Chapter 14

Unplanned Events

CONTENTS

14 UNPLANNED EVENTS

14.1 INTRODUCTION

An unplanned event is defined as 'a reasonably foreseeable event that is not planned to occur as part of the Project, but which may conceivably occur as a result of Project activities (eg accidents), even with a low probability'. Unplanned events may occur during any phase of the Project. This chapter describes the potential unplanned events associated with the Project and provides an assessment of the potential impacts on the receiving environment. Incidents such as minor spills and leaks that tend to occur on any project site during normal activities are considered and assessed in *Chapters 11* to *13*.

The Engineering and EIA Teams have considered a variety of potential unplanned events that may occur throughout the phases of the Project, and have developed a range of design features to reduce the likelihood of such events occurring. A variety of management plans (see *Chapter 17* and *Annex D* to *Annex F*) and mitigation measures have been developed to further reduce potential impacts to the onshore and marine environment. A representative Emergency Response Plan (ERP) is provided in *Annex H*. The ERP defines an organizational structure and provides a framework for responding to a major unplanned event. These proactive measures all serve to reduce the likelihood, extent and duration of adverse impacts resulting from an unplanned event.

Most of the foreseeable unplanned events associated with the Onshore and Near Shore Project components would be readily handled by these management plans, reducing the risk of an event occurring or the significance of any impact should an event occur. However, the vast area covered by the Offshore Project and difficult access to the subsea infrastructure on the seabed hinder an immediate response, should an unplanned event occur. This chapter therefore discusses risks associated with the following unplanned events:

- large volume spills of chemicals or hydrocarbons (1) (see *Section 14.3*); and
- failure of subsea infrastructure (such as well blowout (2) or pipeline failure) (see *Section 14.4*).

Other scenarios may occur during any phase of the Project, with the potential for environmental or social impacts. Such rare events include major fires and explosions, storage tank failures or ruptures, flare ignition failures and production shutdowns due to extreme weather conditions. While it is outside the scope of this EIA to assess quantitatively the probability and outcome of

(1) The activities covered by this EIA are for LNG production from natural gas, and are not anticipated to produce any crude oil. Consequently, the term 'hydrocarbon 'is used to describe the various fuels and condensate from this natural gas production.
(2) A well blowout is an uncontrolled flow of reservoir fluids into the well bore, and sometimes to the surface.

such events, it is appropriate to consider the management of certain scenarios, as they have potentially important environmental, socio-economic and community health and safety implications. Management measures to avoid the risk of such scenarios are presented in *Section 14.5*.

To further reduce the likelihood of unplanned events occurring, a Safety Case / Risk Assessments (1) will be undertaken as part of the FEED process. This will make provision for the identification, assessment, mitigation and management of health and safety hazards and risks associated with the Project. The findings will not only be used to reduce the likelihood of the occurrence of unplanned events, but also to refine and update the management plans and ERP to help the Project manage these risks.

14.2 *METHODOLOGY*

14.2.1 *Assessing Significance of Risks*

The methodology used to assess the risks associated with unplanned events differs from the impact assessment methodology set out in *Chapter 3* of this EIA. Impacts resulting from unplanned events are defined as being a combination of the likelihood (or frequency) of incident occurrence and the consequences of the incident should it occur. The assessment of likelihood takes a qualitative approach based on professional judgement, experience from similar projects and interaction with the Engineering Team. The assessment of consequence is based on specialists' input and professional experience (from the respective specialist disciplines) gained from similar projects.

Definitions used in the assessment for likelihood and consequence are set out in *Box 14.1.*

(1) Safety Case / Risk Assessments are formal processes to demonstrate that the Project has achieved ALARP for each safety-related aspect of the Project.

Box 14.1 Significance Criteria for Unplanned Events

Likelihood
Likelihood describes the probability of an event or incident actually occurring or taking place. It is considered in terms of the following variables:

- **Low**: the event or incident is reported in the oil and gas industry, but rarely occurs;
- **Medium**: the event or incident does occur but is not common; and/or
- **High**: the event or incident is likely to occur several times during the Project's lifetime.

Consequence
The potential consequence of an impact occurring is a culmination of those factors that determine the magnitude of the unplanned impact (in terms of the extent, duration and intensity of the impact). Consequence in unplanned events is similar to magnitude of planned events (see *Chapter 3*) and is classified as either a:

- **minor consequence**: impacts of Low intensity to receptors/resources across a local extent, that can readily recover in the short term with little or no recovery/remediation measures required;
- **moderate consequence**: impacts of Low to Medium intensity across a local to regional extent, to receptors/resources that can recover in the short term to medium term with the intervention of recovery/remediation measures; or
- **major consequence**: exceeds acceptable limits and standards, is of Medium to High intensity affecting receptors/resources across a regional to international extent that will recover in the long term only with the implementation of significant/remediation measures.

Once a rating is determined for likelihood and consequence, the risk matrix in *Table 14.1* is used to determine the impact risk significance for unplanned events. The prediction takes into account the mitigation and/or risk control measures that are already an integral part of the Project design, and the management plans to be implemented by the Project.

Table 14.1 Unplanned Events Risk Significance

Risk Significance Rating				
	Likelihood	Low	Medium	High
Consequence	Minor	Minor	Minor	Moderate
	Moderate	Minor	Moderate	Major
	Major	Moderate	Major	Major

Table 3.7 in *Chapter 3* outlines the definitions of impact significance for planned Project activities. The definitions of MINOR, MODERATE and MAJOR significance are also applicable for unplanned events.

It is not possible to eliminate completely the risk of unplanned events occurring. However, the mitigation strategy to minimise the risk of the occurrence of unplanned events is outlined in *Box 14.2*.

Box 14.2 Mitigation Strategy for Unplanned Events

Control: aims to prevent an incident happening or reduce the risk of it happening to ALARP through: • reducing the likelihood of the event (eg preventative maintenance regimes, reducing chemical usage, traffic calming and speed limits, community road safety awareness training, implementation of state-of-the-art blowout preventative equipment, procedures and training); • reducing the consequence (eg bunds to contain spilled fuels, fire protection); and • a combination of both of these.
Recovery/remediation: includes contingency plans and response, eg: • ERPs (including an Oil Spill Contingency Plan).

14.3 ASSESSMENT OF SPILLS OF CHEMICALS AND HYDROCARBONS

14.3.1 *Overview*

Spillages of chemicals, hydrocarbons and other fluids are considered unplanned events with the potential for significant environmental or social effects. Various substances will be stored and used in bulk during the various Project phases, including:

- chemicals:
  - drilling mud;
  - monoethylene glycol (MEG);
  - corrosion inhibitors and biocides;
  - methanol;
  - refrigerants;
  - solvents; and
  - fertiliser and similar chemicals; and

- hydrocarbons:
  - diesel and fuel oil;
  - aviation fuel;
  - lubricating and hydraulic oils; and
  - condensate.

14.3.2 *Onshore Spills of Chemicals and Hydrocarbons*

The above-mentioned chemicals (excluding drilling mud) will be used and stored onshore; however, the Project design, management plans and mitigation measures (outlined in *Chapter 12*) minimise the risk of adverse impacts resulting from an unplanned event such as a spill. For example, the LNG Process Area will be curbed to confine spills of potentially hazardous materials, and storage areas will be bunded to contain any potential spill to prevent them from impacting adjacent areas. Spill containment and clean-up kits will be available and, in the event of a spill, clean-up will occur as soon as possible after the spill, using appropriate response and safety equipment. Following clean-up, the materials will be stored in appropriate containers (eg drums) and will be managed according to the WMP (see *Annex E*) if they cannot be reused or recycled. In addition, the LNG Process Area will have a dedicated stormwater treatment system (see *Chapter 4*). This system will be designed to treat potentially contaminated run-off water to the applicable standards, prior to discharge into Palma Bay.

The features of the Project design and actions to be taken by Project staff in the event of a spill are anticipated to prevent spills of potentially hazardous materials from impacting onshore receptors. Furthermore, the safety exclusion zones around the Project infrastructure and activities prevent local communities from being directly affected by a spill onshore. The consequences of spills within the Onshore Project Area are, therefore, not assessed in detail, although their causes are discussed and relevant mitigation and management measures are proposed (see *Section 14.3.7*).

14.3.3 Offshore Spills of Chemicals and Hydrocarbons

The majority of the chemicals and hydrocarbon fluids mentioned in *Section 14.3.1* will be used in the Offshore Project Area and in Palma Bay. Spills to the marine environment (within Palma Bay or offshore) could occur during all phases of the Project, due to the malfunction or failure of equipment, vessel collision or human error during transfer or use of such fluids. The following sections provide an overview of potential chemical or hydrocarbon spills to the marine environment.

Chemical Spills

Chemical spills to the marine environment have the potential to occur during the transfer, storage and use of chemicals or in the case of equipment failure (eg release of hydrostatic test water). The impacts associated with chemical spills are related to the nature of the chemical spilled, location (surface or subsea) of spill volume and its behaviour in the marine environment (sink, float, disperse, etc). Drilling chemicals such as drilling muds (which contain barite and bentonite), cement, methanol and MEG will likely be stored in bulk on the drill rigs. These are classified as having low toxicity and have been rated as 'Pose Little or No Risk to the Environment' (PLONAR) (1). Other chemicals (such as solvents) that may not be PLONAR rated will be stored and used in smaller quantities and therefore have a lower risk of impact to the marine environment. Chemicals such as biocides and corrosion inhibitors are classed as having low toxicity in the dilution rates to be used.

In the event of a chemical spill to the marine environment, the chemical would be subject to dispersion and dilution by prevailing currents. The appropriate

(1) The OSPAR List of Substances Used and Discharged Offshore which Are Considered to Pose Little or No Risk to the Environment (OSPAR Agreement 2012-06).

response will depend upon the specifics of the event, including the characteristics of the material spilled, volume, location of spill and environmental conditions at the time of spill (current and wind direction and speed, etc). The Emergency Response Plan will address appropriate responses for the higher-risk chemical spill scenarios in the marine environment.

Spills will likely result in a temporary and highly localised decline in water quality. Such spills are likely to present a limited potential for toxicity to marine organisms, due to temporary exposure and low toxicity as a result of rapid dilution. The impacts associated with such a chemical spill are not considered further; however, measures to minimise the likelihood of chemical spills and management procedures to address such spills are outlined in *Section 14.3.7*.

Hydrocarbon Spills

The Project recognises the category of spills with the highest likelihood of occurrences is hydrocarbons, such as fuels and condensate. Crude oil is not expected to be produced from the offshore wells or stored/transported by the Project; therefore, the likelihood or potential impacts resulting from a spill of crude oil are not considered. A summary of the characteristics and behaviour of these hydrocarbons if spilled in the marine environment are presented below.

14.3.4 Behaviour of Hydrocarbon Spills in Water

Following the release of hydrocarbons into water, a number of processes occur that influence the fate of the spill. These processes are affected by the chemical and physical properties of the hydrocarbons such as its density, chemical composition (eg relative proportions of different hydrocarbons), viscosity, flash point, etc. The most important processes to affect hydrocarbons following a spill are dispersion and weathering. These processes are described in more detail below.

- **Spreading**: tendency to spread on the water surface. This is primarily a function of the viscosity of the hydrocarbon and is affected by temperature.

- **Drift**: the effect of tidal currents and wind. Hydrocarbons will drift at the speed and direction of the tidal current.

- **Weathering**: a complex series of physical, chemical and biological processes by which the volume of the hydrocarbon on the water surface reduces. The principal mechanisms involved in weathering are as follows, and examples of the potential impacts to environmental and social receptors and resources from major hydrocarbon spills are illustrated in *Figure 14.1* and *Figure 14.2*:

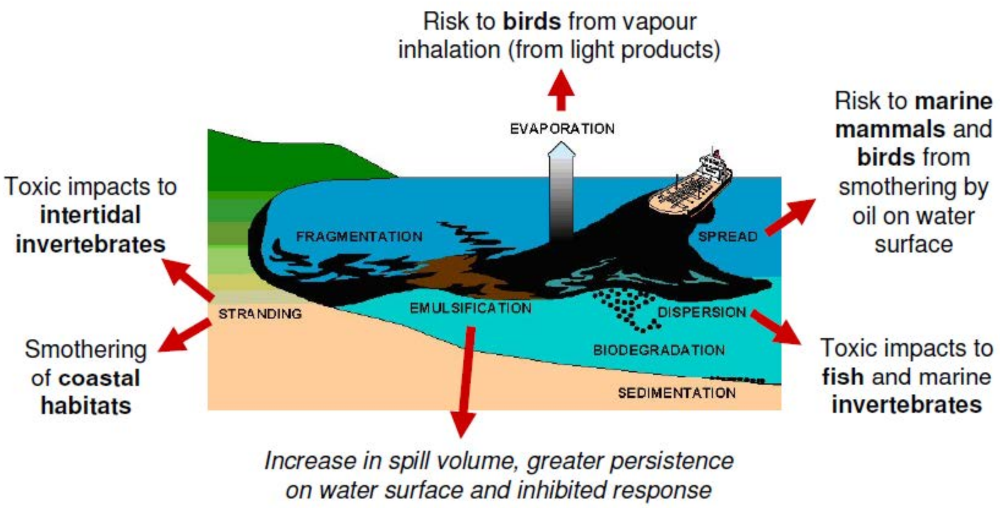
    - **evaporation**: loss of light, low molecular weight fractions;

o **emulsification**: combining with water to form a hydrocarbon/water emulsion;

o **dispersion**: breaking up of the slick into small droplets, which combine with suspended particles and allow the hydrocarbon to be dispersed in the water column and ultimately to sink to the seabed; and

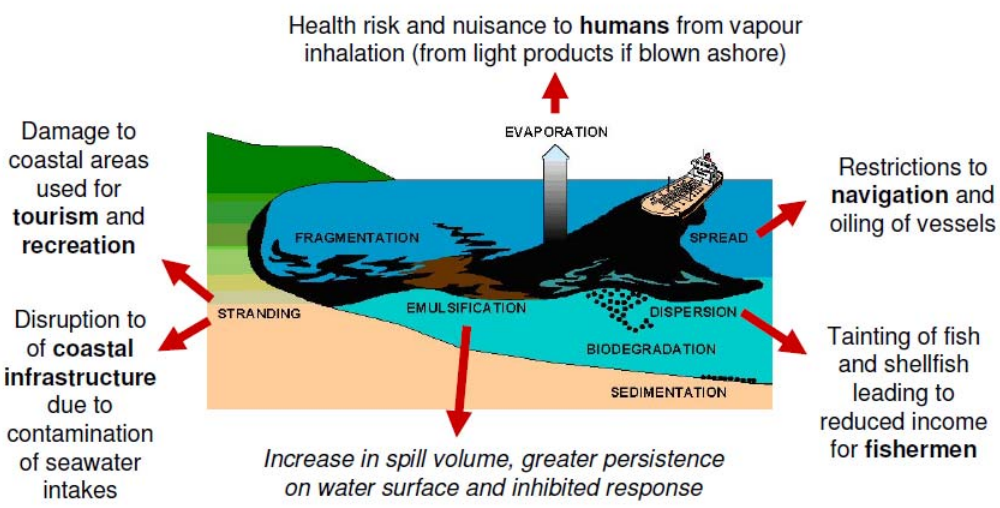
o **oxidation**: chemical/biological processes that break down the hydrocarbon.

Figure 14.1 Example of Potential Ecological Impacts of Major Hydrocarbon Spills



Source: ERM, 2012.

Figure 14.2 Example of Potential Social Impacts of Major Hydrocarbon Spills



Source: ERM, 2012.

The relative importance of these mechanisms is determined by the characteristics of the hydrocarbon spilled and the ambient conditions. The following discussion provides an overview of the characteristics of the hydrocarbons likely to be in use, stored or transported in the marine environment.

Diesel is a low-viscosity fuel that will be used for many engine applications including onshore and offshore construction equipment, vessels, machinery and power generation equipment. Diesel contains a relatively high proportion of volatile light fractions, which will weather and degrade relatively quickly if spilled. Diesel will spread rapidly, with the slick oriented in the direction of the prevailing wind and waves. Evaporation is the dominant process contributing to the removal of the lighter fractions of spilled diesel. The warm prevailing air and sea temperatures present in northern Mozambique are likely to enhance this evaporative loss. Heavier components of diesel tend to persist longer and will tend to disperse as oil droplets in the upper layers of the water column.

Aviation gasoline and jet fuel will be stored near the airport, but are likely to be transported to the Project site by sea. Aviation gasoline and jet fuel are composed of light hydrocarbon fractions; therefore, if spilled in the marine environment, they will evaporate quickly. Both aviation gasoline and jet fuel are toxic to aquatic organisms (1).

Lubricating and hydraulic oil are used in a variety of equipment on vessels and drill rigs. Hydraulic oil is of a light to moderate viscosity and has a rapid spreading rate; therefore it generally dissipates quickly. Lubricating oil is more viscous than diesel and slightly more dense. Lubricating oil is a heavy oil and has few lighter fractions, is therefore more viscous and will weather more slowly than diesel or hydraulic oil. It is less toxic than diesel but will form thicker slicks on the sea surface and therefore be more likely to present a direct impact to marine organisms due to coating.

Synthetic drilling mud is also similar to diesel in terms of physical characteristics, but is less toxic and will disperse more readily (Neff, McKelvie & Ayers, 2000).

Condensate is a hydrocarbon liquid with low viscosity that will generally spread rapidly on the sea surface and evaporate to a greater extent and more quickly than diesel. The rapid spread and evaporation will result in the rapid dissipation of a condensate slick. Spilled condensate will have a low tendency to form an emulsion.

Recovery from a hydrocarbon spill depends on two factors:

(1) Material Safety Data Sheets for jet fuel (eg JET A-1, fuel for aviation turbine engines fitted to aircraft) and aviation gasoline (eg AVGAS 100LL, a low lead content aviation gasoline fuel for piston engine aircraft).

- rate and degree of removal or weathering of the hydrocarbon from the environment; and

- recovery of affected populations and habitats.

Section 14.3.5 discusses the results of preliminary hydrocarbon spill modelling. A detailed spill model will be used to update the Oil Spill Contingency Plan (OSCP) within the ERP, to further develop a plan that is adequate to address potential spills into the marine environment.

14.3.5 Hydrocarbon Spill Modelling

Prior to undertaking exploratory drilling in Area 1, AMA1 commissioned a consultancy, namely The Response Group, to undertake preliminary trajectory modelling for various locations within Area 1 based on spills of 5,000bbl (795m^3) of medium crude oil [(1)]. Trajectory modelling is used to predict the route of a hydrocarbon slick over time and to estimate the weathering profile under specified hydrodynamic and meteorological conditions. Modelling outputs include the predicted slick trajectory and estimates of slick volume, dispersion, emulsification and evaporation over time.

Historical wind data was obtained[(2)] to run hydrocarbon spill simulations with start points at/near the exploratory drill well sites over various months of the year, taking into consideration the prevalent winds for both the dry and wet seasons. The outputs allow the determination of which waters and shorelines are most at risk during various times of the year, and also illustrate the time taken for hydrocarbon to reach the shoreline. Results showed that spills of 5,000bbl of medium crude oil at the Barquentine, Lagosta and Atum well fields could reach the shore in 15 hours to seven days. Initial shoreline impact for all scenarios modelled at these locations is approximately 150km south of Afungi Peninsula, approximately 80km north of Pemba.

Additional spill modelling will be undertaken prior to the commencement of Project activities (see *Section 14.3.7*) to determine additional spill scenarios. This will include various hydrocarbon types, such as diesel and condensate, as the Project recognises that spills of these hydrocarbons have the highest likelihood of occurrences.

The findings of such modelling will be used to update the OSCP within the ERP to develop a plan that is adequate to address potential spills into the marine environment.

(1) Large volumes of crude oil will not be extracted, stored or transported by the Project. However, medium crude oil was selected for the model as a conservative approach prior to exploration drilling (when it was unknown whether there would be natural gas or crude oil present).
(2) From the Department of Defence Pilot Charts.

14.3.6 *Risks to Receptors/Resources from a Hydrocarbon Spill*

Potential Impacts to Marine Habitats and Fauna

At any stage of natural gas field development, or during the operational phase, there is the possibility that a major hydrocarbon spill could occur through a vessel collision (possibly releasing fuel oil) or that a refuelling accident could release diesel fuel into the marine environment. In general, the impacts of diesel or condensate spills will be very localised and of relatively short duration, whereas fuel oil may be more persistent. The likelihood of such an occurrence taking place would be low, but the potential consequence could be major, dependent on the sensitivity and importance of receptors affected. The potential impact on marine life of a major spill of hydrocarbons either offshore or in Palma Bay is assessed below.

The environmental receptors considered vulnerable to the potential effects of a spill, and reasoning for this, are:

- **Fish and invertebrates**: toxicity or oxygen depletion as the hydrocarbons degrade may directly affect various life stages of fish and invertebrates (eg eggs, juveniles, adults, etc).

- **Seabird populations**: species that may be at risk from spilt hydrocarbons include diving birds and/or birds that may alight on the sea surface, such as frigate birds and terns.

- **Marine turtle populations**: because turtles do not appear to demonstrate avoidance behaviour for hydrocarbon slicks, they may be exposed to spills at sea. The primary agents for lethal effects on turtles are complete covering by hydrocarbons for juveniles, or the ingestion of tar balls (Milton et al., 2008). Neither should be caused by diesel, as it does not emulsify. Prolonged exposure (days) may generate respiratory-linked pathologies such as reduced dive times and foraging success, with increased risk of starvation.

- **Cetaceans**: whales and dolphins may be affected by a spill, either by effects on mating/courting behaviour or on their food sources. In most cases, these species would tend to move away from the affected area and would not suffer long-term effects. Because of the conservation status of these fauna, even low-level impacts are considered to be of international concern.

- **Corals and seagrass**: emulsified hydrocarbons may directly affect corals by smothering and toxicity, although the potential for the latter decreases with increasing emulsion. Seagrass beds may be affected by hydrocarbon coating, which can inhibit photosynthesis and cause direct toxic effects.

- **Mangroves and mudflats**: these low-energy environments tend to retain hydrocarbons for long periods of time, potentially becoming chronically contaminated and affecting the associated flora and fauna. The physical effects of hydrocarbons on mangrove species (eg covering or blocking of specialised tissues for respiration or salt management) can be as damaging to mangroves due to the inherent toxicity of the hydrocarbon (Hoff, 2002). Spills entering these environments, particularly mangrove forests, are difficult to clean up without physically damaging the environment in the process.

- **Sand beaches**: may be impacted by hydrocarbon spills, with consequences for various ecological processes (eg impacts on turtles nesting or birds feeding).

In the event of a spill, hydrocarbon can have toxic and/or smothering effects on organisms in the path of the spill, on the sea surface and in the water column. Impacts could extend from an onsite scale to a regional or international scale, based on material spilled, volumes/location/sea conditions and similar factors. Impacts would extend over a short-term period in this climate, as hydrocarbons could be expected to weather or evaporate within weeks; immediate response and clean-up activities would shorten this duration. However, the impact intensity would be High. In particular, coral, mangroves, mudflats, seagrass, marine birds and cetaceans are considered to be highly sensitive receptors to spills. These receptors may recover from a spill, but only with significant management response or remediation measures, depending on the hydrocarbon type and volume. Considering a worst-case scenario, the consequence of a large-volume hydrocarbon spill has the potential to be major. However, the likelihood of a large-volume hydrocarbon spill occurring is Low, and thus the risk significance of the impact is deemed to be MODERATE.

Table 14.2 Impact of Hydrocarbon Spills on Marine Habitats and Fauna

Receptor/ Resource	**Marine Habitats and Fauna**
Extent	Onsite to international
Duration	Short term to medium term
Intensity	High
Consequence	**Major**
Likelihood	**Low**
Risk significance	**MODERATE**

Potential Impacts to Socio-economic Environment

Spills can cause direct damage to fishing resources through toxic effects and tainting, and by disrupting normal fishing activities (eg fouling of nets, vessels). Direct economic losses to the fishing industry due to a hydrocarbon spill can be significant and have both long-term and short-term effects. Hydrocarbon spills can have four main impacts on fisheries resources and fishing activity:

- direct mortality of fish stock (both wild and caged) (1);
- exclusion from the fishing grounds or temporary closure of aquaculture farms;
- fouling of fishing gear; and
- potential decline in market value due to concerns about tainting.

The coastal communities in Cabo Delgado Province are heavily dependent on subsistence fishing for their nutritional well-being. Given that subsistence activities occur throughout the region, it is assumed that potential hydrocarbon spill locations near coastal or island communities in the province could significantly affect subsistence activities. Areas of Palma Bay have been designated for aquaculture development (see *Chapter 9*). Although there are currently no known proposed or active aquaculture farms within the bay, a hydrocarbon spill would likely result in closures.

A large hydrocarbon spill can adversely affect the fishing industry and subsistence fishing through the creation of exclusion zones around the pollution source, thus limiting the access of fishing vessels. As with potential environmental impacts, socio-economic impacts could extend from onsite to a regional or international scale (depending on the material spilled, volume and environmental conditions). The duration would likely be short term, lasting through clean-up and hydrocarbon weathering. Fishing would likely resume post clean-up; however, there may be a potential decline in market value due to concerns about tainting. Therefore, a medium-term impact is possible. Depending on the location of the spill, impact intensity may be High. In a worst-case scenario, impact consequence would be major because a relatively large area of the coastline and sea may be affected. However, the likelihood of a spill occurring is Low; therefore, the overall risk significance of the impact is considered MODERATE.

Table 14.3 Impact of Hydrocarbon Spills on Fisheries and Subsistence

Receptor/ Resource	Fisheries and Subsistence
Extent	Regional to international
Duration	Short term to medium term
Intensity	High
Consequence	**Major**
Likelihood	**Low**
Risk significance	**MODERATE**

Tourism in the Quirimbas Archipelago is dependent on the relatively pristine marine environment. A hydrocarbon spill could have an adverse effect on tourism through a direct impact on coastal areas (including damage resulting from hydrocarbon coating of coral reefs, beaches, etc) or through a belief that the Quirimbas Archipelago are no longer a desirable destination because of a real or perceived loss in pristine wilderness values. A large hydrocarbon spill

(1) There are currently no known proposed or active aquaculture farms within the bay however, approximately 10ha of the bay was declared as a 'Marine Reserve' by Decree no. 71/2011 for aquaculture potential; namely, fish farming and seaweed production (INAQUA, 2011).

is likely to limit tourism-based leisure activities (such as swimming, sailing, fishing, snorkelling and diving) until the area recovers. The duration of the impact could range from days to years, depending upon the specific parameters of the spill event.

The extent of the impact is anticipated to be national, given the importance of tourism in the Quirimbas Archipelago to the national economy, and of short-term to medium-term duration (ie from days to up to five years). The impact intensity has the potential to be High in the event that a spill directly strikes the islands, coastline or the natural resources on which the tourism industry is dependent (eg coral reefs). Impact consequence could be moderate to major as the value/sensitivity of the tourist industry is considered to be High; however, the impact is reversible. The likelihood of a large spill occurring is Low, resulting in an overall risk significance of MODERATE.

Table 14.4 Impact of Hydrocarbon Spills on Tourism

Receptor/ Resource	**Tourism**
Extent	National
Duration	Short term to medium term
Intensity	High
Consequence	**Moderate to major**
Likelihood	**Low**
Risk significance	**MODERATE**

14.3.7 Risk Prevention and Response Measures

Mitigation of chemical and hydrocarbon spills takes two forms: spill prevention and spill response. The primary mitigation measure for avoiding the impacts of a spill is to prevent any such spill taking place in the first place. This is done through the application of technology and operational controls. The Project will implement systems to respond, contain and clean up all spills. These systems will be designed with the capacity to handle various types and volumes of spills, in line with good industry practices.

The proposed measures to prevent and respond to chemical and hydrocarbon spills are:

- During the procurement process, chemicals will be evaluated for environmental, safety and technical performance. As far as practical, least hazardous chemicals will be selected.
- Procedures for response to chemical spills will be included in the ERP. This will include locations of spill containment and recovery equipment.
- The Project will conduct a detailed technical risk assessment. Such a risk assessment would include modelling and consider:
    - the location, eg in the vicinity of the well fields;

    - the event, eg a collision with a bunkering vessel;
    - the spill type and volume, eg 100,000l of diesel; and
    - the pathway or location affected, eg direct to sea.

- A detailed consequence analysis will be undertaken following spill modelling to determine the potential environmental and socio-economic impact. The analysis will focus on the spill size, type(s) of material spilled and potential spill location(s). Results will be incorporated into the ERP and the OSCP to inform risk reduction options, and to be adopted before construction activity begins.

- Implement the ERP, including an OSCP for offshore and near shore spills, and follow appropriate guidelines such as those produced by the OGP and International Association of Drilling Contractors (IADC) and the United Nations Environment Programme (UNEP). The following specific measures should be incorporated into the plans:

    - incorporate hydrocarbon spill prevention measures into operational procedures for construction, operation and decommissioning;

    - adopt specific controls for vessel offloading, bunkering and equipment refuelling;

    - use reinforced hosing for fuel transfers and use shut-off valves to reduce losses to sea should rupture occur;

    - where possible and practical, refuel only in calm weather and sea conditions and during daylight;

    - inform other users of the sea about the exact timing and location of drilling, construction, operational or decommissioning activities through the issuing of Notices to Mariners via the National Maritime Institute (INAMAR), to prevent the risk of vessel collisions;

    - security vessels should intercept and redirect any vessels potentially entering the various designated exclusion zones established in terms of the Law of the Sea;

    - standard communication (constant bridge watch and radio contact) and navigation systems (lighting and signalling systems) must be used on all vessels;

    - immediately inform INP and MICOA of any significant spills, and implement the OSCP as appropriate; and

    - if required, apply only biodegradable dispersants that have previously been approved by the relevant authority in Mozambique.

14.4 BLOWOUTS AND SUBSEA INFRASTRUCTURE FAILURE/RUPTURE

14.4.1 *Introduction*

Well blowouts are a potential risk associated with offshore drilling. A blowout occurs when control of the reservoir fluids into a well bore is lost, and these materials (hydrocarbons, drilling mud, etc) enter the environment. Reservoir fluids in the Golfinho, Prosperidade and Mamba gas fields that would be released to the marine environment in the unlikely event of a blowout include a mixture of natural gas, condensate and produced water (1). The main factors contributing to blowouts are leaks behind casing flows after cementing, equipment failure, casing failure, formation fracture, swabbing and stuck pipes (Minerals Management Service, 2007). During drilling and completion operations, all wells will be equipped with a BOP, consisting of a special assembly of high-pressure valves fitted to the top of a well to prevent high-pressure reservoir fluids from escaping. Blowouts are rare events and, with the implementation of proper risk prevention measures (see *Section 14.4.2*), the risk of a blowout resulting in a spill of reservoir fluids into the marine environment is rare.

Another potential unplanned event may result from damage to the subsea infrastructure, in particular the pipelines or wellheads. Such an event could potentially result in the failure of the system to contain its contents. Potential interactions that may lead to damage or rupture the Subsea Production System and pipelines are detailed below.

- Dropped objects/anchor drag: depending on the size and type of a dropped object (or size of anchor from ships crossing or travelling along the pipelines' route), there is a risk of indentation and/or possible failure.

- Sinking and grounding ships: outside of Palma Bay, the pipeline corridor coincides with the Mozambican shipping channel. There is, therefore, a potential risk of ships sinking and subsequently impacting the unburied portions of the subsea pipelines. In the event that the sinking of a cargo ship were to collide with the subsea pipeline, it is likely to result in a natural gas release or potentially, as a worst-case scenario, a pipeline rupture. However, in the shallow waters of Palma Bay, where the grounding of ships can occur, the pipelines will be buried and the likelihood of grounding ships impacting the pipelines is Low.

- Seismic activity or unstable seabed: the risk of pipeline rupture is increased where pipelines are located across deepwater canyons on the seafloor, given the potential instability of such canyons. Similarly, the Project is located in a seismically active area and, should an earthquake occur, the pipeline is at risk of damage.

(1) The exact composition of the mixture is dependent upon the reservoir being drilled.

Significant damage to the subsea infrastructure may cause failure, resulting in a leak or rupture and the subsequent release of large volumes of natural gas, produced water and smaller volumes of condensate. In the event of a pipeline rupture, the pipeline inlet valve would be closed automatically. Other subsea infrastructure will be equipped with similar shut-off valves. This will to minimise the volumes spilled to the marine environment.

Natural gas is composed largely of methane (CH_4) with trace amounts of higher molecular weight compounds such as ethane, propane, butane and pentane, but may also contain hydrogen sulphide (sour gas, H_2S). In sea water in the presence of oxygen, methane oxidises to carbon dioxide and water (H_2O). However, in a pipeline rupture, approximately 85 percent of the CH_4 released will reach the atmosphere, as the fraction oxidised in the water column amounts to 5 to 15 percent (Ward et al., 1987). In the event of a pipeline rupture, the natural gas will bubble to the surface, where the gas will disperse into the atmosphere. The nature of the dispersion (gas cloud) will depend on the molecular weight and the meteorological conditions.

Hydrogen sulphide is a toxic gas and may be present in natural gas; however, the H_2S content of the natural gas within Golfinho, Prosperidade and Mamba gas fields is negligible. Therefore, the associated environmental risks of an H_2S release into the marine environment are considered to be low. The remaining risks to the marine environment, in the event of a pipeline rupture, are associated with methane, condensate and trace amounts of MEG, methanol and water. Volumes of these in any release would be dependent on the rupture location, ambient pressure and flow rates through the subsea infrastructure, as flow rates affect how liquid accumulates in the pipelines.

The Subsea Production System and pipelines will be designed to withstand pressures well above normal operating pressure, and will be tested extensively during commissioning. The likelihood or frequency of a blowout or rupture event occurring and the subsequent release of natural gas is thus very low, based upon the engineering principles and techniques employed in the design of the pipelines and subsea infrastructure (see *Chapter 4*), but nevertheless the possibility still exists.

14.4.2 *Risks to Receptors/Resources from Blowouts or Subsea Infrastructure Failure/ Rupture*

Potential Impacts to Air Quality

No impact to the physical processes of the Mozambican channel (eg underwater current flows and water exchange) is expected to result from a blowout or pipeline rupture, as the natural gas will disperse into the water, form a gas plume and subsequently disperse into the atmosphere. This impact is therefore not assessed further.

A blowout or failure of subsea infrastructure may result in a contribution to Mozambique's annual emissions of GHGs in terms of global warming potential. The extent of the impact is national, as Mozambique's GHG emissions would be increased. The duration of the impact is regarded as permanent, given the long residence time of GHGs in the atmosphere. The likelihood of the event/incidence occurring is Low. Given the procedures in place to prevent a significant gas release and the measures to reduce the severity of a blowout or failure, the likelihood of the impact is considered Low and the consequence is considered minor. The overall risk significance of the impact is thus MINOR.

Table 14.5 Impact of Blowouts or Pipeline Failure/Rupture on Mozambique's National GHG Emissions

Receptor/ Resource	**National GHG Emissions**
Extent	National
Duration	Permanent
Intensity	Low
Consequence	**Minor**
Likelihood	**Low**
Risk significance	**MINOR**

Potential Impacts to Marine Ecology – Water Quality

A blowout or failure of subsea infrastructure could result in the release of large quantities of natural gas, condensate and trace amounts of chemicals into the marine environment. Chemicals (MEG and biocides) will be in use in such dilute quantities that their release is not likely to have a toxic effect on the marine environment. The remaining constituents likely to be released in such an unplanned event are discussed below.

As stated previously, natural gas is composed largely of methane. In the event of a release, the methane will escape into the atmosphere, with a minor amount dissolving into the water column (due to the low solubility of methane). The dissolved methane will be oxidised to carbon dioxide and water, resulting in low to non-existent toxicity on the water column. Considering the behaviour of methane in water and the negligible hydrogen sulphide content of the natural gas, the impact on marine ecological processes in the water column through toxicity effects will be negligible.

Condensate represents the greatest risk to the marine environment in the event of a blowout or the failure of subsea infrastructure. The impact of a large-scale condensate release would be similar to the impacts described in *Section 14.3.3*. However, it bears note that condensate would represent a small volume of the constituents of a release (due to the composition of the natural gas reservoir). In the event of a pipeline rupture, the pipeline shut-off valves would be closed automatically, minimising the volume of condensate released to the marine environment. Therefore, the impacts of a condensate release are also anticipated to be NEGLIGIBLE.

Potential Impacts to Marine Fauna – Displacement/Mortality

The pressure of the natural gas released from a blowout or rupture of a pipeline may result in death of fish located in the immediate vicinity, as a result of the pressure released. The underwater noise resulting from a pipeline rupture would likely result in the temporary displacement of fish that occur in the immediate area. However, the vast majority of pelagic marine species will immediately vacate the area and thus will not be significantly impacted by noise. Natural gas rising through the water column is not expected to have a significant impact on marine mammals, as discussed previously.

Impacts associated with a blowout or pipeline rupture are expected to be at a local extent around the release point and of temporary duration, as an emergency shutdown control system will be in operation for the Subsea Production System and pipelines, in accordance with good international industry practice. Impact intensity is anticipated to be Low and the consequence minor. Taking into consideration that the likelihood of a blowout or pipeline rupture/failure occurring is Low, the overall risk significance is MINOR.

Table 14.6 Impact of Blowouts or Pipeline Failure/Rupture on Marine Fauna

Receptor/ Resource	**Marine Ecology**
Extent	Local
Duration	Temporary
Intensity	Low
Consequence	**Minor**
Likelihood	**Low**
Risk significance	**MINOR**

Potential Impacts to Socio-economic Environment

A concern surrounding subsea gas leaks or ruptures to the socio-economic environment is whether or not a natural gas plume resulting from a rupture could result in buoyancy loss of shipping or fishing vessels, to the point where a vessel would sink if it were in the plume. Studies undertaken by Milgram (1984) and Hammett (1985) have shown that the loss in buoyancy of a vessel caused by the rising gas can be overcome by the upward momentum of the plume. The flow of water away from the plume will push vessels away from the bubble zone and vessels will not sink (S.L. Ross Environmental Research Ltd. et al., 2009). The impact of a blowout or pipeline rupture will therefore not impact shipping or fishing vessels should they be located directly above or within close proximity of the damaged subsea infrastructure, and therefore this impact is not assessed further.

14.4.3 Risk Prevention and Response Measures

The objectives of the measures outlined below are to reduce the risk of a blowout or pipeline rupture that could result in the release of hydrocarbons or chemicals into the marine environment.

- BOPs will be installed on the subsea wells, in accordance with good international industry practice, during well drilling and completion operations. BOPs will be inspected prior to installation and tested at regular intervals (determined by a combination of risk assessment, local practice, well type and legal requirements) during operations. Blowout contingency measures will be included in the Project's ERP.

- The Subsea Production System will be developed to good international industry practice, with alarm and shutdown systems to maintain the system within its design criteria at all times. The system will be tested, inspected and maintained to verify integrity and performance standards during construction and operations.

14.5 OTHER IDENTIFIED UNPLANNED EVENTS, RISK CONTROL AND REMEDIATION

As mentioned in *Section 14.1*, rare events including major fires and explosions, storage tank failures or ruptures, flare ignition failures and production shutdowns due to extreme weather conditions could occur during Project operations. These rare events could occur both offshore (ie on the drilling vessel) or at the Project's Near Shore or Onshore facilities.

The Project with input from the FEED Contractors will assess the risks of such unplanned events and associated scenarios as part of a Safety Case / Risk Assessment. The findings of this will inform decisions related to the ultimate design and layout of the Project. The FEED Contractors will comply with any response plans developed (including the ERP in *Annex H*) and develop all other necessary relevant response plans and procedures, which will be approved by the Project. Safety and loss prevention systems incorporated into the Project's design will include a minimum of:

- fire and gas detection and alarm systems;
- fire protection systems;
- emergency communications procedures;
- emergency response procedures and equipment;
- area classification and equipment selection; and
- spill (hydrocarbons and non-hydrocarbons) response plans and equipment.

In addition, support vessels will be provided with fire extinguishing and spill contingency equipment (onshore and offshore), and the operational fleet will include a dedicated response boat.

14.5.1 Risk of LNG Release, Fires and Explosions

This section outlines the risks associated with an LNG spill and fires and explosions respectively. The significance of these unplanned events on the environmental and socio-economic environment are not assessed. However, key management measures, based on good international industry practice (eg the IFC EHS Guidelines for LNG Facilities) to avoid the risk of such scenarios occurring, are detailed below.

LNG is a cryogenic liquid (–162°C) and, when spilled, vaporises into boil-off gas (methane). Under certain conditions, it could result in a vapour cloud if released. Uncontrolled releases of LNG could lead to jet or pool fires if an ignition source is present, or if there is the right concentration of LNG vapour in the air (5 to 15 percent).

The LNG carrier industry claims a record of relative safety over the last 50 years, since international LNG shipping began in 1959. More than 135,000 LNG carrier voyages have taken place without major accidents or safety or security problems, either in port or at sea (The International Group of Liquefied Natural Gas Importers, or GIIGNL, 2011). Similarly, the safety record of onshore LNG terminals is considered good; however, large releases of LNG under specific conditions could pose significant risks.

To minimise the risk of an LNG spill occurring during the transfer of LNG or otherwise, the Project will undertake the following, in accordance with good international industry practice.

- The Project will conduct a Safety Case / Risk Assessment. This will make provision for the identification, assessment, mitigation and management of health and safety hazards and risks associated with the release of LNG, both onshore and within the marine environment.

- The findings of the Safety Case / Risk Assessment will be integrated into the ERP, addressing various scenarios and magnitudes of releases of LNG and proposed spill control response procedures. This should be developed in coordination with the relevant local Mozambican regulatory agencies and to appropriate international standards. The plan should be supported by the necessary resources and training. Spill response equipment should be conveniently available to address all types of spills, including small spills.

- Facilities should be equipped with a system for the early detection of gas releases, designed to identify the existence of a gas release and to help pinpoint its source so that operator-initiated Emergency Shutdowns (ESDs) can be rapidly activated, thereby minimising the inventory of gas releases.

- An Emergency Shutdown and Detection (ESD/D) system should be available to initiate automatic transfer shutdown actions in the case of a significant LNG leak.

- Prepare and implement spill prevention procedures for loading/unloading activities involving marine vessels and terminals, according to applicable international standards and guidelines that specifically address advance communications.

- All LNG storage tanks will be of full-containment design, in accordance with good international industry practice. Full-containment tanks typically feature a primary liquid containment open-top inner tank and a concrete outer tank. The outer tank provides primary vapour containment and secondary liquid containment. In the unlikely event of a leak, the outer tank contains the liquid and provides a controlled release of the vapour.

Fire and explosion hazards at LNG facilities may result from the presence of flammable gases or liquids and ignition sources during loading and unloading activities, and/or leaks and spills of flammable products. Possible ignition sources include sparks associated with the build-up of static electricity, lightning and open flames. As outlined above, the accidental release of LNG may generate the formation of an evaporating liquid pool, potentially resulting in a pool fire and/or the dispersion of a cloud of natural gas resulting from pool evaporation. To minimise the risk of a fire or explosion occurring, the Project will implement the following measures, in accordance with good international industry practice.

- LNG facilities will be designed, constructed and operated according to international standards for the prevention and control of fire and explosion hazards, including provisions for safe distances between tanks in the facility and between the facility and adjacent buildings.

- Safety procedures for the loading and unloading of product to transport systems (eg tanker trucks and vessels) will be implemented, including the use of failsafe control valves and ESD/D equipment.

- A formal fire response plan will be prepared, supported by the necessary resources and training, including training in the use of fire suppression equipment and evacuation. Procedures may include coordination activities with local authorities or neighbouring facilities.

- Measures will be taken to prevent sources of potential ignition such as:

  - proper grounding to avoid static electricity build-up and lightning hazards (including formal procedures for the use and maintenance of grounding connections);

  - use of intrinsically safe electrical installations; and

- implementation of permit to work (PTW) systems and formal procedures for conducting any hot work during maintenance activities, including proper tank cleaning and venting.

- Facilities should be properly equipped with fire detection and suppression equipment that meets internationally recognised technical specifications for the type and amount of flammable and combustible materials stored at the facility.

- All fire systems should be located in accessible areas of the facility, protected from the fire by distance or by fire walls.

- Accommodation areas should be protected by distance or by fire walls. Ventilation air intakes should prevent smoke from entering accommodation areas.

- Fire safety training and response will be provided as part of workforce health and safety induction/training, including training in the use of fire suppression equipment and evacuation, with advanced fire safety training provided to a designated fire-fighting team.