ANNEX 4
EMISSIONS ESTIMATION REPORT

1 INTRODUCTION

This documents reports on the estimation of atmospheric emissions from the Alto Maipo Hydroelectric Project (PHAM).

As stated in the EIA, the PHAM is located in the Metropolitan Region, and is therefore required to abide by the region's Atmospheric Prevention and Decontamination Plan (*Plan de Prevención y Descontaminación Atmosférica* - PPDA).

According to the PPDA, all new activities or projects or modifications of existing projects or activities that go through the Environmental Impact Assessment System should meet the following conditions:

1. New activities or projects and their modifications, whatever the development phase, associated with a total annual emission representing an increase relative to the baseline that exceeds the limits shown in the following table, are required to compensate their emissions by 150%.

Table 1-1
Limits for Emissions Determined by the PPDA

Pollutant	Maximum Emissions (tons/year)
PM-10	10
CO	100
NOx	50
HC	100

2. The compensation of emissions will equal 150% of the annual emissions from the activity or project for the pollutant(s) for which the limits stated in the table above have been exceeded. These emissions include direct emissions, i.e. emissions released within the area where the activity is developed, and indirect emissions, such as those resulting from an increase in transport activities associated with the new activity.

In this context, this report addresses the emissions of particulate material (PM-10), carbon monoxide (CO), nitrogen oxides (NO_X), and hydrocarbons (HC) from the Project's construction activities, in order to evaluate compliance with the requirements set forth in the PPDA. In case of non-compliance with the stated emission limits, proposals for compensation are made. It should be noted that the emissions estimated are from the construction phase of the PHAM.

2 OBJECTIVES

The main objectives of this study are to:

1. Identify the activities generating atmospheric emissions;

2. Quantify the emissions generated by the activities identified;

3. Estimate the amount of emissions generated for each pollutant, during the construction phase of the Project, and, where applicable, determine the amount of emissions to be compensated under the Emissions Compensation Program (Programa de Compensación de Emisiones – PCE).

4. Determine the emissions compensation activities included in the PCE, and quantify the emissions to be compensated.

3 PROJECT DESCRIPTION

3.1 PROJECT ACTIVITIES

The Project consists of the construction of four conveyance tunnels: El Volcán, Yeso, Alfalfal, and Las Lajas. Development of the PHAM will also involve the construction of permanent and provisional surface works, as specified under Project Description, Chapter 2, and the detailed description of works attached as Annex 11.

The activities that are expected to produce emissions include:

a) Site preparation for road works;
b) Drilling and blasting;
c) Truck loading;
d) Truck traffic;
e) Truck unloading;
f) Loading of material disposal train wagons and conveyor belt;
g) Unloading of material disposal train wagons and conveyor belt;
h) Truck engines;
i) Equipment engines;
j) Erosion in muck disposal site active zones;
k) Construction of worker camps and other facilities.

All the activities listed above, to be developed mainly at the work fronts, emit PM-10. Activities h) and i) also release CO, HC and NO_X.

The construction of the Project also involves different work areas, where different volumes of material will be moved, and different muck disposal sites set up. There are eight such sites:

1. Volcán
2. El Yeso
3. Aucayes Alto
4. Alfalfal
5. Aucayes Bajo
6. Ventana Las Lajas
7. Ventana Las Puertas
8. Maipo River Discharge

All the works and work sites of the PHAM are shown in the layout included in Annex 1.

According to the Project Schedule (see Annex 2), the construction phase will begin once the corresponding resolution is obtained from COREMA (*Resolución de Calificación Ambiental*), and will last five years.

The external work fronts include all above-ground works, i.e. intakes, delivery canals, siphons, bridges, etc.

Emissions are calculated for each of the work fronts, based on the related works and/or activities, as specified in the Project Schedule, Annex 2. The emissions from the activities undertaken for the installment of work zones, worker camps and waste disposal areas, limited mostly to vehicle traffic, are also considered.

4 CALCULATION OF PROJECT-RELATED EMISSIONS

4.1 EMISSION FACTORS

4.1.1 Methodology Used

The inventory of PM-10 and gas emissions was prepared using information relating to the construction of the Project. The emissions factors of US EPA's AP 42, Compilation of Air Pollutant Emission Factors, Fifth Edition, and CONAMA's 2006 Guide for Estimating Atmospheric Emissions from Building Projects (*Guía para la Estimación de Emisiones Atmosféricas de Proyectos Inmobiliarios*), were subsequently applied. This methodology, reviewed by the competent authority, has been used and validated by Arcadis Geotécnica (AG) in a wide range of projects.

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of the pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per ton of material). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the emission source category.

The general equation for emissions estimation is:

$$TE = A * FE * (1 - RE/100)$$

Where:

TE = emission rate
A = activity rate
FE = emission factor
RE= overall emission reduction efficiency, %.

4.1.2 Emission Factor Equations for PM-10

The equations used to calculate emissions from the activities identified in section 3 above are as follows:

a) *Site Preparation for Road Works*

Emission Factor Equation	Description	Source
$E = \frac{0.75 * 0.45 * (s)^{1.5}}{(M)^{1.4}}$	E: emission factor, in kilograms emitted per hour of activity (kg/hr); s: material silt content (%); M: material moisture content (%).	USA Environmental Protection Agency (EPA), AP-42, Fifth Edition, Chapter 11, Section 11.9, Table 11.9-2, page 11.9.-7. 1998 Update.

The above emission factor represents an emission estimated per hour of activity per bulldozer[1]. To estimate the emission rate (e.g., in kg/day), emission factor (E) should be multiplied by the number of hours during which activities are carried out, and by the number of bulldozers used.

b) Drilling

The emission factor for drilling operations is:

Emission Factor Equation	Description	Source
$E = 0.59$	E: emission factor in kilograms emitted per hole.	USA Environmental Protection Agency (EPA), AP-42, Fifth Edition, Chapter 11, Section 11.9, Table 11.9-4, page 11.9-10. 1998 Update.

The above factor is applicable to PTS emissions. To estimate PM-10 emissions, a factor “k” equal to 0.37, similar to EPA’s recommendation for other emission factors, was considered.

[1] The emission factor equation refers to the movement of material, not to the type of equipment used. Therefore, a different type of equipment other than the bulldozer could be used, and the equation would still be applicable.

c) Blasting

The emission factor for drilling operations is calculated using the following empirical expression:

Emission Factor Equation	Description	Source
$E = 0.52 * 0.00022 * A^{1.5}$	E: emission factor in kilograms emitted per blast. A: horizontal area, with blasting depth ≥ 21 meters.	USA Environmental Protection Agency (EPA), AP-42, Fifth Edition, Chapter 11, Section 11.9, Table 11.9-2, page 11.9-7. 1998 Update.

d) Truck Loading

The equation for calculating the emission factor for truck loading is:

Emission Factor Equation	Description	Source
$E = \dfrac{k * 0.0016 * \left(\dfrac{U}{2.2}\right)^{1.3}}{\left(\dfrac{M}{2}\right)^{1.4}}$	E: emission factor in kilograms emitted per ton of material transferred. k: particle size multiplier (dimensionless). U: wind speed at time of transfer (m/s). M: material moisture content (%).	USA Environmental Protection Agency (EPA), AP-42, Chapter 13, Section 13.2.4, Equation Nº 1, page 13.2.4-3. 1995 Update.

The particle size multiplier (k) varies with aerodynamic particle size range, as follows:

Particle Size	≤30 µm	≤15 µm	≤10 µm	≤5 µm	≤2.5 µm
Multiplier	0.74	0.48	0.35	0.20	0.11

e) Truck Traffic on Unpaved Roads

The emission factor for truck traffic on unpaved roads can be estimated using the following equation:

Emission Factor Equation	Description	Source
$E = k * 281.9 * \left(\dfrac{s}{12}\right)^{0.9} * \left(\dfrac{W}{2.7}\right)^{0.45}$	E: emission factor in grams emitted per vehicle kilometer traveled (g/VKT). k: particle size multiplier (dimensionless). s: surface material silt content (%). W: mean vehicle weight (t).	USA Environmental Protection Agency (EPA), AP-42, Chapter 13, Section 13.2.2, Equation Nº 1a, page 13.2.2-4. 2003 Update.

The particle size multiplier (k) varies with aerodynamic particle size range, as follows:

Particle Size	≤30 µm	≤10 µm	≤2.5 µm
Multiplier	4.9	1.5	0.23

The above emission factor is used for trucks with or without a load, and light-duty vehicles.

f) Truck Traffic on Paved Roads

The emission factor for truck traffic on paved roads can be estimated using the following equation:

Emission Factor Equation	Description	Source
$E = 4.6 * \left(\frac{s}{2}\right)^{0.65} * \left(\frac{W}{3}\right)^{1.5}$	E: emission factor in grams emitted per vehicle kilometer traveled (g/VKT). sL: road surface silt loading (g/m²). W: average weight of the vehicles traveling the road (t).	USA Environmental Protection Agency, AP-42, Chapter 13, Section 13.2.1, Equation Nº1, page 13.2.1-4. 2003 Update.

The above emission factor can be used for all types of vehicles traveling paved roads.

g) Truck Unloading

The same equation used for estimating emissions from truck loading (see *d* above) is used for this activity.

h) Truck Engines

Truck diesel engine emissions can be estimated using the following equation:

Emission Factor Equation	Description	Source
$E = 2.73325 * V^{-0.7054}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects

i) Bus Engines

Emissions from the engines of personnel transport buses can be estimated as follows:

Emission Factor Equation	Description	Source
$E = 1.626345 * V^{-0.7373}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects

j) Equipment and Machinery

The PM-10 emission factor for equipment engines can be estimated using the following equation:

Emission Factor Equation	Description	Source
$E = EF_{SS} * TAF * DF$	E: emission factor (g/hp-hr) EF_{SS}: steady-state emission factor (g/hp-hr) TAF: transient adjustment factor DF: deterioration factor (unit less)	USA Environmental Protection Agency, EPA420-P-04-009, Equation N° 1, page 6. Revised April 2004.

This emission factor varies according to the steady-state emission factor EF, and the adjustment factors TAF and DF, which are mainly a function of the model year and horsepower category. The TAF is also a function of the activity that is being carried out[2].

k) Small-Scale Construction Activities

Emission Factor Equation	Description	Source
$E = 0.493$	E: emission factor (tons/hectare-month).	CARB Area Source Methodology, Section 7.7, Building Construction Fugitive Dust, 1997.

l) Muck Disposal Site Erosion

The emission factor for wind erosion is estimated as follows:

Emission Factor Equation	Description	Source
$E = 1.9 * \left(\frac{s}{1.5}\right) * \left(\frac{f}{15}\right) * \left(\frac{365 - p}{235}\right)$	E: emission factor (kg/day/hectare) s: silt content of soil or aggregate (%) f: percentage of time that the wind speed exceeds 5.4 m/s at the mean pile height p: number of days with ≥ 0.254 mm of precipitation per year.	USA Environmental Protection Agency, AP-42, Fourth Edition, Chapter 11, Section 11.2.3, Equation Nº 3, page 11.2.3-5 (1985)

4.1.3 Emission Factor Equations for CO

m) Truck Engines

The truck engine CO emission factor is as follows:

[2] Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-Compression-Ignition, EPA 420-P-04-009, April 2004

Emission Factor Equation	Description	Source
$E = 16.776 * v^{-0.6945}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects (2006)

n) Bus Engines

Emission Factor Equation	Description	Source
$E = 20.0942 * V^{-0.8393}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects (2006)

o) Equipment and Machinery

Emission Factor Equation	Description	Source
$E = EF_{SS} * TAF * DF$	E: emission factor (g/hp-hr) EF_{SS}: steady-state emission factor (g/hp-hr) TAF: transient adjustment factor DF: deterioration factor (unit less)	USA Environmental Protection Agency, EPA420-P-04-009, Equation N° 1, page 6. Revised April 2004.

4.1.4 Emission Factor Equations for HC

p) Truck Engines

Emission Factor Equation	Description	Source
$E = 18.054 * V^{-0.8774}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects (2006)

q*) Bus Engines*

Emission Factor Equation	Description	Source
$E = 13.928355 * V^{-0.8870}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects (2006)

r*) Equipment and Machines*

The emission factor for HC from construction equipment engines can be calculated using the

following equation:

Emission Factor Equation	Description	Source
$E = EF_{SS} * TAF * DF$	E: emission factor (g/hp-hr) EF_{SS}: steady-state emission factor (g/hp-hr) TAF: transient adjustment factor DF: deterioration factor (unit less)	USA Environmental Protection Agency, EPA420-P-04-009, Equation N° 1, page 6. Revised April 2004.

The emission and adjustment factors were estimated following the same procedure as described in section 4.1.2 (j) above.

4.1.5 Emission Factor Equations for NOx

s) Truck Engines

Truck NO_X emission factors are as follows:

Emission Factor Equation	Description	Source
$E = 46.464 * V^{-0.5859}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects (2006)

t*) Bus Engines*

Bus NO_X emission factors are as follows:

Emission Factor Equation	Description	Source
$E = 35.2436 * V^{-0.6562}$	E: emission factor (g/kg) V: mean speed of vehicles (kph)	CONAMA's Guide for Estimating Atmospheric Emissions from Building Projects (2006)

w*) Equipment and Machinery*

The NO_X emission factor for equipment engines can be estimated using the following equation:

Emission Factor Equation	Description	Source
$E = EF_{SS} * TAF * DF$	E: emission factor (g/hp-hr) EF_{SS}: steady-state emission factor (g/hp-hr) TAF: transient adjustment factor DF: deterioration factor (unit less)	USA Environmental Protection Agency, AP-42, Chapter 11, Section 11.2.3, Equation N°3, page 11.2.3-5. 1983.

The emission and adjustment factors (EF, TAF y DF) were taken from EPA420-P-04-009.

4.2 GENERAL CONSIDERATIONS FOR ESTIMATING EMISSIONS

4.2.1 Project-Related Considerations

The emission factors mentioned in section 4.1 above, taken from EPA AP-42 and CONAMA, are used to calculate the emission rates for the Project's construction activities.
The estimation of emission rates considers variables such as material silt content, moisture content, vehicle weight, etc. Additionally, calculations take into account the intensity of the activity to be carried out, as measured, for example, by the amount of material to be transferred, the number of trips a vehicle makes per day, the number of hours in a work day, etc.

Other aspects of the Project must also be considered to ensure that emissions are not overestimated. These considerations are as follows:

- A significant portion of the material to be removed from the work fronts will be transported to the muck disposal sites on shuttle cars operating on tracks, and via conveyor belts, with above-ground encapsulated conveyance capability. This will significantly reduce fugitive dust emissions associated with the transportation of excavated material to the dump sites. The figure in Annex 28 illustrates the transportation systems for the different areas.

- Even though many activities inside the tunnels emit particulate matter, i.e., drilling, blasting and loading of material, they are carried out underground and far from tunnel entry points. Making a conservative assumption, these emissions travel a maximum distance equivalent to 10 times the width of the tunnel from their point of origin. Therefore, the only emissions from drilling, blasting and loading activities that can exit in the tunnel are those produced at a maximum depth from the portal equivalent to 10 times the width of the tunnel. As a result, air extraction systems will operate inside the tunnels to ensure that working conditions meet all the appropriate comfort and health-related requirements. The systems will include activated carbon filters, impregnated with potassium permanganate, commonly used to capture gases in industrial and mining operations. The number of filters will be determined based on the volume of air to be moved.

- The tunnel excavation system involves working with moistened material to avoid damaging the construction equipment used for tunneling operations. As a result, the moisture content of the material extracted from the tunnels and transported by rail, truck or conveyor belts to the dump sites, will be higher than normal.

- To estimate emissions from bulldozing activities, a progress rate of 100 m^3/hour, taken from the specifications of the Project, was considered.

- The details of the new access roads to be constructed under the Project are shown in Table 4-1 below.

Table 4-1
New Access Roads to be Constructed

Sector	Length (km)	Surface Type
El Volcán – Access to Ventana V1 and Intakes	7.0	Granular
El Yeso - Access to Alfalfal II Tunnel, VA4	4.24	Granular
Aucayes Bajo - Access to Alfalfal II powerhouse	6.14	Double treatment or similar
Aucayes Bajo – Access to Los Maitenes forebay	1.0	Granular
Aucayes Alto - Access to Ventana VA2 and forebay	12.0	Granular
Colorado River – Roads surrounding Route G-345	0.52	Granular
Access to Las Lajas powerhouse	0.58	Double treatment or similar

- The data that were not included in the engineering design of this study, were obtained based on experience with similar works.

The values for the parameters used to estimate emissions are summarized in Table 4.2 below.

Table 4-2
Parameters for Estimating PM-10 Emissions

Type of Material	Parameter	Value	Unit	Source
Ordinary	Material moisture content	2.5	% (M)	Soil analysis by AG for the Los Bronces Development Project EIA, Minera Sur Andes Ltda. (2006)
Rocky	Material moisture content	2	% (M)	Soil analysis by AG for the Los Bronces Development Project EIA, Minera Sur Andes Ltda. (2006)
Ordinary	Silt content	10	% (s)	Soil analysis by AG for the Los Bronces Development Project EIA, Minera Sur Andes Ltda. (2006)
Rocky	Density	2.6	t/m^3	Soil mechanics analysis by AG for "Los Bronces Development Project" EIA, Minera Sur Andes Ltda. (2006)
Ordinary	Density	1.6	t/m^3	Soil mechanics analysis by AG for the Los Bronces Development Project EIA, Minera Sur Andes Ltda. (2006)
N/A	Mean wind speed	8.5	m/s	1991-2000 data for Quinta Normal, Santiago
N/A	Medium-traffic road surface silt loading	0.96	g/m^2	2001 Emissions Inventory for the Metropolitan Region

4.2.2 Data and Parameters Considered

4.2.2.1 Tunnel Construction

Tunnel construction will take place in different work fronts. Access to these work fronts will be through the main portals or through the entry points of the windows to be constructed. The size of the tunnels, and portal areas will affect the amount of emissions of particulate matter, as they will help estimate the volume of material to be removed. Table 4-3 below shows the length and portal area for each tunnel to be constructed.

Table 4-3
Tunnel Length and Portal Area

Tunnel	Portal Area (m^2)	Length (km)
El Volcán	10	14.2
Alfalfal II	16	15 (17)
Las Lajas	38	9.6 (10)
Alfalfal II Discharge	46	3.4 (2)
Las Lajas Discharge	51	13.4 (3.6)
Alfalfal II Access	38	2.4 (2)
Las Lajas Access	38	1.9 (1,4)

Source: Prepared by the author.

Some tunnels will be constructed by means of tunnel boring machines (TBM), a method that does not involve particulate matter emissions, as it requires the prior moistening of the extracted material, thus eliminating the related emission (see the figure in Annex 28).

The more traditional “drill and blast” method used to construct other tunnels will generate emissions.

Table 4-4 below summarizes the tunnel construction sites and methods, and the number of holes per blast. The detailed construction method by area is shown in Annex 28.

Table 4-4
Tunnel Construction Areas and Number of Holes per Blast

Area	Tunnel	Method	Tunnel Portal Area (m2)	Number of Holes / Blast	Length Considered (km)
El Volcán	El Volcán	Drill & Blast	10	40	32
El Yeso	El Volcán	Drill & Blast	10	40	32
	El Volcán	TBM	10		
	El Alfalfal II	Drill & Blast	16	64	40
	El Alfalfal II	TBM	16		
	Interior	Drill & Blast	10	40	32
Aucayes Alto	El Alfalfal II	Drill & Blast	16	64	40
	El Alfalfal II	TBM	16		
Alfalfal	Alfalfal II Access	Drill & Blast	16	64	40
	Alfalfal II Discharge	Drill & Blast	16	64	40
Aucayes Bajo	Alfalfal II Discharge	Drill & Blast	16	64	40
	Las Lajas Upstream Headrace	Drill & Blast	38	152	62
	Las Lajas Downstream Headrace	Drill & Blast	38	152	62
Las Lajas	Las Lajas Upstream Headrace	Drill & Blast	38	152	62
Las Puertas	Las Lajas Access	Drill & Blast	38	152	62
	Las Lajas Discharge	Drill & Blast	38	152	62
Maipo	Las Lajas Discharge	Drill & Blast	38	152	62
	Alfalfal II	TBM	16		

An estimated 1.7 million m³ of rock and sediment will be extracted during the construction of the tunnels, which will be stored in disposal sites located throughout the Project area. The amount of material extracted from each of the work areas, and the ton equivalents are shown in Table 4-5 below. Ton equivalents were estimated using the material densities provided in Table 4-2 above.

The surface works to be undertaken include intakes, delivery canals, siphons, roads, etc. An estimated 0.86 million m³ of material will be shifted for road construction, 0.14 million m³ of which will be re-used to fill in ditches and restore embankments, and the remaining 0.73 million m³ transported to the dump sites.

Table 4-5
Amounts of Waste Material to be Moved from the Work Areas

Work Area	Road Material Removed (m³)		Road Material Re-Used (m³)	Muck Extracted (m³)	Rocky Road Material to Dump (m³)	Ordinary Road Material to Dump (m³)	Road Material Re-Used (Tons)	Ordinary Material (Tons)	Rocky Material (Tons)
	Rocky	Ordinary							
Volcán	14,000	120,000	42,811	107,765	9,527	81,662	73,069	130,659	304,960
El Yeso	15,000	120,000	51,800	293,690	9,653	73,547	88,578	117,675	788,692
Aucayes Alto	62,400	207,000	22,300	273,459	56,800	190,300	268,416	304,480	858,673
Alfalfal	0	0	0	173,400	0	0	0	0	450,840
Aucayes Bajo	108,600	188,000	19,164	418,585	101,118	176,318	37,753	282,109	1,351,228
Ventana Las Lajas	150	25,050	5,300	171,101	133	19,767	8,480	31,627	445,207
Las Puertas	0	0	0	449,219	0	0	0	0	1,167,969
Maipo	0	0	0	210,180	0	0	0	0	546,468

Each work front will have its own muck disposal site.

During the construction phase, 14 muck disposal sites will be sited throughout the Project area. The location and operating details of the disposal sites are described in Annex 6. Table 4-6 below shows the muck disposal sites to be installed for each work area, and the amount of waste material they will receive during the construction phase of the Project.

Table 4-6
Work Area Muck Disposal Sites and Waste Material Deposited

Work Area	Associated Dump Site	Ordinary Material (Tons)	Rock Material (Tons)
Volcán	MDS Nº 1	130,659	304,960
El Yeso	MDS Nº 2	0	309,694
	MDS Nº 3	42,651	73,952
	MDS Nº 4	75,024	405,046
Aucayes Alto	MDS Nº 5	100,174	733,307
	MDS Nº 6	204,306	125,366
Alfalfal	MDS Nº 7	0	315,640
	MDS Nº 8	0	135,200
Aucayes Bajo	MDS Nº 9	282,109	1,351,228
Ventana Las Lajas	MDS Nº 10	0	176,800
	MDS Nº 11	18,507	154,872
	MDS Nº 13	13,120	113,880
Las Puertas	MDS Nº 14	0	1,168,440
Maipo	MDS Nº 12	0	546,000
TOTAL		866,550	5,914,385

As shown in Table 3-1, the Project's construction activities will take place from 2008 to 2013. During this time, the operation of the muck disposal sites will vary. Table 4-7 below shows the amounts of waste material that each muck disposal site will receive per year during the construction phase, and the number of months, in a year, during which dumping will take place.

Table 4-7
Dumping of Waste Material at Muck Disposal Sites, by Type of Material and Year

Work Area	Dump	Type of Material	YEAR									
			2008		2009		2010		2011		2012	
			Tons Dumped	Nº of Months	Tons Dumped	Nº of Months	Tons Dumped	Nº of Months	Tons Dumped	Nº of Months	Tons Dumped	Nº of Months
Volcán	MDS #1	Ordinary	65,329	3	65,329	3						
		Rock	12,385	3	12,385	3						
		Muck			66,361	9	88,481	12	88,481	12	36,867	5
El Yeso	MDS #2	Ordinary										
		Rock										
		Muck			79,636	9	106,181	12	106,181	12	17,697	2
	MDS #3	Ordinary	21,326	3	21,326	3						
		Rock	5,776	3	5,776	3						
		Muck					9,360	3	37,440	12	15,600	5
	MDS #4	Ordinary	37,512	3	37,512	3						
		Rock	6,773	3	6,773	3						
		Muck			135,519	9	180,692	12	75,289	5		
Aucayes Alto	MDS #5	Ordinary			100,174	6						
		Rock			22,000	6						
		Muck			82,074	3	328,296	12	300,938	11		
	MDS #6	Ordinary	102,153	3	102,153	3						
		Rock	62,683	3	62,683	3						
		Muck										
Alfalfal	MDS #7	Ordinary										
		Rock										
		Muck			78,910	9	105,213	12	105,213	12	26,303	3
	MDS #8	Ordinary										
		Rock										
		Muck			101,400	9	33,800	3				
Aucayes Bajo	MDS #9	Ordinary	282,109	6								
		Rock	256,733	6								
		Muck	99,500	3	397,998	12	397,998	12	198,999	6		
Ventana Las Lajas	MDS#10	Ordinary										
		Rock										
		Muck			176,800	7						
	MDS#11	Ordinary	18,507	6								
		Rock	346	6								
		Muck	38,632	3	115,895	9						
	MDS#13	Ordinary	13,120	6								
		Rock										
		Muck	14,235	3	56,940	12	42,705	9				
Las Puertas	MDS#14	Ordinary										
		Rock										
		Muck	85,496	3	341,982	12	341,982	12	341,982	12	56,997	2
Maipo	MDS#12	Ordinary										
		Rock										
		Muck	104,553	9	139,404	12	139,404	12	139,404	12	23,234	2
TOTAL		Ordinary	540,056		326,494		0		0		0	
		Rock	344,696		109,617		0		0		0	
		Muck	342,415		1,772,919		1,774,113		1,393,927		176,698	

4.2.2.2 Project-Related Traffic and Distances Traveled

The development of the Project will generate traffic, particularly traffic of vehicles transporting supplies, workers, and waste. As the routes used by these vehicles are predetermined, the distances traveled will suffer very little variation during the construction phase.

Project-related traffic will follow three mains routes: vehicles coming from the city to the different work areas, traffic inside the work sites, and traffic from the work areas to the muck disposal sites. Vehicles transporting personnel to the work areas will depart from Puente Alto and San José de Maipo; however, only Puente Alto has been considered as a departure point in order to facilitate calculations.

As already mentioned, the majority of the material extracted will be re-used during the construction of the Project, thus reducing the amount of material that needs to be transported from and to other areas. This applies to the construction of intakes, canals, short roadway segments and forebays. In the case of the forebays, the material extracted will be re-used to build protection parapets. This means that the distances traveled to transport material to be used for these construction works will be very short.

Table 4-8 below shows the distances traveled by project-related traffic from the city to the work areas, including travel on new access roads.

Table 4-8
Distances Traveled by Vehicles from the City to the Work Areas

Origin	Destination Work Area	Total Distance (km)	Paved Segment (km)	Unpaved Segment (km)
Puente Alto	Volcán	79.9	44	29.9
Puente Alto	El Yeso	69.2	44	25.2
Puente Alto	Aucayes Alto	54.4	43	11.4
Puente Alto	Aucayes Bajo	48.8	43	5.8
Puente Alto	Ventana Las Lajas	30.5	30	0.5
Puente Alto	Maipo	14.9	14.5	0.4
Puente Alto	Alfalfal	43	43	0

Table 4-9 below shows the distances traveled by the buses transporting workers from the camps to the work fronts for each year of the construction phase.

Table 4-9
Estimated Total Kilometers Traveled by Personnel Transport Buses from Worker Camps to Work Areas

Work Area	2008	2009	2010	2011	2012	2013
Volcán	166	7,464	10,841	12,360	12,177	615
El Yeso	1,766	11,7749	218,343	192,991	46,843	0
Aucayes Alto	3,378	59,186	59,568	89,352	36,001	0
Alfalfal	10,780	78,694	100,156	71,540	3,528	0
Aucayes Bajo	20,240	313,170	385,440	273,020	9,900	0
Ventana Las Lajas	0	30,660	56,940	48,180	0	0
Las Puertas	8,954	287,328	538,740	448,950	0	0
Maipo	41,897	192,583	196,680	196,680	155,705	0

Table 4-10 below shows the average distance between the main work fronts and the muck disposal sites.

Table 4-10
Average Distance from the Muck Disposal Sites to the Main Work Fronts

Work Area	Associated Dump	Average Distance (km)
Volcán	MDS Nº 1	1.23
El Yeso	MDS Nº 2	0.13
	MDS Nº 3	2.10
	MDS Nº 4	1.20
Aucayes Alto	MDS Nº 5	1.50
	MDS Nº 6	2.29
Alfalfal	MDS Nº 7	0.34
	MDS Nº 8	0.14
Aucayes Bajo	MDS Nº 9	1.70
Ventana Las Lajas	MDS Nº 10	0.16
	MDS Nº 11	0.81
	MDS Nº 13	0.16
Las Puertas	MDS Nº 14	6.06
Maipo	MDS Nº 12	0.16

4.3 PM-10 EMISSIONS DURING WORKS

4.3.1 Drilling and Blasting

The emission factor for drilling is expressed in kilograms per hole. This emission factor is applicable to PTS emissions. To estimate PM-10 emissions, a factor “k” equal to 0.37, similar to EPA’s recommendation for other emission factors, was considered.

In the case of blasting activities, the emission factor is expressed in kilograms of PM-10 emitted per blast.

For both drilling and blasting, only those activities undertaken in proximity to tunnel portals are expected to generate emissions. As tunneling works progress, emissions will not disperse enough to exit through the portals.

As already mentioned in section 4.2.11 above, it is assumed that emissions from tunneling activities travel a maximum distance equivalent to 10 times the width of the tunnel from their point of origin.

Tables 4-11 and 4-12 below show the estimated PM-10 emissions from drilling and blasting, respectively.

Table 4-11
PM-10 Emissions from Drilling

Area	Tunnel	Nº of Holes in work	Emission Factor (kg/hole)	PM-10 Factor	Total Emission	Emissions per Year				
						2008	2009	2010	2011	2012
El Volcán	El Volcán	1,423	0.59	0.37	311		311			
El Yeso	El Volcán	1,423	0.59	0.37	311		311			
	El Alfalfal II	1,800	0.59	0.37	393		393			
	Interior	1,423	0.59	0.37	311			311		
Aucayes Alto	El Alfalfal II	1,800	0.59	0.37	393		393			
Alfalfal	Alfalfal II Access	1,800	0.59	0.37	393		393			
	Alfalfal II Discharge	1,800	0.59	0.37	393				393	
Aucayes Bajo	Alfalfal II Discharge	1,800	0.59	0.37	393		393			
	Las Lajas Upst Headrace	2,774	0.59	0.37	606		606			
	Las Lajas Dnst Headrace	2,774	0.59	0.37	606			606		
Las Lajas	Las Lajas Upst Headrace	2,774	0.59	0.37	606		606			
Las Puertas	Las Lajas Access	2,774	0.59	0.37	606		606			
	Las Lajas Discharge	2,774	0.59	0.37	606			606		
Maipo	Las Lajas Discharge	2,774	0.59	0.37	606		606			
TOTAL EMISSION (KG)					**6,530**	**0**	**4,615**	**1,522**	**393**	**0**

Source: Prepared by the author.

Table 4-12
PM-10 Emissions from Blasting

Work Area	Tunnel	Tunnel Portal Area (m²)	Tunnel Length (m)	Progress per Blast (m)	Nº Blasts	Emission Factor kg/blast	Total Emission Works (kg)	Emissions per Year				
								2008	2009	2010	2011	2012
El Volcán	El Volcán	10	32	3.2	10	0.0036	0.04		0.04			
El Yeso	El Volcán	10	32	3.2	10	0.0036	0.04		0.04			
	El Alfalfal II	16	40	4.0	10	0.0073	0.07		0.07			
	Lo Encañado Int.	10	32	3.2	10	0.0036	0.04			0.04		
Aucayes Alto	El Alfalfal II	16	40	4.0	10	0.0073	0.07		0.07			
Alfalfal	Alfalfal II Access	16	40	4.0	10	0.0073	0.07		0.07			
	Alfalfal II Discharge	16	40	4.0	10	0.0073	0.07				0.07	
Aucayes Bajo	Alfalfal II Discharge	16	40	4.0	10	0.0073	0.07		0.07			
	Las Lajas Upst Headrace	38	62	6.2	10	0.0268	0.27		0.27			
	Las Lajas Dnst Headrace	38	62	6.2	10	0.0268	0.27			0.27		
Las Lajas	Las Lajas Upst Headrace	38	62	6.2	10	0.0268	0.27		0.27			
Las Puertas	Las Lajas Access	38	62	6.2	10	0.0268	0.27		0.27			
	Las Lajas Discharge	38	62	6.2	10	0.0268	0.27			0.27		
Maipo	Las Lajas Discharge	38	62	6.2	10	0.0268	0.27		0.27			
TOTAL EMISSION (KG)							**2.08**	**0.00**	**1.44**	**0.57**	**0.07**	**0.00**

Source: Prepared by the author.

4.3.2 Material Loading and Unloading

Approximately 7.2 million tons of material will be moved during the Project (see Tables 4-5 and 4-6 above). Part of this material will be re-used during the construction, but the majority will be dumped at the muck disposal sites. Table 4-13 shows the PM-10 emissions from loading material at the work areas. The emission factor was estimated based on the data provided in Table 4-2.

Table 4-13
PM-10 Emissions from Material Loading

Work Area	Type of Material	Material Loaded per Year (t)					Emission Factor (kg/t)	Total Emissions from Loading per Year (kg)				
		2008	2009	2010	2011	2012		2008	2009	2010	2011	2012
Volcán	Ordinary	98,047	98,047				0.00237	233	233			
	Rock	16,202	16,202				0.00325	53	53			
	Muck		66,361	88,481	88,481	36,867	0.00325		215	287	287	120
El Yeso	Ordinary	98,206	98,206				0.00237	233	233			
	Rock	17,470	17,470				0.00325	57	57			
	Muck		215,155	296,233	218,909	33,297	0,00325		698	961	710	108
Aucayes Alto	Ordinary	205,275	205,275				0.00237	487	487			
	Rock	93,769	93,769				0.00325	304	304			
	Muck		82,074	328,296	300,938		0.00325		266	1.065	977	
Alfalfal	Ordinary						0.00237					
	Rock						0.00325					
	Muck		180,310	139,013	105,213	26,303	0.00325		585	451	341	85
Aucayes Bajo	Ordinary	306,039					0.00237	727				
	Rock	270,557					0.00325	878				
	Muck	99,500	397,998	397,998	198,999		0.00325	323	1.292	1.292	646	
Ventana Las Lajas	Ordinary	31,627					0.00237	75				
	Rock	346					0.00325	103				
	Muck	52,867	349,635	42,705			0.00325	172	1.135	139		
Las Puertas	Ordinary						0.00237					
	Rock						0.00325					
	Muck	85,496	341,982	341,982	341,982	56,997	0.00325	277	1.110	1.110	1.110	185
Maipo	Ordinary						0.00237					
	Rock						0.00325					
	Muck	104,553	139,404	139,404	139,404	23,234	0.00325	339	452	452	452	75
					TOTAL EMISSION (KG)			**4,261**	**7,121**	**5,758**	**4,524**	**573**

The majority of the material loaded will be taken to the muck disposal sites. Table 4-14 below summarizes the type and amount of material deposited in each of the muck disposal sites during the construction phase, together with the related emissions. The emission factor was estimated based on the data provided in Table 4-2.

Table 4-14
Emissions from Unloading Material at the Disposal Sites

Work Area	Dump	Type of Material	Material Unloaded per Year (t)					Emission Factor (kg/t)	Emissions per Year (kg)				
			2008	2009	2010	2011	2012		2008	2009	2010	2011	2012
Volcán	MDS Nº 1	Ordinary	65,329	65,329				0.00237	155	155	0	0	0
		Rock	12,385	12,385				0.00325	40	40	0	0	0
		Muck		66,361	88,481	88,481	36,867	0.00325	0	215	287	287	120
El Yeso	MDS Nº 2	Ordinary											
		Rock											
		Muck		79,636	106,181	106,181	17,697	0.00325	0	258	345	345	57
	MDS Nº 3	Ordinary	21,326	21,326				0.00237	51	51	0	0	0
		Rock	5,776	5,776				0.00325	19	19	0	0	0
		Muck			9,360	37,440	15,600	0.00325	0	0	30	122	51
	MDS Nº 4	Ordinary	37,512	37,512				0.00237	89	89	0	0	0
		Rock	6,773	6,773				0.00325	22	22	0	0	0
		Muck		135,519	180,692	75,289		0.00325	0	440	586	244	0
Aucayes Alto	MDS Nº 5	Ordinary		100,174				0.00237	0	238	0	0	0
		Rock		22,000				0.00325	0	71	0	0	0
		Muck		82,074	328,296	300,938		0.00325	0	266	1,065	977	0
	MDS Nº 6	Ordinary	102,153	102,153				0.00237	243	243	0	0	0
		Rock	62,683	62,683				0.00325	203	203	0	0	0
		Muck											
Alfalfal	MDS Nº 7	Ordinary											
		Rock											
		Muck		78.910	105,213	105,213	26,303	0.00325	0	256	341	341	85
	MDS Nº 8	Ordinary											
		Rock											
		Muck		101,400	33,800			0.00325	0	329	110	0	0
Aucayes Bajo	MDS Nº 9	Ordinary	282,109					0.00237	670	0	0	0	0
		Rock	256,733					0.00325	833	0	0	0	0
		Muck	99,500	397,998	397,998	198,999		0.00325	323	1.292	1.292	646	0
Ventana Las Lajas	MDS Nº 10	Ordinary											
		Rock											
		Muck		176,800				0.00325	0	574	0	0	0
	MDS Nº 11	Ordinary	18,507					0.00237	44	0	0	0	0
		Rock	346					0.00325	1	0	0	0	0
		Muck	38,632	115,895				0.00325	125	376	0	0	0
	MDS Nº 13	Ordinary	13,120					0.00237	31	0	0	0	0
		Rock											
		Muck	14,235	56,940	42,705			0.00325	46	185	139	0	0
Las Puertas	MDS Nº 14	Ordinary											
		Rock											
		Muck	85,496	341,982	341,982	341,982	56,997	0.00325	277	1,110	1,110	1,110	185
Maipo	MDS Nº 12	Ordinary											
		Rock											
		Muck	104,553	139,404	139,404	139,404	23,234	0.00325	339	452	452	452	75
					TOTAL EMISSIONS PER YEAR (KG)				**3,512**	**6,885**	**5,758**	**4,524**	**573**

As already mentioned, part of the excavated material will be re-used for filling and other construction activities. The unloading of this material will also generate emissions. Table 4-15 below summarizes the amount of material that will be re-used in each of the work areas and the emissions generated by unloading this material. As the construction and rehabilitation of roads will take place throughout 2008 and beginning of 2009, emissions are limited to that period.

Table 4-15
Emissions from Unloading Material Re-Used for Road Construction

Work Area	Material Unloaded (t)		Emission Factor (kg/t)	Emissions Generated (kg)	
	2008	2009		2008	2009
Volcán	36,535	36,535	0.00247	90	90
El Yeso	44,289	44,289	0.00247	109	109
Aucayes Alto	134,208	134,208	0.00258	346	346
Alfalfal					
Aucayes Bajo	37,753		0.00269	102	
Las Lajas	8,480		0.00238	20	
Las Puertas					
Maipo					
		TOTAL		**667**	**545**

4.3.3 Vehicle Traffic

The development of the Project will generate a series of traffic flows, which will vary during the construction phase. As already mentioned in section 4.2.2.2 above, project-related traffic will consist of:

- Transportation of supplies and workers from the city (Puente Alto) to the different work areas;
- Transportation of workers from the camps to the work fronts; and
- Transportation of waste material from the work fronts to the disposal sites.

Transport vehicles will follow different routes consisting of both paved and unpaved roadways, as follows:

Paved roads:

- Route G-25, (road to El Volcán), between Puente Alto and Puente El Yeso.
- Route G-345 (access to Los Maitenes), between Route G-25 and Alfalfal.

Unpaved roads:

- Route G-455, between Route G -25 and the El Yeso Reservoir.
- Route G-25 (road to El Volcán), between Puente El Yeso and the work areas.

New access roads: see

Table 4-1 attached to this report.

For emissions estimation purposes, trucks with a capacity of 30 tons and a weight of 15 tons were considered. The surface material silt content is 10%.

4.3.3.1 Traffic Flows from the City

Tables 4-16 and 4-17 below show the number of buses and trucks transporting workers and supplies, respectively, from the city to the different work areas during the construction phase of the Project.

Table 4-16
Buses Transporting Workers from Puente Alto to the Work Areas

Work Area	Year					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Volcán	3	40	59	70	69	14
El Yeso	6	83	152	163	69	0
Aucayes Alto	6	41	32	48	39	0
Alfalfal						
Aucayes Bajo	28	199	246	176	28	0
Las Lajas	6	91	171	144	16	0
Las Puertas						
Maipo	9	47	48	48	38	0
TOTAL	**58**	**501**	**708**	**649**	**259**	**14**

Table 4-17
Trucks Transporting Supplies from the City to the Work Areas

Work Area	Year					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Volcán	70	209	265	265	223	0
El Yeso	58	174	221	221	186	0
Aucayes Alto	56	168	212	212	179	0
Alfalfal	38	113	143	143	120	0
Aucayes Bajo	144	432	547	547	461	0
Las Lajas	136	409	518	518	436	0
Las Puertas						
Maipo	248	745	944	944	795	0
TOTAL	**750**	**2,250**	**2,850**	**2,850**	**2,400**	**0**

Table 4-18 below shows the distances traveled from the city to the different work areas, including travel on segments of paved and unpaved roads.

It should be noted that the Project contemplates the construction of new roads to access the work fronts. As these new access roads will be stabilized using granular material, the application of bischofite to mitigate emissions of particulate matter is not considered. In order to estimate emissions on a conservative basis, the new access roads were considered as unpaved roads with no mitigation measures.

Table 4-18
Distances Traveled for Transport from the City to the Work Areas

Origin	Destination Work Area	New Road with Granular Surface in km [A]	Existing Unpaved Road in km [B]	Total Travel on Unpaved Roads in km ([A]+[B])	Travel on Paved Roads (km)	Total Distance Traveled in km (Unpaved + Paved)
Puente Alto	Volcán	7	22.9	29.9	44	79.9
Puente Alto	El Yeso	4.2	21	25.2	44	69.2
Puente Alto	Aucayes Alto	5.6	5.8	11.4	43	54.4
Puente Alto	Aucayes Bajo	5.8	0	5.8	43	48.8
Puente Alto	Ventana Las Lajas	0.5	0	0.5	30	30.5
Puente Alto	Maipo	0.4	0	0.4	14.5	14.9
Puente Alto	Alfalfal	0	0	0	43	43

Taking into account the number of vehicles and the distances traveled, the total amount of kilometers traveled during Project implementation is calculated. The same data is summarized in Table 4-19 for buses, and in Table 4-20 for trucks, including travel on both paved and unpaved roads.

Table 4-19
Total Kilometers Traveled by Buses Transporting Workers

Origin	Destination Work Area	Total Kilometers Traveled											
		2008		2009		2010		2011		2012		2013	
		Paved	Unpav.	Paved	Unpav.	Paved	Unpav.	Paved	Unpav.	Paved	Unpav.	Paved	Unpav.
Puente Alto	Volcán	264	179	3,520	2,392	5,192	3,528	6,160	4,186	6,072	4,126	1,232	837
Puente Alto	El Yeso	528	302	7,304	4,183	13,376	7,661	14,344	8,215	6,072	3,478	0	0
Puente Alto	Aucayes Alto	516	137	3,526	935	2,752	730	4,128	1,094	3,432	1,966	0	0
Puente Alto	Aucayes Bajo	2,408	325	17,114	2,308	21,156	2,854	15,136	2,042	2,408	325	0	0
Puente Alto	Ventana Las Lajas	360	6	5,460	91	10,260	171	8,640	144	960	16	0	0
Puente Alto	Maipo	261	7	1,363	38	1,392	38	1,392	38	1,102	30	0	0

Table 4-20
Total Kilometers Traveled by Trucks Transporting Supplies

Origin	Destination Work Area	Total Kilometers Traveled									
		2008		2009		2010		2011		2012	
		Paved	Unpav.	Paved	Unpav.	Paved	Unpav.	Paved	Unpav.	Paved	Unpav.
Puente Alto	Volcán	3,070	2,086	9,209	6,258	11,664	7,927	11,664	7,927	9,823	6,675
Puente Alto	El Yeso	2,557	1,464	7,670	4,393	9,716	5,564	9,716	5,564	8,182	4,686
Puente Alto	Aucayes Alto	2,404	637	7,213	1,912	9,136	2,422	9,136	2,422	7,694	2,040
Puente Alto	Aucayes Bajo	6,189	835	18,566	2,504	23,516	3,172	23,516	3,172	19,803	2,671
Puente Alto	Ventana Las Lajas	4,090	68	12,269	204	15,540	259	15,540	259	13,086	218
Puente Alto	Maipo	3,603	99	10,809	298	13,691	378	2,066	57	11,529	318
Puente Alto	Alfalfal	1,613	0	4,838	0	6,128	0	6,128	0	5,160	0

Based on these calculations, the total emissions produced for each of the years during which Project construction activities will be developed are estimated. The estimation considered the emission factors for paved and unpaved roads, and the use of bischofite as a mitigation measure, with an effectiveness of 85% (see Appendix 1). Studies undertaken by the Road Administration Department (*Dirección de Vialidad*) have revealed that applying bischofite can reduce PM-10 emissions by 90% to 96%. However, an 85% reduction is considered here to ensure a conservative estimation.

Among the technical studies undertaken to assess the effectiveness of bischofite as a dust suppressant is the comparative analysis conducted by the Road Administration Department of the Maule Region from November 2005 to July 2006 (*Análisis Comparativo de la Eficiencia de Supresores de Polvo Mediante el Uso de Equipo Dustmate y el Efecto Económico para la Conservación Rutinaria y Periódica de Carpetas Granulares*), shown in Appendix 1. The results of this study show that a reduction of emissions of at least 93% was achieved using bischofite. This is due not only to the fact that the surface sprayed with bischofite brine stays damp, but also because bischofite helps join the fine particles of the road surface. Other similar studies include those conducted by Salmag Ltda. (providers of hexahydrated magnesium chloride) for the Road Administration Departments of Regions VIII and VI (see Appendices 2 and 3).

The first study (Appendix 2) was conducted in the commune of Florida, in the VII Region, in January 2007. The results of this study show a 91% reduction of dust emissions. For the second study (Appendix 3), conducted in October 2005 in the commune of Rengo, in the VI Region, bischofite performance as a dust suppressant was measured at 96%.

The conclusion, based on the above findings, is that the use of bischofite[3] reduces the emission of particulate matter due to vehicle traffic by at least 90%. In order for emissions estimations under the Project to be conservative, however, an effectiveness of 85% is considered. This effectiveness factor was applied only to existing unpaved roads, as the use of bischofite is not considered for new granular surface roads to be constructed as part of the Project.

Tables 4-21 and 4-22 below show the PM-10 emissions from bus and truck traffic, respectively, from the city to the work areas.

Table 4-21
Emissions from Bus Traffic from
Puente Alto to the Work Areas

Origin	Work Area	EF Paved (kg/VKT)	EF Unpav. (kg/VKT)	Effec-tiveness (%)	Total PM-10 Emissions per Year (kg)											
					2008		2009		2010		2011		2012		2013	
					Unpav	Paved	Unpav	Paved	Unpav	Paved	Unpav	Paved	Unpav	Paved	Unpav	Paved
Pte Alto	Volcán	0.2289	1.1473	85	60	17	794	228	1171	336	1389	398	1369	393	278	80
Pte Alto	El Yeso	0.2289	1.1473	85	89	34	1228	472	2250	865	2413	927	1021	393	0	0
Pte Alto	Aucay Alto	0.2289	1.1473	85	65	33	446	228	348	178	522	267	639	222	0	0
Pte Alto	Aucay Bajo	0.2289	1.1473	85	248	156	1765	1107	2182	1368	1561	979	248	156	0	0
Pte Alto	Las Lajas	0.2289	1.1473	85	5	23	70	353	131	663	110	559	12	62	0	0
Pte Alto	Maipo	0.2289	1.1473	85	6	17	29	88	29	90	29	90	23	71	0	0
			TOTAL		**472**	**280**	**4,332**	**2,475**	**6,111**	**3,500**	**6,024**	**3,220**	**3,313**	**1,296**	**278**	**80**

[3] Based on existing evidence of the innocuity of the product (Source: *Revista Área Minera*, www.areaminera.cl), no damaging effects of the use of bischofite on vegetation in the Project area is expected.

Table 4-22
Emissions from Truck Traffic from Puente Alto to the Work Areas

Origin	Work Area	EF Paved (kg/VKT)	EF Unpav. (kg/VKT)	Effec-tiveness (%)	Emisión Total por Año (kg de MP10)											
					2008		2009		2010		2011		2012		2013	
					Unpav	Paved	Unpav	Paved	Unpav	Paved	Unpav	Paved	Unpav	Paved	Unpav	Paved
Pte Alto	Volcán	0.2289	1.1473	85	1,559	703	4,676	2,108	5,923	2,670	5,923	2,670	4,987	2,248	0	0
Pte Alto	El Yeso	0.2289	1.1473	85	914	585	2,743	1,756	3,475	2,224	3,475	2,224	2,926	1,873	0	0
Pte Alto	Auc. Alto	0.2289	1.1473	85	774	550	2,323	1,651	2,943	2,091	2,943	2,091	2,478	1,761	0	0
Pte Alto	Auc. Bajo	0.2289	1.1473	85	1,787	1,416	5,361	4,249	6,791	5,382	6,791	5,382	5,719	4,532	0	0
Pte Alto	Las Lajas	0.2289	1.1473	85	146	936	438	2,808	555	3,557	555	3.557	467	2,995	0	0
Pte Alto	Maipo	0.2289	1.1473	85	213	825	638	2,474	809	3,134	706	473	681	2,639	0	0
Pte Alto	Alfalfall	0.2289	1.1473	85	0	369	0	1,107	0	1,402	0	1,402	0	1,181	0	0
			TOTAL		**5,393**	**5,384**	**16,180**	**16,152**	**20,494**	**20,459**	**20,391**	**17,799**	**17,258**	**17,229**	**0**	**0**

4.3.3.2 Workers Flow from Camps to Work Fronts

The total distances traveled each year by personnel transport buses are shown in Table 4-8 above. It is estimated that approximately 80% of the roads traveled are paved roads and 20% unpaved roads. Based on this, the emissions generated by the buses traveling within the construction work zones were estimated, as shown in Table 4-23 below.

Table 4-23
Emissions from Workers Transportation within Work Areas

Origin	Work Area	EF Pvd (kg/VKT)	EF Unpv (kg/VKT)	% Effective	Total PM-10 Emissions (kg)											
					2008		2009		2010		2011		2012		2013	
					Unpv	Pvd	Unpv	Pvd	Unpv	Pvd	Unpv	Pvd	Unpv	Pvd	Unpv	Pvd
Pte Alto	Volcán	0.1045	1.1080	85	6	14	248	624	360	906	411	1,033	405	1,018	20	51
Pte Alto	El Yeso	0.1045	1.1080	85	59	148	3,914	9,842	7,258	18,249	6,415	16,130	1,557	3,915	0	0
Pte Alto	Aucayes Alt	0.1045	1.1080	85	112	282	1,967	4,947	1,980	4,979	2,970	7,468	1,197	3,009	0	0
Pte Alto	Aucayes Bj	0.1045	1.1080	85	358	901	2,616	6,577	3,329	8,371	2,378	5,979	117	295	0	0
Pte Alto	Las Lajas	0.1045	1.1080	85	673	1,692	10,410	26,176	12,812	32,215	9,075	22,819	329	827	0	0
Pte Alto	Maipo	0.1045	1.1080	85	0	0	1,019	2,563	1,893	4,759	1,602	4,027	0	0	0	0
Pte Alto	Alfalfal	0.1045	1.1080	85	298	748	9,551	24,010	17,908	45,028	14,927	37,523	0	0	0	0
			TOTAL		**1,505**	**3,785**	**29,726**	**74,740**	**45,541**	**114,507**	**37,777**	**94,980**	**3,605**	**9,064**	**20**	**51**

4.3.4 Muck Transportation

Table 4-24 below summarizes the amount of waste material transported by trucks in each of the work areas, by year of the construction phase. In some work areas, muck will be transported mainly by train. Nevertheless, the material coming from road construction and rehabilitation will be transported via trucks, which are included in the table. Some of the muck disposal sites, for instance MDS Nº2, will not receive material from road rehabilitation, meaning that the totality will be transported by train, and is therefore not included in the calculations. In other work areas, muck transportation will be carried out exclusively by trucks.

Table 4-24
Material to be Deposited in each Muck Disposal Site

Work Area	Dump	Amount of Material to be Deposited (t)					
		2008	2009	2010	2011	2012	2013
Volcán	MDS Nº 1	77,715	77,715	0	0	0	0
El Yeso	MDS Nº 2	0	0	0	0	0	0
	MDS Nº 3	27,101	27,101	0	0	0	0
	MDS Nº 4	44,285	44,285	0	0	0	0
Aucayes Alto	MDS Nº 5	0	122,174	0	0	0	0
	MDS Nº 6	164.836	164,836	0	0	0	0
Alfalfal	MDS Nº 7	0	78,910	105,213	105,213	26,303	0
	MDS Nº 8	0	101,400	33,800	0	0	0
Aucayes Bajo	MDS Nº 9	638,342	397,998	397,998	198,999	0	0
Ventana Las Lajas	MDS Nº 10	0	176,800	0	0	0	0
	MDS Nº 11	57,485	115,895	0	0	0	0
	MDS Nº 13	27,355	56,940	42,705	0	0	0
Las Puertas	MDS Nº 14	85,496	341,982	341,982	341,982	56,997	0
Maipo	MDS Nº 12	104,553	139,404	139,404	139,404	23,234	0
TOTAL		**1,227,167**	**1,845,440**	**1,061,103**	**785,599**	**106,534**	**0**

Trucks with a capacity of 30 tons and an empty weight of 15 tons will be used to transport material. Table 4-25 below shows the total number of trips needed to transport all the material to the different disposal sites.

Table 4-25
Total Number of Trips Needed to Transport Material to Muck Disposal Sites

Work Area	Dump	Trips Needed to Transport Material					
		2008	2009	2010	2011	2012	2013
Volcán	MDS Nº 1	2,590	2,590	0	0	0	0
El Yeso	MDS Nº 2	0	0	0	0	0	0
	MDS Nº 3	903	903	0	0	0	0
	MDS Nº 4	1,476	1,476	0	0	0	0
Aucayes Alto	MDS Nº 5	0	4,072	0	0	0	0
	MDS Nº 6	5,495	5,495	0	0	0	0
Alfalfal	MDS Nº 7	0	2,630	3,507	3,507	877	0
	MDS Nº 8	0	3,380	1,127	0	0	0
Aucayes Bajo	MDS Nº 9	21,278	13,267	13,267	6,633	0	0
Las Lajas	MDS Nº 10	0	5,893	0	0	0	0
	MDS Nº 11	1,916	3,863	0	0	0	0
	MDS Nº 13	912	1,898	1,424	0	0	0
Las Puertas	MDS Nº 14	2,850	11,399	11,399	11,399	1,900	0
Maipo	MDS Nº 12	3,485	4,647	4,647	4,647	774	0
TOTAL		**40,906**	**61,515**	**35,370**	**26,187**	**3,551**	**0**

Based on the mean distances from the muck disposal sites to the main work fronts, taken from Table 4-10 above, the emissions generated by transporting waste material to the muck disposal sites were estimated. These are summarized in Table 4-26 below.

Table 4-26
Emissions from Muck Transportation to Disposal Sites

Work Area	Dump	Emission Factor (kg/VKT)	Effectiveness (%)	Emissions per Year (kg)					
				2008	2009	2010	2011	2012	2013
Volcán	MDS Nº 1	2.14	85	1,025	1,025	0	0	0	0
El Yeso	MDS Nº 2	2.14	85	0	0	0	0	0	0
	MDS Nº 3	2.14	85	609	609	0	0	0	0
	MDS Nº 4	2.14	85	569	569	0	0	0	0
Aucayes Alto	MDS Nº 5	2.14	85	0	1,962	0	0	0	0
	MDS Nº 6	2.14	85	4,041	4,041	0	0	0	0
Alfalfal	MDS Nº 7	2.14	85	0	287	383	383	96	0
	MDS Nº 8	2.14	85	0	152	51	0	0	0
Aucayes	MDS Nº 9	2.14	85	11,628	7,250	7,250	3,625	0	0
Las Lajas	MDS Nº 10	2.14	85	0	306	0	0	0	0
	MDS Nº 11	2.14	85	499	1,007	0	0	0	0
	MDS Nº 13	2.14	85	47	99	74	0	0	0
Las Puertas	MDS Nº 14	2.14	85	5,548	22,191	22,191	22,191	3,698	0
Maipo	MDS Nº 12	2.14	85	181	241	241	241	40	0
		TOTAL		**24,146**	**39,737**	**30,189**	**26,440**	**3,834**	**0**

4.3.5 Access Road Construction/Rehabilitation

The Project contemplates the construction of new access roads, and improvements to existing roads. These activities, undertaken throughout 2008 and part of 2009, will release particulate matter (PM-10) into the atmosphere. To estimate these air emissions, the use of a bulldozer, with a progress rate of 100 m^3/hour (taken from Project specifications), is considered. Table 4-27 below summarizes the roads constructed/improved, the amount of material to be removed per road, the estimated time required to complete the works, and the emissions generated.

Table 4-27
Emissions from Road Construction/Rehabilitation

Road	Ordinary Material Moved m³	Rock Material Moved m³	Hours Needed for Removal	Silt Content (%)	Moisture Content (%)	Emission Factor kg/hr)	Emission During Works kg	Emission/Year (kg)	
								2008	2009
Access to works in tunnel area	120,000	14,000	1,340	10	2.5	2.96	3,965	1,983	1,983
Access to Alfalfal II Tunnel	90,000	10,000	1,000	10	2.5	2.96	2,959	1,480	1,480
Access to El Manzanito stream	22,800	3,800	266	10	2.5	2.96	787	394	394
Access to work sites	145,000	20,000	1,650	10	2.5	2.96	4,882	2,441	2,441
Access to Alfalfal II Power Plant	62,000	42,400	1,044	10	2.5	2.96	3,089	1,545	1,545
No road works				10	2.5				
Access to MDS Nº9	60,000	30,000	900	10	2.5	2.96	2,663	2,663	
Secondary access to MDS Nº9	35,000	15,000	500	10	2.5	2.96	1,480	1,480	
Access to Alfalfal II Power Plant	93,000	63,600	1,566	10	2.5	2.96	4,634	4,634	
Access to Las Lajas Power Plant	0	12,000	120	10	2.5	2.96	355	355	
Access to work sites	150	13,050	132	10	2.5	2.96	391	391	
						TOTAL		**17,364**	**7,842**

4.3.6 Equipment Use

Different equipment will be used for Project development, particularly for road construction, rehabilitation and maintenance, and surface civil works. Table 4-28 below shows the equipment used for road-related activities, the estimated equipment hours, the emission factors and the associated PM-10 emissions.

Table 4-28
Equipment Used on Roads and Associated Emissions

Equipment Use	Equipment Type	Total Estimated Equip Hrs	Power hp	Efss (*)	TAF (*)	DF (*)	Emission Factor (g/hp-hr)	Total Emiss (kg/job)	Emissions per Year (kg) 2008	2009	2010	2011	2012
Construction of New Roads	Bulldozer	1500	110	0.2280	1.2300	0.4730	0.133	21.9	22	0	0	0	0
	Truck drill	2400	300	0.2521	1.2300	0.4730	0.147	105.6	106	0	0	0	0
	Compressor	2400	286	0.2521	1.2300	0.4730	0.147	100.7	101	0	0	0	0
	Caterpillar excavator	1800	80	0.4730	1.2300	0.4730	0.275	39.6	22	18	0	0	0
	Motor grader	1900	150	0.2280	1.2300	0.4730	0.133	37.8	16	22	0	0	0
	Road roller	1900	50	0.4730	1.2300	0.4730	0.275	26.1	11	15	0	0	0
	Front loader	3200	280	0.2521	1.9700	0.4730	0.235	210.5	115	96	0	0	0
	Haul truck	4900	380	0.2008	1.2300	0.4730	0.117	217.5	115	102	0	0	0
	Tank truck	2400	300	0.2521	1.2300	0.4730	0.147	105.6	53	53	0	0	0
Annual Road Maintenance	Motor grader	600	150	0.2280	1.23	0.473	0.133	11.9	2	2	2	2	2
	Road roller	600	50	0.473	1.23	0.473	0.275	8.3	2	2	2	2	2
	Tank truck	600	300	0.2521	1.23	0.473	0.147	26.4	5	5	5	5	5
Clearing of Snow & Vehicles from Roads	Motor grader	2400	150	0.22799	1.23	0.473	0.133	47.8	10	10	10	10	10
	Front loaderl	600	280	0.2521	1.97	0.473	0.235	39.5	8	8	8	8	8
	Haul truck	1200	380	0.2008	1.23	0.473	0.117	53.3	11	11	11	11	11
Reconditioning of Existing Roadways	Motor grader	700	150	0.22799	1.23	0.473	0.133	13.9	14	0	0	0	0
	Road roller	700	50	0.473	1.23	0.473	0.275	9.6	10	0	0	0	0
	Front loader	300	280	0.2521	1.97	0.473	0.235	19.7	20	0	0	0	0
	Haul truck	300	380	0.2008	1.23	0.473	0.117	13.3	13	0	0	0	0
	Tank truck	700	300	0.2521	1.23	0.473	0.147	30.8	31	0	0	0	0
Concrete Preparation	Concrete Plant	1400 /mo	180	0.2521	1.23	0.473	0.147	37.0	0	444	444	444	148
	Mixer truck	2800 /mo	360	0.2521	1.23	0.473	0.147	147.8	0	1,774	1,774	1,774	591
	Front loader	1400 /mo	280	0.2521	1.97	0.473	0.235	92.1	0	1,105	1,105	1,105	368
Construction of Forebay & Access Road	Bulldozer	3900	110	0.22799	1.23	0.473	0.133	56.9	0	0	56.9	0	0
	Haul truck	3900	380	0.2008	1.23	0.473	0.117	173.1	0	0	173.1	0	0
	Front loader	3900	280	0.2521	1.97	0.473	0.235	256.5	0	0	256.5	0	0
								TOTAL	**685**	**3,665**	**3,847**	**3,360**	**1,145**

(*): Required for emission factor calculation, taken from EPA 420-P-04-009.

Table 4-29 below shows the equipment used for surface civil works, the emissions and the distribution of these emissions throughout the construction phase of the Project.

Table 4-29
Equipment Used for Surface Civil Works and Associated Emissions

Equipment Type	Total Estimated Equip hrs	Power hp	Efss	TAF	DF	Emission Factor (g/hp-hr)	Total Emis (kg/job)	Emissions per Year (kg) 2008	2009	2010	2011	2012
Bulldozer	45000	110	0.2280	1.2300	0.4730	0.133	656.6	0	94	219	219	125
Truck drill	45000	300	0.2521	1.2300	0.4730	0.147	1980.0	0	283	660	660	377
Compressor	45000	286	0.2521	1.2300	0.4730	0.147	1887.6	0	270	629	629	360
Cat excavator	45000	80	0.4730	1.2300	0.4730	0.275	990.7	0	142	330	330	189
Motor grader	45000	150	0.2280	1.2300	0.4730	0.133	895.3	0	128	298	298	171
Road roller	45000	50	0.4730	1.2300	0.4730	0.275	619.2	0	88	206	206	118
Front loader	45000	280	0.2521	1.9700	0.4730	0.235	2959.9	0	423	987	987	564
Haul truck	45000	380	0.2008	1.2300	0.4730	0.117	1997.7	0	285	666	666	381
Tank truck	45000	300	0.2521	1.2300	0.4730	0.147	1980.0	0	283	660	660	377
						TOTAL		**0**	**1,995**	**4,656**	**4,656**	**2,660**

4.3.7 Active Erosion in Muck Disposal Sites

As already mentioned, 14 muck disposals will be sited throughout the Project area. The surface areas of these sites are subjected to erosion, and consequently the sites generate emissions. In order to estimate these emissions, an active area of 10% has been determined

for each muck disposal site. A total of 34 days with at least 0.254 mm of precipitation has also been considered (1984-2004 average rainfall, data from the Queltehues weather station).

Table 4-30 below shows the estimated PM-10 emissions resulting from erosion in the active areas of the muck disposal sites.

Table 4-30
PM-10 Emissions from Active Erosion in Muck Disposal Sites

Work Area	Dump	Active Area (ha)	Emission Fac. (kg/ha-day)	Daily Emission (kg)	Emissions per Year (kg)				
					2008	2009	2010	2011	2012
Volcán	MDS Nº 1	1.84	7.234	1.331	122	486	486	486	282
El Yeso	MDS Nº 2	2.98	7.234	2.156	0	593	787	787	127
	MDS Nº 3	1.81	7.234	1.310	0	0	121	478	198
	MDS Nº 4	2.29	7.234	1.654	0	455	604	250	0
Aucayes Alto	MDS Nº 5	2.44	7.234	1.769	0	486	646	591	0
	MDS Nº 6	2.24	7.234	1.619	149	146	0	0	0
Alfalfal	MDS Nº 7	4.22	7.234	3.053	0	839	1,114	1,114	275
	MDS Nº 8	3.11	7.234	2.247	0	618	202	0	0
Aucayes Bajo	MDS Nº 9	5.55	7.234	4.016	1,105	1,466	1,466	727	0
Las Lajas	MDS Nº 10	1.74	7.234	1.257	0	343	0	0	0
	MDS Nº 11	1.17	7.234	0.849	234	232	0	0	0
	MDS Nº 13	0.66	7.234	0.479	132	175	131	0	0
Las Puertas	MDS Nº 14	3.07	7.234	2.221	757	3,002	3,002	3,002	485
Maipo	MDS Nº 12	1.85	7.234	1.335	2,352	3,121	3,121	3,121	505
			TOTAL		**4,849**	**11,962**	**11,679**	**10,555**	**1,872**

4.3.8 PM-10 Emissions from Construction Works

Table 4-31 below summarizes the construction works to be undertaken as part of the Project and the estimated emissions from the construction activities.

Table 4-31
Estimated PM-10 Emissions from Project Construction Works

WORK	Area (ha)	Emis. Factor (t/ha-mo)	Emission (t)	Emissions per Year (kg)				
				2008	2009	2010	2011	2012
La Engorda Intake	0.15	0.493	0.074		11	25	25	14
Colina Intake	0.15	0.493	0.074		11	25	25	14
Las Placas Intake	0.15	0.493	0.074		11	25	25	14
El Morado Intake	0.15	0.493	0.074		11	25	25	14
El Yeso water intake structure	0.15	0.493	0.074		11	25	25	14
Quempo water intake structure	0.15	0.493	0.074		11	25	25	14
Maitenes water intake structure	0.15	0.493	0.074		11	25	25	14
Aucayes Bajo water intake structure	0.15	0.493	0.074		11	25	25	14
Access V1 to Volcán Tunnel + Work Front	0.51	0.493	0.251		251			
Access V6 to Volcán Tunnel + Work Front	0.51	0.493	0.251		251			
Access VA4 to Alfalfal II Tunnel + Work Front	0.51	0.493	0.251		251			
Access VA2 to Alfalfal II Tunnel + Work Front	0.51	0.493	0.251		251			
Access VA1 to Alfalfal II Power Plant + Work Front	0.51	0.493	0.251		251			
Access L1 to Las Lajas Tunnel + Work Front	0.51	0.493	0.251		251			
Access VL4 to Las Lajas Power Plant + Work Front	0.51	0.493	0.251		251			
Access VL5 to Las Lajas Tunnel + Work Front	0.51	0.493	0.251		251			
Access VL7 to Las Lajas Tunnel + Work Front	0.51	0.493	0.251		251			
Access VL8 to Las Lajas Tunnel + Work Front	0.51	0.493	0.251		251			
Lo Encañado Work Front	1.90	0.493	0.937			937		
Worker Camp and Installment of Work Zones Nº1 - El Volcán	1.91	0.493	0.943	471	471			
Camp and Installment of Work Zones Nº2 - El Yeso, Lo Encañado	2.19	0.493	1.079	540	540			
Camp and Installment of Work Zones Nº3 - Aucayes Alto	2.85	0.493	1.406	703	703			
Camp and Installment of Work Zones Nº4 - Aucayes Bajo	2.85	0.493	1.406	703	703			
Camp and Installment of Work Zones Nº5 – Sub-Station	0.84	0.493	0.414	207	207			
Camp and Installment of Work Zones Nº6 - Alfalfal II Plant Access	1.99	0.493	0.981	491	491			
Installment of Work Zones Nº7 – Maipo River Discharge**	0.28	0.493	0.137	68	68			
		TOTAL		**3,182**	**5,781**	**1,134**	**197**	**113**

4.3.9 Vehicle Engine Emissions

Tables 4-32 and 4-33 below show the estimated PM-10 emissions from bus and truck engines, respectively. The mean speed considered for both types of vehicles to be used for Project construction works is 35 kph.

Table 4-32
PM-10 Emissions from Bus Engines

Work Area	Speed (kph)	Emission Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	0.11824	443	5,912	8,720	10,346	10,198	2,069	0.1	0.7	1.0	1.2	1.2	0.2
El Yeso	35	0.11824	830	11,487	21,037	22,559	9,550	0	0.1	1.4	2.5	2.7	1.1	0.0
Aucayes Alto	35	0.11824	653	4,461	3,482	5,222	5,398	0	0.1	0.5	0.4	0.6	0.6	0.0
Aucayes Bajo	35	0.11824	2,733	19,422	24,010	17,178	2,733	0	0.3	2.3	2.8	2.0	0.3	0.0
Ventana Las Lajas	35	0.11824	366	5,551	10,431	8,784	976	0	0.0	0.7	1.2	1.0	0.1	0.0
Maipo	35	0.11824	268	1,401	1,430	1,430	1,132	0	0.0	0.2	0.2	0.2	0.1	0.0
							TOTAL		**0.6**	**5.7**	**8.2**	**7.7**	**3.5**	**0.2**

Table 4-33
PM-10 Emissions from Supply Truck Engines

Work Area	Speed (kph)	Emission Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	0.22258	5,156	15,467	19,591	19,591	16,498	0	1.1	3.4	4.4	4.4	3.7	0.0
El Yeso	35	0.22258	4,021	12,063	15,280	15,280	12,867	0	0.9	2.7	3.4	3.4	2.9	0.0
Aucayes Alto	35	0.22258	3,042	9,125	11,558	11,558	9,733	0	0.7	2.0	2.6	2.6	2.2	0.0
Aucayes Bajo	35	0.22258	7,023	21,070	26,688	26,688	22,474	0	1.6	4.7	5.9	5.9	5.0	0.0
Las Lajas	35	0.22258	4,158	12,473	15,799	15,799	13,305	0	0.9	2.8	3.5	3.5	3.0	0.0
Maipo	35	0.22258	3,702	11,107	14,069	2,123	11,848	0	0.8	2.5	3.1	0.5	2.6	0.0
Alfalfal	35	0.22258	1,613	4,838	6,128	6,128	5,160	0	0.4	1.1	1.4	1.4	1.1	0.0
								TOTAL	**6.4**	**19.2**	**24.3**	**21.6**	**20.5**	**0.0**

4.3.10 Emissions from the Construction of the Alfalfal II Forebay Reservoir

The forebay of the Alfalfal II powerhouse will be located in the Alto Aucayes area. This section addresses the emissions from the construction of the forebay reservoir, and the emissions from the construction of a segment of the forebay access road. The construction of the access road was not part of the original engineering design of the PHAM; however, these construction works were subjected to environmental assessment, and are included in the total Project emissions evaluation presented in section 4.5.

The Alfalfal II forebay will have a storage capacity of 48,000 m3. It will be fed by the connection to the Alfalfal II Tunnel and will receive water from the Yeso River intake structure and Alto Volcán II area.

The majority of the forebay will be excavated; the construction of embankments of variable heights is also contemplated.

This section reviews the air emissions from the construction of the Alfalfal II forebay and access road, in order to complement and/or update the emissions study.

The construction of the forebay involves a range of works that will generate emissions, mainly particulate matter emissions. The emission-generating activities can be divided into: forebay construction activities, and access road construction activities.

- Forebay construction activities include:
  - Loading of excavated material;
  - Transportation of filling material;
  - Transportation of remaining material to the muck disposal sites; and,
  - Unloading of remaining material at the muck disposal sites.

- Access road construction activities include:
  - Preparing site for road works;
  - Loading of excavated material;
  - Transportation of material to muck disposal sites; and,
  - Unloading of material at the muck disposal sites.

Construction of the forebay is expected to be undertaken during 2010.

4.3.10.1 Emissions from Forebay Construction Activities

a) Loading and Unloading of Excavated Material

Approximately 60,000 tons of material will be extracted to construct the forebay, and delivered to the nearest dump site (MDS Nº5).

Table 4-34 below shows the material to be loaded and unloaded, the emission factor and the emissions generated.

Table 4-34
Emissions from Forebay Construction Material Loading and Unloading Activities

Activity	Material (t)	Emission Factor (kg/t)	Emissions (kg)
Loading of excavated material	60,000	0.00237	142.2
Unloading of material at MDS Nº 5	60,000	0.00237	142.2
Total Emissions			284.4

b) Transportation of Material

As already mentioned, the excavated material will be delivered to the nearest muck disposal site (MDS Nº 5). Table 4-35 below shows the amount of material to be moved, the distances traveled by the trucks transporting the material, and the emissions generated. Calculations are for trucks with a capacity of 30 tons and an empty weight of 15 tons. Surface material silt content is 10%.

Table 4-35
Emissions from Transporting Forebay Construction Excavated Material

Variable	Material to Dump
Amount of material (t)	60,000
Number of trips required	1,667
Mean distance traveled (km)	7.8
Emission factor (kg/trip)	2.0491
Emissions (kg)	**3,996**

4.3.10.2 Emissions from Access Road Construction Activities

a) Preparing Site for Road Works

The access road to the Alfalfal II forebay will be 7,784 meters long. Table 4-36 below contains data on the moisture content, silt content and estimated equipment hours needed to construct the access road, together with the emissions generated.

Table 4-36
Emissions from Road Site Preparation Activities

Variable	Value	Unit
Moisture content	2.5	%
Silt content	10	%
Emission factor	2.9591	kg/hour
Estimated equipment hours	2,400	hours
Emissions	**7,102**	**kg**

b) Loading and Unloading of Material

Approximately 304,000 tons of ordinary material and 130,000 tons of rock material will be extracted during the construction of the access road. All this material will be delivered to the nearest muck disposal site (MDS Nº 5).

Table 4-37 below shows the amounts of material to be loaded and unloaded, the emission factors and the emissions generated.

Table 4-37
Emissions from Access Road Construction Material Loading and Unloading Activities

Activity	Material (t)	Emission Factor (kg/t)	Emissions (kg)
Loading of extracted material	434,000	0.00237	1,031
Unloading of material at dump	434,000	0.00237	1,031
Total Emissions			**2,061**

c) Transportation of Material

All the material extracted during the construction of the access road will be delivered to a dump located at an average distance of 3.9 km. Table 4-38 below shows the amount of material to be moved, the average distance traveled by the trucks transporting the material and the emissions generated. Calculations are for trucks with a capacity of 30 tons and an empty weight of 15 tons. Surface material silt content is 10%, and the new access road will be sprayed with bischofite, resulting in an 85% reduction of dust emissions.

Table 4-38
Emissions from Transporting Access Road Excavated Material

Variable	Material to Dump
Amount of material (t)	434,000
Number of trips required	14,467
Mean distance traveled (km)	3.9
Emission factor (kg/trip)	2.0491
Bischofite mitigation effectiveness (%)	85
Total Emissions (kg)	**17,342**

4.3.10.3 Summary of Emissions Associated with the Construction of the Forebay

Table 4-39 below summarizes the total emissions associated with the construction of the Alfalfal II forebay. These emissions will be generated during 2010, when construction of the forebay will take place.

Table 4-39
Particulate Matter Emissions Associated with the Construction of the Forebay and Access Road

Phase	Activities	Emissions (kg)
Forebay Construction	Loading and unloading of excavated material	1,662
	Transportation of material	3,996
Access Road Construction	Preparation of road work site	7,102
	Loading and unloading of material	2,061
	Transportation of material	17,342
Total Emissions		**32,163**

4.4 GAS EMISSIONS

The estimation of emissions from the internal combustion engines of the vehicles and equipment used for the Project is discussed in this section.

4.4.1 Carbon Monoxide Emissions (CO)

4.4.1.1 Emissions from Buses and Trucks

Table 4-40
CO Emissions from Buses

Work Area	Speed (kph)	Emission Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	1.01656	443	5,912	8,720	10,346	10,198	2.069	0	6	9	11	10	2
El Yeso	35	1.01656	830	11,487	21,037	22,559	9,550	0	1	12	21	23	10	0
Aucayes Alto	35	1.01656	653	4,461	3,482	5,222	5,398	0	1	5	4	5	5	0
Aucayes Bajo	35	1.01656	2,733	19,422	24,010	17,178	2,733	0	3	20	24	17	3	0
Ventana Las Lajas	35	1.01656	366	5,551	10,431	8,784	976	0	0	6	11	9	1	0
Maipo	35	1.01656	268	1,401	1,430	1,430	1,132	0	0	1	1	1	1	0
								TOTAL	**5**	**49**	**70**	**67**	**30**	**2**

Table 4-41
CO Emissions from Trucks

Work Area	Speed (kph)	Emis Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	1.42015	5,156	15,467	19,591	19,591	16,498	0	7	22	28	28	23	0
El Yeso	35	1.42015	4,021	12,063	15,280	15,280	12,867	0	6	17	22	22	18	0
Aucayes Alto	35	1.42015	3,042	9,125	11,558	11,558	9,733	0	4	13	16	16	14	0
Aucayes Bajo	35	1.42015	7,023	21,070	26,688	26,688	22,474	0	10	30	38	38	32	0
Ventana Las Lajas	35	1.42015	4,158	12,473	15,799	15,799	13,305	0	6	18	22	22	19	0
Maipo	35	1.42015	3,702	11,107	14,069	2,123	11,848	0	5	16	20	3	17	0
Alfalfal	35	1.42015	1,613	4,838	6,128	6,128	5,160	0	2	7	9	9	7	0
								TOTAL	**41**	**122**	**155**	**138**	**130**	**0**

4.4.1.2 Emissions from Equipment

a) Equipment for Road Construction, Rehabilitation and Maintenance

Table 4-42
CO Emissions from Road-Related Equipment

Equipment Use	Equipment Type	Total Estimated Equip Hrs	Power	Efss	TAF	DF	Emission Factor	Total Emis	Emissions per Year (kg)				
			hp				(g/hp-hr)	(kg/job)	2008	2009	2010	2011	2012
Construction of New Roads	Bulldozer	1500	110	0.8667	1.53	0.101	0.134	22.1	22	0	0	0	0
	Truck drill	2400	300	0.7475	2.57	0.101	0.194	139.7	140	0	0	0	0
	Compressor	2400	286	0.7475	2.57	0.101	0.194	133.2	133	0	0	0	0
	Cat Excavator	1800	80	2.3655	1.53	0.101	0.366	52.6	29	23	0	0	0
	Motor grader	1900	150	0.8667	1.53	0.101	0.134	38.2	16	22	0	0	0
	Road roller	1900	50	2.3655	1.53	0.101	0.366	34.7	15	20	0	0	0
	Front loader	3200	280	0.7475	2.57	0.101	0.194	173.8	95	79	0	0	0
	Haul truck	4900	380	1.3060	1.53	0.101	0.202	375.8	199	176	0	0	0
	Tank truck	2400	300	0.7475	1.53	0.101	0.116	83.2	42	42	0	0	0
Annual Road Maintenance	Motor grader	600	150	0.8667	1.53	0.101	0.134	12.1	2	2	2	2	2
	Road roller	600	50	2.3655	1.53	0.101	0.366	11.0	2	2	2	2	2
	Tank truck	600	300	0.7475	1.53	0.101	0.116	20.8	4	4	4	4	4
Clearing of Snow & Vehicles from Roads	Motor grader	2400	150	0.8667	1.53	0.101	0.134	48.2	10	10	10	10	10
	Front loader	600	280	0.7475	2.57	0.101	0.194	32.6	7	7	7	7	7
	Haul truck	1200	380	1.306	1.53	0.101	0.202	92.0	18	18	18	18	18
Reconditioning of Existing Roadways	Motor grader	700	150	0.8667	1.53	0.101	0.134	14.1	14	0	0	0	0
	Road roller	700	50	2.3655	1.53	0.101	0.366	12.8	13	0	0	0	0
	Front loader	300	280	0.7475	2.57	0.101	0.194	16.3	16	0	0	0	0
	Haul truck	300	380	1.306	1.53	0.101	0.202	23.0	23	0	0	0	0
	Tank truck	700	300	0.7475	1.53	0.101	0.116	24.3	24	0	0	0	0
Concrete Preparation	Concrete plant	1400 / mo	180	0.7475	1.53	0.101	0.116	29.1	0	349	349	349	116
	Mixer truck	2800 / mo	360	1.306	1.53	0.101	0.202	203.4	0	2,441	2,441	2,441	814
	Front loader	1400 / mo	280	0.7475	2.57	0.101	0.194	76.1	0	913	913	913	304
Construction of Forebay & Access Road	Bulldozer	3900	110	0.8667	1.53	0.101	0.134	57.5	0	0	57.5	0	0
	Haul truck	3900	380	1.306	1.53	0.101	0.202	299.1	0	0	299.1	0	0
	Front loader	3900	280	0.7475	2.57	0.101	0.194	211.9	0	0	211.9	0	0
							TOTAL		**824**	**4,109**	**4,315**	**3747**	**1,278**

b) Equipment for Surface Civil Works

Table 4-43
CO Emissions from Equipment for Surface Civil Works

Equipment Type	Total Estimated Equip Hrs	Power	Efss	TAF	DF	Emis Factor	Total Emis	Emissions per Year (kg)				
		hp				(g/hp-hr)	(kg/job)	2008	2009	2010	2011	2012
Bulldozer	45000	110	0.8667	1.5300	0.1010	0.134	663.0	0	95	221	221	126
Truck Drill	45000	300	0.7475	2.5700	0.1010	0.194	2619.4	0	374	873	873	499
Compressor	45000	286	0.7475	2.5700	0.1010	0.194	2497.1	0	357	832	832	476
Cat Excavator	45000	80	2.3655	1.5300	0.1010	0.366	1315.9	0	188	439	439	251
Motor Grader	45000	150	0.8667	1.5300	0.1010	0.134	904.0	0	129	301	301	172
Road Roller	45000	50	2.3655	1.5300	0.1010	0.366	822.5	0	117	274	274	157
Front Loader	45000	280	0.7475	2.5700	0.1010	0.194	2444.8	0	349	815	815	466
Haul Truck	45000	380	1.3060	1.5300	0.1010	0.202	3451.1	0	493	1,150	1,150	657
Tank Truck	45000	300	0.7475	1.5300	0.1010	0.116	1559.4	0	223	520	520	297
						TOTAL		**0**	**2,325**	**5,426**	**5,426**	**3,100**

4.4.2 Hydrocarbon Emissions (HC)

4.4.2.1 Emissions from Buses and Trucks

Table 4-44
HC Emissions from Buses

Work Area	Speed (kph)	E. Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	0.59472	443	5912	8720	10346	10198	2069	0	4	5	6	6	1
El Yeso	35	0.59472	830	11487	21037	22559	9550	0	0	7	13	13	6	0
Aucayes Alto	35	0.59472	653	4461	3482	5222	5398	0	0	3	2	3	3	0
Aucayes Bajo	35	0.59472	2733	19422	24010	17178	2733	0	2	12	14	10	2	0
Ventana Las Lajas	35	0.59472	366	5551	10431	8784	976	0	0	3	6	5	1	0
Maipo	35	0.59472	268	1401	1430	1430	1132	0	0	1	1	1	1	0
							Puente Alto		**3**	**29**	**41**	**39**	**18**	**1**

Table 4-45
HC Emissions from Trucks

Work Area	Speed (kph)	E. Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	0.79764	5156	15467	19591	19591	16498	0	4	12	16	16	13	0
El Yeso	35	0.79764	4021	12063	15280	15280	12867	0	3	10	12	12	10	0
Aucayes Alto	35	0.79764	3042	9125	11558	11558	9733	0	2	7	9	9	8	0
Aucayes Bajo	35	0.79764	7023	21070	26688	26688	22474	0	6	17	21	21	18	0
Ventana Las Lajas	35	0.79764	4158	12473	15799	15799	13305	0	3	10	13	13	11	0
Maipo	35	0.79764	3702	11107	14069	2123	11848	0	3	9	11	2	9	0
Alfalfal	35	0.79764	1613	4838	6128	6128	5160	0	1	4	5	5	4	0
							TOTAL		**23**	**69**	**87**	**78**	**73**	**0**

Emissions from Equipment

a) Equipment for Road Construction, Rehabilitation and Maintenance

Table 4-46
HC Emissions from Road-Related Equipment

Equipment Use	Equipment Type	Total Estimated Equip Hrs	Power hp	Efss	TAF	DF	Emission Factor (gr/hp-hr)	Total Emis (kg/obra)	Emissions per Year (kg) 2008	2009	2010	2011	2012
Construction of New Roads	Bulldozer	1500	110	0.3384	1.0500	0.0360	0.013	2.1	2.1	0	0	0	0
	Truck drill	2400	300	0.3085	2.2900	0.0360	0.025	18.3	18.3	0	0	0	0
	Compressor	2400	286	0.3085	2.2900	0.0360	0.025	17.5	17.5	0	0	0	0
	Cat excavator	1800	80	0.5213	1.0500	0.0360	0.020	2.8	1.6	1.3	0	0	0
	Motor grader	1900	150	0.3384	1.0500	0.0360	0.013	3.6	1.5	2.1	0	0	0
	Road roller	1900	50	0.5213	1.0500	0.0360	0.020	1.9	0.8	1.1	0	0	0
	Front loader	3200	280	0.3085	2.2900	0.0360	0.025	22.8	12.4	10.4	0	0	0
	Haul truck	4900	380	0.2025	1.0500	0.0360	0.008	14.3	7.6	6.7	0	0	0
	Tank truck	2400	300	0.3085	1.0500	0.0360	0.012	8.4	4.2	4.2	0	0	0
Annual Road Maintenance	Motor grader	600	150	0.3384	1.05	0.036	0.013	1.2	0.2	0.2	0.2	0.2	0.2
	Road roller	600	50	0.5213	1.05	0.036	0.020	0.6	0.1	0.1	0.1	0.1	0.1
	Tank truck	600	300	0.3085	1.05	0.036	0.012	2.1	0.4	0.4	0.4	0.4	0.4
Clearing of Snow & Vehicles from Roads	Motor grader	2400	150	0.3384	1.05	0.036	0.013	4.6	0.9	0.9	0.9	0.9	0.9
	Front loader	600	280	0.3085	2.29	0.036	0.025	4.3	0.9	0.9	0.9	0.9	0.9
	Haul truck	1200	380	0.2025	1.05	0.036	0.008	3.5	0.7	0.7	0.7	0.7	0.7
Reconditioning of Existing Roadways	Motor grader	700	150	0.3384	1.05	0.036	0.013	1.3	1.3	0	0	0	0
	Road roller	700	50	0.5213	1.05	0.036	0.020	0.7	0.7	0	0	0	0
	Front loader	300	280	0.3085	2.29	0.036	0.025	2.1	2.1	0	0	0	0
	Haul truck	300	380	0.2025	1.05	0.036	0.008	0.9	0.9	0	0	0	0
	Tank truck	700	300	0.3085	1.05	0.036	0.012	2.4	2.4	0	0	0	0
Concrete Preparation	Concrete Plant	1400 / mo	180	0.3085	1.05	0.036	0.012	2.9	0	35.3	35.3	35.3	11.8
	Mixer truck	2800 / mo	360	0.2025	1.05	0.036	0.008	7.7	0	92.6	92.6	92.6	30.9
	Front loader	1400 / mo	280	0.3085	2.29	0.036	0.025	10.0	0	119.6	119.6	119.6	39.9
Construction of Forebay & Access Road	Bulldozer	3900	110	0.3384	1.05	0.036	0.013	5.5	0	0	5.5	0	0
	Haul truck	3900	380	0.2025	1.05	0.036	0.008	11.3	0	0	11.3	0	0
	Front loader	3900	280	0.3085	2.29	0.036	0.025	27.8	0	0	27.8	0	0
							TOTAL		**77**	**276**	**295**	**251**	**86**

b) Equipment for Surface Civil Works

Table 4-47
HC Emissions from Equipment for Surface Civil Works

Equipment Type	Total Estimated Equip Hrs	Power hp	Efss	TAF	DF	E.Factor (g/hp-hr)	Total Emis (kg/job)	Emissions per Year (kg) 2008	2009	2010	2011	2012
Bulldozer	45000	110	0.3384	1.0500	0.0360	0.013	63.3	0	9	21	21	12
Truck Drill	45000	300	0.3085	2.2900	0.0360	0.025	343.3	0	49	114	114	65
Compressor	45000	286	0.3085	2.2900	0.0360	0.025	327.3	0	47	109	109	62
Cat Excavator	45000	80	0.5213	1.0500	0.0360	0.020	70.9	0	10.1	24	24	14
Motor Grader	45000	150	0.3384	1.0500	0.0360	0.013	86.3	0	12.3	29	29	16
Road Roller	45000	50	0.5213	1.0500	0.0360	0.020	44.3	0	6.3	15	15	8
Front Loader	45000	280	0.3085	2.2900	0.0360	0.025	320.5	0	45.8	107	107	61
Haul Truck	45000	380	0.2025	1.0500	0.0360	0.008	130.9	0	18.7	44	44	25
Tank Truck	45000	300	0.3085	1.0500	0.0360	0.012	157.4	0	22.5	52	52	30
						TOTAL		**0**	**221**	**515**	**515**	**294**

4.4.3 Nitrogen Oxide Emissions (NOx)

4.4.3.1 Emissions from Buses and Trucks

Table 4-48
NOx Emissions from Buses

Work Area	Speed (kph)	E. Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	3.41871	443	5912	8720	10346	10198	2069	2	20	30	35	35	7
El Yeso	35	3.41871	830	11487	21037	22559	9550	0	3	39	72	77	33	0
Aucayes Alto	35	3.41871	653	4461	3482	5222	5398	0	2	15	12	18	18	0
Aucayes Bajo	35	3.41871	2733	19422	24010	17178	2733	0	9	66	82	59	9	0
Ventana Las Lajas	35	3.41871	366	5551	10431	8784	976	0	1	19	36	30	3	0
Maipo	35	3.41871	268	1401	1430	1430	1132	0	1	5	5	5	4	0
							TOTAL		**18**	**165**	**236**	**224**	**103**	**7**

Table 4-49
NOx Emissions from Trucks

Work Area	Speed (kph)	E. Factor (g/km)	Total Kilometers Traveled						Total Emissions Generated (kg)					
			2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Volcán	35	5.78692	5156	15467	19591	19591	16498	0	30	90	113	113	95	0
El Yeso	35	5.78692	4021	12063	15280	15280	12867	0	23	70	88	88	74	0
Aucayes Alto	35	5.78692	3042	9125	11558	11558	9733	0	18	53	67	67	56	0
Aucayes Bajo	35	5.78692	7023	21070	26688	26688	22474	0	41	122	154	154	130	0
Ventana Las Lajas	35	5.78692	4158	12473	15799	15799	13305	0	24	72	91	91	77	0
Maipo	35	5.78692	3702	11107	14069	2123	11848	0	21	64	81	12	69	0
Alfalfal	35	5.78692	1613	4838	6128	6128	5160	0	9	28	35	35	30	0
							TOTAL		**166**	**498**	**631**	**562**	**532**	**0**

4.4.3.2 Emissions from Equipment

a) Equipment for Road Construction, Rehabilitation and Maintenance

Table 4-50
NOx Emissions from Road-Related Equipment

Equipment Use	Equipment Type	Total Estimated Equip Hrs	Power hp	Efss	TAF	DF	Emission Factor (g/hp-hr)	Total Emis (kg/job)	Emissions per Year (kg) 2008	2009	2010	2011	2012
Construction of New Roads	Bulldozer	1500	110	5.6523	0.9500	0.0240	0.129	21.3	21	0	0	0	0
	Truck drill	2400	300	5.5772	1.1000	0.0240	0.147	106.0	106	0	0	0	0
	Compressor	2400	286	5.5772	1.1000	0.0240	0.147	101.1	101	0	0	0	0
	Cat excavator	1800	80	5.5988	0.9500	0.0240	0.128	18.4	10	8	0	0	0
	Motor Grader	1900	150	5.6523	0.9500	0.0240	0.129	36.7	15	21	0	0	0
	Road roller	1900	50	5.5988	0.9500	0.0240	0.128	12.1	5	7	0	0	0
	Front loader	3200	280	5.5772	1.1000	0.0240	0.147	131.9	72	60	0	0	0
	Haul Truck	4900	380	6.0153	0.9500	0.0240	0.137	255.4	136	120	0	0	0
	Tank truck	2400	300	5.5772	0.9500	0.0240	0.127	91.6	46	46	0	0	0
Annual Road Maintenance	Motor grader	600	150	5.6523	0.95	0.024	0.129	11.6	2	2	2	2	2
	Road roller	600	50	5.5988	0.95	0.024	0.128	3.8	1	1	1	1	1
	Tank truck	600	300	5.5772	0.95	0.024	0.127	22.9	5	5	5	5	5
Clearing of Snow & Vehicles from Roads	Motor grader	2400	150	5.6523	0.95	0.024	0.129	46.4	9	9	9	9	9
	Front loader	600	280	5.5772	1.1	0.024	0.147	24.7	5	5	5	5	5
	Haul truck	1200	380	6.0153	0.95	0.024	0.137	62.5	5	5	5	5	5
Reconditioning of Existing Roads	Motor grader	700	150	5.6523	0.95	0.024	0.129	13.5	14	0	0	0	0
	Road roller	700	50	5.5988	0.95	0.024	0.128	4.5	4	0	0	0	0
	Front loader	300	280	5.5772	1.1	0.024	0.147	12.4	12	0	0	0	0
	Haul truck	300	380	6.0153	0.95	0.024	0.137	15.6	16	0	0	0	0
	Tank truck	700	300	5.5772	0.95	0.024	0.127	26.7	27	0	0	0	0
Concrete Preparation	Concrete plant	1400 / mo	180	5.5772	0.95	0.024	0.127	32.0	0	385	385	385	128
	Mixer truck	2800 / mo	360	6.0153	0.95	0.024	0.137	138.2	0	1,659	1,659	1,659	553
	Front loader	1400 / mo	280	5.5772	1.1	0.024	0.147	57.7	0	693	693	693	231
Construction of Forebay & Access Road	Bulldozer	3900	110	5.6523	0.95	0.024	0.129	55.3	0	0	55.3	0	0
	Haul truck	3900	380	6.0153	0.95	0.024	0.137	203.3	0	0	203.3	0	0
	Front loader	3900	280	5.5772	1.1	0.024	0.147	160.8	0	0	160.8	0	0
							TOTAL		**612**	**3,025**	**3,182**	**2,763**	**939**

b) Equipment for Surface Civil Works

Table 4-51
NOx Emissions from Equipment for Surface Civil Works

Equipment Type	Total Estimated Equip Hrs	Power hp	Efss	TAF	DF	Emission Factor (g/hp-hr)	Total Emis (kg/job)	Emissions per Year (kg) 2008	2009	2010	2011	2012
Bulldozer	45000	110	5.6523	0.9500	0.0240	0.129	637.9	0	91	213	213	122
Truck Drill	45000	300	5.5772	1.1000	0.0240	0.147	1987.7	0	284	663	663	379
Compressor	45000	286	5.5772	1.1000	0.0240	0.147	1895.0	0	271	632	632	361
Cat Excavator	45000	80	5.5988	0.9500	0.0240	0.128	459.5	0	66	153	153	88
Motor Grader	45000	150	5.6523	0.9500	0.0240	0.129	869.9	0	124	290	290	166
Road Roller	45000	50	5.5988	0.9500	0.0240	0.128	287.2	0	41	96	96	55
Front Loader	45000	280	5.5772	1.1000	0.0240	0.147	1855.2	0	265	618	618	353
Haul Truck	45000	380	6.0153	0.9500	0.0240	0.137	2345.2	0	335	782	782	447
Tank Truck	45000	300	5.5772	0.9500	0.0240	0.127	1716.7	0	245	572	572	327
						TOTAL		**0**	**1,722**	**4,018**	**4,018**	**2,296**

4.5 TOTAL PROJECT-RELATED EMISSIONS

4.5.1 Summary of PM-10 Emissions

Table 4-52 below summarizes the PM-10 emissions estimated for the Project's construction phase.

Table 4-52
Summarized PM-10 Emissions

Activity	Emissions per Year (kg)					
	2008	2009	2010	2011	2012	2013
Preparation of New Road Construction Sites	17,364	7,842	0	0	0	0
Drilling & Blasting	0	4,617	1,522	393	0	0
Loading and Unloading of Material	8,441	14,552	11,516	9,048	1,147	0
Vehicle Traffic	16,820	143,606	210,612	180,188	51,765	429
Transportation of Muck	24,146	39,737	30,189	26,440	3,834	0
Construction of Surface Works	3,182	5,781	1,134	197	113	0
Erosion in Muck Disposal Sites	4,849	11,962	11,679	10,555	1,872	0
Road Equipment Engines	685	3,665	3,847	3,360	1,145	0
Vehicle Engines	7	25	32	29	24	0
Surface Construction Equipment Engines	0	1,995	4,656	4,656	2,660	0
Construction of Aucayes Alto Forebay & Access Road	0	0	32,163	0	0	0
Total PM-10 Emissions (kg)	**75,495**	**233,782**	**307,349**	**234,867**	**62,560**	**430**
Total PM-10 Emissions (t)	**75.5**	**233.8**	**307.3**	**234,9**	**62.6**	**0.4**

A number of natural factors serve as mitigation measures in the case of particulate matter emissions, for example, precipitation. EPA recommends that the number of rainy days be deducted from total fugitive dust emissions.

In the case of the PHAM, rainfall data were taken from the records of the Queltehues weather station, because of its location. For the period 1984-2004, the records showed an average of 34 rainy days per year. By deducting the number of rainy days from the total emissions generated per year, a reduction of approximately 10% of the emissions indicated in Table 4-52 above was obtained. Table 4-53 below reflects this reduction, showing the final emissions produced each year during the construction phase of the Project.

Table 4-53
Summary of Total PM-10 Emissions Considering Natural Mitigation Measures

Activity	Emissions per Year (kg)					
	2008	2009	2010	2011	2012	2013
Preparation of New Road Construction Sites	15,746	7,111	0	0	0	0
Drilling and Blasting	0	4,187	1,381	356	0	0
Loading and Unloading of Material	7,654	13,196	10,443	8,205	1,040	0
Vehicle Traffic	15,253	130,229	190,993	163,404	46,943	389
Transportation of Muck	21,897	36,036	27,377	23,977	3,477	0
Construction of Surface Works	2,886	5,243	1,028	179	102	0
Erosion in Muck Disposal Sites	4,398	10,848	10,591	9,572	1,697	0
Road Equipment Engines	621	3,324	3,488	3,047	1,038	0
Vehicle Engines	6	23	29	27	22	0
Surface Construction Equipment Engines	0	1,809	4,222	4,222	2,413	0
Construction of Aucayes Alto Forebay and Access Road	0	0	28,947	0	0	0
Total PM-10 Emissions (kg)	**68,462**	**212,005**	**277,118**	**212,989**	**56,733**	**390**
Total PM-10 Emissions (t)	**68.5**	**212.0**	**277.1**	**213.0**	**56.73**	**390**

The highest level of emissions, 277.1 tons per year, occurs in 2010, due to the materialization of the different works and activities required for the Project.

The PM-10 emission limit established by the PPDA for the Metropolitan Region is 10 tons per year. Therefore, at its highest emission level, the Project exceeds the limit by almost 267 tons per year. Accordingly, the corresponding emission compensation proposals are made in Section 5 of this document and in Annex 5 of the EIA.

4.5.2 Summary of CO, HC and NOx Emissions

Tables 4-54, 4-55 and 4-56 below summarize the CO, HC and NOx emissions estimated for each year of the construction phase of the Project. These emissions are produced by the engines of the vehicles and equipment used for the Project.

Table 4-54
Summarized CO Emissions

Activity	Emissions per Year (kg)					
	2008	2009	2010	2011	2012	2013
Road Equipment Engines	824	4,109	4,315	3,747	1,278	0
Vehicle Engines	46	171	225	205	161	2
Surface Construction Equipment Engines	0	2,325	5,426	5,426	3,100	0
Total CO Emissions (kg)	**871**	**6,606**	**9,966**	**9,377**	**4,539**	**2**
Total CO Emissions (t)	**0.87**	**6.61**	**9.97**	**9.38**	**4.54**	**0.00**

Table 4-55
Summarized HC Emissions

Activity	Emissions per Year (kg)					
	2008	2009	2010	2011	2012	2013
Road Equipment Engines	77	276	295	251	86	0
Vehicle Engines	26	97	128	116	91	1
Surface Construction Equipment Engines	0	221	515	515	294	0
Total HC Emissions (kg)	**103**	**594**	**938**	**882**	**471**	**1**
Total HC Emissions (t)	**0.10**	**0.59**	**0.94**	**0.88**	**0.47**	**0.00**

Table 4-56
Summarized NOx Emissions

Activity	Emissions per Year (kg)					
	2008	2009	2010	2011	2012	2013
Road Equipment Engines	612	3.025	3.182	2.763	939	0
Vehicle Engines	184	663	868	786	634	7
Surface Construction Equipment Engines	0	1,722	4,018	4,018	2,296	0
Total NOx Emissions (kg)	**796**	**5,410**	**8,068**	**7,567**	**3,869**	**7**
Total NOx Emissions (t)	**0.80**	**5.41**	**8.07**	**7.57**	**3.87**	**0.01**

As seen in these summarized tables, CO, HC and NOx emissions from Project-related activities do not exceed the limits set in Article 51 of MINSEGPRES Supreme Decree N°58, approving the PPDA.

5 EMISSIONS COMPENSATION PROGRAM (PCE)

5.1 PROJECT-RELATED EMISSIONS

The results of the estimation of emissions from the construction of the PHAM, indicate that the highest level of PM-10 emissions, 277.1 tons per year, will occur in 2010 (see Table 4-53 above).

As already mentioned, the PPDA for the Metropolitan Region sets an emission limit of 10 tons per year for all new activities or projects and their modifications. When the limit is exceeded, emissions must be compensated by 150%.

In view of the above, an Emissions Compensation Program should be put in place to compensate for the emissions in excess of the emission limit. Considering that the highest level of Project-related emissions exceeds the limit by almost 267 tons, the total emissions to be compensated are in the order of 415.5 tons.

5.2 EMISSIONS COMPENSATION PROPOSAL

The compensation proposal consists of improvements to existing access roads: 22 km of Route G-455, between Route G-25 and the El Yeso Reservoir, and 21 km of Route G-25, between Baños Morales and the work area. The improvements will include restoring road surfaces with a well-graded granular layer, and application of bischofite as a dust suppressant. Installing road signals and protection barriers is also contemplated.

The present state of the road segments mentioned above, together with the traffic of heavy-weight vehicles traveling the roads to access mining sites, represent the main source of particulate matter emissions in the area. Therefore, the implementation of the compensation measures will have an immediate effect on the total emissions generated.

To estimate the reduction of emissions resulting from the compensation proposal, a comparison is made between the current situation, and the projected emissions after road improvements. To ensure that the estimation is conservative, only the reduction of emissions due to road improvements is be considered.

5.3 EMISSIONS ESTIMATION IN CURRENT SITUATION

The estimation of the emissions in the current situation was based on the following:

- A traffic count, targeting light vehicles, 2-axle and larger trucks, and buses, carried out on 15 November 2007. Three observation points were set up to record traffic, one on Route G-455, one on Route G-25, before the turnoff to Baños Morales, and a third point on Route G-25, at the turnoff to Baños Morales. The traffic count at points 1 and 3 were considered representative.

- Inspections confirmed that the roadways are sprayed with water, at least twice a day, using another company's water tank truck. According to the estimates, this reduces the dust emissions by approximately 50% (Area for Road Impact Assessment dated 23 November 2006).

- Data from the Queltehues weather station, showing an average of 34 rainy days per year for the area.

The traffic flow data collected on 15 November 2007 are summarized in Table 5-1 below.

Table 5-1
Traffic Count on Route G-455[4]

Route	Distance (km)	Nº of Vehicles by Type			
		Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses
G-455	22	34	3	8	0
G-25	21	73	43	277	1

Source: Ambitrans Traffic Count, 15 November 2007.

Table 5-2 below shows the mean weight and emission factor considered for each vehicle type. The emission factor is for unpaved roads, as per section 4.1.2 above. The material silt content is 10%.

[4] Traffic count carried out on Thursday, 23 November 2007, at the intersection of Routes G-455 and G-12. Point 13 of the Baseline Report.

Table 5-1
Vehicle Mean Weights and Emission Factors

Route	Mean Weight by Vehicle Type (t)				Emission Factors by Vehicle Type (kg/VKT)			
	Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses	Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses
G-455	2	45	45	30	0.3300	1.3395	1.3395	1.1161
G-25	2	45	45	30	0.3300	1.3395	1.3395	1.1161

Table 5-3 below shows the total distances traveled by vehicle type and the associated emissions. The 50% effectiveness of water spraying was considered in the emissions estimation, as well as a 331-day year to exclude the 34 rainy days when no emissions are registered.

Table 5-3
Total Distances Traveled by Vehicle Type and Associated Emissions

Route	Total Distances Traveled				Emissions Generated (kg/day)				Total Emissions (t/yr)
	Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses	Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses	
G-455	748	66	176	0	123	44	118	0	94
G-25	1,533	903	5,817	21	253	605	3,896	12	1,577
							TOTAL		**1,672**

Based on the current traffic flow on Routes G-455 and G-25, 1,672 tons of PM-10 are released to the air each year.

5.4 EMISSIONS ESTIMATION AFTER ROAD IMPROVEMENTS

Improvements to existing access roads, as already described above, are expected to increase the reduction of dust emissions from 50% to 85%. Appendices 2 and 3 present details on the effectiveness of the dust suppressant to be used.

Table 5-4 below shows the emissions associated with the vehicle traffic on Routes G-455 and G-25. The same parameters defined in Tables 5-1 and 5-2 were used to estimate emissions.

Table 5-4
Vehicle Emissions Considering Bischofite Application

Route	Total Distances Traveled (km)				Emissions Generated (kg/day)				Total Emissions (t/yr)
	Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses	Light Vehicles	2-axle Trucks	2-axle+ Trucks	Buses & Taxibuses	
G-455	748	66	176	0	37	13	35	0	28
G-25	1,533	903	5,817	21	76	181	1,169	4	473
							TOTAL		**502**

A comparison of Tables 5-3 and 5-4 reveals that the application of bischofite resulted in a reduction of PM-10 emissions from 1,672 to 502 tons per year. This reduction is more than needed to offset the 415.5 tons of Project-related emissions to be compensated.

6 CONCLUSIONS

During the construction phase of the Alto Maipo Hydroelectric Power Project, CO, HC and NOx emissions will remain below the limits established in the Atmospheric Prevention and Decontamination Plan for the Metropolitan Region.

According to the results of this study, the PM-10 emissions from Project activities will exceed the PPDA permissible limits by a maximum of 267 tons per year. To compensate for the excess emissions, the Project proposes to make improvements to a segment of Route G-455 (between Route G -25 and the El Yeso Reservoir), and a segment of Route G-25 (between Baños Morales and the work area). The details of the proposal are included in Annex 19.

The proposed improvements will reduce current PM-10 emissions estimated for the road segments mentioned by 1,170 tons per year. This reduction will meet the 150% emissions compensation requirement provided for in the PPDA.

The emissions compensation proposal was developed based on the calculations and criteria recommended by CONAMA, and is expected to be approved by the competent authorities.

COMPARATIVE ANALYSIS OF THE EFFICIENCY OF DUST SUPRESSORS THROUGH THE USE OF DUSTMATE AND THE ECONOMIC EFFECT FOR ROUTINARY AND PERIODIC MAINTENANCE OF GRANULAR PAVEMENT

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SUMMARY

The present work describes the outcomes of an experience developed by the Highway Administration Office of the Maule region, with the objective of determining the efficiency of the Permazyme, Sodium Chloride (Salt) and Magnesium chloride hexahydrate (bischofita), used both in stabilization as well as for dust suppressing tasks on the roads of the seventh region.

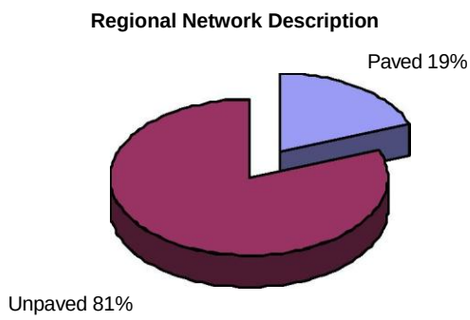
The analysis was based on the visual follow-up of the test stretches and the Dust Measurement Protocol designed by DICTUC of Pontificia Universidad Católica de Chile using Dustmate equipment, which allowed quantifying for the first time and in an objective manner, dust emissions and, consequently, the performance of dust suppressing treatments (DST).

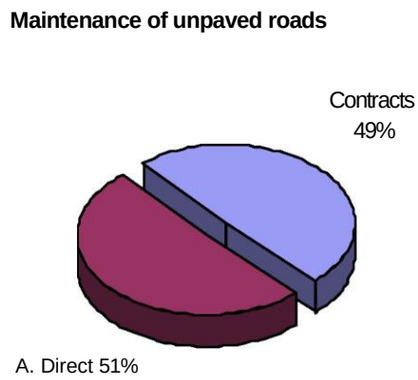
Finally, an economic assessment of the rutinary maintenance policies is presented through the comparison of: Simple Re-profiling and Granular Gravel v/s a Dust Suppressing Treatment (TSP). This assessment considers aspects as the decreasing in the loss of granular material and an improvement in the road service levels.

1. OVERVIEW

1.1 REGIONAL NETWORK DESCRIPTION

The VII region has a total of 7,385 km of roads. There are approximately 1,424 km. of paved roads, and the remaining are 5,961 km. of granular pavement wearing courses and a lower percentage of natural soil. Out of the entire number of unpaved roads, 48.29% are under maintenance systems of "Global Maintenance Contracts," thus leaving the remaining 51.71% of the gravel and dirt roads in charge of the Direct Administration. This means that at least in 3,000 km. of roads, maintenance tasks are carried out directly by the staff and with the machinery that belongs to the Road Administration Regional Office of the VII Region [1].





1.2 MAINTENANCE IN THE VII REGION: LOCAL PROBLEMS AND CURRENT STRATEGIES.

The network under Direct Administration (DA) is generally made up by unpaved roads that provide access to towns and agricultural and forestry areas. The DA carries out maintenance works through simple re-profiling, compacting and by incorporating chemical stabilizers.

According to the regional experience, the duration of these operations, and therefore, their profitability, is mainly determined by two factors: a) weather effects, and b) traffic. This is why the attention has been centered on improving the control on these variables and in the necessary efforts for determining the best maintenance policies, which has led to the quest of new methodologies and materials.

1.2.1 WEATHER AND TRAFFIC EFFECTS OF THE VII REGION ON GRANULAR PAVEMENT.

The region has two distinct seasons: the dry season (September-March) and the rainy season (April-August.) The main problems that arise due to traffic are:

Rainy season: The considerable amount of rainfall recorded annually in the area (735 mm/year on average) [2], the lack of the necessary clearing works and the bad condition of the roads due to the ongoing vehicle and road graders traffic during the summer, produces an accumulation of rainwater on the areas that do not have a pumping system and weaknesses due to the saturation of the pavement. Under these conditions, vehicle traffic on the road leads to its deformation. After each rain event, profiling works must take place once again.

Dry Season: High temperatures and the lack of rain make granular pavements lose their moisture, and therefore, the cohesion between those fine and thick particle weakens. Road traffic and the abrasion produced end up breaking the fine-thick link and the smallest material arises as dust, depositing a large part of it on the sides of the road, and mainly on houses and crops. The thickest material, after losing the fine one that linked them together disintegrates, forming calamines and chuckholes. Every month the grader repairs these deformations, re-profiling the surface, but at the same time making the supporting pavement thinner. The cohesion of the particles can be recovered in part with compacting and watering, but for a minimum amount of time, limited to its inevitable evaporation.

Currently, a great concern is dust generation during the summer. Its emission produces severe damages to the quality of life of people and to their productive activities. Unfortunately, up to now there have not been many serious efforts conducted for decreasing emissions. Next, there is a brief summary of some concepts that help understand the importance of the issue.

1.2.2 PROBLEMS ASSOCIATED TO DUST GENERATION

Dust consists of small particles carried by air currents, mostly formed by the disintegration or fracture of solid materials. According to estimations, annually there is an accumulation between 2,000 and 3,000 million tons of dust in the atmosphere [URL1]. The main dust sources come from wind erosion, earthquakes and volcanoes, mining, agricultural and industrial activities. Dust is classified by its size in 2 primary categories:

a) Inhalable dust (PM10):
It is the fraction of dust that enters the body, but that is trapped in the nose, throat and in the upper respiratory tract. The diameter measurement of this dust is of approximately 10 µm.

b) Breathable dust (PM2.5):
It is those particles that are small enough to penetrate the nose and the upper respiratory tract deeply into the lungs. The particles that penetrate the body exceed its natural clearing mechanisms and they have a greater probability of remaining in the body

PM10 and PM2.5 particles can cause health problems. Since they travel deeper into the lungs and because they are made up by some toxic elements (such as heavy metals and organic compounds), PM2.5 particles may produce coughing, and difficulty breathing, worsen asthma, cause lung problems (including the reduction of its functions and lifetime respiratory diseases), and in extreme cases death in individuals with heart and lung diseases.

The presence of dust in agriculture creates problems with the appearance of crops, pests, low yields, and health problems for workers. There are also other costs associated to frequent water irrigation, installation of meshes and barriers and the use of acaricides.

2 GENERAL DESCRIPTION OF THE PROJECT

2.1 OBJECTIVES

The Highway Administration Office of the VII Region faced the challenge of creating experiences for unpaved road maintenance with new materials. In concrete terms, the main objective of this experience was to obtain a methodology that would allow:

a) Avoiding the loss of fine particles during the dry season, in order to keep the cohesion, and increase the life of the roads and lower dust emissions.
b) Having better roads at the beginning of the rainy season, so as to improve the water drainage process through pumping.

For this there was a project whose aim was to determine the actual behavior of pavements treated with three chemical stabilizers. The stretches used were assessed according the following:

i) The monthly evolution of quality in the wearing courses, measured through visual evaluation and a photo follow-up process ii) The level of dust suppression attained by each product, measured with the instrument Dustmate, which is described below.

2.2 TEST ROAD

Location: The test road is officially called "Arboledas – FFCC por Piedra Blanca" Rol J-410, located in the Commune of Teno, a town located 20 km. north from the city of Curicó and near Route 5 South at approximately. km. 160.

Geometry: Average width 5.8 m, length 5.0 km. It is described as a road without considerable variations, with sharp horizontal curves and a low ratio

Traffic: The estimated T.M.D.A. ranges between 150 and 200 vehicles, from which a large percentage is comprised by simple double axle trucks.

Rain: The rainy season, as in the rest of the region, frequently takes place between April to August, and the area has an average of 700 mm. of annual rainfall.

Social impact: The road is basically for agricultural use, with ongoing traffic of trucks and machinery. There is a small community that lives in the lands near the road.

Maintenance: Traditionally this road has been maintained by the DA in charge of the Provincial Road Administration Office of Curicó, by carrying out simple re-profiling works on a monthly basis, with an average annual investment of $1.2 million.

2.3 PRODUCTS USED

The products chosen for this experience were 3:

1. <u>Sodium Chloride (Salt):</u> It is applied in bulk, and the product is homogenized with the material of the pavement. The application dose varies between 2% and 5%, which translates into 50 to 100 ton/km. It is not practical to be distributed dissolved as irrigation, since it would be necessary to use too much water for dissolving the proper dose[1]. Its use is exclusive for pavement stabilization and it requires a minimum of 6% of plasticity of the granular material to be used.

2. <u>Permazyme:</u> It is an enzymatic product of organic origin that is diluted in water and is applied before compacting. It acts on organic fines, producing a cementation and compacting effect. The dose is of 1 liter per 33 m3 of material, this means that for one kilometer of road there are approximately 33 liters of solution used and that are later dissolved in water for irrigation. Just as with Sodium Chloride, it works with materials with a PI over 6%.

Under laboratory conditions, it is not possible to dissolve more than 300 g of Sodium Chloride per liter of water.

3. Magnesium Chloride Hexahydrate (Bischofita): It is a highly hygroscopic compound[2] obtained as a by-product of lithium production. The application dose for stabilized material ranges between 3% and 5% (approximately 60 to 100 ton/km) depending on the PI of the granular material, and it may be applied in pavements without plasticity. The product is highly soluble in water being able to dissolve up to 1.5 kilos per liter of water, and therefore its application in the means of irrigation is recommended. For superficial dust controls there is a dosage of 3 kg/m2 used.

2.4 DESCRIPTION OF THE STRETCHES

The following chart shows the stretches set for the experience:

STRETCH	LOCATION	LENGTH (m)	PRODUCT	TREATMENT	DOSE	CONSTRUCTION DATE
1	KM 0.0 TO 0.5	500	Bischofita	Stabilization	80 kg/m3	Jan-17-2006
2	KM 0.5 TO 1.2	700	Salt	Stabilization	65 kg/m3	Jan-19-2006
3	KM 1.2 TO 2.5	1,300	Bischofita	Dust Control	3 kg/m2	Dec-12-2005
4	KM 2.5 TO 3.5	1,000	Permazyme	Stabilization	0.03 lt/m3	Dec-15-2005
5	3.5 TO 5.0	1,500	Salt	Stabilization	65 kg/m3	Dec-12-2005

The length of each stretch was determined by the availability of each product that the Regional Office had, according to the dose recommended by each supplier.

Pavement Material: In the test stretches there was a crushed granular material supply used, and its characteristics are described as follows:

Tam Trial iz (m m)	Mesh	Sample
50	2	100%
25	1"	84%
10 5	3/8"	59%
2	#4	50%
0,50	#10	85%
0,08	#40	25%
	#200	11%

MCS Density	2,201
Optimum Humidity	6.9
Natural Humidity	1.5%
I. Plasticity (PI)	5.9%
Non-submerged CBR	89

For stretch N°2 for Dust Control with Bischofita, the existing material of the road was used.

2.5 TYPE OF FOLLOW-UP AND COMMENTS

2.5.1 VISUAL FOLLOW-UP AND PHOTO REGISTRY

All of the test stretches were visited on a monthly basis, in order to assess the quality of the service of each one of them. Each visit took place with a photo registry of the condition of each segment, being careful of taking the pictures in the same places during each inspection.

[2] It captures environment humidity from relative humidity levels over 32%

2.5.2 DUST EMISSION CONTROL WITH DUSTMATE

The research team of the Regional Office, motivated by the work performed by the CIIV[3] of DICTUC de la Pontificia Universidad Católica de Chile with the use of DustMate [4], was in charge of the incorporation of this machine in the project so as to objectively quantify the efficiency of the different products applied in the test stretches.

The DustMate is a machine manufactured by Turnkey Instruments, which through a 600 cc/min capacity internal pump, can obtain directly a sample of surrounding air. The absorbed particles are analyzed for their quantity and size with a laser photometer, providing results for particle concentration of PM1, PM2,5 and PM10 sizes with a frequency of up to 1 sample per second [3].

In order to carry out measurements, the vacuum is installed in the rear bumper, right behind the back wheel, in order to directly obtain the amount of dust generated by the traction of the wheel with the pavement. As the vehicle travels over the road it allows the equipment to collect data second by second on the dust level at each point, with which it is possible to finally build the distance v/s emission curves with which the different stretches are considered in this experience.

To determine the efficiency there was an emission level measurement carried out in the test road before applying any type of product. With this it was possible to quantify the before and after behavior of each stretch, considering measurements every 50 days.

Measurement #	Date	Day #	Span measurements (days)
1	Nov-24-05	Measurement before	applications
2	Jan-18-06	0	
3	Mar-10-06	51	51
4	Apr-27-06	99	48
5	Jun-21-06	154	55

3 RESULTS

3.1 VISUAL AND PHOTO FOLLOW-UP

These are the results of the visual follow-up and photo registry of the stretches, taken from each one of their mid points. Although the follow-up was done on a monthly basis, only the first and last inspection photographs are included, so as to make the report brief.

Centro de Investigación e Ingeniería Vial [4] Efficiency of the Dust Control Treatment in Radomiro Tomic Mine between 2003 and 2005, and whose results were presented during the Provial Congress in 2004.

Stretch #1: Stabilization with Magnesium Chloride Hexahydrate (bischofita)
Construction Date: January 17, 2006

The upper photograph shows the condition of Stretch #1, 37 days after its construction, showing a surface with no degree of wear, well stabilized and without dust emissions. After a period of heavy rains in May and June, the loss of surface fines is seen in this stretch (see texture.) The final inspection, carried out 184 days after its construction, shows a stretch with its initial characteristics almost intact, free of chuckholes and wear.

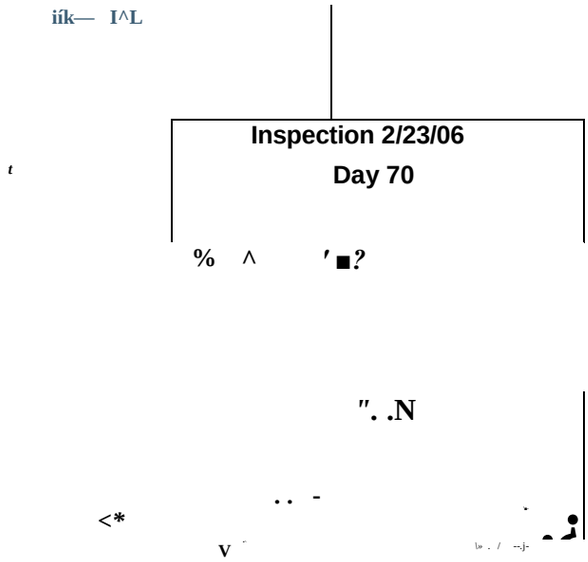
Stretch #2: Stabilization with Sodium Chloride (salt)
Construction Date: January 19, 2006

The upper photography shows the condition of Stretch #2, 35 days after its construction, showing a surface without wear, compact and free of dust emissions. By mid-April the pavement is very hard, without dust, and the first chuckholes after the beginning of the rainy season have started to appear. The final inspection, carried out 182 days after its construction, shows a stretch with a series of chuckholes and with a loss of cohesion and material in several areas.

Stretch #3: Dust Control with Magnesium Chloride Hexahydrate (Bischofita)
Construction Date: December 12, 2005

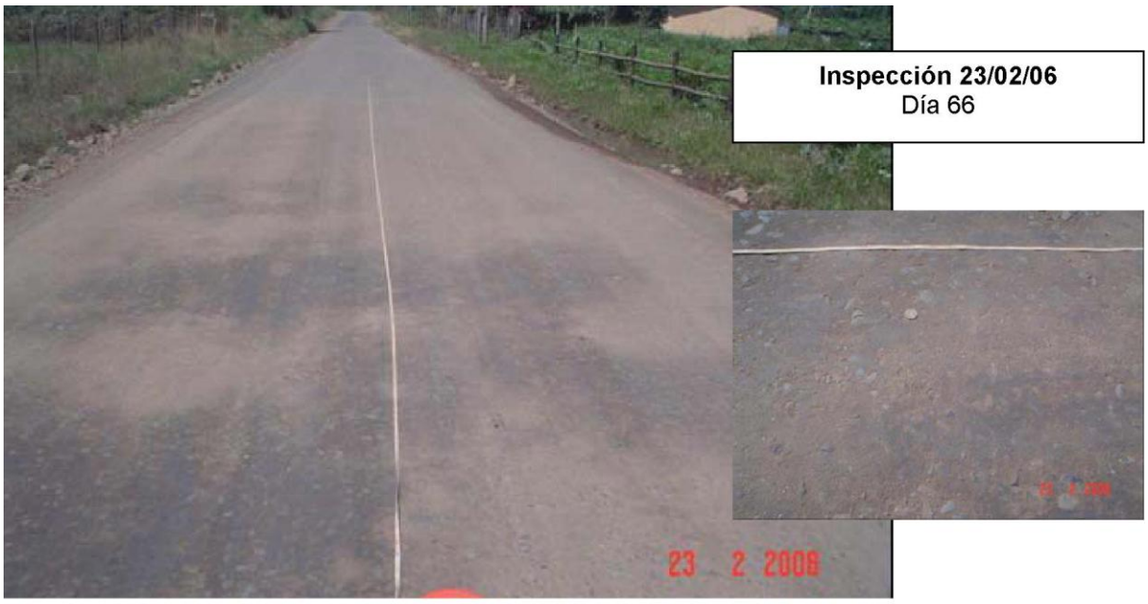
The upper photography shows the condition of Stretch #3, 73 days after its construction, showing a leveled surface and free of dust emissions. This stretch consisted in a surface application of bischofita watering (3kg/m2), only re-profiling the existing material in the pavement. By mid-march the formation of a hard superficial crust which provides a high-quality wearing course is seen, and that becomes softer during rain episodes, becoming more consolidated after some days. After the heavy rain season in May, the loss of product is seen and we start seeing the appearance of the first chuckholes. During the final inspection carried out 220 days after the application, there are areas where the initial quality of wearing courses has been lost, and the product almost completely, but the cohesion of the material is preserved. The humidity left by the rains kept the effect of dust elimination up to date.

Stretch #4: Stabilization with Permazyme
Construction Date: December 15, 2005



Stretch #4 70 days after its construction is the one that shows the worse performance, not presenting cohesion of fine particles and with a large amount of dust. During the inspection of March 22 (97 days after its construction) the stretch presented a high level of wear, and therefore the decision was to take action on it and end the follow-up.

Stretch #5: Stabilization with Sodium Chloride (Salt)
Construction Date: December 19, 2005



During the first visual inspection, 66 days after the construction of the stretch, there is a pavement with a good condition seen, with a high consolidation level, a good quality wearing course, without any chuckholes or dust. By the end of April, the appearance of the first chuckholes is seen along with the first rains. After May and June the stretch shows a considerable wear given the appearance of several "cup type" chuckholes which become larger with rains.

3.2 DUST EMISSION CONTROL RESULTS WITH DUSTMATE 3.2.1 INITIAL MEASUREMENT

STRETCH	LOCATION LENGTH (m)		PRODUCT	TREATMENT	PM 1 0 11/24/05
1	KM 0.0 TO 0.5	500	Bischofita	Stabilization	4,727.1
2	KM 0.5 TO 1.2	700	Salt	Stabilization	4,016.9
3	KM 1.2 TO 2.5	1,300	Bischofita	Dust Control	3,253.8
4	KM 2.5 TO 3.5	1,000	Permazyme	Stabilization	4,348.8
5	3.5 TO 5.0	1,500	Salt	Stabilization	4,202.5
				AVERAGE	**4,1 09.8**

The chart shows the initial values of the emission of PM10 particulate matter of the road, before the application of products (Measurement # 1). In the photograph the visual level of dust that the road presented is seen in the date of the initial measurement, produced by a vehicle that was travelling at 50 km/h by stretches 2 and 3 respectively.

3.2.2 POST CONSTRUCTION MEASUREMENTS

3.2.2.1 EFFICIENCY OF THE PRODUCTS

It was stated that the most representative index for determining the effectiveness of each one of the products was to quantify the percentage reduction of emissions compared to the initial situation (measurement #1.) This has been called “efficiency” and its value is obtained from:

Efficiency = 100*(1-(PM after / PM before))

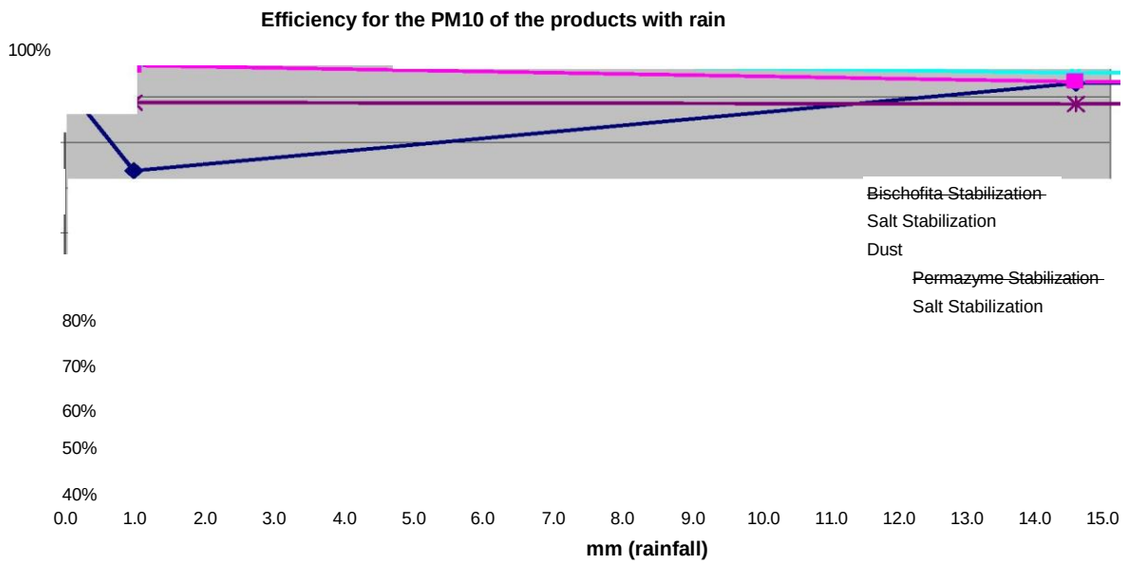
The *PMbefore* and *PMafter* values represent the averages of each measured stretch. The chart shows a summary of the post-application measurements with which the efficiencies of each product were obtained.

STRETCH	LOCATION	LENGTH (m)	PRODUCT	TREATMENT	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06	PM10 6/21/06
1	KM 0.0 TO 0.5	500	Bischofita	Stabilization	53.6	84.7	223.5	36.0
2	KM 0.5 TO 1.2	700	Salt	Stabilization	357.7	1,056.4	281.3	57.8
3	KM 1.2 TO 2.5	1,300	Bischofita	Dust Control	133.2	106.4	219.4	69.7
4	KM 2.5 TO 3.5	1,000	Permazyme	Stabilization	2,011.0	2,410.6	295.0	114.1
5	3.5 TO 5.0	1,500	Salt	Stabilization	147.2	477.5	490.2	52.4

3.2.2.2 THE EFFECT OF RAINS ON THE ANALYSIS

Measurement #	Date	a Date	Rainfall (mm)	Days elapsed from the last rain event
	Nov-24-05		-	-
	Jan-18-06		0.0	-
	Mar-10-06		1.0	12
	Apr-27-06		14.5	9
	Jun-21-06		266.0	3

This is the behavior of the different stretches with the presence of rain in the area.



The chart shows the behavior of the stretches until the 4th measurement, when the rainfall is of 14 mm [5]. The stretches treated with **Bischofita** keep their initial efficiency standard during the dry season (over 93%) which is explained because the hygroscopicity of this product allows preserving an optimum level from relative humidity over 32%. The stretches treated with **Sodium Chloride and Permazyme lower** their efficiency during the dry season (rates lower than 90%.) S**odium Chloride** improves gradually with the first rains by progressively recovering the pavement to its optimal humidity. The stretch with **Permazyme** had to be re-built before the beginning of the rainy season due to its premature wear.

The last measurement took place on June 21st, when the rainfall was of 266 mm and only 3 days after heavy rain, which gave efficiency rates of almost 100% in all of the stretches. Given the difficulty to determine the efficiency level of the products separately under these conditions, the results of this last measurement were not considered in this work.

3.2.2.3 EFFICIENCY RESULTS PER STRETCH

<u>Stretch 1 (Stabilization with Magnesium Chloride Hexahydrate (Bischofita))</u>

STRETCH LOCATION	PRODUCT	TREATMENT	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06
1 KM 0.0 TO 0.5	Bischofita	Stabilization	99%	98%	95%

Stretch # 1 shows an initial emission decrease of 99% compared to natural soil and that manages to keep itself almost inalterable in the next measurements, with rates of 98% on March and 95% on April. Bischofita as a stabilizer shows a high performance level as dust suppressor.

Stretch 2 (Stabilization wit Sodium Chloride (Salt))

STRETCH	LOCATION	PRODUCT	TREATMENT	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06
2	KM 0.5 TO 1.2	Salt	Stabilization	92%	74%	93%

Stretch 2 also shows a considerable initial particle abatement reaching a 92% efficiency. The later measurement of March shows an effectiveness loss with 75% particle abatement. Based on the measurement carried out on April 27th, the effectiveness value increases (93%), which can be attributed to the moisture provided by the first rains of the season.

Stretch 3: (Dust Control with Magnesium Chloride Hexahydrate (Bischofita))

STRETCH	LOCATION	PRODUCT	TREATMENT	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06
3	KM 1.2 TO 2.5	Bischofita	Dust Control	96%	97%	93%

There is an initial 96% decrease and a 97% increase in the next measurement for Stretch 3, which can be explained due to the consolidation by traffic in the stretch after the application, considering the fact that this stretch was not stabilized, but that the product was directly applied on the existing ground. By mid-April the measurements showed a 93% effectiveness, a decrease that can be explained by the beginning of the rainy season and the loss of concentration of the product, whose application dose is 4 times lower than for a stabilized one.

Stretch 4 (Stabilization with Permazyme)

STRETCH	LOCATION	PRODUCT	TREATMENT	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06
4	KM 2.5 TO 3.5	Permazyme	Stabilization	54%	45%	-

This stretch had the lowest performance, with an initial 54% and decreasing to 45% by mid-march. At the beginning of April, it became necessary to re-build the stretch due to its bad condition, leading to stop its follow-up.

Stretch 5: (Stabilization with Sodium Chloride (Salt))

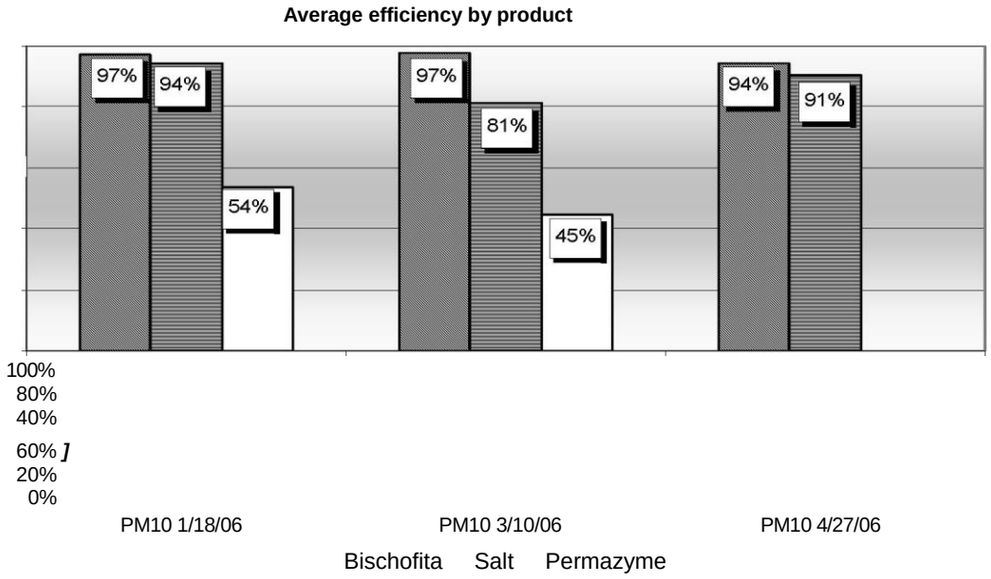
STRETCH	LOCATION	PRODUCT	TREATMENT	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06
5	3.5 TO 5.0	Salt	Stabilization	96%	89%	88%

The last stretch also presented a good particle abatement level at the beginning (96%) and it lowered its effect until getting to an 88% efficiency on April.

3.2.2.4 RESULTS BY PRODUCTS

Product	PM10 1/18/06	PM10 3/10/06	PM10 4/27/06	Average
Bischofita	97%	97%	94%	96%
Salt	94%	81%	91%	89%
Permazyme	54%	45%	-	49%

Within the results after getting the average from product efficiencies as dust suppressors, the most effective one is Magnesium Chloride Hexahydrate (bischofita) with a 96% average, followed by Sodium Chloride (salt) with an 89%, and finally Permazyme with a 49%.



4 ECONOMIC ASSESSMENT

4.1 JUSTIFICATION

The purpose of the entire road maintenance office is to provide the best service possible to its users, maximizing profitability in the investments done on the road. Fine particles loss in pavements is a very bad business for road administration offices: it shows signs of accelerated wear and provides a low comfort level for users; the migration of fine particles lowers the level of cohesion to the supporting structure, which leads to the appearance of chuckholes and calamines, and mostly, dust generation. The application of a good dust control treatment is not only for eliminating contaminant effects, but it also represents savings in the use of machinery for maintenance and granular material in the pavement. The increase in the surface cohesion between fine and thick particles increases its life during most of the dry season.

Once the performances of the products were known, the aim was to assess the convenience, in financial terms, of implementing a dust control solution for the summer season comparing it to traditional conservation alternatives, that is to say, without the use of products. ***Bischofita*** was taken for the assessment, which had a better performance on the test stretches.

4.2 SERVICE LEVEL AND PROFITABILITY CALCULATION (ESTIMATION FOR 6 MONTHS OF DRY SEASON)

The standard or service level wanted for the road must be set. Considering this, the element or elements of the road are identified and their expected performance level is then set, as shown in the following table:

Element	Variable	N. S. Expected	Alternative	Necessary Activities
Pavement	Wearing Courses Quality	1. Without calamines or chuckholes 2. Roads without visible dust generation for light and heavy traffic	Water	Simple Re-profiling Water irrigation
			Bischofita	33% of granular material reposition Initial re-profiling and compacting of the road Product irrigation

Item	$/km	Total amount of interventions in 6 months: Dust Control with Bischofita	Total amount of interventions in 6 months: Simple re-profiling
Re-profiling	$ 33,000	1	6
Compacting	$ 80,000	1	0
Material Loss (*)	$ 1,21 2,750	0	1
Water Irrigation	$ 2,000	0	360
Bischofita Watering	$ 1,750,000	1	0
	Total	**$ 1,863,000**	**$ 2,130,750**
	Km /month Cost	**$ 310,500**	**$ 355,125**

(*): equivalent to 33% of the total cost of the pavement's granular material

The unitary averages correspond to the averages obtained by the regional SAM[5].

Month	Conservation Type: With bischofita ($/km)	Conservation Type: Traditional ($/km)
	1,863,000	
		355,125
		355,125
		355,125
		355,125
		355,125
VAN	**1,863,000**	355,125 **1,892,630**

Discount Rate: 5.0% TIR: 6%

The findings of the calculation is that carrying out dust control processes are completely recovered at the end of the season, and “granular material loss” and “water irrigation”, are those items that attain significant savings.

The analysis does not consider other benefits such as: i) increased road safety levels due to visibility improvement, ii) greater well-being for people that live near the road, iii) lower costs for vehicle operation and maintenance, iv) greater availability of machinery for maintenance of other routes v) quality improvement of crops y vi) lower levels of losses caused by damages to transported goods

[5] Denomination given to the Regional Maintenance Administration System for maintenance works

5 CONCLUSIONS AND RECOMMENDATIONS OF THE EXPERIENCE

5.1 CONCLUSIONS BY PRODUCT

• The ***Magnesium Chloride Hexahydrate (Bischofita) solution presented the greatest level of efficiency*** applied to a granular base type wearing course pavement. The prior is demonstrated not only by its immediate effect as a dust suppressor, but also due to the fact that it also keeps high services standards overtime in the road. Once the rains have started and until the last visit to the stretch stabilized with bischofita (6/20/06), this kept its excellent condition, where considering that to that date, rainfalls in the area were of 280 mm., it did not present any level of wear. This stretch under ongoing rain conditions kept a better shape and its profile for a longer time, as well as its cohesion compared to the rest of the stretches, apparently due to the good quality of the wearing course surface which allowed for a better transversal rainwater evacuation. Up to date, this first experience on the use of this product as a stabilizer in the central-southern area is considered to be successful. However, in order to have a more detailed opinion on how it works, there should be a follow-up process of a couple of years more.

The stretch with dust control surface treatment with bischofita achieves the total suppression of particulate matter and its efficiency remains consistent over time, gradually decreasing its effect with the appearance of the first rains. This type of application forms a pavement with a very good wearing course surface quality and its performance does not depend on traffic, being this a factor that even helps consolidating the product. Under permanent rain conditions it goes back to its normal condition and simply behaves as a "wet dirt road." Once the rain event is over, the road loses its saturation, and when vehicles travel it is compacted and consolidated again. Considering the low application dose necessary to achieve the desired effect (3 kg/m2 or an equivalent to 20 ton/km[6]) and given its proven durability in this experience during the entire dry season, its use is highly recommendable at the beginning of each summer season, being this an efficient and cost-effective solution and that allows to differ during the entire spring-summer season the traditional tasks of rutinary maintenance.

Since its initial application it was not necessary to intervene the stretches during the rest of the dry season. The pavements kept their initial aspect, free of chuckholes, calamines and dust. A determining factor for the good behavior of the products is the initial quality of the pavement, thus being very convenient to prepare the stretches prior to the application, either through re-profiling or with scarification and compacting.

• The roads stabilized with **Sodium Chloride** attain a good condition and allows having pavements with a high cohesion level, free of dust and with a good performance in terms of surface quality. However, great care must be taken in the construction phase in order to achieve a great homogenization of the product, since, as it has to be applied dry, can create volumes with lower concentration, creating weak spots that in the mid-term become a series chuckholes along the road. On June the stretches with salt presented a high level of roughness but at the same time they showed signs of "small cup type" deformations and chuckholes, distributed along the road.

The product reached a high initial efficiency percentage according to the data provided by the DustMate (over 92%), meeting the objective of mitigating emissions, which could also be observed visually in each inspection, since after vehicles travelled on the road it was not possible to see signs of dust generation. As the high temperatures season goes by, it is observed that these type of pavements become dry, decrease their efficiency level and generate dust, though in a minimum amount, due to which it is advisable to hydrate them frequently through water irrigation.

[6] Considering an average width of 6 to 7 meters.

Since the application of the product it was not necessary to intervene the stretches during the rest of the dry season. The pavements kept their initial aspect free of chuckholes, calamines and dust until the first rain events.

• The stretch treated with **Permazyme** did not show a good performance, wearing out soon after the product's application. It initially attained a 54% abatement according to the readings of the DustMate, which is considered to be insufficient since this part of the road presented visual dust some days after the product was applied. It did not keep a good cohesion either during the follow-up period, recording loose material soon after the stretch was built along with the appearance of chuckholes and calamines.

5.2 GENERAL CONCLUSIONS

• A determining factor for the good behavior of the products is the initial quality of the pavement, being highly convenient to prepare the stretches prior to the application, either with simple re-profiling, scarification and compacting or, if the resources are available, to build stabilized pavements with the required thickness and with a surface sealing in order to control its emissions and wear.

• The problem with dust emission is a phenomenon that must be addressed at the beginning of the dry season. With the beginning of the rainy season comes a natural emission abatement of almost 100%, according to the readings of the DustMate. The implementation of a dust control strategy improves the feeling of quality of life in people, according to the testimonials of the people that lived near the road. Together with a much higher quality of wearing courses compared to untreated roads, the mitigation of emissions created a considerable increase in road safety due to a better visibility.

• Users increase driving speeds in the treated roads. A 25% increase in travelling speed compared to the initial situation is estimated, therefore it is highly recommendable to design a road safety plan that incorporates signaling and speed limits.

• The possible or probable negative effects that the application of new products implies, may always be present, being this a concern. Regarding that, there must be awareness about this situation, so as to be able to detect problems in early stages of the process and to take mitigation actions that avoid damages. In spite of this, it is considered that it would be worse to have a fearful attitude in relation to products that are not as well-known. Instead, the recommendation is to be willing to take risks and innovate, improving the works being built. Regarding this, we were able to see that up to the date of the last inspection, the surrounding vegetation did not show any level of damage after the application of each product. On the contrary, the reduction in the levels of dust that go into leafs creates a positive effect on nearby crops and in flora in general.

• Undoubtedly, the work procedures do have a remarkable influence on the good outcomes obtained with this experience. Something that may seem obvious, is that the way in which the stabilizer is applied is as important as its quality. Following well developed work plans and having proper materials and human resources, a high safety level will be attained for meeting the objectives. It is important to point out that the Direct Administration staff that executed the works shows a positive attitude, since they have an opportunity to become involved in tasks different from their daily tasks and they express their interest on participating in different operations, with different, new and more technical work procedures.

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REPORT N°1

DUST SUPPRESSOR EFFICIENCY TREATMENT

DUST EMISSIONS PM10 MEASURES WITH DUSTMATE EQUIPMENT

1. Road background

Type of application: Road Dust
Control: Puente 7 - Roa
Municipality: Florida
Region: VIII
Application Date:: January 10th, 2007
Measuring date January 31st, 2007
Client: Regional Road Directorate

photo.: DustMate Equipment

2. Average results

Tranche	Name	Location		Length	Average PM10 per cc (*)	Efficiency % to 21st day (**)
		Km begg.	Km end.			
T1	RoadMag 3 kg/m2	0.000	1.540	1.540	85.6	95%.
T2	RoadMag 1.5 kg/m2	1.540	2.000	0.460	142.3	92%.
T3	Without product	2.000	7.710	5.710	1882.0	-
T4	Calcium chloride	7.710	9.530	1.820	171.7	91%.
T5	Without product	9.530	10.460	0.930	1806.2	-
T6	Calcium chloride	10.460	11.290	0.830	85.2	95%.

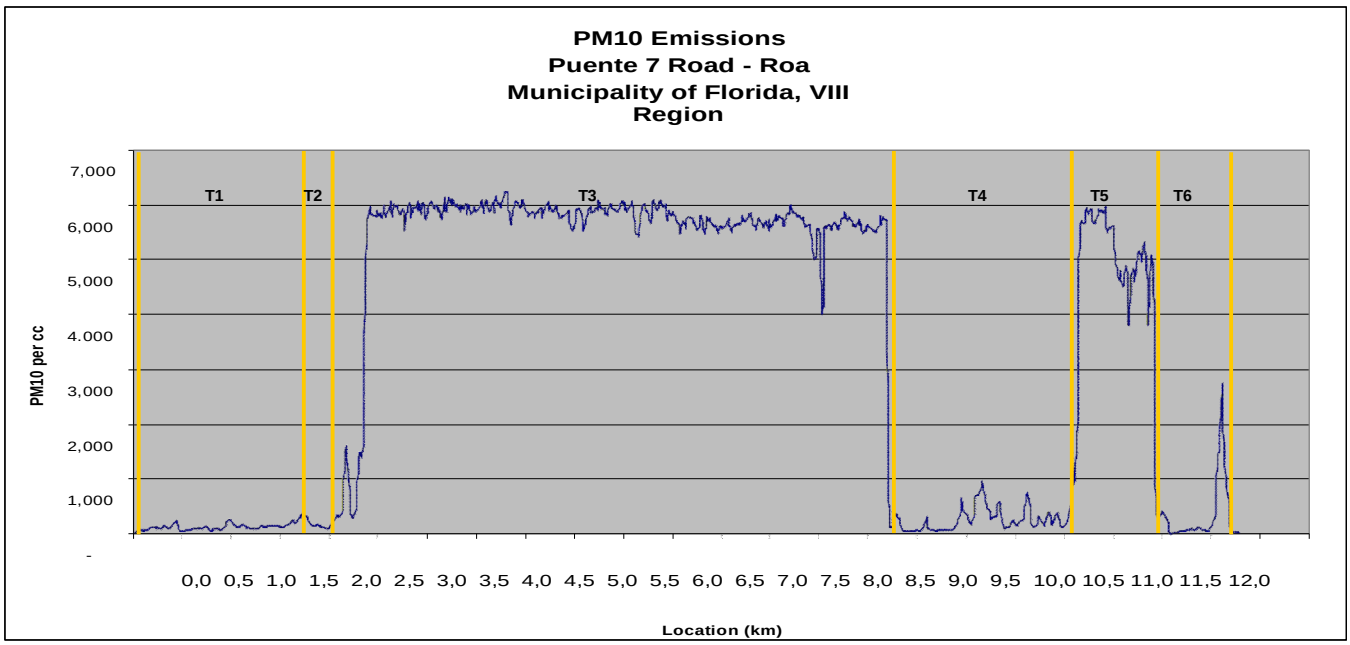
(*) emissions obtained with a vehicle circulating at 50km/h
(**) calculated with regards the average of the tranches without product

3 Comments

1 Rain registered between the RoadMag application and the current measure did not affect the efficiency of the product, reaching a value of 95% for Tranche N°1.

2 The recommended dose for dust control with magnesium chloride (3 kg/m2) has efficiently complied up to the date, not being necessary to use applications of conservations during the dry season nor water irrigation.

4. Graph



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SALMAG LTDA.
El Trovador #4285, Piso 4, Las Condes, Santiago.
Phone. 425-2215 Fax 425-2434
www.salmag.cl

TEST REPORT N°2	**Report Date** January 30th, 2006	**Test Date** October 24th and 25th, 2005
Project Stabilization and dust control test	**Client** Regional Road Directorate VI Region	
Reason Determining the RoadMag behaviour as dust suppressor and stabiliser in roads of the VI Region.		
Participants Road Department VI Region: Christian Osses, Víctor Zúñiga SALMAG : José Tomás Ovalle, Felipe Domínguez		
Content of the report (1) Photographic follow up (2) Dust measures results of the test tranche		

Development

This report presents the follow up and dust measures results performed in the road "Callejón Los Migueles", Municipality of Rengo, VI Region, location where a test of the RoadMag (bischofite) functioning in October 2005.

Test Tranches

TRANCHE	BEG KM	END KM	LENGTH (m)	WIDTH (m)	TEST	DOSE	UNIT	SOLUTION IN TRANCHE (m3)	ADITIONAL WATER (m3)
1M	0.400	0.950	550	6.000	DUST CONTROL	3	KG/M2	13.2	0
2M	0.950	1.100	150	6.000	DUST CONTROL	3	KG/M2	3.6	4
1E	1.100	1.250	150	6.000	STABILIZED	72.8	KG/M3	10	0
2E	1.250	1.300	50	6.000	STABILIZED	63	KG/M3	3	0
							TOTAL	**29.8**	**M3**

Dust Measures

Through the use of DustMate and according to the DICTUC-SALMAG protocol, measures of the particulate matter PM2.5, were done after the application of the product, taking in consideration surveys of the 4 tested tranches described in the previous chart and a tranche without the application (pattern tranche) located between the km 1.300 to 2.200. The dates of these measures are the following:

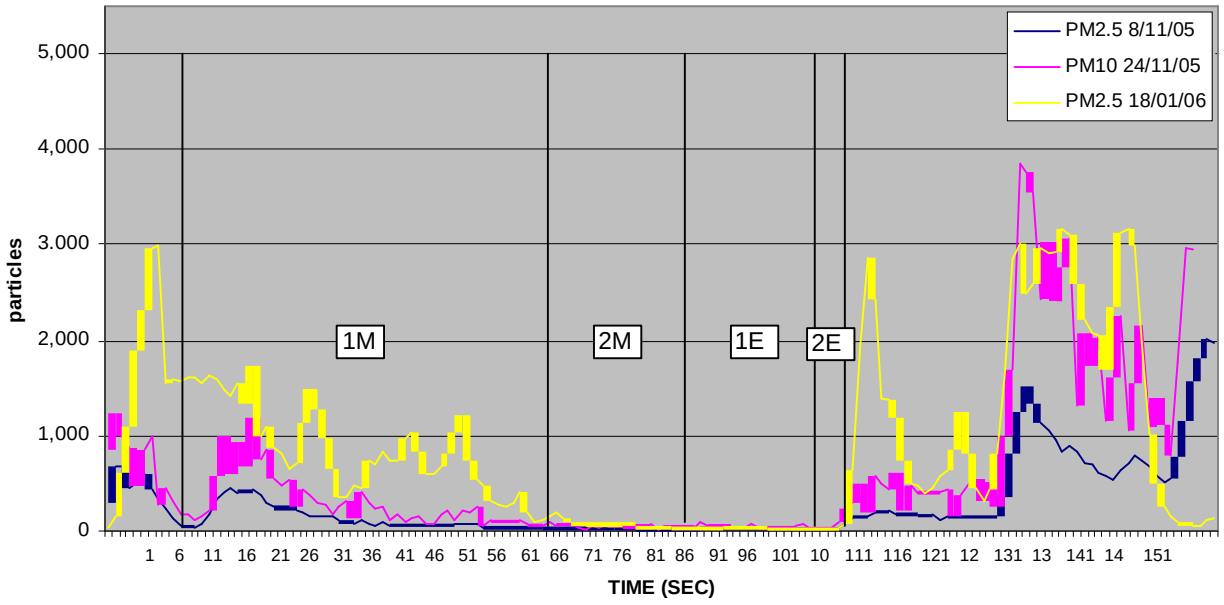
Date	Day	Activity
24-10-2005	0	RoadMag Application
08-11-2005	15	Measure N°1
24-11-2005	31	Measure N°2
15-11-2006	86	Measure N°3

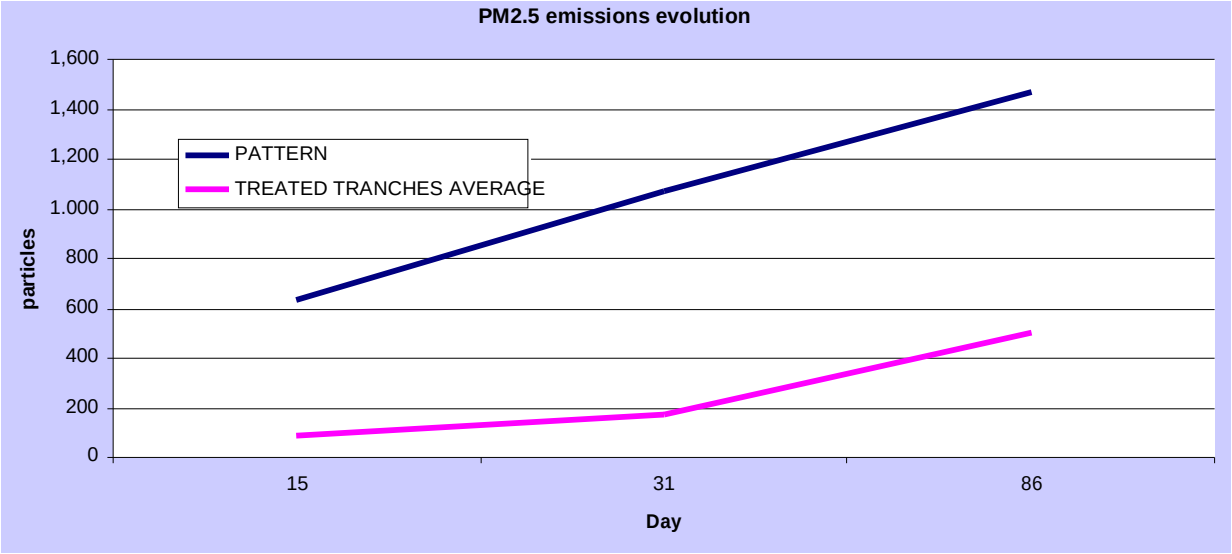
Average Results

PM2.5 MATTER - AVERAGE PER TRANCHE

	1M	2M	1E	2E	PATTERN
8-Nov-05	140,7	25,1	26,9	37,2	629,9
24-Nov-05	278,1	47,7	46,0	61,8	1071,9
18-Jan-06	1157,3	71,1	33,7	32,1	1470,0

PM2.5 Emissions
Los Migueles - km 0,4 al 2,2





Analysis per tranche.

Tranche 1M

Material: Embankment Quinta de Tilcoco well, brown colour
Application: Dust Control.

Comments: This tranche presents the greatest deterioration with regards the rest of the tranches. From the photographic record is possible to see that initially the tranche presented superficial problems at the beginning, mainly due to a deficient work in the re-profiling of the preparation. Nevertheless, after almost three months of the application, it still presents an important degree of abatement of the particulate matter (41% in PM2.5). Although the surface today presents some loose superficial material, the effect of the application of RoadMag can be seen on the sides of the road and visually low dust emission. Besides, the tranche in its entirety neither presents potholes nor corrugated iron.

PM2.5

	Day	1M	PATTERN	EFFICIENCY %
8-Nov-05	15	140.7	629.9	0.86
24-Nov-05	31	278.1	1071.9	0.83
18-Jan-06	86	862.4	1470.1	0.66

12-12-05

18-01-06

Tranche 2M

Material: Gravel Malloa well, yellow colour.
Application: Dust Control.

Comments: This tranche is in very good conditions, not presenting corrugated iron, potholes or dust. The surface is superficially sealed and without deterioration, although this is an area of a 90° curve where greater traction is generated by the vehicles. Out of the photographic set of this tranche, it can be seen a seal of hardened crust type and of a darker colour with regards the natural yellow of this material. At higher relative humidity hours, spots of humidity absorbed by the surface can be seen. The efficiency percentage to the date with regards the pattern tranche is 95% in PM2.5

PM2.5

	Day	2M	PATTERN	EFFICIENCY %
8-Nov-05	15	25.1	629.9	0.96
24-Nov-05	31	47.7	1071.9	0.96
18-Jan-06	86	71.1	1470.0	0.95

TRAMO 2M

07-11-05

23-11-05

12-12-05

18-01-06

Tranche 1E

Material: Embankment Quinta de Tilcoco well, brown colour
Application: Stabilized.

Comments: This tranche presented some constructive deficiencies in its beginning (humidity excess due to rain, lack of thickening control and oversize). To the date, the tranche has been consolidated and it presents a good look, without deformations of neither corrugated iron nor potholes and mainly, without dust. The efficiency percentage in dust control is the following:

PM2.5

	Day	**1E**	PATTERN	EFFICIENCY %
8-Nov-05	15	26.9	629.9	0.96
24-Nov-05	31	46.0	1071.9	0.96
18-Jan-06	86	33.7	1470.0	0.98

12-12-05

18-01-06

Tranche 2E

Material: Gravel Malloa well, yellow colour.
Application: Stabilized.

Comments: Visually is the best tranche of them all. It presents a high degree of consolidation and superficial ending, even better than newly finished. It presents a grey colour due to the traffic and corrugated iron or potholes are not seen. There is no loose superficial material and at sight, there is no dust emission. The stabilized presents a high degree of hardness, which can be seen when is impossible to manually break the surface with a sharp object.

PM2.5

	Day	2E	PATTERN	EFFICIENCY %
8-Nov-05	15	37.2	629.9	0.94
24-Nov-05	31	61.8	1071.9	0.94
18-Jan-06	86	32.1	1470.0	0.98

TRAMO 2E

07-11-05

23-11-05

12-12-05

18-01-06

Comments.

1. The application is considered successful up to the date. In spite of the initial constructive inconvenient, the four tranches present an important degree of efficiency with regards the non-treated tranche.

2. The behavior in gravel is a different story. Both tranches of this material have had excellent results, having them today in identical or better conditions than newly finished.

3. In order to continue with the correct follow up of this trial, it is recommended not to irrigate nor re-profiling this road.

FDM- SALMAG
30.01.06