criteria air contaminants (Table C-51 through C-62).

C-2.6.1.1 1 Hour Risks

Table C-51 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 2 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	4.9E-02	3.0E-01	-
R9	Nema	NA	NA	1.5E-01	**1.8E+00**	-
R12	Sandjal	NA	NA	1.0E-02	3.7E-02	-
R15	Sara Loba	NA	NA	1.5E-02	1.2E-01	-
R22	Tungina	NA	NA	5.7E-02	2.6E-01	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

Table C-52 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	1.1E-01	**1.3E+00**	-
R9	Nema	NA	NA	6.1E-02	6.9E-01	-
R12	Sandjal	NA	NA	9.6E-03	3.4E-02	-
R15	Sara Loba	NA	NA	3.0E-02	1.9E-01	-
R22	Tungina	NA	NA	3.8E-02	3.1E-01	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

Table C-53 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*

		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	1.6E-01	**1.5E+00**	-
R9	Nema	NA	NA	5.5E-02	4.1E-01	-
R12	Sandjal	NA	NA	1.0E-02	4.6E-02	-
R15	Sara Loba	NA	NA	1.4E-01	**1.7E+00**	-
R22	Tungina	NA	NA	1.3E-02	8.5E-02	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

Table C-54 Summary of 1-Hour Concentration Ratios for Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		1-Hour	*1-Hour*	*1-Hour*	*1-Hour*	*1-Hour*
R2	Bani	NA	NA	7.8E-02	8.1E-01	-
R9	Nema	NA	NA	4.3E-02	3.2E-01	-
R12	Sandjal	NA	NA	2.4E-02	8.2E-02	-
R15	Sara Loba	NA	NA	5.7E-02	5.0E-01	-
R22	Tungina	NA	NA	1.2E-02	6.9E-02	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

C-2.6.1.2 8-Hour and 24-Hour Risks

Table C-55 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 2 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour	*24-Hour*	*24-Hour*	*24-Hour*	*8-Hour*
R2	Bani	-	-	3.0E-01	NA	-
R9	Nema	-	-	4.4E-01	NA	-
R12	Sandjal	-	-	1.1E-01	NA	-
R15	Sara Loba	-	-	1.5E-01	NA	-
R22	Tungina	-	-	2.7E-01	NA	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

Table C-56 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour	*24-Hour*	*24-Hour*	*24-Hour*	*8-Hour*
R2	Bani	-	-	3.1E-01	NA	-

Table C-56 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour	*24-Hour*	*24-Hour*	*24-Hour*	*8-Hour*
R9	Nema	-	-	2.0E-01	NA	-
R12	Sandjal	-	-	1.2E-01	NA	-
R15	Sara Loba	-	-	1.6E-01	NA	-
R22	Tungina	-	-	2.0E-01	NA	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

Table C-57 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour	*24-Hour*	*24-Hour*	*24-Hour*	*8-Hour*
R2	Bani	-	-	5.6E-01	NA	-
R9	Nema	-	-	2.4E-01	NA	-
R12	Sandjal	-	-	1.2E-01	NA	-
R15	Sara Loba	-	-	4.3E-01	NA	-
R22	Tungina	-	-	1.2E-01	NA	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

Table C-58 Summary of 8-Hour and 24-Hour Concentration Ratios for Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		24-Hour	*24-Hour*	*24-Hour*	*24-Hour*	*8-Hour*
R2	Bani	-	-	2.5E-01	NA	-
R9	Nema	-	-	1.8E-01	NA	-
R12	Sandjal	-	-	2.1E-01	NA	-
R15	Sara Loba	-	-	2.1E-01	NA	-
R22	Tungina	-	-	1.1E-01	NA	-

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.

C-2.6.1.3 Annual Average Risks

Table C-59 Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 2 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual	*Annual*	*Annual*	*Annual*	*Annual*
R2	Bani	**5.1E+00**	**2.5E+00**	4.0E-02	3.6E-01	NA
R9	Nema	**4.9E+00**	**2.4E+00**	5.1E-02	6.1E-01	NA
R12	Sandjal	**3.7E+00**	**1.5E+00**	2.8E-02	1.1E-01	NA
R15	Sara Loba	**3.9E+00**	**1.6E+00**	3.0E-02	1.5E-01	NA
R22	Tungina	**4.0E+00**	**1.7E+00**	3.4E-02	2.4E-01	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-60 Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 8 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual	*Annual*	*Annual*	*Annual*	*Annual*
R2	Bani	**4.4E+00**	**2.0E+00**	4.6E-02	4.8E-01	NA
R9	Nema	**4.3E+00**	**1.9E+00**	3.9E-02	3.4E-01	NA
R12	Sandjal	**3.6E+00**	**1.4E+00**	2.8E-02	1.1E-01	NA
R15	Sara Loba	**3.7E+00**	**1.5E+00**	3.1E-02	1.7E-01	NA
R22	Tungina	**4.0E+00**	**1.7E+00**	3.2E-02	1.9E-01	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-61 Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 15 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location		Criteria Air Contaminants (CACs)				
		Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
		Annual	*Annual*	*Annual*	*Annual*	*Annual*
R2	Bani	**6.8E+00**	**4.0E+00**	5.0E-02	9.3E-01	NA
R9	Nema	**4.8E+00**	**2.3E+00**	3.5E-02	4.0E-01	NA
R12	Sandjal	**3.7E+00**	**1.5E+00**	2.8E-02	1.3E-01	NA
R15	Sara Loba	**4.7E+00**	**2.4E+00**	5.2E-02	1.0E+00	NA
R22	Tungina	**3.9E+00**	**1.6E+00**	2.9E-02	1.5E-01	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

Table C-62 Summary of Annual Average Concentration Ratios for Criteria Air Contaminants for Year 25 Operations from Baseline + Project at Receptor Locations near Mine Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*

		Annual	*Annual*	*Annual*	*Annual*	*Annual*
R2	Bani	**4.5E+00**	**2.1E+00**	3.9E-02	5.4E-01	NA
R9	Nema	**4.1E+00**	**1.8E+00**	3.3E-02	3.0E-01	NA
R12	Sandjal	**3.8E+00**	**1.5E+00**	3.1E-02	2.2E-01	NA
R15	Sara Loba	**4.0E+00**	**1.7E+00**	3.4E-02	3.5E-01	NA
R22	Tungina	**3.7E+00**	**1.5E+00**	2.9E-02	1.4E-01	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.

C-2.6.2 Metals

Risks from metals were not determined due to the absence of adequate baseline PM_{10} data.

C-3.0 RECEPTOR LOCATIONS NEAR THE PORT SITE

This section provides exposure and risk estimate tables for receptor locations near the Port site for the Baseline, Project Alone, and Baseline + Project scenarios for all Project operational years.

C-3.1 Estimated Exposures for Baseline Scenario

This section provides exposure estimate tables for the Baseline Scenario.

C-3.1.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average exposure estimate tables for the criteria air contaminants (Table C-63).

Table C-63 Estimated Average Baseline Air Concentrations of Criteria Air Contaminants for Receptor Locations near Port Site

Receptor Location	Criteria Air Contaminants (CACs) (µg/m³)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
1-Hour Average Concentrations					
R69	NA	NA	1.38E+00	3.76E+00	-
R70	NA	NA	1.38E+00	3.76E+00	-
8-Hour Average Concentrations					
R69	NA	NA	NA	NA	-
R70	NA	NA	NA	NA	-
24-Hour Average Concentrations					
R69	-	-	1.38E+00	NA	NA
R70	-	-	1.38E+00	NA	NA
Annual Average Concentrations					
R69	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA
R70	6.96E+01	1.37E+01	1.38E+00	3.76E+00	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
R69 Receptor location, Village Chief
R70 Receptor location, Fishing Beach

C-3.1.2 Metals

Exposures to metals were not determined due to the absence of adequate baseline PM_{10} data.

C-3.2 Estimated Exposures for Project Alone Scenario

This section provides exposure estimate tables for the Project Alone Scenario.

C-3.2.1 Criteria Air Contaminants

This section provides maximum 1-hour, maximum 8-hour, maximum 24-hour, and annual average exposure estimate tables for the criteria air contaminants (Table C-64).

Table C-64 Predicted Air Concentrations of Criteria Air Contaminants for All Years from Project Alone at Receptor Locations near Port Site

Receptor	Criteria Air Contaminants (CACs) (µg/m³)

Location	Coarse Particulate Matter (PM_{10})	Fine Particulate Matter ($PM_{2.5}$)	Sulphur Dioxide (SO_2)	Nitrogen Dioxide (NO_2)	Carbon Monoxide (CO)
1-Hour Maximum Concentrations [a,b]					
R69	NA	NA	2.42E+01	8.90E+01	2.92E+02
R70	NA	NA	6.29E+01	2.32E+02	7.99E+02
8-Hour Maximum Concentrations					
R69	NA	NA	NA	NA	8.73E+01
R70	NA	NA	NA	NA	1.38E+02
24-Hour Maximum Concentrations [c,d]					
R69	1.34E+01	3.56E+00	9.73E+00	NA	NA
R70	7.88E+00	2.92E+00	2.16E+01	NA	NA
Annual Average Concentrations [e]					
R69	3.61E+00	9.88E-01	9.49E-01	5.07E+00	NA
R70	3.03E+00	1.12E+00	4.77E+00	5.44E+01	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
R69 Receptor location, Village Chief
R70 Receptor location, Fishing Beach
[a] The 1-hour concentrations of SO_2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO_2 presented are the 98th percentile values.
[c] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.
[d] The 24-hour concentrations of SO_2 presented are the 99th percentile values.
[e] The annual average concentrations presented for all CACs are 3-year averages.

C-3.2.2 Metals

This section provides exposure estimate tables for metals in air. Only chronic-duration (*i.e.,* annual exposures) were considered in the assessment (Table C-65).

Table C-65 Predicted Annual Average Air Concentrations of Metals for Operational Years from Project Alone at Receptor Locations near Port Site

COPC	Fraction of Metal in Product	Receptor Location	
		R69	R70
		Village Chief	Fishing Beach
		Predicted Metals Concentrations in Air ($\mu g/m^3$)[b]	
Annual Average PM_{10}[a]	NA	3.61E+00	3.03E+00
Aluminum	4.25E-03	1.54E-02	1.29E-02
Antimony	6.51E-06	2.35E-05	1.97E-05
Arsenic	3.75E-06	1.36E-05	1.14E-05
Beryllium	5.01E-06	1.81E-05	1.52E-05
Cadmium	2.18E-05	7.86E-05	6.60E-05
Chromium (III)	4.76E-04	1.72E-03	1.44E-03
Cobalt	3.50E-05	1.26E-04	1.06E-04
Iron	3.75E-02	1.36E-01	1.14E-01
Lead	5.76E-06	2.08E-05	1.74E-05
Lithium	NV	-	-
Manganese	6.51E-04	2.35E-03	1.97E-03
Nickel	1.60E-04	5.78E-04	4.85E-04
Selenium	2.75E-05	9.94E-05	8.34E-05
Thallium	1.58E-06	5.69E-06	4.78E-06
Uranium	2.50E-04	9.03E-04	7.58E-04
Vanadium	3.25E-04	1.17E-03	9.86E-04
Zinc	5.26E-04	1.90E-03	1.59E-03

Table C-65 Predicted Annual Average Air Concentrations of Metals for Operational Years from Project Alone at Receptor Locations near Port Site			
COPC	***Fraction of Metal in Product***	***Receptor Location***	
		R69	R70
		Village Chief	Fishing Beach

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the metals air quality assessment.
NV The geochemical analysis of the dust source (*i.e.,* product) did not include this chemical parameter. As a result, the fraction of this metal in the dust source was not available.
[a] The annual average concentrations presented for PM_{10} is a 3-year annual average.
[b] Predicted concentrations of metals in air are the product of the annual average PM_{10} concentration and the fraction of the metal in the PM_{10} source (*i.e.,* product).

C-3.3 Estimated Exposure for Baseline + Project Scenario

This section provides exposure estimate tables for the Baseline + Project Scenario.

C-3.3.1 Criteria Air Contaminants

This section provides maximum 1-hour, maximum 8-hour, maximum 24-hour, and annual average exposure estimate tables for the criteria air contaminants (Table C-66).

Table C-66 Predicted Air Concentrations of Criteria Air Contaminants for All Operational Years from Baseline + Project at Receptor Locations near Port Site					
Receptor Location	**Criteria Air Contaminants (CACs) (µg/m³)**				
	Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
1-Hour Maximum Concentrations [a,b]					
R69	NA	NA	2.55E+01	9.27E+01	-
R70	NA	NA	6.43E+01	2.36E+02	-
8-Hour Maximum Concentrations					
R69	NA	NA	NA	NA	-
R70	NA	NA	NA	NA	-
24-Hour Maximum Concentrations [c,d]					
R69	-	-	1.11E+01	NA	NA
R70	-	-	2.30E+01	NA	NA
Annual Average Concentrations [e]					
R69	7.49E+01	1.49E+01	2.33E+00	8.83E+00	NA
R70	7.43E+01	1.50E+01	6.15E+00	5.81E+01	NA

NA Not applicable. Air concentrations for this chemical parameter were not evaluated as part of the air quality assessment due to the absence of applicable exposure limits.
\- Predicted Baseline + Project air concentration could not be calculated due to the absence of adequate baseline air data.
R69 Receptor location, Village Chief
R70 Receptor location, Fishing Beach
[a] The 1-hour concentrations of SO_2 presented are the 99th percentile values.
[b] The 1-hour concentrations of NO_2 presented are the 98th percentile values.
[c] The 24-hour concentrations of PM_{10} and $PM_{2.5}$ presented are the 99th percentile values.
[d] The 24-hour concentrations of SO_2 presented are the 99th percentile values.
[e] The annual average concentrations presented for all CACs are 3-year averages.

C-3.3.2 Metals

Exposures to metals were not determined due to the absence of adequate baseline PM_{10} data.

C-3.4 Risk Estimates for Baseline Scenario

This section provides risk estimate tables for the Baseline Scenario.

C-3.4.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average risks estimate tables for the criteria air contaminants (Table C-67).

Table C-67 Summary of Baseline Concentrations Ratios for Criteria Air Contaminants for Receptor Locations near Port Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
1-Hour Average Concentrations					
R69	NA	NA	6.9E-03	2.0E-02	-
R70	NA	NA	6.9E-03	2.0E-02	-
8-Hour Average Concentrations					
R69	NA	NA	NA	NA	-
R70	NA	NA	NA	NA	-
24-Hour Average Concentrations					
R69	-	-	6.9E-02	NA	NA
R70	-	-	6.9E-02	NA	NA
Annual Average Concentrations					
R69	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA
R70	**3.5E+00**	**1.4E+00**	2.8E-02	9.4E-02	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
R69 Receptor location, Village Chief
R70 Receptor location, Fishing Beach

C-3.4.2 Metals

Risks from metals were not determined due to the absence of adequate baseline PM_{10} data.

C-3.5 Risk Estimates for Project Alone Scenario

This section provides risk estimate tables for the Project Alone Scenario.

C-3.5.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average risks estimate tables for the criteria air contaminants (Table C-68).

Table C-68 Summary of Concentrations Ratios for Criteria Air Contaminants for All Operational Years from Project Alone at Receptor Locations near Port Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
1-Hour Maximum Concentrations					
R69	NA	NA	1.2E-01	4.7E-01	9.7E-03
R70	NA	NA	3.1E-01	**1.2E+00**	2.7E-02

Table C-68	Summary of Concentrations Ratios for Criteria Air Contaminants for All Operational Years from Project Alone at Receptor Locations near Port Site				
Receptor Location	**Criteria Air Contaminants (CACs)**				
	Coarse Particulate Matter (PM_{10})	***Fine Particulate Matter ($PM_{2.5}$)***	***Sulphur Dioxide (SO_2)***	***Nitrogen Dioxide (NO_2)***	***Carbon Monoxide (CO)***
8-Hour Maximum Concentrations					
R69	NA	NA	NA	NA	8.7E-03
R70	NA	NA	NA	NA	1.4E-02
24-Hour Maximum Concentrations					
R69	2.7E-01	1.4E-01	4.9E-01	NA	NA
R70	1.6E-01	1.2E-01	**1.1E+00**	NA	NA
Annual Average Concentrations					
R69	1.8E-01	9.9E-02	1.9E-02	1.3E-01	NA
R70	1.5E-01	1.1E-01	9.5E-02	**1.4E+00**	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
R69 Receptor location, Village Chief
R70 Receptor location, Fishing Beach

C-3.5.2 Metals

This section provides risk estimate tables for metals in air. Only chronic-duration (*i.e.,* annual exposures) were considered in the assessment (Table C-69).

Table C-69	Summary of Risk Estimates for Metals for All Operational Years from Project Alone at Receptor Locations near Port Site			
COPC	***Receptor Location***			
	R69		R70	
	Village Chief		Fishing Beach	
	Risk Estimates			
	CR	***ILCR***	***CR***	***ILCR***
Aluminum	3.1E-03	NA	2.6E-03	NA
Antimony	1.2E-04	NA	9.9E-05	NA
Arsenic	9.0E-04	8.7E-08	7.6E-04	7.3E-08
Beryllium	2.6E-03	4.3E-08	2.2E-03	3.6E-08
Cadmium	1.6E-02	7.7E-07	1.3E-02	6.5E-07
Chromium (III)	4.2E-02	NA	3.5E-02	NA
Cobalt	1.3E-03	NA	1.1E-03	NA
Iron	2.7E-02	NA	2.3E-02	NA
Lead	1.4E-04	NA	1.2E-04	NA
Lithium	NA/NV	NA/NV	NA/NV	NA/NV
Manganese	4.7E-02	NA	3.9E-02	NA
Nickel	1.4E-02	NA	1.2E-02	NA
Selenium	5.0E-04	NA	4.2E-04	NA
Thallium	5.7E-05	NA	4.8E-05	NA
Uranium	NA	NA	NA	NA
Vanadium	1.2E-02	NA	9.9E-03	NA
Zinc	9.5E-04	NA	8.0E-04	NA

Bolded values highlighted in grey are in excess of a non-cancer CR of 1.0 or an ILCR of 1.0E-05 (1-in-100,000 cancer risk level).
NA Not assessed. Indicates that an appropriate exposure limit was not available for this chemical parameter for this endpoint.
NV The geochemical analysis of the dust source (*i.e.,* product) did not include this chemical parameter. As a result, exposures and subsequently, risks, could not be estimated.

C-3.6 Risk Estimates for Baseline + Project Scenario

This section provides risk estimate tables for the Baseline + Project Scenario.

C-3.6.1 Criteria Air Contaminants

This section provides 1-hour, 8-hour, 24-hour, and annual average risks estimate tables for the criteria air contaminants (Table C-70).

Table C-70 Summary of Concentrations Ratios for Criteria Air Contaminants for All Operational Years from Baseline + Project at Receptor Locations near Port Site

Receptor Location	Criteria Air Contaminants (CACs)				
	Coarse Particulate Matter (PM_{10})	*Fine Particulate Matter ($PM_{2.5}$)*	*Sulphur Dioxide (SO_2)*	*Nitrogen Dioxide (NO_2)*	*Carbon Monoxide (CO)*
1-Hour Maximum Concentrations					
R69	NA	NA	1.3E-01	4.9E-01	-
R70	NA	NA	3.2E-01	**1.2E+00**	-
8-Hour Maximum Concentrations					
R69	NA	NA	NA	NA	-
R70	NA	NA	NA	NA	-
24-Hour Maximum Concentrations					
R69	-	-	5.6E-01	NA	NA
R70	-	-	**1.2E+00**	NA	NA
Annual Average Concentrations					
R69	**3.7E+00**	**1.5E+00**	4.7E-02	2.2E-01	NA
R70	**3.7E+00**	**1.5E+00**	1.2E-01	**1.5E+00**	NA

Bolded values highlighted in grey are in excess of a CR of 1.0.
NA Indicates that an appropriate exposure limit was not available for this chemical parameter.
- Predicted Baseline + Project risks could not be calculated due to the absence of adequate baseline air data.
R69 Receptor location, Village Chief
R70 Receptor location, Fishing Beach

C-3.6.2 Metals

Risks from metals were not determined due to the absence of adequate baseline PM_{10} data.

APPENDIX D

MULTI–PATHWAY EXPOSURE AND RISK ESTIMATES

APPENDIX D: MULTI–PATHWAY EXPOSURE AND RISK ESTIMATES

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D-1.0 INTRODUCTION

This appendix provides multi-pathway media concentrations, exposure estimate tables, and risk estimate tables for receptor locations near the Farim Mine site and Port site for the Baseline, Project Alone, and Baseline + Project scenarios evaluated within the HHRA component of the HHERA.

D-2.0 MEDIA CONCENTRATIONS

This section provides media concentration tables for receptor locations near the Farim Mine site and Port site for the Baseline, Project Alone, and Baseline + Project scenarios.

Table D-1 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R2

Chemical of Potential Concern	*Scenario*	*Total Deposition Rate*[a]	*Soil*[b]	*Dust*[c]	*Groundwater*	*Exposed Aboveground Produce*	*Belowground Produce*	*Protected Aboveground Produce*	*Fish*
		mg/m²/yr	*mg/kg dw*	*µg/m³*	*mg/L*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*
Aluminum	Baseline	0.00E+00	9.44E+03	2.36E+00	4.03E-03	2.11E+00	7.98E-01	9.20E-01	0.00E+00
	Project Alone	1.71E+03	1.43E+03	3.58E-01	0.00E+00	2.37E+00	1.21E-02	1.40E-02	0.00E+00
	Baseline + Project	1.71E+03	1.09E+04	2.72E+00	4.03E-03	4.48E+00	8.10E-01	9.34E-01	0.00E+00
Arsenic	Baseline	0.00E+00	1.34E+00	3.36E-04	1.30E-03	1.27E-03	1.40E-03	8.06E-04	1.26E+00
	Project Alone	3.62E-01	3.03E-01	7.58E-05	0.00E+00	5.24E-04	3.15E-05	1.82E-05	0.00E+00
	Baseline + Project	3.62E-01	1.65E+00	4.11E-04	1.30E-03	1.80E-03	1.43E-03	8.24E-04	1.26E+00
Cadmium	Baseline	0.00E+00	7.70E-01	1.92E-04	4.60E-04	1.44E-02	6.41E-03	7.16E-03	1.38E-02
	Project Alone	3.48E-02	2.92E-02	7.29E-06	0.00E+00	1.02E-04	2.43E-05	2.71E-05	0.00E+00
	Baseline + Project	3.48E-02	7.99E-01	2.00E-04	4.60E-04	1.45E-02	6.43E-03	7.19E-03	1.38E-02
Iron	Baseline	0.00E+00	8.31E+03	2.08E+00	1.19E+00	2.18E+00	1.08E+00	1.25E+00	3.18E+01
	Project Alone	1.34E+03	1.13E+03	2.82E-01	0.00E+00	1.87E+00	1.47E-02	1.69E-02	0.00E+00
	Baseline + Project	1.34E+03	9.43E+03	2.36E+00	1.19E+00	4.05E+00	1.09E+00	1.26E+00	3.18E+01
Lead	Baseline	0.00E+00	8.39E+00	2.10E-03	2.00E-04	1.71E-02	9.82E-03	1.13E-02	1.04E-02
	Project Alone	4.63E-01	3.89E-01	9.71E-05	0.00E+00	7.14E-04	4.55E-05	5.25E-05	0.00E+00
	Baseline + Project	4.63E-01	8.78E+00	2.19E-03	2.00E-04	1.78E-02	9.86E-03	1.14E-02	1.04E-02
Vanadium	Baseline	0.00E+00	2.15E+01	5.37E-03	5.00E-04	1.17E-02	8.38E-03	9.67E-03	0.00E+00
	Project Alone	3.33E+00	2.79E+00	6.97E-04	0.00E+00	4.71E-03	1.09E-04	1.26E-04	0.00E+00
	Baseline + Project	3.33E+00	2.43E+01	6.07E-03	5.00E-04	1.64E-02	8.49E-03	9.79E-03	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

Table D-2 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R9

Chemical of Potential Concern	*Scenario*	*Total Deposition Rate*[a]	*Soil*[b]	*Dust*[c]	*Groundwater*	*Exposed Aboveground Produce*	*Belowground Produce*	*Protected Aboveground Produce*	*Fish*
		mg/m²/yr	*mg/kg dw*	*µg/m³*	*mg/L*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*
Aluminum	Baseline	0.00E+00	9.44E+03	2.36E+00	4.03E-03	2.11E+00	7.98E-01	9.20E-01	0.00E+00
	Project Alone	1.08E+03	9.08E+02	2.27E-01	0.00E+00	1.50E+00	7.67E-03	8.85E-03	0.00E+00
	Baseline + Project	1.08E+03	1.03E+04	2.59E+00	4.03E-03	3.61E+00	8.05E-01	9.29E-01	0.00E+00
Arsenic	Baseline	0.00E+00	1.34E+00	3.36E-04	1.30E-03	1.27E-03	1.40E-03	8.06E-04	1.26E+00
	Project Alone	2.29E-01	1.92E-01	4.80E-05	0.00E+00	3.32E-04	2.00E-05	1.15E-05	0.00E+00
	Baseline + Project	2.29E-01	1.53E+00	3.84E-04	1.30E-03	1.61E-03	1.42E-03	8.17E-04	1.26E+00
Cadmium	Baseline	0.00E+00	7.70E-01	1.92E-04	4.60E-04	1.44E-02	6.41E-03	7.16E-03	1.38E-02
	Project Alone	2.20E-02	1.85E-02	4.62E-06	0.00E+00	6.48E-05	1.54E-05	1.72E-05	0.00E+00
	Baseline + Project	2.20E-02	7.88E-01	1.97E-04	4.60E-04	1.45E-02	6.42E-03	7.18E-03	1.38E-02
Iron	Baseline	0.00E+00	8.31E+03	2.08E+00	1.19E+00	2.18E+00	1.08E+00	1.25E+00	3.18E+01
	Project Alone	8.52E+02	7.14E+02	1.79E-01	0.00E+00	1.18E+00	9.28E-03	1.07E-02	0.00E+00
	Baseline + Project	8.52E+02	9.02E+03	2.26E+00	1.19E+00	3.37E+00	1.09E+00	1.26E+00	3.18E+01
Lead	Baseline	0.00E+00	8.39E+00	2.10E-03	2.00E-04	1.71E-02	9.82E-03	1.13E-02	1.04E-02
	Project Alone	2.94E-01	2.46E-01	6.15E-05	0.00E+00	4.52E-04	2.88E-05	3.32E-05	0.00E+00
	Baseline + Project	2.94E-01	8.64E+00	2.16E-03	2.00E-04	1.76E-02	9.85E-03	1.14E-02	1.04E-02
Vanadium	Baseline	0.00E+00	2.15E+01	5.37E-03	5.00E-04	1.17E-02	8.38E-03	9.67E-03	0.00E+00
	Project Alone	2.11E+00	1.77E+00	4.42E-04	0.00E+00	2.98E-03	6.89E-05	7.95E-05	0.00E+00
	Baseline + Project	2.11E+00	2.33E+01	5.81E-03	5.00E-04	1.47E-02	8.45E-03	9.75E-03	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

Table D-3 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R12

Chemical of Potential Concern	*Scenario*	*Total Deposition Rate*[a]	*Soil*[b]	*Dust*[c]	*Groundwater*	*Exposed Aboveground Produce*	*Belowground Produce*	*Protected Aboveground Produce*	*Fish*
		mg/m²/yr	*mg/kg dw*	*µg/m³*	*mg/L*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*
Aluminum	Baseline	0.00E+00	9.44E+03	2.36E+00	4.03E-03	2.11E+00	7.98E-01	9.20E-01	0.00E+00
	Project Alone	9.52E+02	7.98E+02	2.00E-01	0.00E+00	1.32E+00	6.75E-03	7.78E-03	0.00E+00
	Baseline + Project	9.52E+02	1.02E+04	2.56E+00	4.03E-03	3.43E+00	8.04E-01	9.28E-01	0.00E+00
Arsenic	Baseline	0.00E+00	1.34E+00	3.36E-04	1.30E-03	1.27E-03	1.40E-03	8.06E-04	1.26E+00
	Project Alone	2.01E-01	1.69E-01	4.22E-05	0.00E+00	2.92E-04	1.76E-05	1.01E-05	0.00E+00
	Baseline + Project	2.01E-01	1.51E+00	3.78E-04	1.30E-03	1.57E-03	1.41E-03	8.16E-04	1.26E+00
Cadmium	Baseline	0.00E+00	7.70E-01	1.92E-04	4.60E-04	1.44E-02	6.41E-03	7.16E-03	1.38E-02
	Project Alone	1.94E-02	1.62E-02	4.06E-06	0.00E+00	5.70E-05	1.35E-05	1.51E-05	0.00E+00
	Baseline + Project	1.94E-02	7.86E-01	1.97E-04	4.60E-04	1.45E-02	6.42E-03	7.18E-03	1.38E-02
Iron	Baseline	0.00E+00	8.31E+03	2.08E+00	1.19E+00	2.18E+00	1.08E+00	1.25E+00	3.18E+01
	Project Alone	7.49E+02	6.28E+02	1.57E-01	0.00E+00	1.04E+00	8.16E-03	9.42E-03	0.00E+00
	Baseline + Project	7.49E+02	8.93E+03	2.23E+00	1.19E+00	3.22E+00	1.09E+00	1.26E+00	3.18E+01
Lead	Baseline	0.00E+00	8.39E+00	2.10E-03	2.00E-04	1.71E-02	9.82E-03	1.13E-02	1.04E-02
	Project Alone	2.58E-01	2.16E-01	5.41E-05	0.00E+00	3.98E-04	2.53E-05	2.92E-05	0.00E+00
	Baseline + Project	2.58E-01	8.61E+00	2.15E-03	2.00E-04	1.75E-02	9.84E-03	1.14E-02	1.04E-02
Vanadium	Baseline	0.00E+00	2.15E+01	5.37E-03	5.00E-04	1.17E-02	8.38E-03	9.67E-03	0.00E+00
	Project Alone	1.85E+00	1.55E+00	3.88E-04	0.00E+00	2.62E-03	6.06E-05	6.99E-05	0.00E+00
	Baseline + Project	1.85E+00	2.30E+01	5.76E-03	5.00E-04	1.43E-02	8.44E-03	9.74E-03	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

Table D-4 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R15

Chemical of Potential Concern	Scenario	Total Deposition Rate[a]	Soil[b]	Dust[c]	Groundwater	Exposed Aboveground Produce	Belowground Produce	Protected Aboveground Produce	Fish
		mg/m²/yr	mg/kg dw	µg/m³	mg/L	mg/kg ww	mg/kg ww	mg/kg ww	mg/kg ww
Aluminum	Baseline	0.00E+00	9.44E+03	2.36E+00	4.03E-03	2.11E+00	7.98E-01	9.20E-01	0.00E+00
	Project Alone	1.15E+03	9.66E+02	2.42E-01	0.00E+00	1.60E+00	8.16E-03	9.42E-03	0.00E+00
	Baseline + Project	1.15E+03	1.04E+04	2.60E+00	4.03E-03	3.71E+00	8.06E-01	9.30E-01	0.00E+00
Arsenic	Baseline	0.00E+00	1.34E+00	3.36E-04	1.30E-03	1.27E-03	1.40E-03	8.06E-04	1.26E+00
	Project Alone	2.44E-01	2.04E-01	5.11E-05	0.00E+00	3.53E-04	2.13E-05	1.23E-05	0.00E+00
	Baseline + Project	2.44E-01	1.55E+00	3.87E-04	1.30E-03	1.63E-03	1.42E-03	8.18E-04	1.26E+00
Cadmium	Baseline	0.00E+00	7.70E-01	1.92E-04	4.60E-04	1.44E-02	6.41E-03	7.16E-03	1.38E-02
	Project Alone	2.34E-02	1.97E-02	4.92E-06	0.00E+00	6.90E-05	1.64E-05	1.83E-05	0.00E+00
	Baseline + Project	2.34E-02	7.90E-01	1.97E-04	4.60E-04	1.45E-02	6.42E-03	7.18E-03	1.38E-02
Iron	Baseline	0.00E+00	8.31E+03	2.08E+00	1.19E+00	2.18E+00	1.08E+00	1.25E+00	3.18E+01
	Project Alone	9.06E+02	7.60E+02	1.90E-01	0.00E+00	1.26E+00	9.88E-03	1.14E-02	0.00E+00
	Baseline + Project	9.06E+02	9.07E+03	2.27E+00	1.19E+00	3.44E+00	1.09E+00	1.26E+00	3.18E+01
Lead	Baseline	0.00E+00	8.39E+00	2.10E-03	2.00E-04	1.71E-02	9.82E-03	1.13E-02	1.04E-02
	Project Alone	3.12E-01	2.62E-01	6.55E-05	0.00E+00	4.81E-04	3.06E-05	3.54E-05	0.00E+00
	Baseline + Project	3.12E-01	8.65E+00	2.16E-03	2.00E-04	1.76E-02	9.85E-03	1.14E-02	1.04E-02
Vanadium	Baseline	0.00E+00	2.15E+01	5.37E-03	5.00E-04	1.17E-02	8.38E-03	9.67E-03	0.00E+00
	Project Alone	2.24E+00	1.88E+00	4.70E-04	0.00E+00	3.17E-03	7.33E-05	8.46E-05	0.00E+00
	Baseline + Project	2.24E+00	2.34E+01	5.84E-03	5.00E-04	1.49E-02	8.45E-03	9.75E-03	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

Table D-5 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R22

Chemical of Potential Concern	*Scenario*	*Total Deposition Rate*[a]	*Soil*[b]	*Dust*[c]	*Groundwater*	*Exposed Aboveground Produce*	*Belowground Produce*	*Protected Aboveground Produce*	*Fish*
		mg/m²/yr	*mg/kg dw*	*µg/m³*	*mg/L*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*
Aluminum	Baseline	0.00E+00	9.44E+03	2.36E+00	4.03E-03	2.11E+00	7.98E-01	9.20E-01	0.00E+00
	Project Alone	4.62E+02	3.87E+02	9.68E-02	0.00E+00	6.41E-01	3.27E-03	3.77E-03	0.00E+00
	Baseline + Project	4.62E+02	9.83E+03	2.46E+00	4.03E-03	2.75E+00	8.01E-01	9.24E-01	0.00E+00
Arsenic	Baseline	0.00E+00	1.34E+00	3.36E-04	1.30E-03	1.27E-03	1.40E-03	8.06E-04	1.26E+00
	Project Alone	9.76E-02	8.19E-02	2.05E-05	0.00E+00	1.41E-04	8.52E-06	4.91E-06	0.00E+00
	Baseline + Project	9.76E-02	1.42E+00	3.56E-04	1.30E-03	1.42E-03	1.40E-03	8.10E-04	1.26E+00
Cadmium	Baseline	0.00E+00	7.70E-01	1.92E-04	4.60E-04	1.44E-02	6.41E-03	7.16E-03	1.38E-02
	Project Alone	9.39E-03	7.88E-03	1.97E-06	0.00E+00	2.76E-05	6.56E-06	7.33E-06	0.00E+00
	Baseline + Project	9.39E-03	7.78E-01	1.94E-04	4.60E-04	1.45E-02	6.41E-03	7.17E-03	1.38E-02
Iron	Baseline	0.00E+00	8.31E+03	2.08E+00	1.19E+00	2.18E+00	1.08E+00	1.25E+00	3.18E+01
	Project Alone	3.63E+02	3.04E+02	7.61E-02	0.00E+00	5.05E-01	3.96E-03	4.57E-03	0.00E+00
	Baseline + Project	3.63E+02	8.61E+03	2.15E+00	1.19E+00	2.69E+00	1.08E+00	1.25E+00	3.18E+01
Lead	Baseline	0.00E+00	8.39E+00	2.10E-03	2.00E-04	1.71E-02	9.82E-03	1.13E-02	1.04E-02
	Project Alone	1.25E-01	1.05E-01	2.62E-05	0.00E+00	1.93E-04	1.23E-05	1.42E-05	0.00E+00
	Baseline + Project	1.25E-01	8.50E+00	2.12E-03	2.00E-04	1.73E-02	9.83E-03	1.13E-02	1.04E-02
Vanadium	Baseline	0.00E+00	2.15E+01	5.37E-03	5.00E-04	1.17E-02	8.38E-03	9.67E-03	0.00E+00
	Project Alone	8.98E-01	7.53E-01	1.88E-04	0.00E+00	1.27E-03	2.94E-05	3.39E-05	0.00E+00
	Baseline + Project	8.98E-01	2.22E+01	5.56E-03	5.00E-04	1.30E-02	8.41E-03	9.70E-03	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

Table D-6 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R69

Chemical of Potential Concern	*Scenario*	*Total Deposition Rate*[a]	*Soil*[b]	*Dust*[c]	*Groundwater*	*Exposed Aboveground Produce*	*Belowground Produce*	*Protected Aboveground Produce*	*Fish*
		mg/m²/yr	*mg/kg dw*	*µg/m³*	*mg/L*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*	*mg/kg ww*
Aluminum	Baseline	0.00E+00	3.74E+04	9.36E+00	4.03E-03	8.36E+00	3.16E+00	3.65E+00	0.00E+00
	Project Alone	3.20E+00	2.68E+00	6.71E-04	0.00E+00	4.44E-03	2.27E-05	2.62E-05	0.00E+00
	Baseline + Project	3.20E+00	3.75E+04	9.36E+00	4.03E-03	8.36E+00	3.16E+00	3.65E+00	0.00E+00
Arsenic	Baseline	0.00E+00	1.39E+01	3.49E-03	1.30E-03	1.32E-02	1.45E-02	8.36E-03	1.26E+00
	Project Alone	2.82E-03	2.37E-03	5.92E-07	0.00E+00	4.09E-06	2.46E-07	1.42E-07	0.00E+00
	Baseline + Project	2.82E-03	1.39E+01	3.49E-03	1.30E-03	1.32E-02	1.45E-02	8.37E-03	1.26E+00
Cadmium	Baseline	0.00E+00	2.21E+00	5.53E-04	4.60E-04	4.15E-02	1.84E-02	2.06E-02	1.38E-02
	Project Alone	1.64E-02	1.37E-02	3.44E-06	0.00E+00	4.82E-05	1.14E-05	1.28E-05	0.00E+00
	Baseline + Project	1.64E-02	2.23E+00	5.57E-04	4.60E-04	4.16E-02	1.84E-02	2.06E-02	1.38E-02
Iron	Baseline	0.00E+00	6.06E+04	1.52E+01	1.19E+00	1.59E+01	7.88E+00	9.09E+00	3.18E+01
	Project Alone	2.82E+01	2.37E+01	5.92E-03	0.00E+00	3.93E-02	3.08E-04	3.55E-04	0.00E+00
	Baseline + Project	2.82E+01	6.06E+04	1.52E+01	1.19E+00	1.59E+01	7.88E+00	9.09E+00	3.18E+01
Lead	Baseline	0.00E+00	2.40E+01	6.00E-03	2.00E-04	4.90E-02	2.81E-02	3.24E-02	1.04E-02
	Project Alone	4.33E-03	3.63E-03	9.08E-07	0.00E+00	6.67E-06	4.25E-07	4.90E-07	0.00E+00
	Baseline + Project	4.33E-03	2.40E+01	6.00E-03	2.00E-04	4.90E-02	2.81E-02	3.24E-02	1.04E-02
Vanadium	Baseline	0.00E+00	9.40E+01	2.35E-02	5.00E-04	5.11E-02	3.67E-02	4.23E-02	0.00E+00
	Project Alone	2.45E-01	2.05E-01	5.13E-05	0.00E+00	3.46E-04	8.01E-06	9.24E-06	0.00E+00
	Baseline + Project	2.45E-01	9.42E+01	2.36E-02	5.00E-04	5.15E-02	3.67E-02	4.23E-02	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

Table D-7 Summary of Exposure Point Concentrations for Environmental Media – Receptor Location R70

Chemical of Potential Concern	Scenario	Total Deposition Rate[a]	Soil[b]	Dust[c]	Groundwater	Exposed Aboveground Produce	Belowground Produce	Protected Aboveground Produce	Fish
		mg/m²/yr	mg/kg dw	µg/m³	mg/L	mg/kg ww	mg/kg ww	mg/kg ww	mg/kg ww
Aluminum	Baseline	0.00E+00	3.74E+04	9.36E+00	4.03E-03	8.36E+00	3.16E+00	3.65E+00	0.00E+00
	Project Alone	3.26E+00	2.74E+00	6.84E-04	0.00E+00	4.53E-03	2.31E-05	2.67E-05	0.00E+00
	Baseline + Project	3.26E+00	3.75E+04	9.36E+00	4.03E-03	8.36E+00	3.16E+00	3.65E+00	0.00E+00
Arsenic	Baseline	0.00E+00	1.39E+01	3.49E-03	1.30E-03	1.32E-02	1.45E-02	8.36E-03	1.26E+00
	Project Alone	2.88E-03	2.42E-03	6.04E-07	0.00E+00	4.17E-06	2.51E-07	1.45E-07	0.00E+00
	Baseline + Project	2.88E-03	1.39E+01	3.49E-03	1.30E-03	1.32E-02	1.45E-02	8.37E-03	1.26E+00
Cadmium	Baseline	0.00E+00	2.21E+00	5.53E-04	4.60E-04	4.15E-02	1.84E-02	2.06E-02	1.38E-02
	Project Alone	1.67E-02	1.40E-02	3.50E-06	0.00E+00	4.91E-05	1.17E-05	1.30E-05	0.00E+00
	Baseline + Project	1.67E-02	2.23E+00	5.57E-04	4.60E-04	4.16E-02	1.84E-02	2.06E-02	1.38E-02
Iron	Baseline	0.00E+00	6.06E+04	1.52E+01	1.19E+00	1.59E+01	7.88E+00	9.09E+00	3.18E+01
	Project Alone	2.88E+01	2.42E+01	6.04E-03	0.00E+00	4.01E-02	3.14E-04	3.62E-04	0.00E+00
	Baseline + Project	2.88E+01	6.06E+04	1.52E+01	1.19E+00	1.59E+01	7.88E+00	9.09E+00	3.18E+01
Lead	Baseline	0.00E+00	2.40E+01	6.00E-03	2.00E-04	4.90E-02	2.81E-02	3.24E-02	1.04E-02
	Project Alone	4.42E-03	3.70E-03	9.26E-07	0.00E+00	6.80E-06	4.33E-07	5.00E-07	0.00E+00
	Baseline + Project	4.42E-03	2.40E+01	6.00E-03	2.00E-04	4.90E-02	2.81E-02	3.24E-02	1.04E-02
Vanadium	Baseline	0.00E+00	9.40E+01	2.35E-02	5.00E-04	5.11E-02	3.67E-02	4.23E-02	0.00E+00
	Project Alone	2.50E-01	2.09E-01	5.23E-05	0.00E+00	3.53E-04	8.16E-06	9.42E-06	0.00E+00
	Baseline + Project	2.50E-01	9.42E+01	2.36E-02	5.00E-04	5.15E-02	3.67E-02	4.23E-02	0.00E+00

[a] Annual deposition rates were used to predict soil concentrations and deposition onto vegetation after 26 years of deposition.
[b] Surface soil concentrations used to evaluate the incidental soil ingestion pathway were predicted assuming a 2 cm mixing zone as per US EPA (2005).
[c] Dust represents re-suspended dust from surface soil.

D-3.0 MULTI-PATHWAY EXPOSURE ESTIMATES

This section provides multi-pathway exposure estimates tables for receptor locations near the Farim Mine site and Port site for the Baseline and Project Alone scenarios. Tables D-8 through D-14 present exposure estimates at the Mine and Port sites for the Baseline scenario. Tables D-15 through D-21 present exposure estimates at the Mine and Port sites for the Baseline scenario

Table D-8	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R2								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.89E+02	6.05E+00	3.92E+01	1.62E+01	5.65E+02	0.00E+00	8.15E+02	1.15E+01
	Adolescent	1.89E+02	4.03E+00	3.68E+01	1.43E+01	5.44E+02	0.00E+00	7.88E+02	1.32E+01
	Child	1.89E+02	3.22E+00	3.42E+01	9.86E+00	4.25E+02	0.00E+00	6.61E+02	2.01E+01
	Toddler	7.55E+02	2.42E+00	1.96E+01	6.49E+00	2.87E+02	0.00E+00	1.07E+03	6.49E+01
	Infant	1.89E+02	1.21E+00	5.19E+00	4.40E+00	0.00E+00	0.00E+00	2.00E+02	2.43E+01
Arsenic	Adult	2.69E-02	1.95E+00	5.57E-03	6.90E-03	4.27E-01	1.01E+00	3.42E+00	4.84E-02
	Adolescent	2.69E-02	1.30E+00	5.24E-03	6.12E-03	4.42E-01	1.01E+00	2.79E+00	4.67E-02
	Child	2.69E-02	1.04E+00	4.87E-03	4.21E-03	3.34E-01	8.31E-01	2.24E+00	6.81E-02
	Toddler	1.07E-01	7.80E-01	2.79E-03	2.77E-03	2.23E-01	5.03E-01	1.62E+00	9.81E-02
	Infant	2.69E-02	3.90E-01	7.38E-04	1.88E-03	0.00E+00	0.00E+00	4.19E-01	5.12E-02
Cadmium	Adult	1.54E-02	6.90E-01	3.20E-03	1.32E-03	4.16E+00	5.52E-01	5.43E+00	7.67E-02
	Adolescent	1.54E-02	4.60E-01	3.00E-03	1.17E-03	4.05E+00	5.52E-01	5.08E+00	8.51E-02
	Child	1.54E-02	3.68E-01	2.79E-03	8.05E-04	3.15E+00	4.55E-01	3.99E+00	1.21E-01
	Toddler	6.16E-02	2.76E-01	1.60E-03	5.30E-04	2.12E+00	2.76E-01	2.74E+00	1.66E-01
	Infant	1.54E-02	1.38E-01	4.23E-04	3.59E-04	0.00E+00	0.00E+00	1.54E-01	1.88E-02
Iron	Adult	1.66E+02	1.79E+03	3.45E+01	1.42E+01	6.72E+02	1.27E+03	3.95E+03	5.58E+01
	Adolescent	1.66E+02	1.19E+03	3.24E+01	1.26E+01	6.56E+02	1.27E+03	3.33E+03	5.58E+01
	Child	1.66E+02	9.54E+02	3.01E+01	8.68E+00	5.10E+02	1.05E+03	2.72E+03	8.26E+01
	Toddler	6.65E+02	7.15E+02	1.72E+01	5.72E+00	3.43E+02	6.36E+02	2.38E+03	1.44E+02
	Infant	1.66E+02	3.58E+02	4.57E+00	3.87E+00	0.00E+00	0.00E+00	5.32E+02	6.49E+01
Lead	Adult	1.68E-01	3.00E-01	3.48E-02	1.44E-02	5.74E+00	4.16E-01	6.68E+00	9.44E-02
	Adolescent	1.68E-01	2.00E-01	3.27E-02	1.28E-02	5.64E+00	4.16E-01	6.47E+00	1.08E-01
	Child	1.68E-01	1.60E-01	3.04E-02	8.77E-03	4.37E+00	3.43E-01	5.08E+00	1.54E-01
	Toddler	6.71E-01	1.20E-01	1.74E-02	5.77E-03	2.94E+00	2.08E-01	3.96E+00	2.40E-01
	Infant	1.68E-01	6.00E-02	4.62E-03	3.91E-03	0.00E+00	0.00E+00	2.36E-01	2.88E-02
Vanadium	Adult	4.30E-01	7.50E-01	8.92E-02	3.68E-01	4.50E+00	0.00E+00	6.14E+00	8.68E-02
	Adolescent	4.30E-01	5.00E-01	8.38E-02	3.27E-01	4.46E+00	0.00E+00	5.80E+00	9.72E-02
	Child	4.30E-01	4.00E-01	7.79E-02	2.25E-01	3.44E+00	0.00E+00	4.57E+00	1.39E-01
	Toddler	1.72E+00	3.00E-01	4.46E-02	1.48E-01	2.31E+00	0.00E+00	4.52E+00	2.74E-01
	Infant	4.30E-01	1.50E-01	1.18E-02	1.00E-01	0.00E+00	0.00E+00	6.92E-01	8.43E-02

Table D-9	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R9								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.89E+02	6.05E+00	3.92E+01	1.62E+01	5.65E+02	0.00E+00	8.15E+02	1.15E+01
	Adolescent	1.89E+02	4.03E+00	3.68E+01	1.43E+01	5.44E+02	0.00E+00	7.88E+02	1.32E+01
	Child	1.89E+02	3.22E+00	3.42E+01	9.86E+00	4.25E+02	0.00E+00	6.61E+02	2.01E+01
	Toddler	7.55E+02	2.42E+00	1.96E+01	6.49E+00	2.87E+02	0.00E+00	1.07E+03	6.49E+01
	Infant	1.89E+02	1.21E+00	5.19E+00	4.40E+00	0.00E+00	0.00E+00	2.00E+02	2.43E+01
Arsenic	Adult	2.69E-02	1.95E+00	5.57E-03	6.90E-03	4.27E-01	1.01E+00	3.42E+00	4.84E-02
	Adolescent	2.69E-02	1.30E+00	5.24E-03	6.12E-03	4.42E-01	1.01E+00	2.79E+00	4.67E-02
	Child	2.69E-02	1.04E+00	4.87E-03	4.21E-03	3.34E-01	8.31E-01	2.24E+00	6.81E-02
	Toddler	1.07E-01	7.80E-01	2.79E-03	2.77E-03	2.23E-01	5.03E-01	1.62E+00	9.81E-02
	Infant	2.69E-02	3.90E-01	7.38E-04	1.88E-03	0.00E+00	0.00E+00	4.19E-01	5.12E-02
Cadmium	Adult	1.54E-02	6.90E-01	3.20E-03	1.32E-03	4.16E+00	5.52E-01	5.43E+00	7.67E-02
	Adolescent	1.54E-02	4.60E-01	3.00E-03	1.17E-03	4.05E+00	5.52E-01	5.08E+00	8.51E-02
	Child	1.54E-02	3.68E-01	2.79E-03	8.05E-04	3.15E+00	4.55E-01	3.99E+00	1.21E-01
	Toddler	6.16E-02	2.76E-01	1.60E-03	5.30E-04	2.12E+00	2.76E-01	2.74E+00	1.66E-01
	Infant	1.54E-02	1.38E-01	4.23E-04	3.59E-04	0.00E+00	0.00E+00	1.54E-01	1.88E-02
Iron	Adult	1.66E+02	1.79E+03	3.45E+01	1.42E+01	6.72E+02	1.27E+03	3.95E+03	5.58E+01
	Adolescent	1.66E+02	1.19E+03	3.24E+01	1.26E+01	6.56E+02	1.27E+03	3.33E+03	5.58E+01
	Child	1.66E+02	9.54E+02	3.01E+01	8.68E+00	5.10E+02	1.05E+03	2.72E+03	8.26E+01
	Toddler	6.65E+02	7.15E+02	1.72E+01	5.72E+00	3.43E+02	6.36E+02	2.38E+03	1.44E+02
	Infant	1.66E+02	3.58E+02	4.57E+00	3.87E+00	0.00E+00	0.00E+00	5.32E+02	6.49E+01
Lead	Adult	1.68E-01	3.00E-01	3.48E-02	1.44E-02	5.74E+00	4.16E-01	6.68E+00	9.44E-02
	Adolescent	1.68E-01	2.00E-01	3.27E-02	1.28E-02	5.64E+00	4.16E-01	6.47E+00	1.08E-01
	Child	1.68E-01	1.60E-01	3.04E-02	8.77E-03	4.37E+00	3.43E-01	5.08E+00	1.54E-01
	Toddler	6.71E-01	1.20E-01	1.74E-02	5.77E-03	2.94E+00	2.08E-01	3.96E+00	2.40E-01
	Infant	1.68E-01	6.00E-02	4.62E-03	3.91E-03	0.00E+00	0.00E+00	2.36E-01	2.88E-02
Vanadium	Adult	4.30E-01	7.50E-01	8.92E-02	3.68E-01	4.50E+00	0.00E+00	6.14E+00	8.68E-02
	Adolescent	4.30E-01	5.00E-01	8.38E-02	3.27E-01	4.46E+00	0.00E+00	5.80E+00	9.72E-02
	Child	4.30E-01	4.00E-01	7.79E-02	2.25E-01	3.44E+00	0.00E+00	4.57E+00	1.39E-01
	Toddler	1.72E+00	3.00E-01	4.46E-02	1.48E-01	2.31E+00	0.00E+00	4.52E+00	2.74E-01
	Infant	4.30E-01	1.50E-01	1.18E-02	1.00E-01	0.00E+00	0.00E+00	6.92E-01	8.43E-02

Table D-10	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R12								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.89E+02	6.05E+00	3.92E+01	1.62E+01	5.65E+02	0.00E+00	8.15E+02	1.15E+01
	Adolescent	1.89E+02	4.03E+00	3.68E+01	1.43E+01	5.44E+02	0.00E+00	7.88E+02	1.32E+01
	Child	1.89E+02	3.22E+00	3.42E+01	9.86E+00	4.25E+02	0.00E+00	6.61E+02	2.01E+01
	Toddler	7.55E+02	2.42E+00	1.96E+01	6.49E+00	2.87E+02	0.00E+00	1.07E+03	6.49E+01
	Infant	1.89E+02	1.21E+00	5.19E+00	4.40E+00	0.00E+00	0.00E+00	2.00E+02	2.43E+01
Arsenic	Adult	2.69E-02	1.95E+00	5.57E-03	6.90E-03	4.27E-01	1.01E+00	3.42E+00	4.84E-02
	Adolescent	2.69E-02	1.30E+00	5.24E-03	6.12E-03	4.42E-01	1.01E+00	2.79E+00	4.67E-02
	Child	2.69E-02	1.04E+00	4.87E-03	4.21E-03	3.34E-01	8.31E-01	2.24E+00	6.81E-02
	Toddler	1.07E-01	7.80E-01	2.79E-03	2.77E-03	2.23E-01	5.03E-01	1.62E+00	9.81E-02
	Infant	2.69E-02	3.90E-01	7.38E-04	1.88E-03	0.00E+00	0.00E+00	4.19E-01	5.12E-02
Cadmium	Adult	1.54E-02	6.90E-01	3.20E-03	1.32E-03	4.16E+00	5.52E-01	5.43E+00	7.67E-02
	Adolescent	1.54E-02	4.60E-01	3.00E-03	1.17E-03	4.05E+00	5.52E-01	5.08E+00	8.51E-02
	Child	1.54E-02	3.68E-01	2.79E-03	8.05E-04	3.15E+00	4.55E-01	3.99E+00	1.21E-01
	Toddler	6.16E-02	2.76E-01	1.60E-03	5.30E-04	2.12E+00	2.76E-01	2.74E+00	1.66E-01
	Infant	1.54E-02	1.38E-01	4.23E-04	3.59E-04	0.00E+00	0.00E+00	1.54E-01	1.88E-02
Iron	Adult	1.66E+02	1.79E+03	3.45E+01	1.42E+01	6.72E+02	1.27E+03	3.95E+03	5.58E+01
	Adolescent	1.66E+02	1.19E+03	3.24E+01	1.26E+01	6.56E+02	1.27E+03	3.33E+03	5.58E+01
	Child	1.66E+02	9.54E+02	3.01E+01	8.68E+00	5.10E+02	1.05E+03	2.72E+03	8.26E+01
	Toddler	6.65E+02	7.15E+02	1.72E+01	5.72E+00	3.43E+02	6.36E+02	2.38E+03	1.44E+02
	Infant	1.66E+02	3.58E+02	4.57E+00	3.87E+00	0.00E+00	0.00E+00	5.32E+02	6.49E+01
Lead	Adult	1.68E-01	3.00E-01	3.48E-02	1.44E-02	5.74E+00	4.16E-01	6.68E+00	9.44E-02
	Adolescent	1.68E-01	2.00E-01	3.27E-02	1.28E-02	5.64E+00	4.16E-01	6.47E+00	1.08E-01
	Child	1.68E-01	1.60E-01	3.04E-02	8.77E-03	4.37E+00	3.43E-01	5.08E+00	1.54E-01
	Toddler	6.71E-01	1.20E-01	1.74E-02	5.77E-03	2.94E+00	2.08E-01	3.96E+00	2.40E-01
	Infant	1.68E-01	6.00E-02	4.62E-03	3.91E-03	0.00E+00	0.00E+00	2.36E-01	2.88E-02
Vanadium	Adult	4.30E-01	7.50E-01	8.92E-02	3.68E-01	4.50E+00	0.00E+00	6.14E+00	8.68E-02
	Adolescent	4.30E-01	5.00E-01	8.38E-02	3.27E-01	4.46E+00	0.00E+00	5.80E+00	9.72E-02
	Child	4.30E-01	4.00E-01	7.79E-02	2.25E-01	3.44E+00	0.00E+00	4.57E+00	1.39E-01
	Toddler	1.72E+00	3.00E-01	4.46E-02	1.48E-01	2.31E+00	0.00E+00	4.52E+00	2.74E-01
	Infant	4.30E-01	1.50E-01	1.18E-02	1.00E-01	0.00E+00	0.00E+00	6.92E-01	8.43E-02

Table D-11	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R15								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.89E+02	6.05E+00	3.92E+01	1.62E+01	5.65E+02	0.00E+00	8.15E+02	1.15E+01
	Adolescent	1.89E+02	4.03E+00	3.68E+01	1.43E+01	5.44E+02	0.00E+00	7.88E+02	1.32E+01
	Child	1.89E+02	3.22E+00	3.42E+01	9.86E+00	4.25E+02	0.00E+00	6.61E+02	2.01E+01
	Toddler	7.55E+02	2.42E+00	1.96E+01	6.49E+00	2.87E+02	0.00E+00	1.07E+03	6.49E+01
	Infant	1.89E+02	1.21E+00	5.19E+00	4.40E+00	0.00E+00	0.00E+00	2.00E+02	2.43E+01
Arsenic	Adult	2.69E-02	1.95E+00	5.57E-03	6.90E-03	4.27E-01	1.01E+00	3.42E+00	4.84E-02
	Adolescent	2.69E-02	1.30E+00	5.24E-03	6.12E-03	4.42E-01	1.01E+00	2.79E+00	4.67E-02
	Child	2.69E-02	1.04E+00	4.87E-03	4.21E-03	3.34E-01	8.31E-01	2.24E+00	6.81E-02
	Toddler	1.07E-01	7.80E-01	2.79E-03	2.77E-03	2.23E-01	5.03E-01	1.62E+00	9.81E-02
	Infant	2.69E-02	3.90E-01	7.38E-04	1.88E-03	0.00E+00	0.00E+00	4.19E-01	5.12E-02
Cadmium	Adult	1.54E-02	6.90E-01	3.20E-03	1.32E-03	4.16E+00	5.52E-01	5.43E+00	7.67E-02
	Adolescent	1.54E-02	4.60E-01	3.00E-03	1.17E-03	4.05E+00	5.52E-01	5.08E+00	8.51E-02
	Child	1.54E-02	3.68E-01	2.79E-03	8.05E-04	3.15E+00	4.55E-01	3.99E+00	1.21E-01
	Toddler	6.16E-02	2.76E-01	1.60E-03	5.30E-04	2.12E+00	2.76E-01	2.74E+00	1.66E-01
	Infant	1.54E-02	1.38E-01	4.23E-04	3.59E-04	0.00E+00	0.00E+00	1.54E-01	1.88E-02
Iron	Adult	1.66E+02	1.79E+03	3.45E+01	1.42E+01	6.72E+02	1.27E+03	3.95E+03	5.58E+01
	Adolescent	1.66E+02	1.19E+03	3.24E+01	1.26E+01	6.56E+02	1.27E+03	3.33E+03	5.58E+01
	Child	1.66E+02	9.54E+02	3.01E+01	8.68E+00	5.10E+02	1.05E+03	2.72E+03	8.26E+01
	Toddler	6.65E+02	7.15E+02	1.72E+01	5.72E+00	3.43E+02	6.36E+02	2.38E+03	1.44E+02
	Infant	1.66E+02	3.58E+02	4.57E+00	3.87E+00	0.00E+00	0.00E+00	5.32E+02	6.49E+01
Lead	Adult	1.68E-01	3.00E-01	3.48E-02	1.44E-02	5.74E+00	4.16E-01	6.68E+00	9.44E-02
	Adolescent	1.68E-01	2.00E-01	3.27E-02	1.28E-02	5.64E+00	4.16E-01	6.47E+00	1.08E-01
	Child	1.68E-01	1.60E-01	3.04E-02	8.77E-03	4.37E+00	3.43E-01	5.08E+00	1.54E-01
	Toddler	6.71E-01	1.20E-01	1.74E-02	5.77E-03	2.94E+00	2.08E-01	3.96E+00	2.40E-01
	Infant	1.68E-01	6.00E-02	4.62E-03	3.91E-03	0.00E+00	0.00E+00	2.36E-01	2.88E-02
Vanadium	Adult	4.30E-01	7.50E-01	8.92E-02	3.68E-01	4.50E+00	0.00E+00	6.14E+00	8.68E-02
	Adolescent	4.30E-01	5.00E-01	8.38E-02	3.27E-01	4.46E+00	0.00E+00	5.80E+00	9.72E-02
	Child	4.30E-01	4.00E-01	7.79E-02	2.25E-01	3.44E+00	0.00E+00	4.57E+00	1.39E-01
	Toddler	1.72E+00	3.00E-01	4.46E-02	1.48E-01	2.31E+00	0.00E+00	4.52E+00	2.74E-01
	Infant	4.30E-01	1.50E-01	1.18E-02	1.00E-01	0.00E+00	0.00E+00	6.92E-01	8.43E-02

Table D-12	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R22								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.89E+02	6.05E+00	3.92E+01	1.62E+01	5.65E+02	0.00E+00	8.15E+02	1.15E+01
	Adolescent	1.89E+02	4.03E+00	3.68E+01	1.43E+01	5.44E+02	0.00E+00	7.88E+02	1.32E+01
	Child	1.89E+02	3.22E+00	3.42E+01	9.86E+00	4.25E+02	0.00E+00	6.61E+02	2.01E+01
	Toddler	7.55E+02	2.42E+00	1.96E+01	6.49E+00	2.87E+02	0.00E+00	1.07E+03	6.49E+01
	Infant	1.89E+02	1.21E+00	5.19E+00	4.40E+00	0.00E+00	0.00E+00	2.00E+02	2.43E+01
Arsenic	Adult	2.69E-02	1.95E+00	5.57E-03	6.90E-03	4.27E-01	1.01E+00	3.42E+00	4.84E-02
	Adolescent	2.69E-02	1.30E+00	5.24E-03	6.12E-03	4.42E-01	1.01E+00	2.79E+00	4.67E-02
	Child	2.69E-02	1.04E+00	4.87E-03	4.21E-03	3.34E-01	8.31E-01	2.24E+00	6.81E-02
	Toddler	1.07E-01	7.80E-01	2.79E-03	2.77E-03	2.23E-01	5.03E-01	1.62E+00	9.81E-02
	Infant	2.69E-02	3.90E-01	7.38E-04	1.88E-03	0.00E+00	0.00E+00	4.19E-01	5.12E-02
Cadmium	Adult	1.54E-02	6.90E-01	3.20E-03	1.32E-03	4.16E+00	5.52E-01	5.43E+00	7.67E-02
	Adolescent	1.54E-02	4.60E-01	3.00E-03	1.17E-03	4.05E+00	5.52E-01	5.08E+00	8.51E-02
	Child	1.54E-02	3.68E-01	2.79E-03	8.05E-04	3.15E+00	4.55E-01	3.99E+00	1.21E-01
	Toddler	6.16E-02	2.76E-01	1.60E-03	5.30E-04	2.12E+00	2.76E-01	2.74E+00	1.66E-01
	Infant	1.54E-02	1.38E-01	4.23E-04	3.59E-04	0.00E+00	0.00E+00	1.54E-01	1.88E-02
Iron	Adult	1.66E+02	1.79E+03	3.45E+01	1.42E+01	6.72E+02	1.27E+03	3.95E+03	5.58E+01
	Adolescent	1.66E+02	1.19E+03	3.24E+01	1.26E+01	6.56E+02	1.27E+03	3.33E+03	5.58E+01
	Child	1.66E+02	9.54E+02	3.01E+01	8.68E+00	5.10E+02	1.05E+03	2.72E+03	8.26E+01
	Toddler	6.65E+02	7.15E+02	1.72E+01	5.72E+00	3.43E+02	6.36E+02	2.38E+03	1.44E+02
	Infant	1.66E+02	3.58E+02	4.57E+00	3.87E+00	0.00E+00	0.00E+00	5.32E+02	6.49E+01
Lead	Adult	1.68E-01	3.00E-01	3.48E-02	1.44E-02	5.74E+00	6.68E+00	9.44E-02	1.57E-01
	Adolescent	1.68E-01	2.00E-01	3.27E-02	1.28E-02	5.64E+00	6.47E+00	1.08E-01	1.81E-01
	Child	1.68E-01	1.60E-01	3.04E-02	8.77E-03	4.37E+00	5.08E+00	1.54E-01	2.57E-01
	Toddler	6.71E-01	1.20E-01	1.74E-02	5.77E-03	2.94E+00	3.96E+00	2.40E-01	4.00E-01
	Infant	1.68E-01	6.00E-02	4.62E-03	3.91E-03	0.00E+00	2.36E-01	2.88E-02	4.80E-02
Vanadium	Adult	4.30E-01	7.50E-01	8.92E-02	3.68E-01	4.50E+00	0.00E+00	6.14E+00	8.68E-02
	Adolescent	4.30E-01	5.00E-01	8.38E-02	3.27E-01	4.46E+00	0.00E+00	5.80E+00	9.72E-02
	Child	4.30E-01	4.00E-01	7.79E-02	2.25E-01	3.44E+00	0.00E+00	4.57E+00	1.39E-01
	Toddler	1.72E+00	3.00E-01	4.46E-02	1.48E-01	2.31E+00	0.00E+00	4.52E+00	2.74E-01
	Infant	4.30E-01	1.50E-01	1.18E-02	1.00E-01	0.00E+00	0.00E+00	6.92E-01	8.43E-02

Table D-13	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R69								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	7.49E+02	6.05E+00	1.55E+02	6.41E+01	2.24E+03	0.00E+00	3.21E+03	4.55E+01
	Adolescent	7.49E+02	4.03E+00	1.46E+02	5.69E+01	2.16E+03	0.00E+00	3.12E+03	5.22E+01
	Child	7.49E+02	3.22E+00	1.36E+02	3.91E+01	1.69E+03	0.00E+00	2.61E+03	7.94E+01
	Toddler	3.00E+03	2.42E+00	7.77E+01	2.58E+01	1.14E+03	0.00E+00	4.24E+03	2.57E+02
	Infant	7.49E+02	1.21E+00	2.06E+01	1.75E+01	0.00E+00	0.00E+00	7.88E+02	9.61E+01
Arsenic	Adult	2.79E-01	1.95E+00	5.79E-02	7.16E-02	4.43E+00	1.01E+00	7.80E+00	1.10E-01
	Adolescent	2.79E-01	1.30E+00	5.44E-02	6.36E-02	4.59E+00	1.01E+00	7.29E+00	1.22E-01
	Child	2.79E-01	1.04E+00	5.05E-02	4.37E-02	3.47E+00	8.31E-01	5.72E+00	1.74E-01
	Toddler	1.12E+00	7.80E-01	2.89E-02	2.88E-02	2.32E+00	5.03E-01	4.77E+00	2.89E-01
	Infant	2.79E-01	3.90E-01	7.67E-03	1.95E-02	0.00E+00	0.00E+00	6.96E-01	8.49E-02
Cadmium	Adult	4.43E-02	6.90E-01	9.19E-03	3.79E-03	1.20E+01	5.52E-01	1.33E+01	1.88E-01
	Adolescent	4.43E-02	4.60E-01	8.63E-03	3.36E-03	1.16E+01	5.52E-01	1.27E+01	2.13E-01
	Child	4.43E-02	3.68E-01	8.02E-03	2.31E-03	9.05E+00	4.55E-01	9.93E+00	3.02E-01
	Toddler	1.77E-01	2.76E-01	4.59E-03	1.52E-03	6.09E+00	2.76E-01	6.83E+00	4.14E-01
	Infant	4.43E-02	1.38E-01	1.22E-03	1.03E-03	0.00E+00	0.00E+00	1.85E-01	2.25E-02
Iron	Adult	1.21E+03	1.79E+03	2.51E+02	1.04E+02	4.91E+03	1.27E+03	9.53E+03	1.35E+02
	Adolescent	1.21E+03	1.19E+03	2.36E+02	9.21E+01	4.79E+03	1.27E+03	8.79E+03	1.47E+02
	Child	1.21E+03	9.54E+02	2.20E+02	6.33E+01	3.72E+03	1.05E+03	7.22E+03	2.19E+02
	Toddler	4.85E+03	7.15E+02	1.26E+02	4.17E+01	2.50E+03	6.36E+02	8.87E+03	5.38E+02
	Infant	1.21E+03	3.58E+02	3.33E+01	2.82E+01	0.00E+00	0.00E+00	1.63E+03	1.99E+02
Lead	Adult	4.80E-01	3.00E-01	9.97E-02	4.11E-02	1.64E+01	4.16E-01	1.78E+01	2.51E-01
	Adolescent	4.80E-01	2.00E-01	9.37E-02	3.65E-02	1.61E+01	4.16E-01	1.74E+01	2.91E-01
	Child	4.80E-01	1.60E-01	8.71E-02	2.51E-02	1.25E+01	3.43E-01	1.36E+01	4.13E-01
	Toddler	1.92E+00	1.20E-01	4.98E-02	1.65E-02	8.40E+00	2.08E-01	1.07E+01	6.50E-01
	Infant	4.80E-01	6.00E-02	1.32E-02	1.12E-02	0.00E+00	0.00E+00	5.65E-01	6.89E-02
Vanadium	Adult	1.88E+00	7.50E-01	3.90E-01	1.61E+00	1.97E+01	0.00E+00	2.43E+01	3.44E-01
	Adolescent	1.88E+00	5.00E-01	3.67E-01	1.43E+00	1.95E+01	0.00E+00	2.37E+01	3.97E-01
	Child	1.88E+00	4.00E-01	3.41E-01	9.83E-01	1.51E+01	0.00E+00	1.87E+01	5.67E-01
	Toddler	7.52E+00	3.00E-01	1.95E-01	6.47E-01	1.01E+01	0.00E+00	1.88E+01	1.14E+00
	Infant	1.88E+00	1.50E-01	5.17E-02	4.38E-01	0.00E+00	0.00E+00	2.52E+00	3.07E-01

Table D-14	Multi-Pathway Exposure Estimates – Baseline Scenario - Receptor Location R70								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	7.49E+02	6.05E+00	1.55E+02	6.41E+01	2.24E+03	0.00E+00	3.21E+03	4.55E+01
	Adolescent	7.49E+02	4.03E+00	1.46E+02	5.69E+01	2.16E+03	0.00E+00	3.12E+03	5.22E+01
	Child	7.49E+02	3.22E+00	1.36E+02	3.91E+01	1.69E+03	0.00E+00	2.61E+03	7.94E+01
	Toddler	3.00E+03	2.42E+00	7.77E+01	2.58E+01	1.14E+03	0.00E+00	4.24E+03	2.57E+02
	Infant	7.49E+02	1.21E+00	2.06E+01	1.75E+01	0.00E+00	0.00E+00	7.88E+02	9.61E+01
Arsenic	Adult	2.79E-01	1.95E+00	5.79E-02	7.16E-02	4.43E+00	1.01E+00	7.80E+00	1.10E-01
	Adolescent	2.79E-01	1.30E+00	5.44E-02	6.36E-02	4.59E+00	1.01E+00	7.29E+00	1.22E-01
	Child	2.79E-01	1.04E+00	5.05E-02	4.37E-02	3.47E+00	8.31E-01	5.72E+00	1.74E-01
	Toddler	1.12E+00	7.80E-01	2.89E-02	2.88E-02	2.32E+00	5.03E-01	4.77E+00	2.89E-01
	Infant	2.79E-01	3.90E-01	7.67E-03	1.95E-02	0.00E+00	0.00E+00	6.96E-01	8.49E-02
Cadmium	Adult	4.43E-02	6.90E-01	9.19E-03	3.79E-03	1.20E+01	5.52E-01	1.33E+01	1.88E-01
	Adolescent	4.43E-02	4.60E-01	8.63E-03	3.36E-03	1.16E+01	5.52E-01	1.27E+01	2.13E-01
	Child	4.43E-02	3.68E-01	8.02E-03	2.31E-03	9.05E+00	4.55E-01	9.93E+00	3.02E-01
	Toddler	1.77E-01	2.76E-01	4.59E-03	1.52E-03	6.09E+00	2.76E-01	6.83E+00	4.14E-01
	Infant	4.43E-02	1.38E-01	1.22E-03	1.03E-03	0.00E+00	0.00E+00	1.85E-01	2.25E-02
Iron	Adult	1.21E+03	1.79E+03	2.51E+02	1.04E+02	4.91E+03	1.27E+03	9.53E+03	1.35E+02
	Adolescent	1.21E+03	1.19E+03	2.36E+02	9.21E+01	4.79E+03	1.27E+03	8.79E+03	1.47E+02
	Child	1.21E+03	9.54E+02	2.20E+02	6.33E+01	3.72E+03	1.05E+03	7.22E+03	2.19E+02
	Toddler	4.85E+03	7.15E+02	1.26E+02	4.17E+01	2.50E+03	6.36E+02	8.87E+03	5.38E+02
	Infant	1.21E+03	3.58E+02	3.33E+01	2.82E+01	0.00E+00	0.00E+00	1.63E+03	1.99E+02
Lead	Adult	4.80E-01	3.00E-01	9.97E-02	4.11E-02	1.64E+01	4.16E-01	1.78E+01	2.51E-01
	Adolescent	4.80E-01	2.00E-01	9.37E-02	3.65E-02	1.61E+01	4.16E-01	1.74E+01	2.91E-01
	Child	4.80E-01	1.60E-01	8.71E-02	2.51E-02	1.25E+01	3.43E-01	1.36E+01	4.13E-01
	Toddler	1.92E+00	1.20E-01	4.98E-02	1.65E-02	8.40E+00	2.08E-01	1.07E+01	6.50E-01
	Infant	4.80E-01	6.00E-02	1.32E-02	1.12E-02	0.00E+00	0.00E+00	5.65E-01	6.89E-02
Vanadium	Adult	1.88E+00	7.50E-01	3.90E-01	1.61E+00	1.97E+01	0.00E+00	2.43E+01	3.44E-01
	Adolescent	1.88E+00	5.00E-01	3.67E-01	1.43E+00	1.95E+01	0.00E+00	2.37E+01	3.97E-01
	Child	1.88E+00	4.00E-01	3.41E-01	9.83E-01	1.51E+01	0.00E+00	1.87E+01	5.67E-01
	Toddler	7.52E+00	3.00E-01	1.95E-01	6.47E-01	1.01E+01	0.00E+00	1.88E+01	1.14E+00
	Infant	1.88E+00	1.50E-01	5.17E-02	4.38E-01	0.00E+00	0.00E+00	2.52E+00	3.07E-01

Table D-15	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R2								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	2.87E+01	0.00E+00	5.95E+00	2.45E+00	3.29E+02	0.00E+00	3.66E+02	5.18E+00
	Adolescent	2.87E+01	0.00E+00	5.59E+00	2.18E+00	2.89E+02	0.00E+00	3.26E+02	5.45E+00
	Child	2.87E+01	0.00E+00	5.20E+00	1.50E+00	2.36E+02	0.00E+00	2.71E+02	8.24E+00
	Toddler	1.15E+02	0.00E+00	2.97E+00	9.86E-01	1.61E+02	0.00E+00	2.80E+02	1.70E+01
	Infant	2.87E+01	0.00E+00	7.88E-01	6.68E-01	0.00E+00	0.00E+00	3.01E+01	3.67E+00
Arsenic	Adult	6.06E-03	0.00E+00	1.26E-03	1.56E-03	6.25E-02	0.00E+00	7.14E-02	1.01E-03
	Adolescent	6.06E-03	0.00E+00	1.18E-03	1.38E-03	5.63E-02	0.00E+00	6.49E-02	1.09E-03
	Child	6.06E-03	0.00E+00	1.10E-03	9.51E-04	4.54E-02	0.00E+00	5.35E-02	1.63E-03
	Toddler	2.43E-02	0.00E+00	6.29E-04	6.26E-04	3.09E-02	0.00E+00	5.64E-02	3.42E-03
	Infant	6.06E-03	0.00E+00	1.67E-04	4.24E-04	0.00E+00	0.00E+00	6.66E-03	8.12E-04
Cadmium	Adult	5.83E-04	0.00E+00	1.21E-04	4.99E-05	2.23E-02	0.00E+00	2.31E-02	3.26E-04
	Adolescent	5.83E-04	0.00E+00	1.14E-04	4.43E-05	2.10E-02	0.00E+00	2.18E-02	3.65E-04
	Child	5.83E-04	0.00E+00	1.06E-04	3.05E-05	1.66E-02	0.00E+00	1.73E-02	5.26E-04
	Toddler	2.33E-03	0.00E+00	6.05E-05	2.01E-05	1.12E-02	0.00E+00	1.36E-02	8.26E-04
	Infant	5.83E-04	0.00E+00	1.60E-05	1.36E-05	0.00E+00	0.00E+00	6.13E-04	7.48E-05
Iron	Adult	2.25E+01	0.00E+00	4.68E+00	1.93E+00	2.61E+02	0.00E+00	2.90E+02	4.11E+00
	Adolescent	2.25E+01	0.00E+00	4.40E+00	1.71E+00	2.30E+02	0.00E+00	2.58E+02	4.33E+00
	Child	2.25E+01	0.00E+00	4.09E+00	1.18E+00	1.87E+02	0.00E+00	2.15E+02	6.54E+00
	Toddler	9.02E+01	0.00E+00	2.34E+00	7.76E-01	1.28E+02	0.00E+00	2.21E+02	1.34E+01
	Infant	2.25E+01	0.00E+00	6.20E-01	5.25E-01	0.00E+00	0.00E+00	2.37E+01	2.89E+00
Lead	Adult	7.77E-03	0.00E+00	1.61E-03	6.65E-04	1.14E-01	0.00E+00	1.24E-01	1.75E-03
	Adolescent	7.77E-03	0.00E+00	1.52E-03	5.91E-04	1.02E-01	0.00E+00	1.12E-01	1.88E-03
	Child	7.77E-03	0.00E+00	1.41E-03	4.06E-04	8.24E-02	0.00E+00	9.20E-02	2.80E-03
	Toddler	3.11E-02	0.00E+00	8.06E-04	2.67E-04	5.61E-02	0.00E+00	8.83E-02	5.35E-03
	Infant	7.77E-03	0.00E+00	2.14E-04	1.81E-04	0.00E+00	0.00E+00	8.17E-03	9.96E-04
Vanadium	Adult	5.58E-02	0.00E+00	1.16E-02	4.78E-02	6.82E-01	0.00E+00	7.98E-01	1.13E-02
	Adolescent	5.58E-02	0.00E+00	1.09E-02	4.24E-02	6.05E-01	0.00E+00	7.14E-01	1.20E-02
	Child	5.58E-02	0.00E+00	1.01E-02	2.92E-02	4.91E-01	0.00E+00	5.86E-01	1.78E-02
	Toddler	2.23E-01	0.00E+00	5.79E-03	1.92E-02	3.35E-01	0.00E+00	5.83E-01	3.54E-02
	Infant	5.58E-02	0.00E+00	1.53E-03	1.30E-02	0.00E+00	0.00E+00	7.03E-02	8.58E-03

Table D-16	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R9								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.82E+01	0.00E+00	3.77E+00	1.55E+00	2.09E+02	0.00E+00	2.32E+02	3.28E+00
	Adolescent	1.82E+01	0.00E+00	3.54E+00	1.38E+00	1.83E+02	0.00E+00	2.06E+02	3.45E+00
	Child	1.82E+01	0.00E+00	3.29E+00	9.49E-01	1.49E+02	0.00E+00	1.72E+02	5.22E+00
	Toddler	7.27E+01	0.00E+00	1.88E+00	6.25E-01	1.02E+02	0.00E+00	1.77E+02	1.07E+01
	Infant	1.82E+01	0.00E+00	4.99E-01	4.23E-01	0.00E+00	0.00E+00	1.91E+01	2.33E+00
Arsenic	Adult	3.84E-03	0.00E+00	7.97E-04	9.87E-04	3.96E-02	0.00E+00	4.53E-02	6.40E-04
	Adolescent	3.84E-03	0.00E+00	7.49E-04	8.76E-04	3.57E-02	0.00E+00	4.11E-02	6.89E-04
	Child	3.84E-03	0.00E+00	6.96E-04	6.02E-04	2.88E-02	0.00E+00	3.39E-02	1.03E-03
	Toddler	1.54E-02	0.00E+00	3.99E-04	3.96E-04	1.96E-02	0.00E+00	3.57E-02	2.17E-03
	Infant	3.84E-03	0.00E+00	1.06E-04	2.69E-04	0.00E+00	0.00E+00	4.22E-03	5.14E-04
Cadmium	Adult	3.70E-04	0.00E+00	7.67E-05	3.16E-05	1.41E-02	0.00E+00	1.46E-02	2.07E-04
	Adolescent	3.70E-04	0.00E+00	7.21E-05	2.81E-05	1.33E-02	0.00E+00	1.38E-02	2.31E-04
	Child	3.70E-04	0.00E+00	6.70E-05	1.93E-05	1.05E-02	0.00E+00	1.10E-02	3.33E-04
	Toddler	1.48E-03	0.00E+00	3.83E-05	1.27E-05	7.11E-03	0.00E+00	8.64E-03	5.24E-04
	Infant	3.70E-04	0.00E+00	1.02E-05	8.61E-06	0.00E+00	0.00E+00	3.88E-04	4.74E-05
Iron	Adult	1.43E+01	0.00E+00	2.96E+00	1.22E+00	1.66E+02	0.00E+00	1.84E+02	2.60E+00
	Adolescent	1.43E+01	0.00E+00	2.79E+00	1.09E+00	1.46E+02	0.00E+00	1.64E+02	2.74E+00
	Child	1.43E+01	0.00E+00	2.59E+00	7.46E-01	1.19E+02	0.00E+00	1.36E+02	4.14E+00
	Toddler	5.71E+01	0.00E+00	1.48E+00	4.91E-01	8.11E+01	0.00E+00	1.40E+02	8.50E+00
	Infant	1.43E+01	0.00E+00	3.93E-01	3.33E-01	0.00E+00	0.00E+00	1.50E+01	1.83E+00
Lead	Adult	4.92E-03	0.00E+00	1.02E-03	4.21E-04	7.19E-02	0.00E+00	7.83E-02	1.11E-03
	Adolescent	4.92E-03	0.00E+00	9.60E-04	3.74E-04	6.48E-02	0.00E+00	7.10E-02	1.19E-03
	Child	4.92E-03	0.00E+00	8.92E-04	2.57E-04	5.22E-02	0.00E+00	5.83E-02	1.77E-03
	Toddler	1.97E-02	0.00E+00	5.11E-04	1.69E-04	3.55E-02	0.00E+00	5.59E-02	3.39E-03
	Infant	4.92E-03	0.00E+00	1.35E-04	1.15E-04	0.00E+00	0.00E+00	5.17E-03	6.31E-04
Vanadium	Adult	3.53E-02	0.00E+00	7.33E-03	3.03E-02	4.32E-01	0.00E+00	5.05E-01	7.15E-03
	Adolescent	3.53E-02	0.00E+00	6.89E-03	2.69E-02	3.83E-01	0.00E+00	4.52E-01	7.57E-03
	Child	3.53E-02	0.00E+00	6.41E-03	1.85E-02	3.11E-01	0.00E+00	3.71E-01	1.13E-02
	Toddler	1.41E-01	0.00E+00	3.67E-03	1.22E-02	2.12E-01	0.00E+00	3.70E-01	2.24E-02
	Infant	3.53E-02	0.00E+00	9.72E-04	8.24E-03	0.00E+00	0.00E+00	4.46E-02	5.43E-03

Table D-17	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R12								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.60E+01	0.00E+00	3.31E+00	1.37E+00	1.83E+02	0.00E+00	2.04E+02	2.89E+00
	Adolescent	1.60E+01	0.00E+00	3.11E+00	1.21E+00	1.61E+02	0.00E+00	1.81E+02	3.04E+00
	Child	1.60E+01	0.00E+00	2.89E+00	8.34E-01	1.31E+02	0.00E+00	1.51E+02	4.59E+00
	Toddler	6.39E+01	0.00E+00	1.66E+00	5.49E-01	8.98E+01	0.00E+00	1.56E+02	9.45E+00
	Infant	1.60E+01	0.00E+00	4.39E-01	3.72E-01	0.00E+00	0.00E+00	1.68E+01	2.05E+00
Arsenic	Adult	3.38E-03	0.00E+00	7.01E-04	8.67E-04	3.48E-02	0.00E+00	3.98E-02	5.63E-04
	Adolescent	3.38E-03	0.00E+00	6.59E-04	7.70E-04	3.14E-02	0.00E+00	3.62E-02	6.06E-04
	Child	3.38E-03	0.00E+00	6.12E-04	5.29E-04	2.53E-02	0.00E+00	2.98E-02	9.06E-04
	Toddler	1.35E-02	0.00E+00	3.50E-04	3.49E-04	1.72E-02	0.00E+00	3.14E-02	1.90E-03
	Infant	3.38E-03	0.00E+00	9.29E-05	2.36E-04	0.00E+00	0.00E+00	3.71E-03	4.52E-04
Cadmium	Adult	7.68E-02	0.00E+00	1.59E-02	6.57E-02	9.75E-01	0.00E+00	1.13E+00	1.60E-02
	Adolescent	7.68E-02	0.00E+00	1.50E-02	5.84E-02	8.68E-01	0.00E+00	1.02E+00	1.71E-02
	Child	7.68E-02	0.00E+00	1.39E-02	4.01E-02	7.04E-01	0.00E+00	8.34E-01	2.54E-02
	Toddler	3.07E-01	0.00E+00	7.97E-03	2.64E-02	4.80E-01	0.00E+00	8.22E-01	4.98E-02
	Infant	7.68E-02	0.00E+00	2.11E-03	1.79E-02	0.00E+00	0.00E+00	9.68E-02	1.18E-02
Iron	Adult	1.26E+01	0.00E+00	2.61E+00	1.08E+00	1.46E+02	0.00E+00	1.62E+02	2.29E+00
	Adolescent	1.26E+01	0.00E+00	2.45E+00	9.55E-01	1.28E+02	0.00E+00	1.44E+02	2.41E+00
	Child	1.26E+01	0.00E+00	2.28E+00	6.56E-01	1.04E+02	0.00E+00	1.20E+02	3.64E+00
	Toddler	5.02E+01	0.00E+00	1.30E+00	4.32E-01	7.13E+01	0.00E+00	1.23E+02	7.47E+00
	Infant	1.26E+01	0.00E+00	3.45E-01	2.93E-01	0.00E+00	0.00E+00	1.32E+01	1.61E+00
Lead	Adult	4.33E-03	0.00E+00	8.98E-04	3.71E-04	6.32E-02	0.00E+00	6.88E-02	9.73E-04
	Adolescent	4.33E-03	0.00E+00	8.44E-04	3.29E-04	5.70E-02	0.00E+00	6.25E-02	1.05E-03
	Child	4.33E-03	0.00E+00	7.85E-04	2.26E-04	4.59E-02	0.00E+00	5.12E-02	1.56E-03
	Toddler	1.73E-02	0.00E+00	4.49E-04	1.49E-04	3.13E-02	0.00E+00	4.92E-02	2.98E-03
	Infant	4.33E-03	0.00E+00	1.19E-04	1.01E-04	0.00E+00	0.00E+00	4.55E-03	5.55E-04
Vanadium	Adult	3.11E-02	0.00E+00	6.45E-03	2.66E-02	3.80E-01	0.00E+00	4.44E-01	6.28E-03
	Adolescent	3.11E-02	0.00E+00	6.06E-03	2.36E-02	3.37E-01	0.00E+00	3.97E-01	6.66E-03
	Child	3.11E-02	0.00E+00	5.63E-03	1.62E-02	2.74E-01	0.00E+00	3.26E-01	9.92E-03
	Toddler	1.24E-01	0.00E+00	3.22E-03	1.07E-02	1.87E-01	0.00E+00	3.25E-01	1.97E-02
	Infant	3.11E-02	0.00E+00	8.55E-04	7.24E-03	0.00E+00	0.00E+00	3.92E-02	4.78E-03

Table D-18	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R15								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	1.93E+01	0.00E+00	4.01E+00	1.65E+00	2.22E+02	0.00E+00	2.47E+02	3.49E+00
	Adolescent	1.93E+01	0.00E+00	3.77E+00	1.47E+00	1.95E+02	0.00E+00	2.19E+02	3.68E+00
	Child	1.93E+01	0.00E+00	3.50E+00	1.01E+00	1.59E+02	0.00E+00	1.83E+02	5.56E+00
	Toddler	7.73E+01	0.00E+00	2.00E+00	6.65E-01	1.09E+02	0.00E+00	1.89E+02	1.14E+01
	Infant	1.93E+01	0.00E+00	5.31E-01	4.50E-01	0.00E+00	0.00E+00	2.03E+01	2.48E+00
Arsenic	Adult	4.09E-03	0.00E+00	8.48E-04	1.05E-03	4.22E-02	0.00E+00	4.81E-02	6.81E-04
	Adolescent	4.09E-03	0.00E+00	7.97E-04	9.32E-04	3.80E-02	0.00E+00	4.38E-02	7.33E-04
	Child	4.09E-03	0.00E+00	7.41E-04	6.41E-04	3.06E-02	0.00E+00	3.61E-02	1.10E-03
	Toddler	1.64E-02	0.00E+00	4.24E-04	4.22E-04	2.08E-02	0.00E+00	3.80E-02	2.31E-03
	Infant	4.09E-03	0.00E+00	1.12E-04	2.86E-04	0.00E+00	0.00E+00	4.49E-03	5.47E-04
Cadmium	Adult	3.93E-04	0.00E+00	8.16E-05	3.37E-05	1.50E-02	0.00E+00	1.55E-02	2.20E-04
	Adolescent	3.93E-04	0.00E+00	7.67E-05	2.99E-05	1.42E-02	0.00E+00	1.47E-02	2.46E-04
	Child	3.93E-04	0.00E+00	7.13E-05	2.05E-05	1.12E-02	0.00E+00	1.17E-02	3.55E-04
	Toddler	1.57E-03	0.00E+00	4.08E-05	1.35E-05	7.56E-03	0.00E+00	9.19E-03	5.57E-04
	Infant	3.93E-04	0.00E+00	1.08E-05	9.16E-06	0.00E+00	0.00E+00	4.13E-04	5.04E-05
Iron	Adult	1.52E+01	0.00E+00	3.15E+00	1.30E+00	1.76E+02	0.00E+00	1.96E+02	2.77E+00
	Adolescent	1.52E+01	0.00E+00	2.96E+00	1.16E+00	1.55E+02	0.00E+00	1.74E+02	2.92E+00
	Child	1.52E+01	0.00E+00	2.75E+00	7.94E-01	1.26E+02	0.00E+00	1.45E+02	4.41E+00
	Toddler	6.08E+01	0.00E+00	1.58E+00	5.23E-01	8.63E+01	0.00E+00	1.49E+02	9.04E+00
	Infant	1.52E+01	0.00E+00	4.18E-01	3.54E-01	0.00E+00	0.00E+00	1.60E+01	1.95E+00
Lead	Adult	5.24E-03	0.00E+00	1.09E-03	4.48E-04	7.65E-02	0.00E+00	8.33E-02	1.18E-03
	Adolescent	5.24E-03	0.00E+00	1.02E-03	3.98E-04	6.89E-02	0.00E+00	7.56E-02	1.27E-03
	Child	5.24E-03	0.00E+00	9.50E-04	2.74E-04	5.55E-02	0.00E+00	6.20E-02	1.88E-03
	Toddler	2.10E-02	0.00E+00	5.44E-04	1.80E-04	3.78E-02	0.00E+00	5.95E-02	3.61E-03
	Infant	5.24E-03	0.00E+00	1.44E-04	1.22E-04	0.00E+00	0.00E+00	5.50E-03	6.71E-04
Vanadium	Adult	3.76E-02	0.00E+00	7.80E-03	3.22E-02	4.60E-01	0.00E+00	5.38E-01	7.60E-03
	Adolescent	3.76E-02	0.00E+00	7.33E-03	2.86E-02	4.07E-01	0.00E+00	4.81E-01	8.06E-03
	Child	3.76E-02	0.00E+00	6.82E-03	1.97E-02	3.31E-01	0.00E+00	3.95E-01	1.20E-02
	Toddler	1.50E-01	0.00E+00	3.90E-03	1.29E-02	2.26E-01	0.00E+00	3.93E-01	2.38E-02
	Infant	3.76E-02	0.00E+00	1.03E-03	8.76E-03	0.00E+00	0.00E+00	4.74E-02	5.78E-03

Table D-19	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R22								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	7.74E+00	0.00E+00	1.61E+00	6.63E-01	8.89E+01	0.00E+00	9.89E+01	1.40E+00
	Adolescent	7.74E+00	0.00E+00	1.51E+00	5.88E-01	7.81E+01	0.00E+00	8.79E+01	1.47E+00
	Child	7.74E+00	0.00E+00	1.40E+00	4.05E-01	6.37E+01	0.00E+00	7.32E+01	2.23E+00
	Toddler	3.10E+01	0.00E+00	8.03E-01	2.66E-01	4.35E+01	0.00E+00	7.56E+01	4.58E+00
	Infant	7.74E+00	0.00E+00	2.13E-01	1.80E-01	0.00E+00	0.00E+00	8.14E+00	9.92E-01
Arsenic	Adult	1.64E-03	0.00E+00	3.40E-04	4.21E-04	1.69E-02	0.00E+00	1.93E-02	2.73E-04
	Adolescent	1.64E-03	0.00E+00	3.19E-04	3.73E-04	1.52E-02	0.00E+00	1.75E-02	2.94E-04
	Child	1.64E-03	0.00E+00	2.97E-04	2.57E-04	1.23E-02	0.00E+00	1.45E-02	4.39E-04
	Toddler	6.55E-03	0.00E+00	1.70E-04	1.69E-04	8.35E-03	0.00E+00	1.52E-02	9.24E-04
	Infant	1.64E-03	0.00E+00	4.50E-05	1.14E-04	0.00E+00	0.00E+00	1.80E-03	2.19E-04
Cadmium	Adult	1.58E-04	0.00E+00	3.27E-05	1.35E-05	6.02E-03	0.00E+00	6.23E-03	8.81E-05
	Adolescent	1.58E-04	0.00E+00	3.07E-05	1.20E-05	5.68E-03	0.00E+00	5.88E-03	9.86E-05
	Child	1.58E-04	0.00E+00	2.86E-05	8.23E-06	4.48E-03	0.00E+00	4.68E-03	1.42E-04
	Toddler	6.30E-04	0.00E+00	1.63E-05	5.42E-06	3.03E-03	0.00E+00	3.68E-03	2.23E-04
	Infant	1.58E-04	0.00E+00	4.33E-06	3.67E-06	0.00E+00	0.00E+00	1.66E-04	2.02E-05
Iron	Adult	6.09E+00	0.00E+00	1.26E+00	5.21E-01	7.06E+01	0.00E+00	7.84E+01	1.11E+00
	Adolescent	6.09E+00	0.00E+00	1.19E+00	4.63E-01	6.21E+01	0.00E+00	6.98E+01	1.17E+00
	Child	6.09E+00	0.00E+00	1.10E+00	3.18E-01	5.06E+01	0.00E+00	5.81E+01	1.77E+00
	Toddler	2.44E+01	0.00E+00	6.32E-01	2.09E-01	3.46E+01	0.00E+00	5.98E+01	3.62E+00
	Infant	6.09E+00	0.00E+00	1.67E-01	1.42E-01	0.00E+00	0.00E+00	6.40E+00	7.80E-01
Lead	Adult	2.10E-03	0.00E+00	4.36E-04	1.80E-04	3.07E-02	0.00E+00	3.34E-02	4.72E-04
	Adolescent	2.10E-03	0.00E+00	4.09E-04	1.60E-04	2.76E-02	0.00E+00	3.03E-02	5.07E-04
	Child	2.10E-03	0.00E+00	3.80E-04	1.10E-04	2.23E-02	0.00E+00	2.48E-02	7.55E-04
	Toddler	8.40E-03	0.00E+00	2.18E-04	7.22E-05	1.52E-02	0.00E+00	2.38E-02	1.44E-03
	Infant	2.10E-03	0.00E+00	5.77E-05	4.89E-05	0.00E+00	0.00E+00	2.21E-03	2.69E-04
Vanadium	Adult	1.51E-02	0.00E+00	3.13E-03	1.29E-02	1.84E-01	0.00E+00	2.15E-01	3.05E-03
	Adolescent	1.51E-02	0.00E+00	2.94E-03	1.15E-02	1.63E-01	0.00E+00	1.93E-01	3.23E-03
	Child	1.51E-02	0.00E+00	2.73E-03	7.87E-03	1.33E-01	0.00E+00	1.58E-01	4.81E-03
	Toddler	6.03E-02	0.00E+00	1.56E-03	5.18E-03	9.05E-02	0.00E+00	1.58E-01	9.55E-03
	Infant	1.51E-02	0.00E+00	4.14E-04	3.51E-03	0.00E+00	0.00E+00	1.90E-02	2.32E-03

Table D-20	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R69								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	5.37E-02	0.00E+00	1.11E-02	4.60E-03	6.17E-01	0.00E+00	6.86E-01	9.70E-03
	Adolescent	5.37E-02	0.00E+00	1.05E-02	4.08E-03	5.42E-01	0.00E+00	6.10E-01	1.02E-02
	Child	5.37E-02	0.00E+00	9.73E-03	2.81E-03	4.42E-01	0.00E+00	5.08E-01	1.54E-02
	Toddler	2.15E-01	0.00E+00	5.57E-03	1.85E-03	3.02E-01	0.00E+00	5.24E-01	3.18E-02
	Infant	5.37E-02	0.00E+00	1.48E-03	1.25E-03	0.00E+00	0.00E+00	5.64E-02	6.88E-03
Arsenic	Adult	4.74E-05	0.00E+00	9.83E-06	1.22E-05	4.89E-04	0.00E+00	5.58E-04	7.89E-06
	Adolescent	4.74E-05	0.00E+00	9.24E-06	1.08E-05	4.40E-04	0.00E+00	5.07E-04	8.50E-06
	Child	4.74E-05	0.00E+00	8.59E-06	7.43E-06	3.55E-04	0.00E+00	4.18E-04	1.27E-05
	Toddler	1.90E-04	0.00E+00	4.92E-06	4.89E-06	2.42E-04	0.00E+00	4.41E-04	2.67E-05
	Infant	4.74E-05	0.00E+00	1.30E-06	3.31E-06	0.00E+00	0.00E+00	5.20E-05	6.34E-06
Cadmium	Adult	2.75E-04	0.00E+00	5.70E-05	2.35E-05	1.05E-02	0.00E+00	1.09E-02	1.54E-04
	Adolescent	2.75E-04	0.00E+00	5.36E-05	2.09E-05	9.91E-03	0.00E+00	1.03E-02	1.72E-04
	Child	2.75E-04	0.00E+00	4.98E-05	1.44E-05	7.82E-03	0.00E+00	8.16E-03	2.48E-04
	Toddler	1.10E-03	0.00E+00	2.85E-05	9.45E-06	5.29E-03	0.00E+00	6.42E-03	3.89E-04
	Infant	2.75E-04	0.00E+00	7.56E-06	6.40E-06	0.00E+00	0.00E+00	2.89E-04	3.52E-05
Iron	Adult	4.74E-01	0.00E+00	9.83E-02	4.06E-02	5.49E+00	0.00E+00	6.10E+00	8.63E-02
	Adolescent	4.74E-01	0.00E+00	9.24E-02	3.60E-02	4.83E+00	0.00E+00	5.43E+00	9.10E-02
	Child	4.74E-01	0.00E+00	8.59E-02	2.48E-02	3.94E+00	0.00E+00	4.52E+00	1.37E-01
	Toddler	1.90E+00	0.00E+00	4.92E-02	1.63E-02	2.69E+00	0.00E+00	4.65E+00	2.82E-01
	Infant	4.74E-01	0.00E+00	1.30E-02	1.10E-02	0.00E+00	0.00E+00	4.98E-01	6.07E-02
Lead	Adult	7.27E-05	0.00E+00	1.51E-05	6.22E-06	1.06E-03	0.00E+00	1.16E-03	1.63E-05
	Adolescent	7.27E-05	0.00E+00	1.42E-05	5.52E-06	9.56E-04	0.00E+00	1.05E-03	1.76E-05
	Child	7.27E-05	0.00E+00	1.32E-05	3.80E-06	7.70E-04	0.00E+00	8.60E-04	2.61E-05
	Toddler	2.91E-04	0.00E+00	7.54E-06	2.50E-06	5.25E-04	0.00E+00	8.25E-04	5.00E-05
	Infant	7.27E-05	0.00E+00	2.00E-06	1.69E-06	0.00E+00	0.00E+00	7.63E-05	9.31E-06
Vanadium	Adult	4.11E-03	0.00E+00	8.52E-04	3.52E-03	5.02E-02	0.00E+00	5.87E-02	8.30E-04
	Adolescent	4.11E-03	0.00E+00	8.01E-04	3.12E-03	4.45E-02	0.00E+00	5.25E-02	8.80E-04
	Child	4.11E-03	0.00E+00	7.44E-04	2.15E-03	3.61E-02	0.00E+00	4.31E-02	1.31E-03
	Toddler	1.64E-02	0.00E+00	4.26E-04	1.41E-03	2.47E-02	0.00E+00	4.29E-02	2.60E-03
	Infant	4.11E-03	0.00E+00	1.13E-04	9.57E-04	0.00E+00	0.00E+00	5.18E-03	6.31E-04

Table D-21	Multi-Pathway Exposure Estimates – Project Alone Scenario - Receptor Location R70								
Chemical of Potential Concern	***Receptor Group***	**Soil Ingestion**	**Groundwater Ingestion**	**Dust Ingestion**	***Dermal Contact***	***Produce Ingestion***	***Fish Ingestion***	***Total Estimated Daily Intake***	
		µg/day	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/day***	***µg/kg/day***
Aluminum	Adult	5.47E-02	0.00E+00	1.14E-02	4.69E-03	6.29E-01	0.00E+00	6.99E-01	9.89E-03
	Adolescent	5.47E-02	0.00E+00	1.07E-02	4.16E-03	5.52E-01	0.00E+00	6.22E-01	1.04E-02
	Child	5.47E-02	0.00E+00	9.92E-03	2.86E-03	4.50E-01	0.00E+00	5.18E-01	1.57E-02
	Toddler	2.19E-01	0.00E+00	5.68E-03	1.88E-03	3.08E-01	0.00E+00	5.34E-01	3.24E-02
	Infant	5.47E-02	0.00E+00	1.51E-03	1.28E-03	0.00E+00	0.00E+00	5.75E-02	7.02E-03
Arsenic	Adult	4.83E-05	0.00E+00	1.00E-05	1.24E-05	4.98E-04	0.00E+00	5.69E-04	8.05E-06
	Adolescent	4.83E-05	0.00E+00	9.42E-06	1.10E-05	4.49E-04	0.00E+00	5.17E-04	8.67E-06
	Child	4.83E-05	0.00E+00	8.75E-06	7.57E-06	3.62E-04	0.00E+00	4.26E-04	1.30E-05
	Toddler	1.93E-04	0.00E+00	5.01E-06	4.98E-06	2.46E-04	0.00E+00	4.49E-04	2.72E-05
	Infant	4.83E-05	0.00E+00	1.33E-06	3.38E-06	0.00E+00	0.00E+00	5.30E-05	6.46E-06
Cadmium	Adult	2.80E-04	0.00E+00	5.81E-05	2.40E-05	1.07E-02	0.00E+00	1.11E-02	1.57E-04
	Adolescent	2.80E-04	0.00E+00	5.46E-05	2.13E-05	1.01E-02	0.00E+00	1.05E-02	1.75E-04
	Child	2.80E-04	0.00E+00	5.08E-05	1.46E-05	7.97E-03	0.00E+00	8.31E-03	2.53E-04
	Toddler	1.12E-03	0.00E+00	2.91E-05	9.64E-06	5.39E-03	0.00E+00	6.55E-03	3.97E-04
	Infant	2.80E-04	0.00E+00	7.70E-06	6.53E-06	0.00E+00	0.00E+00	2.94E-04	3.59E-05
Iron	Adult	4.83E-01	0.00E+00	1.00E-01	4.13E-02	5.60E+00	0.00E+00	6.22E+00	8.80E-02
	Adolescent	4.83E-01	0.00E+00	9.42E-02	3.67E-02	4.92E+00	0.00E+00	5.54E+00	9.27E-02
	Child	4.83E-01	0.00E+00	8.75E-02	2.52E-02	4.01E+00	0.00E+00	4.61E+00	1.40E-01
	Toddler	1.93E+00	0.00E+00	5.01E-02	1.66E-02	2.74E+00	0.00E+00	4.74E+00	2.87E-01
	Infant	4.83E-01	0.00E+00	1.33E-02	1.13E-02	0.00E+00	0.00E+00	5.08E-01	6.19E-02
Lead	Adult	7.41E-05	0.00E+00	1.54E-05	6.34E-06	1.08E-03	0.00E+00	1.18E-03	1.67E-05
	Adolescent	7.41E-05	0.00E+00	1.44E-05	5.63E-06	9.75E-04	0.00E+00	1.07E-03	1.79E-05
	Child	7.41E-05	0.00E+00	1.34E-05	3.87E-06	7.85E-04	0.00E+00	8.77E-04	2.66E-05
	Toddler	2.96E-04	0.00E+00	7.68E-06	2.55E-06	5.35E-04	0.00E+00	8.41E-04	5.10E-05
	Infant	7.41E-05	0.00E+00	2.04E-06	1.73E-06	0.00E+00	0.00E+00	7.78E-05	9.49E-06
Vanadium	Adult	4.19E-03	0.00E+00	8.69E-04	3.58E-03	5.12E-02	0.00E+00	5.98E-02	8.46E-04
	Adolescent	4.19E-03	0.00E+00	8.16E-04	3.18E-03	4.54E-02	0.00E+00	5.35E-02	8.97E-04
	Child	4.19E-03	0.00E+00	7.59E-04	2.19E-03	3.68E-02	0.00E+00	4.40E-02	1.34E-03
	Toddler	1.67E-02	0.00E+00	4.34E-04	1.44E-03	2.51E-02	0.00E+00	4.38E-02	2.65E-03
	Infant	4.19E-03	0.00E+00	1.15E-04	9.75E-04	0.00E+00	0.00E+00	5.28E-03	6.44E-04

D-4.0 MULTI-PATHWAY RISK ESTIMATES

This section provides multi-pathway risk estimates tables for receptor locations near the Farim Mine site and Port site for the Baseline and Project Alone scenarios. Tables D-22 through D-27 present risk estimates at the Farim Mine site receptor locations. Tables D-28 and D-29 present risk estimates at the Port site receptor locations.

Table D-22	Multi-Pathway Risk Estimates –Receptor Location R2					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**4.5E-01**	1.2E-01	**5.7E-01**	NA		
Arsenic	**3.3E-01**	1.1E-02	**3.4E-01**	9.9E-05	2.4E-06	1.0E-04
Cadmium	1.7E-01	8.3E-04	1.7E-01	NA		
Iron	**2.1E-01**	1.9E-02	**2.3E-01**	NA		
Lead	**4.0E-01**	8.9E-03	**4.1E-01**	NA		
Vanadium	1.4E-01	1.8E-02	1.5E-01	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

Table D-23	Multi-Pathway Risk Estimates –Receptor Location R9					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**4.5E-01**	7.5E-02	**5.3E-01**	NA		
Arsenic	**3.3E-01**	7.2E-03	**3.3E-01**	9.9E-05	1.5E-06	1.0E-04
Cadmium	1.7E-01	5.2E-04	1.7E-01	NA		
Iron	**2.1E-01**	1.2E-02	**2.2E-01**	NA		
Lead	**4.0E-01**	5.6E-03	**4.1E-01**	NA		
Vanadium	1.4E-01	1.1E-02	1.5E-01	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

Table D-24	Multi-Pathway Risk Estimates –Receptor Location R12					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**4.5E-01**	6.6E-02	**5.2E-01**	NA		
Arsenic	**3.3E-01**	6.3E-03	**3.3E-01**	9.9E-05	1.3E-06	1.0E-04
Cadmium	1.7E-01	4.6E-04	1.7E-01	NA		
Iron	**2.1E-01**	1.1E-02	**2.2E-01**	NA		
Lead	**4.0E-01**	5.0E-03	**4.0E-01**	NA		
Vanadium	1.4E-01	9.8E-03	1.5E-01	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

Table D-25	Multi-Pathway Risk Estimates –Receptor Location R15					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**4.5E-01**	8.0E-02	**5.3E-01**	NA		
Arsenic	**3.3E-01**	7.7E-03	**3.3E-01**	9.9E-05	1.6E-06	1.0E-04
Cadmium	1.7E-01	5.6E-04	1.7E-01	NA		
Iron	**2.1E-01**	1.3E-02	**2.2E-01**	NA		
Lead	**4.0E-01**	6.0E-03	**4.1E-01**	NA		
Vanadium	1.4E-01	1.2E-02	1.5E-01	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

Table D-26	Multi-Pathway Risk Estimates –Receptor Location R22					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**4.5E-01**	3.2E-02	**4.9E-01**	NA		
Arsenic	**3.3E-01**	3.1E-03	**3.3E-01**	9.9E-05	6.4E-07	1.0E-04
Cadmium	1.7E-01	2.2E-04	1.7E-01	NA		
Iron	**2.1E-01**	5.2E-03	**2.1E-01**	NA		
Lead	**4.0E-01**	2.4E-03	**4.0E-01**	NA		
Vanadium	1.4E-01	4.8E-03	1.4E-01	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

Table D-27	Multi-Pathway Risk Estimates –Receptor Location R69					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**1.8E+00**	2.2E-04	**1.8E+00**	NA		
Arsenic	**9.6E-01**	8.9E-05	**9.6E-01**	2.5E-04	1.9E-08	2.5E-04
Cadmium	**4.1E-01**	3.9E-04	**4.1E-01**	NA		
Iron	**7.7E-01**	4.0E-04	**7.7E-01**	NA		
Lead	**1.1E+00**	8.3E-05	**1.1E+00**	NA		
Vanadium	**5.7E-01**	1.3E-03	**5.7E-01**	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

Table D-28	Multi-Pathway Risk Estimates –Receptor Location R70					
Chemical of Potential Concern	***Hazard Quotients for Non-Carcinogenic Effects[a]***			***Lifetime Cancer Risk/Incremental Lifetime Cancer Risk[b]***		
	Baseline	***Project Alone***	***Baseline + Project***	***Baseline LCR***	***Project Alone ILCR***	***Baseline + Project LCR***
Aluminum	**1.8E+00**	2.3E-04	**1.8E+00**	NA		
Arsenic	**9.6E-01**	9.1E-05	**9.6E-01**	2.5E-04	1.9E-08	2.5E-04
Cadmium	**4.1E-01**	4.0E-04	**4.1E-01**	NA		
Iron	**7.7E-01**	4.1E-04	**7.7E-01**	NA		
Lead	**1.1E+00**	8.5E-05	**1.1E+00**	NA		
Vanadium	**5.7E-01**	1.3E-03	**5.7E-01**	NA		

Bolded values highlighted in grey are non-carcinogenic HQ values greater than 0.2 and below 10.

[a] The hazard quotients (HQs) presented for non-carcinogenic effects are the highest predicted HQ of the 5 receptor life stages for each specific COPC and exposure scenario

[b] The LCR/ILCRs presented for carcinogenic effects are based on predicted exposures of the composite (or lifetime) receptor

RADIOLOGICAL ASSESSMENT OF RISK TO HUMAN HEALTH AND THE ENVIRONMENT AT THE FARIM PHOSPHATE PROJECT

By:
Colin Macdonald, Ph.D.
Northern Environmental Consulting & Analysis (NECA)
Pinawa MB, Canada R0E 1L0
Ph: 1 204 753-2244
e: northern@granite.mb.ca

Submitted to:

Knight Piésold Ltd.
1650 Main Street West
North Bay | Ontario | Canada | P1B 8G5

September 2015

EXECUTIVE SUMMARY

An analysis and radiological assessment of the Farim Phosphate Project was conducted to assess whether the levels of naturally-occurring radiation is a concern for human health or the environment. The analysis was prompted by the presence of uranium (U-nat) in ore, tailings and product at concentrations that are elevated from background soil. Radioactivity was not evaluated in earlier studies at the site even though uranium is known to be associated with phosphate rock. To overcome the information gap, samples of several media from the site were specifically analysed in the summer of 2015 for major natural isotopes to better understand their distribution and concentrations at the proposed mine.

Radionuclides in the ^{238}U and ^{232}Th decay chains are present in surface soils at concentrations within global ranges, however higher levels are found in the ore. The highest levels are found in product, where all the major nuclides in the ^{238}U chain are in secular equilibrium at roughly 1000 Bq/kg. Radon was not measured at the site, but the elevated levels of ^{226}Ra suggest that it may be an issue in enclosed areas (e.g., shed, warehouses) on the site.

The risk to the public and workers from long term exposure was evaluated using the site-specific nuclide data and general exposure models for the public (a child and an adult) and workers. The scenario for the public included an agricultural setting in which vegetables and meat products that are grown on the site consumed all year. The estimated background radiation doses from the scenario are close to the global average (2-3 mSv/y). Calculated dose levels based on nuclide concentrations measured in the phosphate ore would increase the exposure dose to levels that exceed the protective guideline of 1 mSv/y by an order of magnitude. This scenario sets the upper bounds for the radiation dose assessment and, although not proposed by GB Minerals, corresponds to a post-closure setting in which ore is uncapped and on the ground surface. Protective measures such as capping exposed ore would reduce this exposure. Doses to workers under this scenario of exposed ore is low, since they spend less time on the site and consume food from off-site.

The assessment tool ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management) was used to study the dose rates and potential ecological effects to representative plants and animals. Generic plant and animal species that occupied most major ecological niches were assumed to live on the mine site under the same conditions that were used for the human health assessment. Grasses and shrubs received the highest doses, largely because of the accumulation of ^{226}Ra. Birds and mammals received much lower doses from background soil and ore-level concentrations of radionuclides. Without the application of an uncertainty factor, the risk quotient (RQ) for birds and mammals was less than one, using ore concentrations of nuclides, however the RQ for shrubs exceeded 3 due to internal radiation from ^{226}Ra. The results indicate that the accumulation of nuclides from soil may be a significant exposure pathway for plants and wildlife.

Several recommendations and gaps in information arose from the analysis:

1) Targeted site monitoring plans should be developed which include radioactivity in key environmental components. These include surface soil samples and a limited number of plants and animals, particularly those that might be harvested by the local communities.

2) Radon measurements should be conducted in storage areas during initial mine operations and, if deemed necessary, continued monitoring of radon to ensure that concentrations do not exceed 1000 Bq/m^3. Control measures may be required (e.g., improved ventilation, restrictions worker time in the area, etc.).

3) This assessment does not assess the radiological impact of dust inhalation to workers on the site, or fugitive dust depositing outside the mine proper. It is acknowledged, however, that much of the particulate matter generated during the mine life is from baseline sources, and the proportion of Project emissions of particulate matter that is ore is small, based on a 10 waste : 1 ore stripping ratio for the Project. Nonetheless, initial monitoring of radionuclides in particulate matter is recommended to validate that dust inhalation does not represent a meaningful exposure pathway to workers.

4) There was inconsistency in the quality of analysis of radionuclides, which may lead to an incomplete assessment of the risks from radiation at the site. Any further analysis should be conducted with clear performance parameters (limit of detection, nuclides reported, etc.) to remove this source of uncertainty.

5) The diet used in the human health assessment was essentially a western diet using Farim-specific site data. A more appropriate diet for the local inhabitants should be used in any further exposure models.

6) This assessment provides a comprehensive analysis of the potential impacts of the radiation doses at Farim using conservative assumptions and site specific data. The models relied on single value concentration ratios which provide an accepted screening approach. A more advanced probabilistic assessment (Tier 3) would provide a more realistic assessment and greater flexibility of exposure conditions, and may be warranted if monitoring confirms an exceedance of the risk quotient.

7) The assessment only examined the conditions on the mine site and did not assess exposures during transportation or shipping. These additional sites can be effectively monitored through hand held gamma counters and, possibly, radon detectors.

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1.0 INTRODUCTION

This review and analysis of radiological conditions at the Farim Phosphate Project is an independent technical supporting document for the Environmental and Social Impact Assessment (ESIA). The ESIA is being conducted by Knight Piésold Ltd. on behalf of GB Minerals Limited. Northern Environmental Consulting and Analysis (NECA) was retained by Knight Piésold to review and assess the potential radiological risks of elevated uranium present in the Farim phosphate ore. Identifying potential risks from radioactivity will assist in managing the development, operation and closure of the mine. The objective of the assessment is to evaluate the concentrations of uranium and other naturally occurring radionuclides in Farim soils, ore, tailings and waste overburden using international standards for human safety and protection of the environment. The review was to determine the steps necessary, if any, to maintain the safety of workers and the public and to ensure that the environmental impact of the project is maintained as low as technologically feasible.

Radioactivity in phosphate ores is a well-known issue and has been studied by various international scientific bodies due to the potential implications for the health of workers and the public. Many of the mines are in developing countries, with few regulators, and need to rely on international organisations for radiation protection advice. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported in 2008 that phosphate ores typically contain 1500 Bq/kg of uranium and radium (primarily ^{226}Ra), although some deposits may contain much higher amounts. The separation of the individual nuclides in the uranium and thorium decay chains during ore processing can require additional monitoring during plant operation and management of product streams to reduce radiological exposure risk to workers. For this reason, estimates of radiation exposure need to be considered in all phases of the operation.

Background radiation to humans globally is estimated to be about 2-3 mSv/y (milliSieverts per year), with the major source being radon (^{222}Rn) (Table 1), a nuclide in the uranium decay chain that degasses from rocks and accumulates in buildings. External radiation, from uranium and thorium in the ground accounts for 0.35 mSv/y while internal radiation caused by the decay of radionuclides inside the body accounts for roughly the same amount. This assessment of the conditions at Farim evaluates these same sources of radiation for a critical group of humans and representative non-human species using internationally recognized methods to estimate exposure, and to compare the radiation received with standards of radiation assessment and protection.

The assessment follows the general framework for risk assessment by combining site-specific data on the environmental concentrations of individual radionuclides with conservative assumptions and exposure scenarios to predict the radiation received by humans and non-human

species. The scenarios include background and extreme conditions. The problem formulation involves the selection of a group of representative humans with general anatomical and physiological characteristics and generic plants and animals with which to predict exposures and to identify gaps in information. Radionuclide concentrations are taken from measurements of soils, ore, overburden, and product. Where possible, mean values and upper 95th% confidence intervals (CI) are used to provide a range of values and to help determine uncertainty.

Table 1 Sources of average background radiation dose (Health Canada 2010).

Radiation Source	Annual Dose (mSv/y)	Percent of Total Dose
Radon (^{222}Rn)	ca. 1	50%
External radiation, or "groundshine"	ca. 0.35	17.5%
Internal radiation	ca. 0.35	17.5%
Cosmic radiation	ca. 0.30	15%
Total Dose received	2 – 3	

2.0 NATURAL RADIONUCLIDE DECAY CHAINS

Naturally occurring radiation arises from the decay of three long-lived isotopes: ^{238}U, ^{232}Th and ^{235}U (Fig. A1, A2, and A3). These isotopes decay spontaneously through well-known pathways with clearly defined half-lives. Based on global data, the most common nuclides in phosphate rock are from the ^{238}U chain, which includes ^{226}Ra, ^{222}Rn (or radon), ^{210}Pb and ^{210}Po. Depending on the ore involved, significant amounts of the ^{232}Th chain may also be present. Due to the different chemical properties and the long-half-lives of some of the isotopes, some nuclides may accumulate to higher levels in media to the extent that actions may need to be taken to ensure safety of the public and workers. For example, in some phosphate mining operations, uranium can become enriched in the product, while roughly 80% of ^{226}Ra is deposited in the waste (UNSCEAR 2008).

A major consideration in the assessment of uranium in the workplace and in homes, is the presence of radon gas (^{222}Rn) that is formed by the decay of ^{226}Ra, and which may accumulate in closed spaces (e.g., sheds, warehouses, storage areas). In a recent assessment (ICRP 2014), the ICRP doubled the risk coefficient for radon exposure and now recommends a maximum level of 300 Bq/m^3 in homes (which corresponds to a dose of 10 mSv/y to people occupying the house). For workers who are in the workplace for a much shorter time than the public is in homes, a value of 1000 Bq/m^3 has been used as a guidance level for monitoring, with a maximum workplace value of 1500 Bq/m^3. The current guidelines indicate that workplace specific values

should be used, which take into account several factors, including the time spent in the area, measured radon concentrations and dust levels. The recommended dose guideline for this exposure pathway is 10 mSv/y.

3.0 RADIATION SAFETY

The methods and recommendations for exposure and risk to humans and the environment in this analysis are consistent with those recommended by several international scientific organisations. The International Commission on Radiological Protection (ICRP - www.icrp.org) publishes recommendations that provide the foundation for radiation protection standards internationally. The latest set of general recommendations (ICRP 2007) modified earlier risk coefficients and protective dose rates and indicated an increased emphasis on the protection of the environment. UNSCEAR (United Nations Scientific Committee in the Effects of Atomic Radiation - www.unscear.org*)* reviews global research on biological effects of low level radiation exposure, and the background and occupational radiation exposure for workers and the public. In Canada, Health Canada establishes guidelines of exposure to NORM (Naturally-Occurring Radioactive Material) (Health Canada 2010, 2011) that are consistent with the standards published by the ICRP.

This review evaluates the radiation risk by summing the radiation exposure from all major pathways and known radionuclides to give a total annual dose received. This is termed the annual effective dose rate, E, (in Sieverts/year or milliSieverts/year). This dose is a strong indicator of the risks of adverse health effects over the long-term. For example, ICRP uses a nominal risk coefficient for detriment (i.e., cancer and heritable effects) of 5.7×10^{-2} per Sievert for the whole population, or 4.2×10^{-2} per Sievert for adults (ICRP 2007). In this assessment, every effort is made to include all relevant nuclides and all potential exposure pathways to conservatively estimate risk.

Internationally, the safety of workers and the public from the exposure to radiation is regulated by maintaining doses below levels that are considered to be safe (e.g., Health Canada 2010, 2011). Guidelines for handling naturally-occurring radioactive materials state that exposure from all sources from an operation should not exceed an additional dose of 1 mSv/y to the public, in addition to the natural background exposure of 2-3 mSv/y. For safety, a dose constraint of 0.3 mSv/y from any particular source (i.e. background exposure, radon exposure) should not be exceeded. By comparison, medical procedures may range from 0.02 mSv/y for chest X-rays to 8 mSv/y for CT scans of the abdomen. For occupationally-exposed workers, doses of 20 mSv/y are permitted, with a limit of 100 mSv over a 5 year period. The dose cannot exceed 50 mSv in any one year.

4.0 ASSESSMENT OF FARIM PHOSPHATE OPERATIONS

4.1 Environmental Concentrations of Radionuclides

4.1.1 Preliminary Estimates from Chemical Analysis

Uranium has been reported in multi-element analyses in ore, soil and product in earlier studies conducted by Golder Associates at Farim. This measurement is called U-nat (i.e. natural uranium) and includes the three major uranium isotopes, ^{238}U, ^{234}U and ^{235}U. In order to obtain a rough estimate of ^{238}U radioactivity, the U-nat concentrations was converted to ^{238}U concentration using a specific activity conversion of 12.95 Bq per mg U-nat (Health Canada 2010) (Table 2). These data provide a first order estimate of ^{238}U concentrations in the environmental media.

Initial estimates indicate that the mean concentration of ^{238}U in soil is about 16.7 Bq/kg (maximum of 80 Bq/kg) from the mine site and 65.8 Bq/kg dw (maximum of 240 Bq/kg) at the Port site. UNSCEAR (2000) compiled global data on ^{238}U concentration in soils and reported a median concentration of 35 Bq/kg (range of 16-110 Bq/kg) for ^{238}U, consistent with Farim soils.

Chambers (2015) reported a global range of 30 to 3,000 Bq/kg of ^{238}U in phosphate rock. This range is consistent with the Farim data which showed an average ^{238}U concentration of 886 in 156 samples, much higher than in soils, and a maximum of 2590 Bq/kg (Table 2). Higher concentrations of ^{238}U are estimated for product and tailings, although the number of samples is small. Based on these data, and the likelihood of elevated levels of radiation exposure to workers, it was recommended that more detailed analysis of radionuclides should be conducted at Farim in 2015 to allow a screening level assessment of doses.

Table 2 Preliminary estimate of ^{238}U concentrations in soils and ore at Farim from multi-element chemical analysis.

Media	Number of Samples	Uranium Chemical Concentration (U-nat)		Estimated ^{238}U[1] (Bq/kg dw)	
		Average (mg/kg)	Maximum (mg/kg)	Average	Maximum
Surface soils (Mine site)	36	1.29	6.17	16.7	80
Surface soils (Port site)	15	5.08	18.5	65.8	240
Ore	156	68.4	200	886	2590
Phosphate Product	1	100	-	1295	-
Tailings	1	115	-	1489	-
Waste Overburden	22	4.61	29.0	59.7	376

[1] - ^{238}U radioactivity calculated from U-nat using a conversion of 12.95 Bq ^{238}U/mg U-nat. (Health Canada 2010).

4.1.2 Radionuclide Analyses

In 2015, surface soil, ore and product samples from Farim were submitted for analysis specifically to address the need for more data on individual radionuclides. The preliminary data from the multi-element chemical analysis suggested that ^{238}U would be elevated in ore, but nuclide specific data were not available.

4.1.2.1 Soil

Twelve soil samples from separate locations were analysed by gamma spectrometry by ALS Laboratories in the Czech Republic. Thirteen naturally occurring radionuclides were quantified, including ^{40}K, 5 nuclides of the ^{238}U chain, 2 of the ^{232}Th chain and 5 of the ^{232}U chain (Table 3). Concentrations were consistent within each chain, indicating secular equilibrium with the parent nuclides.

Summarised data are presented in Table 3, with the raw data provided in Table 4. The data are also graphed in Figure 1, with the upper bars indicating upper 95th confidence intervals. The average concentration of ^{238}U is within the range of 16.7 to 65.8 Bq/kg, confirming the earlier estimates from the chemical analysis (NECA 2015[1]). The highest levels for most nuclides were detected at the Port site (sample PortRice1), consistent with the earlier estimates. These data also

[1] NECA. 2015. Preliminary Radiological Assessment of Farim Phosphate Project. Memo to Knight Piésold. July 2015

show that the ^{232}Th chain is roughly equivalent to the ^{238}U chain of nuclides and may be a significant contributor to background dose.

Table 3 Summary of naturally-occurring radionuclides in soil at the Farim Phosphate Project. Concentrations are in Bq/kg dry weight.

Element	Number of Samples	Average	St. Dev.	Min	Max	+95% C.I.
Dry matter @ 105°C	12	97.3	2.9	91.5	99.6	98.9
Potassium 40	12	85.4	126	17.0	464	157
Uranium-238 Decay Chain						
Uranium 238	12	54.6	41.4	14.0	141	78.0
Thorium 234	12	49.2	39.4	12.0	132	71.5
Thorium 230	12	-	-	<50	<184	-
Radium 226	12	38.4	24.3	12.5	82.3	52.1
Lead 210	12	-	-	<50	106	-
Thorium-232 Decay Chain						
Radium 228	12	41.2	28.8	12.2	101	57.4
Thorium 228	12	40.3	28.6	12.0	101	56.5
Uranium-235 Decay Chain						
Uranium 235	12	2.57	1.86	<1.4	6.50	3.62
Protactinium 231	12	-	-	<5.0	<9.2	-
Thorium 227	12	-	-	<1.3	4.1	-
Actinium 227	12	-	-	<1.6	3.3	-
Radium 223	12	-	-	<1.8	<7.4	-

Figure 1 Mean concentrations of ^{238}U, ^{232}Th and ^{235}U decay chain isotopes in Farim soils, as determined by gamma spectrometry. Upper bars indicate upper 95% confidence limit of 12 samples. Cross hatched bars are half the Limit of Detection.

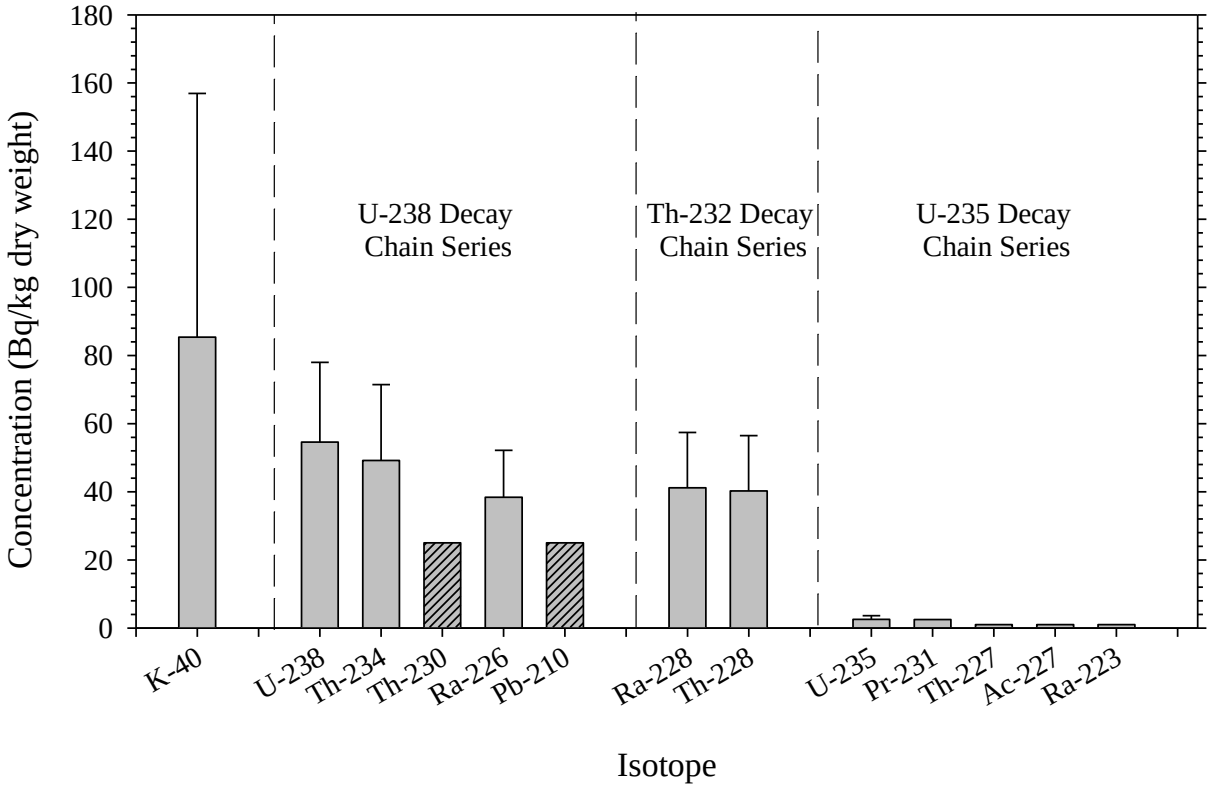


Table 4 The concentrations of decay chain nuclides and potassium-40 (^{40}K) in soils at Farim. Concentrations in Bq/kg dry weight.

Lab Report No	**LOR**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**	**PR1543642**
Lab Sample No		001	002	003	004	005	006	007	008	009	010	011	012
Client Sample No.		Canico-Res3	Canico-Rice1	Canico-Crops1	Nema Res1	TruckLoad Area1	Farim Agric1	P.Zeca Rice1	P.Zeca Crop1	P.Zeca Res1	S.HEDIM Res1	Port Rice1	Port Res1
Sample Date		07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015	07/07/2015
Dry matter @ 105°C	0.10	98.7	99.6	99.5	99.4	91.5	93.7	97.1	98.2	99.4	98.7	93	98.9
K-40	10	32	17	28	28	146	101	103	35	23	21	464	27
Uranium-238 Chain													
U-238	10	25	14	49	23	88	106	91	41	26	29	141	22
Th-234	10	15	12	35	20	99	72	90	43	27	22	132	23
Th-230	50	<54	<50	<104	<58	<91	<114	<96	<84	<51	<56	<184	<56
Ra-226	1.0	16.8	12.5	28.2	20.8	66.6	82.3	68.4	47.4	22.3	18	55.7	21.6
Pb-210	50	<50	<50	52	<50	63	92	106	<50	<50	<50	97	<50
Thorium-232 Chain													
Ra-228	1.0	16.2	12.2	31.4	23.6	67.5	57.2	77.9	46.5	21	20.5	101	19
Th-228	1.0	15.2	12	30.4	23.2	66.5	55.2	75.7	46	20.1	20.1	101	17.8
Uranium-235 Chain													
U-235	1.0	1.2	<1.4	2.2	1.1	4.1	4.9	4.2	1.9	1.2	1.3	6.5	<2.1
Pr-231	5.0	<5.0	<5.0	<6.7	<5.0	<5.8	<7.8	<6.0	<5.4	<5.0	<5.0	<9.2	<5.0
Th-227	1.0	<1.5	<1.3	<2.7	<1.7	4.1	<3.2	<2.7	<2.3	<1.4	<1.6	<4.2	<1.5
Ac-227	1.0	<2.1	<1.9	<4.0	<2.4	3.3	<4.7	<3.7	<3.2	<1.6	<2.8	<5.8	<2.2
Ra-223	1.0	<2.7	<2.5	<5.2	<3.0	<4.7	<6.2	<4.7	<4.1	<1.8	<3.0	<7.4	<2.8

4.1.2.2 Ore

Six ore samples were analysed by gamma spectrometry at Becquerel Laboratories in Mississauga, ON, Canada. The lab used the same general methods to analyse the samples as the ALS Lab, but quantified 8 nuclides, only three of which were above detection. The data are presented in Table 5, with the mean, standard deviation and 95th% confidence interval.

^{210}Pb, ^{226}Ra and ^{234}Th, all of which are in the ^{238}U chain, were above detection and quantified. Unlike in the background soil samples, ^{228}Ra and ^{228}Th were below detection limits (DL<100 Bq/kg), as was ^{235}U. ^{238}U was not reported in the analysis but its concentration was estimated from the earlier chemical analysis to be 792 Bq/kg, close to the secular equilibrium value with the progeny from the decay chain. ^{40}K was below detection (DL<100 Bq/kg) in all samples, which is surprising given the high levels of phosphate in the ore.

Table 5 Concentration of radionuclides in Farim ore, as measured by gamma spectrometry. Units are in Bq/kg dw. ^{238}U was estimated from multi-elemental analysis using the methods outlined in the text.

Lab ID	n	ARF231	ARF239	ARF240	ARF241	ARF242	ARF243	Mean	St. Dev.	+95% C.I.
		SB9-1 (ORE)	SB9-2 (ORE)	SC10-1 (ORE)	SC10-2 (ORE)	SC11-1 (ORE)	SC11-2 (ORE)			
Potassium-40	6	<100	<100	<100	<100	<100	<100	-	-	-
U-238[1]	154							792	430	860
Thorium-234	6	650	870	610	570	700	740	690	107	776
Thorium-230	6	<800	<800	<800	<800	<800	<800	-	-	-
Thorium-228	6	<100	<100	<100	<100	<100	<100	-	-	-
Radium-226	6	800	880	640	640	710	900	762	116	854
Lead-210	6	700	860	640	550	670	780	700	109	787
Radium-228	6	<100	<100	<100	<100	<100	<100	-	-	-
Uranium-235	6	<100	<100	<100	<100	<100	<100	-	-	-

[1]– estimated from chemical analysis assuming a specific activity of 12.95 Bq ^{238}U/mg U-nat.

4.1.2.3 Product

Two product samples generated by pilot plant metallurgical testing of the same bulk ore sample tested above, were also analysed for radionuclides concentrations. Four nuclides present in the ^{238}U decay chain were above detection, at roughly 1100 Bq/kg dw. ^{238}U was not quantified in the analysis, but estimates from the multi-element analysis place the concentration at roughly 1295 Bq/kg, which is consistent with the concentrations of progeny.

Table 6 Concentrations of nuclides in Farim product as determined by gamma spectrometry. Units are in Bq/kg dry weight.

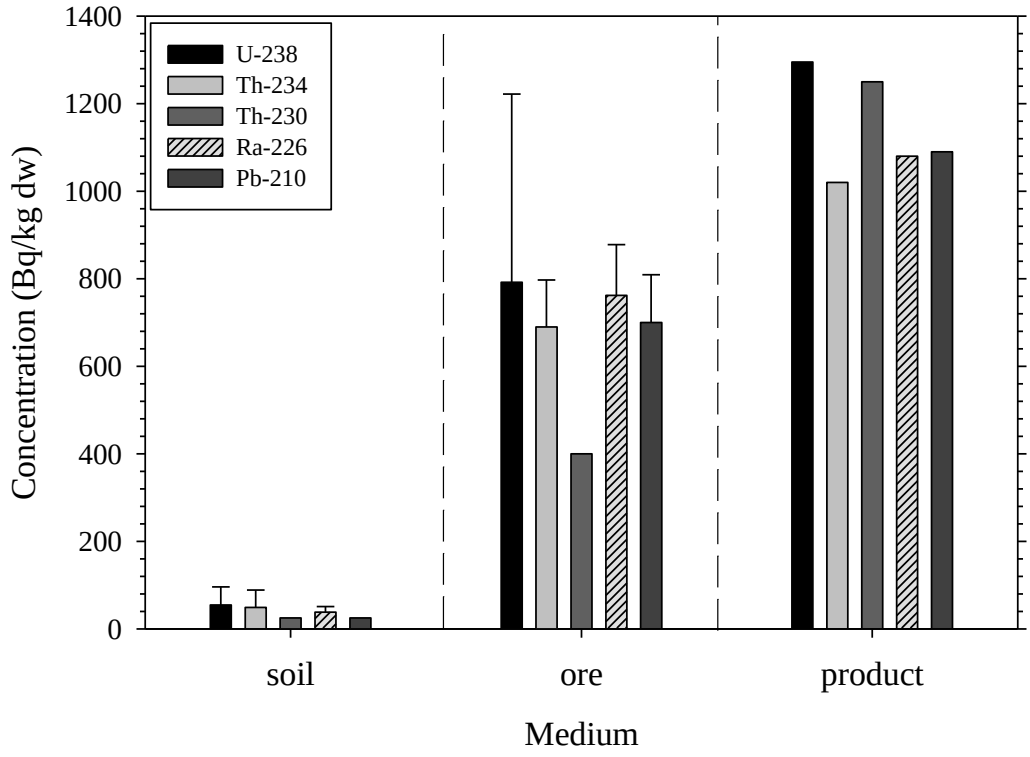
Nuclide	**RDL**	**ARF244**	**ARF245**
		CP-1 (COARSE PRODUCT)	**FP-2 (FINE PRODUCT)**
^{40}K	1.0	<1000	<1.0
^{238}U[1]	-	-	1295
^{234}Th	0.050	890	1020
^{230}Th	0.80	<800	1250
^{226}Ra	0.10	950	1080
^{210}Pb	0.10	820	1090
^{228}Ra	0.10	<100	<0.10
^{232}Th	0.10	<100	<0.10
^{235}U	0.10	<100	<0.10

[1] – estimated from chemical analysis (Table 2) assuming a specific activity of 12.95 Bq ^{238}U/g U-nat.

4.1.2.4 Radionuclide Summary

The radionuclide specific analysis shows a wide range of uranium and U-progeny that is consistent with global reviews of uranium levels in phosphate rock. A comparison between different media from the Farim Phosphate Project (Fig. 2) shows a wide range of ^{238}U concentrations reaching a maximum in the product. The major nuclides of the ^{238}U chain are in secular equilibrium with the parent nuclide, making it possible to make assumptions about the contributions of nuclides to total dose that could not be analysed by gamma spectrometry. The presence of the ^{232}Th-chain nuclides in the background soils are not present in the ore or product samples and are only be included in the background dose.

Figure 2 Comparison of ^{238}U and associated nuclides in soil, ore and fine product.



5.0 RISK ASSESSMENT

5.1 Methods

The radiation doses received by humans and non-human species are a function of the energy absorbed within the body from a radiation source and the length of time of exposure. The energy arises from the three main types of radiation (alpha, beta and gamma) which derive from the transformation of radionuclides. The three types of radiation have very different characteristics that need to be considered in the estimation of dose. For example, external exposure from soil (also called "groundshine") only needs to consider gamma energy because alpha and beta are shielded by the air. Similarly, internal exposure estimates need to consider alpha radiation because of the high levels of energy deposited at the site of decay. These specific features of individual nuclides and their impact are usually considered through models that have been developed by the international scientific community and are published to provide uniformity and consistency in radiation protection.

The total background radiation dose is estimated by summing all known sources of radiation, including cosmic rays, radon inhalation and exposure to natural radiation in soils, water, food and air. For this review, it assumed that most sources of radiation remain the same, except those impacted by the mine operation. The effect of mine activities will be estimated using a generic exposure model, with site specific concentrations of nuclides.

5.2 Exposure Model

The general model used to estimate background dose received by the public and workers makes assumptions about the size, physiology and activities of a child and an adult (Table 7). The model also assumes that the person lives on the site and eats plant and meat products grown on the site (Figure 3). The range of possible exposures is set as the soil nuclide concentrations forming the baseline conditions and the nuclide concentrations in ore forming the upper bound conditions. This range of values will form the parameters of exposure under which the mine will operate. External exposure is estimated from the concentration in the soil and the length of time spent on the soil. Internal exposure is estimated by assuming that the public grows vegetables and farm animals on background soil, or on soil with the nuclide concentrations equivalent to ore.

Figure 3 Summary of model used to predict transfer of nuclides from soil to humans in an agricultural setting.

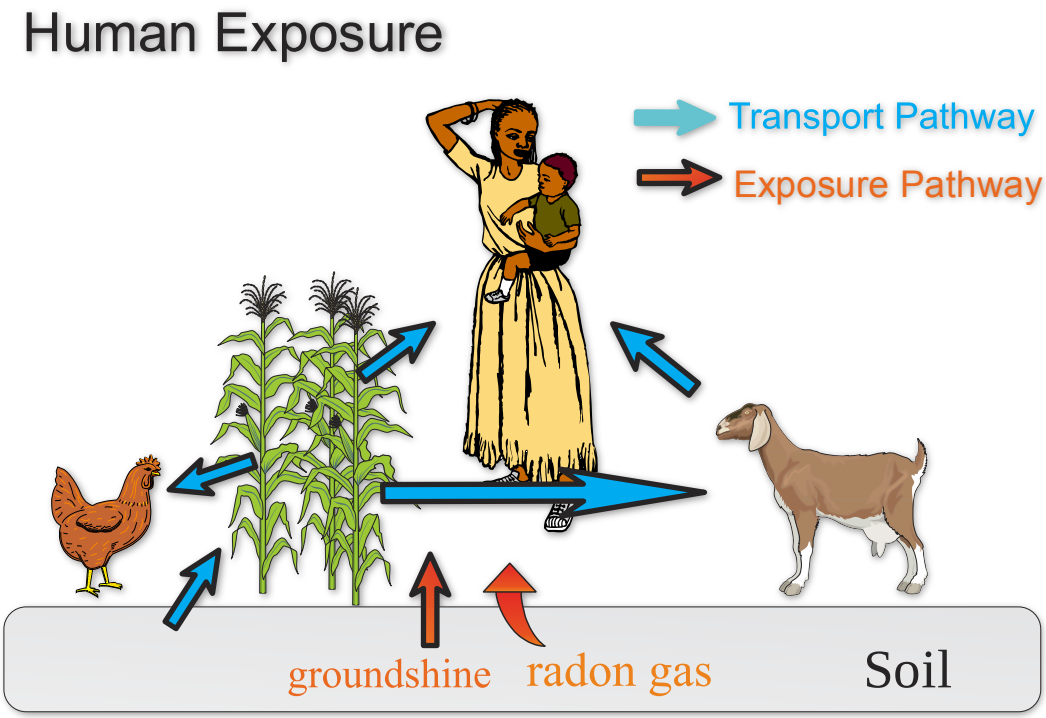


Table 7 Summary of anatomical and physiological characteristics used to develop dose and exposure models and radiation protection guidelines. (Source: ICRP 2002, Health Canada 2010).

	Child	**Adult**	**References**
Height (cm)	109	176	ICRP 2003
Mass (kg)	19	73	ICRP 2003
Surface Area (m^2)	0.78	1.90	ICRP 2003
Basal Metabolic Rate (kcal/h)	45	68	ICRP 2003
Total Energy Expenditure (kcal/d)	1600	2800	ICRP 2003
Ventilation (m^3/d)	8.8	22.2	ICRP 2003
Ventilation (Occupational – heavy worker) (m^3/d)		sleeping (8 h) - 3.6 occupational (8 h) - 13.5 non-occupational (8 h) - 9.6	ICRP 2003
Ventilation (m^3/d)	sleep (12 h) – 2.9 sitting (4.0 h) – 1.3 exercise (8 h) – 4.6	sleep (8 h) – 3.6 sitting (6 h) – 3.2 exercise (10 h) – 15.4	ICRP 2003
Time budget (public) (h/d)	indoors – 21 outdoors - 3	indoors – 22 outdoors - 2	ICRP 2003
Water intake in food and fluids (ml/d)	-	2600	ICRP 2003
Food (g/d)	vegetables - 890 meat products - 826	vegetables – 937 meat products - 563	Health Canada 2010
Soil ingestion (g/d)	2	2	Health Canada 2010

5.3 Calculation of Dose Rates

Total dose rate is calculated as the sum of external and internal dose rates for each measured, or estimated, radionuclide (EQ 1). Radon exposure is addressed separately. An uncertainty factor is generally applied to include sensitive individuals. External dose (mSv/y) is calculated directly from the concentrations of nuclides in the soil (EQ 2). Internal dose rates are calculated by estimating the concentrations of nuclides in plants and livestock, the amount of food consumed daily, and the fraction of each nuclide absorbed into the blood stream. This internal concentration of nuclide is multiplied by a DCF to estimate the radiation received from the concentration of the nuclides in humans. Inhalation and dermal exposure are considered to be zero in this Tier 2 model. Water is assumed to be a minor source of radioactivity based on analysis of water samples in August 2015 showing all nuclides were below detection limits.

Total Dose Rate (mSv/y) = Σ[External $Dose_i$ rate (mSv/y) + Internal Dose $Rate_i$ (mSv/y) + Inhalation + Dermal exposure] x UF. (EQ 1)

i = individual radionuclides
Inhalation = radiation from radionuclides inhaled from air
Dermal exposure = radiation absorbed by the skin (also called "skyshine")
UF = Uncertainty Factor = 3; no units.

External Dose Rate (mSv/y) = Σ $[\text{Soil Concentration}]_i$ x $DCF_{ext,i}$ x time (EQ 2)

Soil concentration = Bq/kg dry weight
DCF_{ext} = external dose conversion factor (nSv/h per Bq/kg dry weight soil) = 0.32 nSv/h per Bq ^{238}U/kg
time = hours (8766 hours for the public, 2000 hours for workers).

Internal Dose Rate (mSv/y) = Σ $[[\text{Soil Concentration}_i \times CR_{veg,i} \times ING_{veg,i}] + [\text{Soil Concentration}_i \times CR_{meat,i} \times ING_{meat,i}] + (SI \times [\text{Soil Concentration}_i]) \times f_{ing,i}] \times DCF_{int,i} \times RBE$

Soil concentration = Bq/kg dry weight
CR_{veg} = concentration ratio (Bq/kg fresh weight vegetable per Bq/kg dry weight soil)
ING_{veg} = ingestion rate of vegetable (g/d)
CR_{meat} = concentration ratio (Bq/kg fresh weight meat product per Bq/kg dry weight soil)
$ING_{meat,i}$ = ingestion rate of meat product (g/d)
$f_{ing,i}$ = fraction of nuclide i absorbed into blood stream
SI = soil ingestion (g/d)
$DCF_{int,i}$ = internal dose conversion factor (Sv per Bq)
RBE = relative biological effectiveness (20 for alpha radiation, 3 for beta, 1 for gamma).

Concentration ratios (CRs) and nuclide specific dose conversion factors (DCFs) were taken from several published databases. The concentrations ratios for vegetables were taken from Vandenhove *et al*. 2009 which reported means of CRs from studies with a number of soil types. The values used in this assessment were gross geometric means from a number of soil types. The CRs for animal products were taken from a compendium of values from the IAEA (Table 8).

Table 8 Concentration ratios for vegetable and animal products grown on Farim soil. Data are from Vandenhove *et al*. (2009)(vegetables) and IAEA (2014)(animals).

Nuclide	Vegetable (Bq/kg fresh weight per Bq/kg soil)	Animal (Bq/kg fresh weight per Bq/kg soil)
Uranium	2.27E-02	3.3E-01
Thorium	3.49E-03	6.2E-03
Radium	4.06E-02	1.8E-01
Lead	2.01E-02	7.7E-02

External dose is estimated from ^{238}U concentration since the DCF includes the emissions from the full ^{238}U decay chain (UNSCEAR 2000). Nuclide specific internal DCFs (Table 9) for all major nuclides were taken from ICRP (2012) however in some cases, the energies from short-lived progeny are included with the parent and may comprise a major portion of the total energy emitted by the parent. These nuclides were not analysed directly but are assumed to be in equilibrium with the parent. For nuclides such as ^{226}Ra the progeny are short-lived and contribute a large fraction of the dose from the parent nuclide.

Table 9 Internal dose conversion factors for ingested radionuclides (ICRP 2012).

Nuclide	Fraction Absorbed	Child (Sv/Bq)	Adult (Sv/Bq)
U-238	0.02	8.0E-08	4.5E-08
Th-234	0.0005	1.3E-08	3.4E-09
Th-230	0.0005	3.1E-07	2.1E-07
Ra-226	0.3 (adult = 0.2)	6.2E-07	2.8E-07
Pb-210	0.4 (adult = 0.2)	2.2E-06	6.9E-07
Ra-228	0.3 (adult = 0.2)	3.4E-06	6.9E-07
Th-228	0.0005	2.2E-07	7.2E-08
U-235	0.02	8.5E-08	4.7E-08

6.0 HUMAN HEALTH

6.1 External Dose

External doses from background soil conditions range from 0.05 mSv/y on soils at the mine site to slightly higher levels at the Port site due to marginally higher U-nat concentrations (Table 10). External doses to the public are estimated assuming 100% occupancy of the site for the whole year, and are considered to be highly conservative, consistent with the Tier 2 level of the model. Doses from ore, product and tailings are markedly higher, although the long occupancy and extended time near the radiation source is overly conservative and unlikely. Workers will only be on-site for about 2000 hours per year, which reduces external exposure considerably.

6.2 Internal Dose

The internal dose to the public from the consumption of vegetables and animals (Table 11) products results in a dose of 0.50 mSv/y for a child and 0.25 mSv/y for an adult (Table 12). The dose for a child is higher due to the consumption of larger amount of animal products, such as milk. Doses from agriculture from ore are markedly higher, and although an unlikely scenario, is the equivalent of farming on uncapped ore or tailings in a post closure environment. The internal doses in this scenario exceed the incremental dose of 1 mSv/y considered to be protective of public health. This does not consider dustfall onto the leaves of plants as a significant source of contamination prior to the mine operation. A western diet was assumed, which includes approximately equal amounts of vegetables and meat, and probably overestimates the consumption of meat products in the Farim area.

Table 10 Estimation of external annual dose produced by uranium in surface soils, ore and tailings.

Media	**Number of Samples**	**Uranium Chemical Concentration (U-nat)**		**Radioactivity (^{238}U only)[1]**		**External Dose Estimate[2,3] (Full year - 8766 h)**		**External Dose Estimate[2,3] (Work year – 2000 h)**	
		Average (mg/kg)	**Maximum (mg/kg)**	**Average (Bq/kg)**	**Maximum (Bq/kg)**	**Average (mSv/y)**	**Maximum (mSv/y)**	**Average (mSv/y)**	**Maximum (mSv/y)**
Surface soils (Mine site)	36	1.29	6.17	16.7	80	0.05	0.22	0.01	0.05
Surface soils (Port site)	15	5.08	18.5	65.8	240	0.18	0.67	0.04	0.15
Ore	156	68.4	200	886	2590	2.48	7.25	0.57	1.66
Phosphate Product	1	100	-	1295	-	3.63	-	0.83	-
Tailings	1	115	-	1489	-	4.17	-	0.95	-
Waste Overburden	22	4.61	29.0	59.7	376	0.17	1.05	0.04	0.24

Legend:

1. ^{238}U radioactivity calculated from U-nat using a conversion of 12.95 Bq/mg. Total U activity (^{238}U, ^{234}U and ^{235}U) calculated from a specific activity of 26.5 Bq/mg (Health Canada 2010).

2. Conversion coefficient: Air absorbed dose rate for ^{238}U of 0.462 nGy/h per Bq ^{238}U/kg in soil. Effective dose conversion of 0.7 Sv/Gy, giving an effective dose of 0.32 nSv/h per Bq/kg or 2.8 µSv/y per Bq/kg for the public (8766 hours/year) or 0.64 µSv/y per Bq/kg for workers (2000 hours/y) (UNSCEAR 2000).

Table 11 Estimated concentration of major nuclides in vegetables and animals products grown on Farim soils. Values for ^{230}Th and ^{210}Pb are based on half the detection limit, with no upper 95th% CI.

Nuclide	Background Soil	95% CI	Ore	95% CI	Product
Concentration in Plants/Vegetables (Bq/kg ww)					
^{238}U	1.24	1.77	18.0	19.5	29.4
^{234}Th	0.17	0.25	2.41	2.71	3.56
^{230}Th	0.09	-	1.40	-	4.36
^{226}Ra	1.56	2.12	30.9	34.7	43.8
^{210}Pb	0.50	-	14.1	15.8	21.9
Concentration in Meat Products (Bq/kg ww)					
^{238}U	18.1	25.8	262	285	429
^{234}Th	0.30	0.44	4.28	4.81	6.3
^{230}Th	0.16	-	2.48	-	7.8
^{226}Ra	6.91	9.39	137	154	194
^{210}Pb	1.93	-	53.9	60.6	83.9

Table 12 Internal dose (mSv/y) from consuming vegetables and meat products under base background conditions and upper bound conditions.

Nuclide	Background Soil	95% CI	Ore	95% CI	Product
Child					
^{238}U	9.42E-03	1.35E-02	1.37E-01	1.48E-01	2.24E-01
^{234}Th	1.19E-06	1.73E-06	1.67E-05	1.88E-05	2.47E-05
^{230}Th	1.45E-05	-	2.31E-04	0.00E+00	7.23E-04
^{226}Ra	4.87E-01	6.61E-01	9.66E+00	1.08E+01	1.37E+01
^{210}Pb	6.70E-04	-	1.88E-02	2.11E-02	2.92E-02
Total	**4.97E-01**	**6.75E-01**	**9.82E+00**	**1.10E+01**	**1.40E+01**
Adult					
^{238}U	6.68E-03	9.55E-03	9.70E-02	1.05E-01	1.59E-01
^{234}Th	1.02E-06	1.49E-06	1.43E-05	1.61E-05	2.12E-05
^{230}Th	1.24E-05	-	1.98E-04	0.00E+00	6.20E-04
^{226}Ra	2.46E-01	3.34E-01	4.88E+00	5.46E+00	6.91E+00
^{210}Pb	2.58E-04	-	7.22E-03	8.11E-03	1.12E-02
Total	**2.53E-01**	**3.43E-01**	**4.98E+00**	**5.58E+00**	**7.08E+00**

6.3 Total Effective Dose

The total effective dose for the farming scenario under base conditions and with ore and product is summarised in Table 13. A child and adult would receive 0.61 and 0.37 mSv/y under baseline

conditions, very close to the global average. The upper 95th CI is close to 1 mSv/y, largely due to the intake of meat products. Effective dose to members of the public with the ore and product are substantially higher, primarily from the accumulation of the nuclides in vegetables and animals. This unlikely scenario shows the effect of sustained exposure to ore or product and establishes the upper bounds for effective dose, especially under potential post closure scenarios.

Table 13 Effective dose under different exposure scenarios at Farim. The conditions for each exposure scenario are described in the last column.

	Background Soil	**95th% CI**	**Ore**	**95th% CI**	**Product**	**Conditions**
Child	0.61	1.12	12.3	18.3	17.6	Living on mine site prior to operation, farming, 8776 hours per year; also post-closure if no capping of ore
Adult	0.37	0.79	7.46	12.8	10.7	Living on mine site prior to operation, farming, 8776 hours per year; also post-closure if no capping of ore
Worker	0.28	0.42	0.82	2.00	0.83	On mine site for 2,000 hours per year, eats food from off-site: internal exposure is at background levels. External exposure ranges from background to dose from ore and product

6.4 Radon

Radon concentrations have not been measured at Farim, however using an emanation rate of 1 Bq/m^3 of ^{222}Rn in air for every Bq/kg ^{226}Rn in soil (Health Canada 2010) as an approximation, then there is a potential for elevated radon levels in sheds and storage areas at the Farim operation. Radon is generally considered to be not very radiotoxic, however it decays to several short-lived alpha-emitting progeny that bind to air particulates and accumulate in the lung and irradiate lung tissue.

Radon exposure is measured by the amount of radiation from radon and its progeny that emit 1.3x10^5 meV of alpha energy. This is called a Working Level (WL) and a Working Level Month is defined as the exposure of 1 WL for a period of 170 hours (1 month). The ICRP now states that 1 WLM equates to a dose of 13 mSv for homes (assuming a radon concentration of 300 Bq/m^3 and fractionation of 0.4) and 11 mSv per WLM for mines (ICRP 2014). The recent re-assessment of cancer risk by the ICRP has doubled the risk coefficient to a lifetime excess absolute risk of 5 x 10^4 per WLM (ICRP 2010). The ICRP recommends an upper level of 300 Bq/m^3 for a general recommendation for homes, and an entry level of 1000 Bq ^{222}Rn for applying occupational protection requirements (ICRP 2014).

Radon exposure (WLM) = ([Rn](Bq/m^3) / 3700 x F) x exposure time (h)/170,
where F = radon equilibrium fraction (value of 0.4 assumed for homes, but higher in dusty environments such as a working mine).

The value of 762 Bq/kg of ^{226}Ra in ore would result in roughly the same amount of ^{222}Rn in air. This would result in a dose of 0.1WLM, or about 1.2 mSv/y, assuming a fractionation of 0.4. A higher fractionation value (0.7) for a dusty environment would result in an annual dose of 1.7 mSv. The ^{226}Ra concentration in the product (1080 Bq/kg) would result in ^{222}Rn concentrations close to the guidance level of 1000 Bq/m^3 as an entry level for monitoring the workplace.

6.5 Human Health Risk Summary

The analysis of radionuclides in soil and other media from Farim support the earlier estimates of ^{238}U concentrations. The concentrations of individual radionuclides show that the distribution of nuclides in the ^{238}U chain remain consistent through the processing and increase in concentration. The dominant contributor to dose is ^{226}Ra due to its short-lived progeny. The concentrations are not considered to be high by global standards but are in the range where further measurements may be required and monitoring is recommended. The risk to workers is relatively low but the uncertainties in the estimation of radon levels in the work place, particularly in the ore processing and storage of product may require special consideration.

This analysis does not include radionuclides that were not measured but may be present in significant amounts. For example, ^{210}Po is a decay product of ^{210}Pb and is an alpha emitter that may be a significant contributor to internal dose.

It is recommended that a monitoring program be developed to ensure that the concentrations of metals and radionuclides fall within specific parameters to ensure the safety of the public and workers. The program should also include the monitoring of radon, at least initially to ensure that the levels remain below 1000 Bq/m^3.

7.0 ECOLOGICAL RISK ASSESSMENT

The international regulatory community, such as the International Atomic Energy Agency and others (IAEA 1999, Howard *et al*. 2010, ICRP 2003, 2008) has recommended methods for protecting non-human species (e.g., plants, birds, mammals, fish) at sites where radiation may become elevated. Uranium and other nuclides released during mine operations can accumulate in surface soils and result in elevated external exposure to plants and animals. These transport pathways are similar to the accumulation of nuclides by agricultural crops and domestic animals that were considered in the human health risk assessment (Section 6.0). For subsistence-based communities that harvest local plants and animals, radiation exposure and uptake may be a major concern from the operation of a mine.

High doses of radiation can have significant impacts on populations of highly exposed plants and animals (Hosseini *et al*. 2012). Effects reported in the literature include decreased growth, reproduction and reduced productivity. Dose guidelines have been published that are considered to be protective of all species, and ensure that the plants and animals are not affected by operations that increase radiation locally (Garnier-LaPlace *et al*. 2010). The ecological risk assessment usually uses a tiered approach with a dose guideline of 10 µGy/h used for an initial Tier 1 level screening (Andersson *et al*. 2009, Garnier-LaPlace *et al*. 2010), followed by more stringent guidelines to protect plants, birds and mammals from radionuclide accumulation. The dose guidelines are based on a consensus of the international scientific community of radiation levels that are protective of wild and domestic plants and animals (Copplestone *et al*. 2004).

7.1 The ERICA Assessment Tool

The ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management) tool (http://www.erica-tool.eu/) is a well-established screening tool (Brown *et al*. 2008) for the early evaluation of ecological risks due to radioactivity (Figure 4). The ERICA model estimates the radiation dose from external exposure to radionuclides in soil (also called “groundshine”) and the internal exposure to plants accumulating nuclides from soil and to animals consuming those plants.

The model requires site specific data on the concentrations of major radionuclides in the ^{238}U chain (e.g., ^{226}Ra, ^{210}Pb, and ^{210}Po), ^{232}Th-232 and ^{235}U chains to estimate external doses to plants, birds and mammals. The more site specific data that are available for input, reduces the uncertainty of the estimates of radiation dose. Data for Farim soil, ore and product were used for the exposure scenarios (Tables 3, 5, 6). As in the human health assessment, the data were used to estimate the background radiation exposure (with 95th% confidence limit) and the upper bound of exposure, using the example of ore.

A general model of generic plants and animals living on the Farim site prior to the mine operation was constructed (Table 14, Figure 5). The model estimates external and internal doses to generic Valued Ecosystem Components (VECs) using published uptake coefficients (soil to plant, soil to animal, etc.), or concentration ratios (CR), and dose conversion factors (DCFs) (µGy/h per Bq/kg) (Howard *et al*. 2009). The physical characteristics of the representative organisms are summarised in Table 14. Scenarios were conducted as a Tier 2 level assessment due to the lack of data on uncertainty and the spatial variation in radionuclide concentrations in environmental media at Farim.

Figure 4 General framework for ecological risk assessment under the ERICA assessment tool (Source: Brown, accessed 2015[2]). Dose conversion coefficients (DCC) are the same as the term dose conversion factors (DCF) used in this report

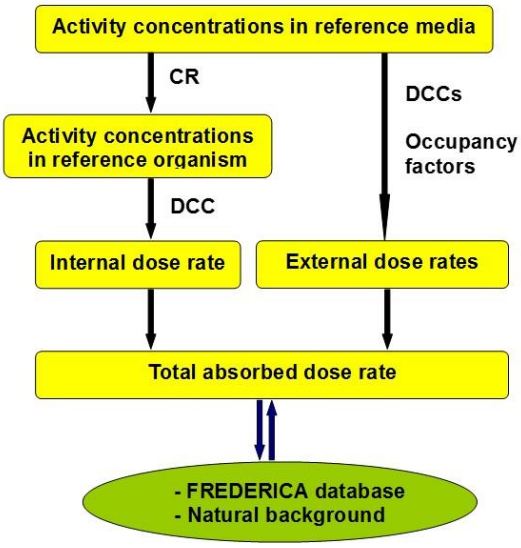
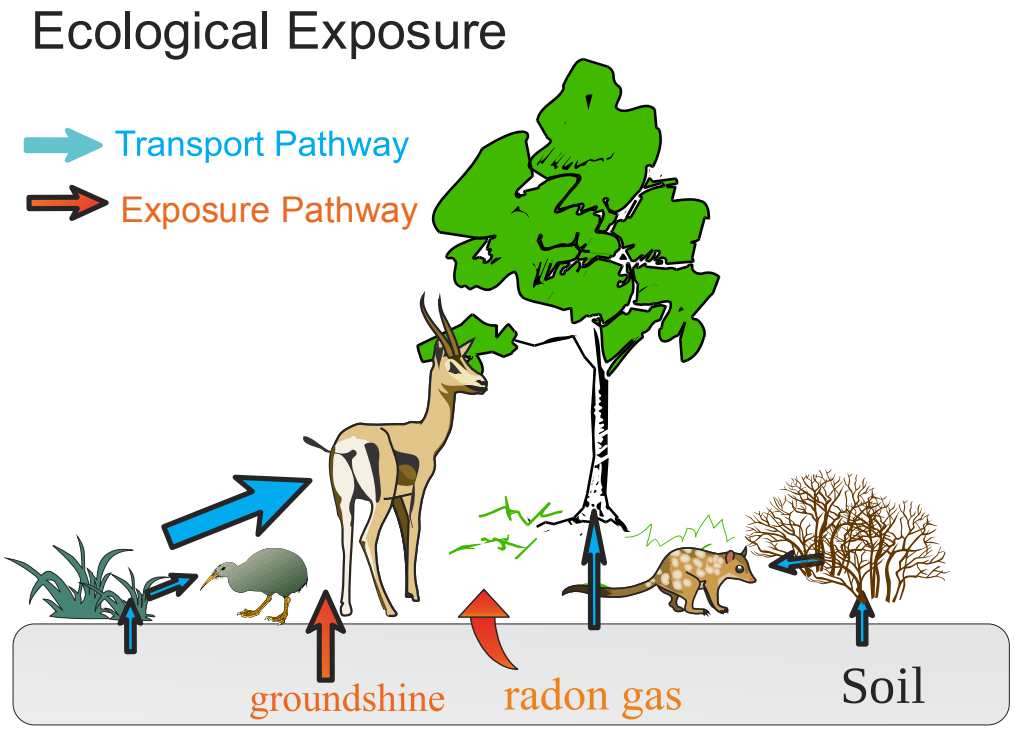


Figure 5 Generic terrestrial ecosystem used in the ecological risk assessment under the ERICA assessment tool.



[2] *www-ns.iaea.org/downloads/.../presentation-wg2-**erica-tool**.ppt*

Table 14 Characteristics of generic organisms that are used to estimate the radiation dose under different exposure scenarios at Farim, with examples of organisms in Guinea-Bissau. The body size, geometry and ecological characteristics are described in details in ICRP (2003, 2008).

Organism Name	Examples of Representative Organisms in Guinea-Bissau	Habitat	Dimensions (cm)	Mass (kg)
Grass	Grasses and herbs	On soil	5 x 1 x 1	2.62×10^{-3}
Shrub	Shrub	On soil	-	2.62×10^{-3}
Tree	Trees	On soil	1000 x 30 x 30	471
Bird	Partridge, guinea fowl, crake	On soil	30 x 10 x 8	1.26
Small mammal	Rat, hare, hyrax	50% on soil, 50% in ground	20 x 6 x 5	0.314
Large Mammal	Gazelle, duiker, antelope	On soil	130 x 60 x 60	245

7.2 Calculation of Dose Rates

As in the human health assessment, the total dose rate received by any organism is calculated as the sum of external and internal dose rates for each quantified, or estimated, radionuclide. External dose, or groundshine, is calculated directly from the concentrations of nuclides in the soil, using published external dose conversion factors (DCF_e) (Table 15). The short-lived progeny that are included with the longer-lived nuclides are listed in Table 16. Of the three major types of radiation, only gamma is considered due to the shielding of beta and alpha energy by the air.

Internal dose rates are calculated from the concentration of the nuclides in each organism. The internal concentration of radionuclides were estimated from concentration ratios included in the ERICA database (Table 17), which were modified from several sources (Taranenko *et al.* 2004, Copplestone *et al*. 2013, Wood *et al*. 2013, IAEA 2014).The energy absorbed by the organism during nuclide decay is calculated from internal dose conversion factors (DCF_i) (Table 18). Internal dose calculations include the energy from all decay types, assuming 100% of the energy is absorbed by the organism.

Table 15 External dose conversion coefficient (DCF_e) used to estimate absorbed dose in organisms at Farim (Ulanovsky and Pröhl 2008)

Nuclide	**Grasses & Herbs**	**Shrub**	**Tree**	**Bird**	**Small Burrowing Animal**		**Large Mammal**
					External Dose, on soil	**External Dose, in soil**	
U-238	1.0E-7	4.0E-8	6.9E-9	4.8E-8	4.7E-8	1.0E-7	1.0E-8
Th-234	4.7E-6	4.3E-6	3.7E-6	4.6E-6	4.5E-6	1.1E-5	2.2E-6
Th-230	1.4E-7	7.8E-8	4.4E-8	7.0E-8	6.9E-8	1.8E-7	2.5E-8
Ra-226	3.3E-4	3.2E-4	2.7E-4	3.4E-4	3.4E-4	8.5E-4	1.8E-4
Pb-210	4.0E-7	2.0E-7	1.3E-7	2.8E-7	2.8E-7	5.2E-7	7.7E-8
Th-232	1.1E-7	5.0E-8	2.1E-8	4.3E-8	4.2E-8	1.2E-7	1.3E-8
Ra-228	1.9E-4	1.8E-4	1.5E-4	1.9E-4	1.9E-4	4.7E-4	9.7E-5
Th-228	2.8E-4	2.7E-4	2.3E-4	2.9E-4	2.9E-4	7.4E-4	1.6E-4
U-235	3.1E-5	2.8E-5	2.4E-5	2.9E-5	2.9E-5	6.3E-5	1.3E-5

Table 16 Nuclides included in the calculation of the dose conversion factors for the nuclides evaluated in the non-human biota assessment (Gómez-Ros *et al*. 2004).

Main Nuclide	**Progeny included in dose conversion factors**
U-238	-
Pb-210	Bi-210
Ra-226	At-218, Po-218, Bi-214, Pb-214, Rn-222, Po-214
Ra-228	Ac-228
Th-228	Po-216, Tl-208, Bi-212, Pb-212, Rn-220, Po-212, Ra-224
Th-230	-
Th-232	
Th-234	Pa-234m, Pa-234
U-235	Th-231

Table 17 Concentrations ratios (CR) used to estimate the concentration of nuclides in plants and animals in the Farim region, based on the concentrations. Units are Bq/kg fresh weight per Bq/kg dry weight soil. (Source: IAEA 2014)

Nuclide	Bird	Large Mammal	Small Burrowing Animal	Grasses & Herbs	Shrub	Tree
U	1.26E-3	5.47E-3	5.47E-3	1.28E-1	6.10E-2	6.60E-3
Th	3.89E-4	1.36E-4	1.36E-4	1.60E-1	6.10E-2	1.26E-3
Ra	3.62E-2	4.43E-2	4.43E-2	1.80E-1	3.30E-1	1.16E-2
Pb	6.08E-2	3.74E-2	3.74E-2	1.20E-1	3.20E-1	6.97E-2

Table 18 Internal dose conversion factors (DCF_i) used to estimate absorbed dose in organisms at Farim (Ulanovsky and Pröhl 2008). Units are µGy/h per Bq/kg.

Nuclide	Grass & Herb	Shrub	Tree	Bird	Small Burrowing Mammal	Large Mammal
Internal exposure - alpha energy						
U-238	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03
Th-232	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.30E-03
Ra-226	1.36E-02	1.36E-02	1.40E-02	1.43E-02	1.34E-02	1.38E-02
Ra-228	0	0	0	0	0	0
Pb-210	0	0	0	0	0	0
Th-234	0	0	0	0	0	0
U-235	2.57E-03	2.57E-03	2.51E-03	2.57E-03	2.57E-03	2.51E-03
Th-228	1.84E-02	1.84E-02	1.90E-02	1.82E-02	1.82E-02	1.88E-02
Th-230	2.70E-03	2.70E-03	2.70E-03	2.70E-03	2.70E-03	2.70E-03
Internal exposure – high energy beta and gamma						
U-238	0	0	0	0	0	0
Th-232	0	0	0	0	0	0
Ra-226	5.60E-04	5.60E-04	0.00105	7.50E-04	7.00E-04	0.0012
Ra-228	2.52E-04	2.52E-04	5.59E-04	3.49E-04	3.20E-04	6.04E-04
Pb-210	2.16E-04	2.16E-04	2.45E-04	2.45E-04	2.35E-04	2.45E-04
Th-234	4.00E-04	4.00E-04	5.20E-04	5.00E-04	4.90E-04	5.20E-04
U-235	1.08E-04	1.08E-04	1.89E-04	1.35E-04	1.35E-04	1.89E-04
Th-228	5.70E-04	5.70E-04	0.001	7.60E-04	7.60E-04	0.0012
Th-230	0	0	0	0	0	0
Internal exposure – low energy beta						
U-238	0	0	0	0	0	0
Th-232	0	0	0	0	0	0
Ra-226	0	0	0	0	0	0
Ra-228	7.80E-06	7.80E-06	1.14E-05	1.08E-05	9.90E-06	6.10E-06
Pb-210	4.40E-06	4.40E-06	5.00E-06	5.00E-06	4.80E-06	5.00E-06
Th-234	0	0	0	0	0	0
U-235	0	0	0	0	0	0
Th-228	0	0	0	0	0	0
Th-230	0	0	0	0	0	0

7.3 Background (Base) Conditions

The data for nuclides in Farim soil (Table 3) were used to establish the absorbed dose rate for the generic organisms under base conditions at the Farim site. These are the conditions that are expected to be at the Farim site prior to development or disturbance.

The estimated background dose under average background conditions show that the maximum doses are received by grasses and shrubs (Figure 6), with a risk quotient below 1, even at the 95th% CI levels. Virtually all the total dose is due to the accumulation of nuclides from the soil. With the exception of grasses, the dominant contributor to dose for the organisms is ^{226}Ra, which includes the input from a number of short lived progeny, including radon ^{222}Rn (Figure 7). ^{228}Th is the major contributor to dose in grasses and herbs because of the inputs from short lived progeny in the ^{232}Th decay chain.

Using the upper 95th% CI concentrations (Table 3) provided doses that were about 50% higher, reaching 3.56 µGy/h in grasses and 3.27 µGy/h in shrubs. The lowest doses under base conditions were calculated for the small mammal (0.30 µGy/h, 95th% CI= 0.40 µGy/h) and large mammals (0.26 µGy/h, 95th% CI = 0.36 µGy/h) (Figure 6). The risk coefficient for all organisms was low under mean base conditions, and extended up to over 0.3 for plant species using the upper 95th CI concentrations. If the uncertainty factor of 3 is applied, the estimated background dose received by grasses and shrubs approaches the 10 µGy/h screening level, indicating that additional assessment should be conducted.

Table 19 Total weighted absorbed dose (µGy/h) to the generic organisms under Farim base conditions. Dose rates do not include the uncertainty factor.

Nuclide	Grasses & Herbs	Shrub	Tree	Bird	Small mammal	Large mammal
Total Dose Rate (µGy/h)						
U-238	1.68E-01	7.99E-02	8.65E-03	1.65E-03	7.17E-03	7.17E-03
Th-232	1.47E-01	5.61E-02	1.16E-03	3.60E-04	1.28E-04	1.25E-04
Ra-226	9.55E-01	1.74E+00	7.25E-02	2.12E-01	2.52E-01	2.43E-01
Ra-228	9.66E-03	1.10E-02	6.30E-03	8.19E-03	1.39E-02	5.02E-03
Pb-210	6.96E-04	1.84E-03	4.56E-04	4.02E-04	2.43E-04	2.45E-04
Th-234	3.37E-03	1.41E-03	2.09E-04	2.30E-04	3.74E-04	1.09E-04
U-235	8.54E-03	4.11E-03	4.89E-04	1.56E-04	4.78E-04	3.88E-04
Th-228	1.20E+00	4.65E-01	1.87E-02	1.42E-02	2.12E-02	7.31E-03
Th-230	1.08E-01	4.12E-02	8.54E-04	2.64E-04	9.45E-05	9.21E-05
Total Dose	**2.60E+00**	**2.40E+00**	**1.09E-01**	**2.37E-01**	**2.96E-01**	**2.64E-01**

Figure 6 Total dose rate and risk quotient for generic organisms under base conditions. Error bars indicate dose at the upper 95th% confidence for nuclide concentrations in soil.

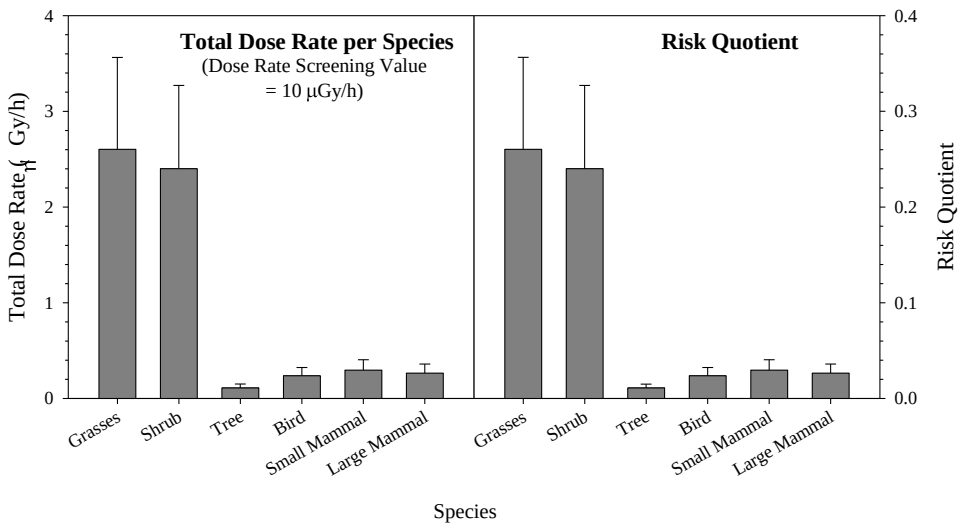
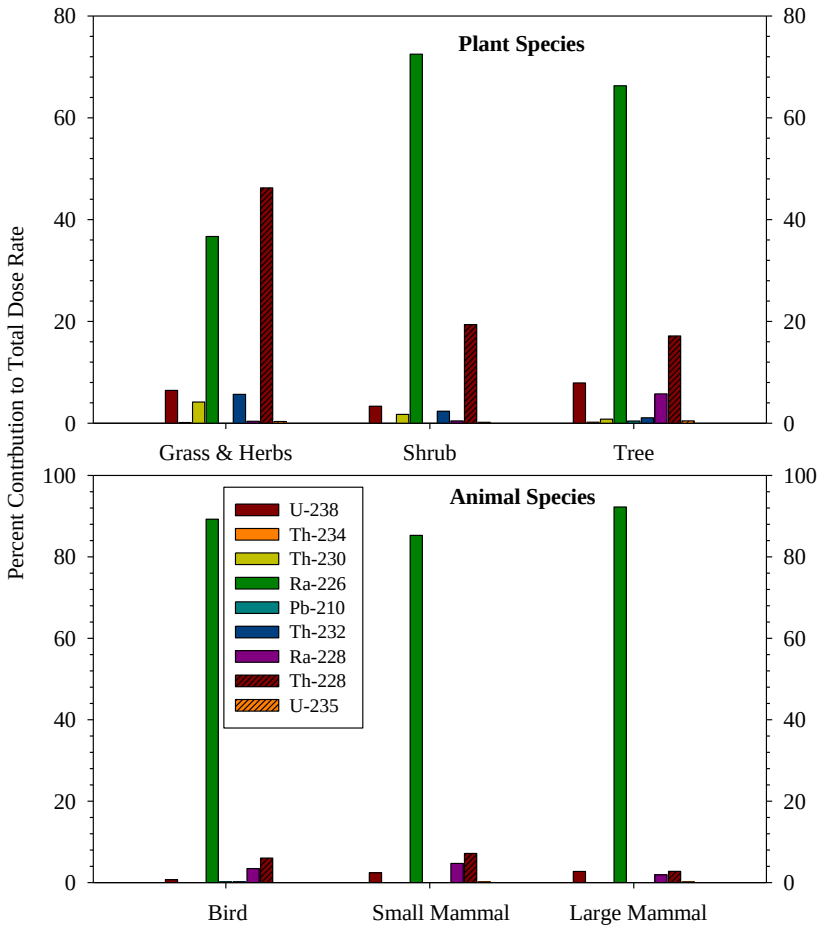


Figure 7 Contribution to total dose from individual nuclides under base conditions.



7.4 Upper Bound Conditions (Ore)

The concentrations of nuclides in ore samples (Table 5) were used to estimate the upper bounds of weighted absorbed doses to the representative organisms as a result of the Project. The scenario is equivalent to a situation in which ore is mixed into overburden soils, or organisms are living on exposed ore, such as in a post closure scenario.

The model predicts high doses to the plants, well in excess of the screening dose rate, primarily from the accumulation of ^{226}Ra and its progeny (Table 20, Figure 8). Doses to shrubs are estimated at 34.5 µGy/h at mean concentrations, and 19.0 µGy/h to grasses and herbs. Doses to birds and mammals are much lower with hazard quotients less than 1.

Upper 95th% CI concentrations provided maximum weighted absorbed dose rates of 40 µGy/h in the shrubs and 24 µGy/h in grasses. The risk quotient increased to 4 for the shrub, and 12 using an uncertainty factor of 3. The dose was dominated again by ^{226}Ra and its progeny, which accounted for over 95% of the weighted absorbed dose.

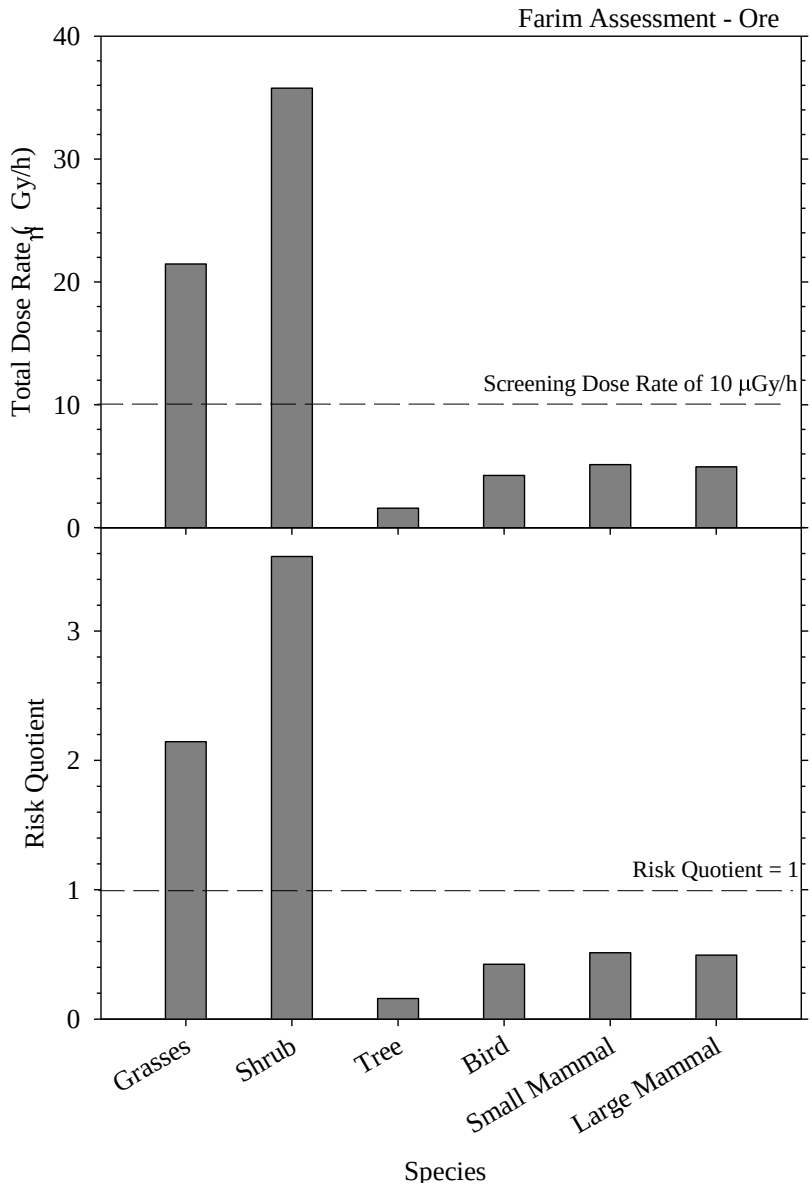
Table 20 Total weighted absorbed dose rate estimated for generic organisms living on soils with radionuclide concentrations equivalent to Farim ore. Units are in µGy/h.

Nuclide	Grasses & Herbs	Shrub	Tree	Bird	Small mammal	Large mammal
U-238	2.43	1.16	0.13	0.02	0.10	0.10
Pb-210	0.02	0.05	0.01	0.01	0.01	0.01
Ra-226	19.0	34.5	1.44	4.21	5.01	4.84
Th-234	0.047	0.02	0.003	0.003	0.005	0.002
Total Dose	**21.5**	**35.8**	**1.59**	**4.24**	**5.13**	**4.95**

7.5 Summary of Ecological Effects

The use of the ERICA model allows the screening of site specific data in terms of absorbed doses known to cause effects in populations of plants and animals. The data from the Farim Mine show that elevated levels of uranium and associated nuclides may produce environmental impacts if ore or product is exposed at the soil surface. The results support the human health risk assessment that shows potential effects may occur in situations where ore or product is unprotected in the environment for extended periods of time. The high levels of nuclides accumulated by grasses and shrubs will probably not have a significant impact on the populations of plants, but may transfer significant amounts of nuclides to birds and mammals.

Figure 8 Total absorbed dose received (upper) received by organisms and risk quotient (lower) on soils with nuclides at concentrations found in ore.



8.0 REFERENCES

Andersson, P., J. Garnier-Laplace, N.A. Beresford, D. Copplestone, B.J. Howard, P. Howe, D. Oughton and P. Whitehouse. 2009. Protection of the environment from ionising radiation in a regulatory context: proposed numerical benchmark values. Journal of Environmental Radioactivity 100:1100-1108.

Brown, J.E., B. Alfonso, R. Avila, N.A. Beresford, D. Copplestone, G. Pröhl and A. Ulanovsky. 2008. The ERICA Tool. Journal of Environmental Radioactivity 99:1371-1383.

Chambers, D.B. 2015. Radiological protection in North American naturally occurring radioactive material industries. Ann ICRP 44:202-213.

Copplestone, D., B.J. Howard and F. Brechignac. 2004. The ecological relevance of current approaches for environmental protection from exposure to ionising radiation. Journal of Environmental Radioactivity 74:31-41.

Copplestone, D., N.A. Beresford, J.E. Brown and T. Yankovich. 2013. An international database of radionuclide concentration ratios for wildlife: development and uses. Journal of Environmental Radioactivity 126:288-298.

Garnier-Laplace, J., C. Della-Vedova, P. Andersson, D. Copplestone, C. Cailes, N.A. Beresford, B.J. Howard, P. Howe and P. Whitehouse. 2010. A multi-criteria weight of evidence approach for deriving ecological benchmarks for radioactive substances. Journal of Radiological Protection 30:215-233.

Gómez-Ros, J.M., G. Pröhl and V. Taranenko. 2004. Estimation of internal and external exposures of terrestrial reference organisms to natural radionuclides in the environment: Journal of Radiological Protection. Journal of Radiological Protection 24:A79-A88

Gómez Ros, J.M., M. Moraleda, M.A. Lopez, T. Navarro and J.F. Navarro. 2007. Monte Carlo based voxel phantoms for in vivo internal dosimetry. Radiation Protection Dosimetry 125:161-165.

Health Canada. 2010. Federal contaminated site risk assessment, Part VI: Guidance on human health detailed quantitative radiological risk assessment ($DQRA_{RAD}$). Ottawa, ON.

Health Canada. 2011. Canadian guidelines for the management of naturally occurring radioactive materials (NORM). Revised 2011. 70 pp.

Hosseini, A., J.E. Brown, J.P. Gwynn and M. Dowdall. 2012. Review of research on impacts to biota of discharges of naturally occurring radionuclides in produced water to the marine environment. Sci. Total Environ. 438:325-333.

Howard, B.J., N.A. Beresford, C.L. Barnett and S. Fesenko. 2009. Radionuclide transfer to animal products: revised recommended transfer coefficient values. Journal of Environmental Radioactivity 100:263-273.

Howard, B.J., N.A. Beresford, P. Andersson, J.E. Brown, D. Copplestone, K. Beaugelin-Seiller, J. Garnier-Laplace, P.D. Howe, D. Oughton and P. Whitehouse. 2010. Protection of the environment from ionising radiation in a regulatory context - an overview of the PROTECT coordinated action project. Journal of Radiological Protection 30:195-214.

IAEA (International Atomic Energy Agency). 1999. Protection of the environment from the effects of ionizing radiation. IAEA, Vienna. IAEA-TECDOC-1091. 57 pp.

IAEA (International Atomic Energy Agency). 2014. Handbook of parameter values for the prediction of radionuclide transfer to wildlife. Technical Report Series No. 479. 228 pp.

ICRP (International Commission on Radiological Protection). 2002. Basic anatomical and physiological data for use in radiological protection. ICRP Publication 89. Ann. ICRP 32 (3/4).

ICRP (International Commission on Radiological Protection). 2003. A framework for assessing the impact of ionising radiation on non-human species. ICRP Publication 91. Annals of the ICRP 33 (3).

ICRP (International Commission on Radiological Protection). 2007. The 2007 recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP.

ICRP (International Commission on Radiological Protection). 2008. Environmental protection: the concept and use of Reference Animals and Plants. ICRP Publication 108. Ann. ICRP 38(4–6).

ICRP (International Commission on Radiological Protection). 2010. Lung cancer risk from radon and progeny and statement on radon. ICRP Publication 115. Ann. ICRP 40(1). 64 pp.

ICRP (International Commission on Radiological Protection). 2012. ICRP Publication 119: Compendium of Dose Coefficients based on ICRP Publication 60. Ann. ICRP 41: 1-130

ICRP (International Commission on Radiological Protection). 2014. Radiological protection against radon exposure. ICRP Publication 126. Ann. ICRP 42 (3):5-73.

Taranenko, V., G. Pröhl and J.M. Gómez-Ros. 2004. Absorbed dose rate conversion coefficients for reference terrestrial biota for external photon and internal exposures. Journal of Radiological Protection 24:A35-A62.

Ulanovsky, A. and G. Pröhl. 2008. Tables of dose conversion coefficients for estimating internal and external radiation exposures to terrestrial and aquatic biota. Radiation and Environmental Biophysics 47:195-203.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 2000. Report to the General Assembly. Annex B: Exposure from natural radiation sources. 74 pages.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 2008. Sources and effects of ionizing radiation. Report to the general assembly with scientific annexes. Volume 1. 245 pages.

Wood, M.D., N.A. Beresford, B.J. Howard and D. Copplestone. 2013. Evaluating summarised radionuclide concentration ratio datasets for wildlife. Journal of Environmental Radioactivity 126:314-325.

Vandenhove, H., G. Olyslaegers, N. Sanzharova, O. Shubine, E. Reed, Z. Shang and H. Velasco. 2009. Proposal for new best estimates of the soil-to-plant transfer factor of U, Th, Ra, Pb, and Po. Journal of Environmental Radioactivity 100:721-732.

APPENDIX 1

NATURALLY-OCCURRING RADIONUCLIDE DECAY CHAINS

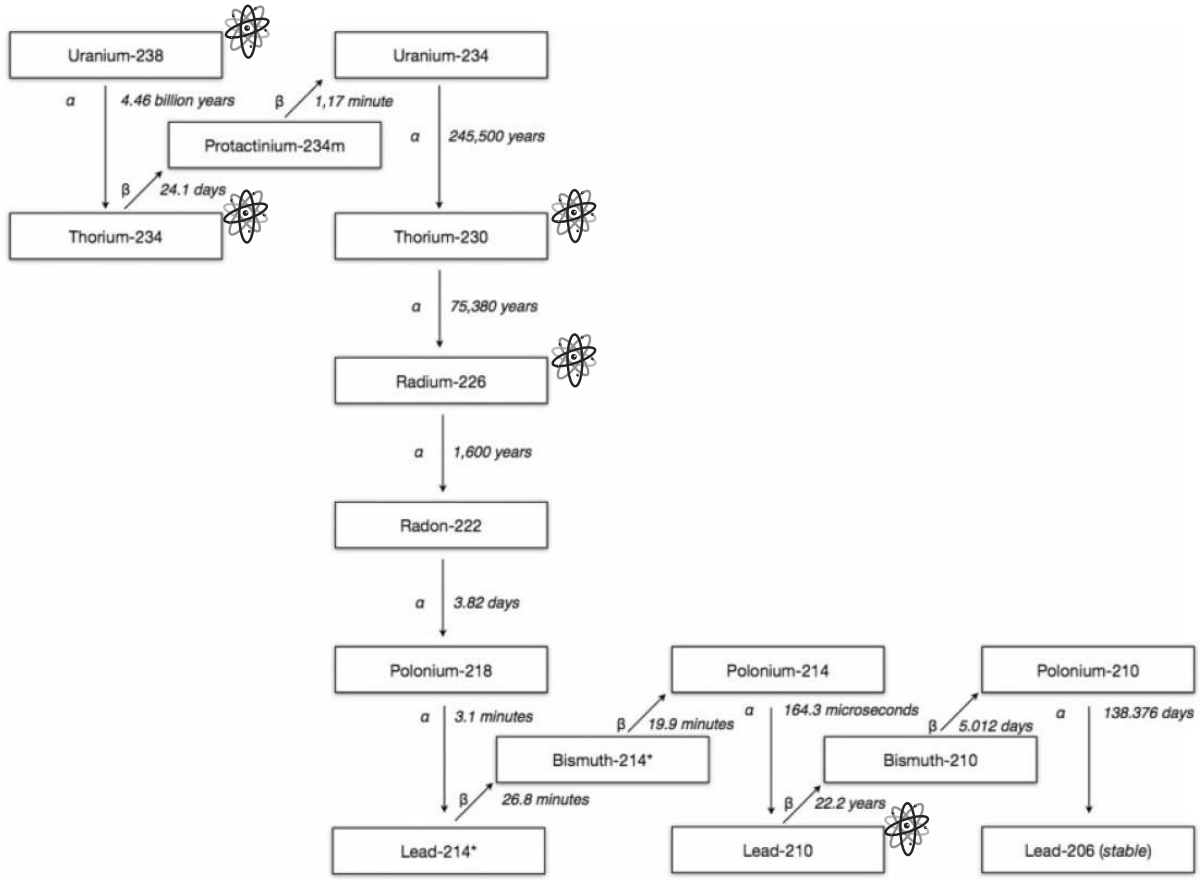


Figure A1 ^{238}U decay chain. Nuclides measured by gamma analysis in Farim samples are indicated by symbol.

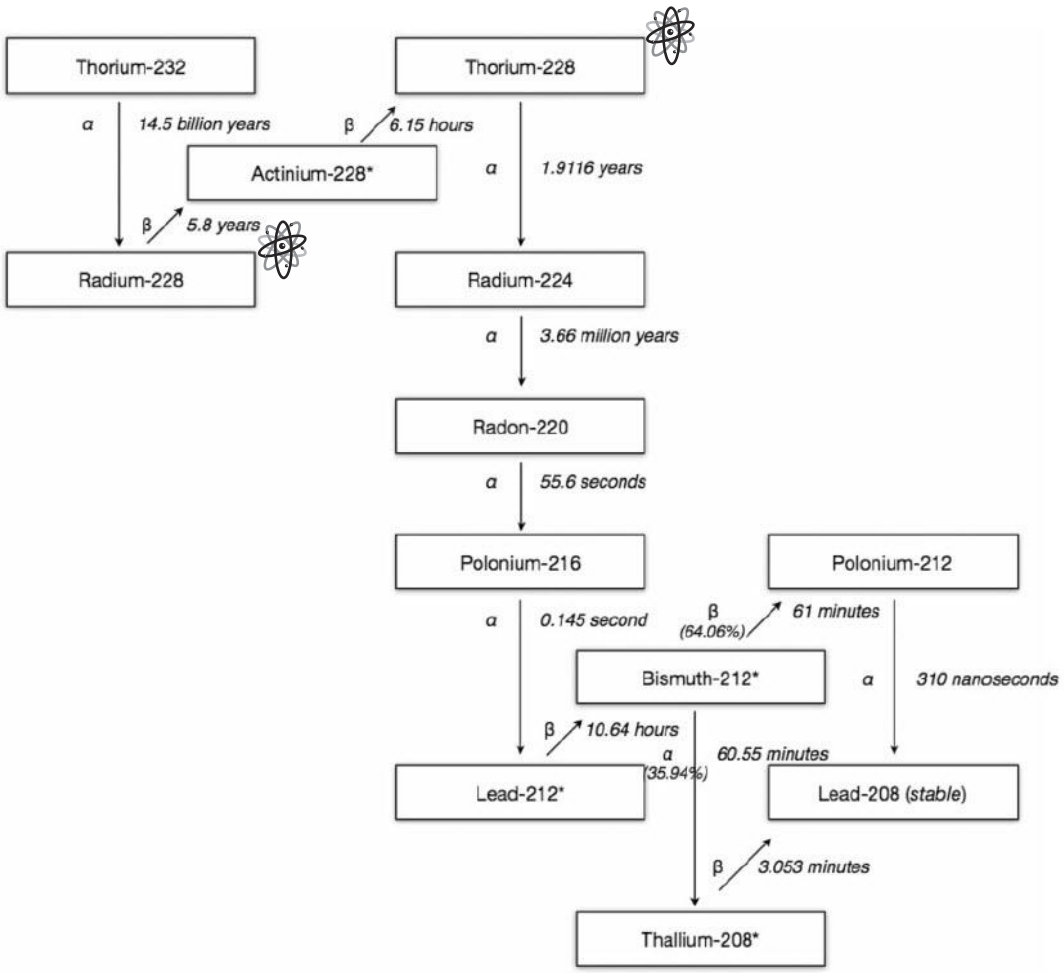


Figure A2 ^{232}Th decay chain. Nuclides measured by gamma analysis in Farim samples are indicated by symbol.

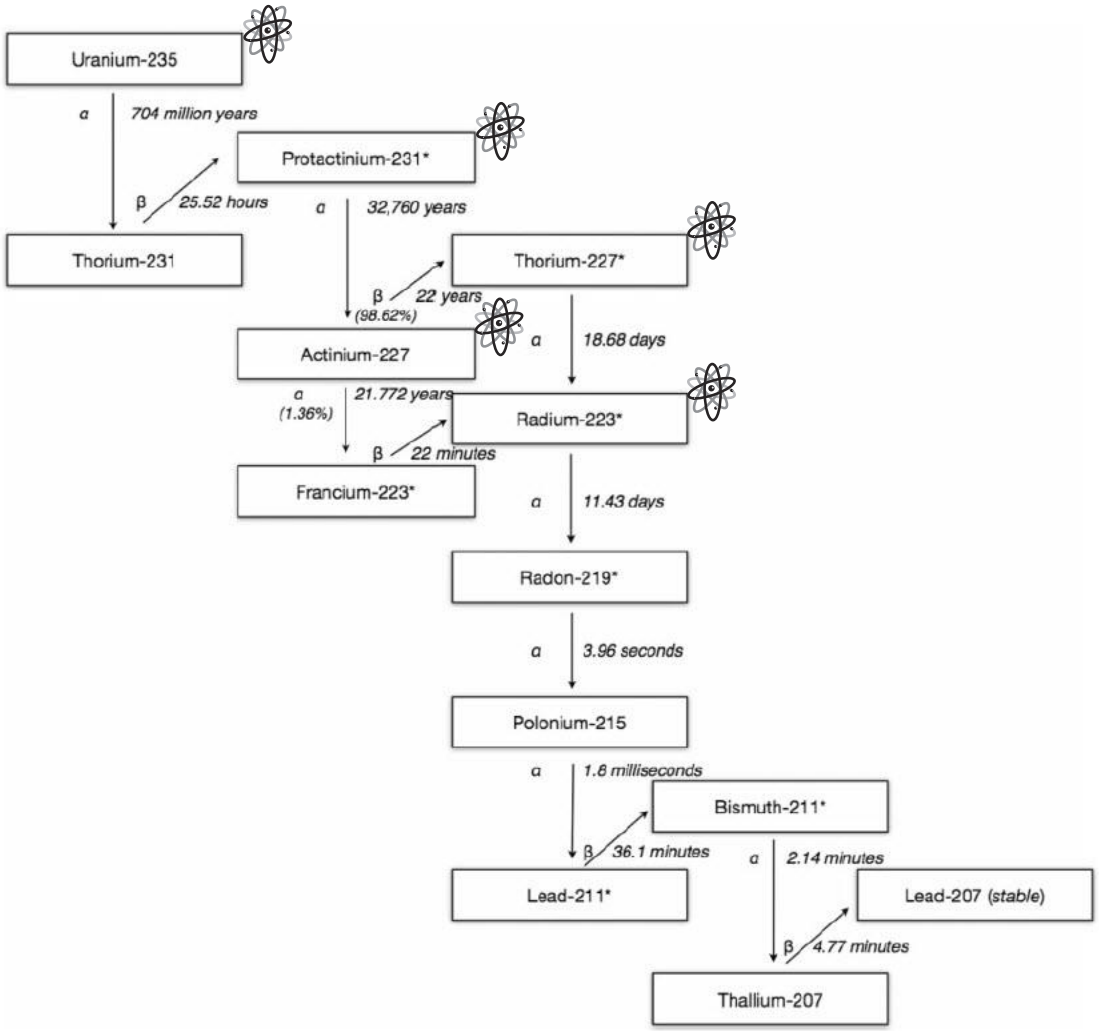


Figure A3 ^{235}U decay chain. Nuclides measured by gamma analysis in Farim samples are indicated by symbol.