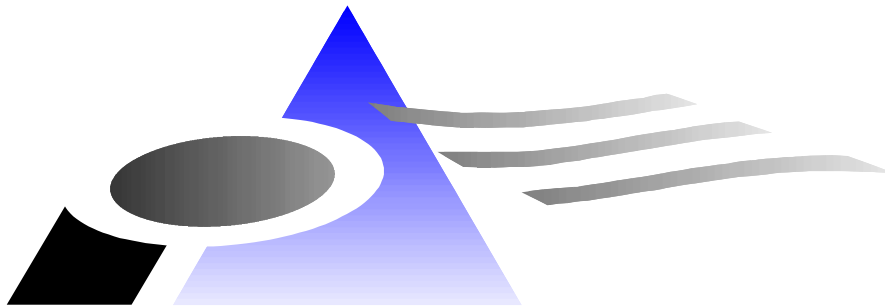




Pacific Air & Environment

FINAL REPORT

AIR QUALITY ASSESSMENT

ALCAN GOVE ALUMINA REFINERY

Prepared for:

URS

Pacific Air & Environment Pty Ltd

ABN 23 887 350 026
Level 1, 59 Melbourne St
South Brisbane Qld 4101
PO Box 3306 South Brisbane Qld 4101
Tel + 61 7 3004 6400
Fax + 61 7 3844 5858
E-mail: enquiries@pae.net.au
Website: www.pae.net.au

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TABLE OF CONTENTS

1	INTRODUCTION.....	1
2	GENERAL APPROACH TO THE ASSESSMENT.....	1
3	AMBIENT AIR QUALITY GUIDELINES	3
3.1	NEPM FOR AMBIENT AIR QUALITY	3
3.2	ODOUR	5
3.2.1	<i>Introductory comments and definitions.....</i>	<i>5</i>
4	THE EXISTING REFINERY.....	6
4.1	EMISSIONS TO AIR.....	7
4.2	EMISSIONS ESTIMATION.....	8
4.2.1	<i>Point Sources</i>	<i>8</i>
4.2.2	<i>Fugitive Sources.....</i>	<i>9</i>
4.3	SUMMARY OF EXISTING REFINERY EMISSIONS	10
5	THE EXPANDED (STAGE 3) REFINERY.....	10
5.1	EMISSIONS TO AIR.....	10
5.2	EMISSION ESTIMATION	11
5.2.1	<i>Scenario 1: Future Plant: 100% Gas Fuel with the Solid Liquid Calciner (SLC)</i>	<i>11</i>
5.2.2	<i>Scenario 2: Future Plant: 100% Gas Fuel without the Solid Liquid Calciner (SLC) ..</i>	<i>11</i>
5.2.3	<i>Scenario 3: Future Plant: most likely “worst case” emission conditions</i>	<i>11</i>
5.2.4	<i>Scenario 4: Expanded Refinery: fuel switching scenario</i>	<i>12</i>
5.3	SUMMARY OF FUTURE REFINERY EMISSIONS.....	12
6	EXISTING AIR QUALITY MONITORING PROGRAM.....	13
6.1	SULPHUR DIOXIDE (SO ₂) MONITORING.....	13
6.2	PARTICULATE (PM ₁₀) MONITORING	13
6.3	METEOROLOGICAL DATA	13
6.4	STACK TESTING.....	14
7	MEASURES TO CONTROL EMISSIONS	14
8	METEOROLOGICAL CONDITIONS	17
8.1	LONG-TERM CLIMATIC CONDITIONS	17
8.2	SURFACE WINDS	18
8.3	MIXING HEIGHT	20
8.4	VALIDATION OF METEOROLOGICAL MODELLING	22
9	MODELLING METHODOLOGY	24
9.1	INTRODUCTION.....	24
9.2	STATUS OF MODELS.....	24
9.3	SELECTED MODELS AND METHODOLOGY	25

9.4	TAPM	26
9.5	CALMET	27
9.6	CALPUFF	27
9.6.1	Model Description.....	27
9.6.2	Sources Modelled.....	28
9.7	PREVIOUS DISPERSION MODELLING	29
10	VALIDATION OF DISPERSION MODEL.....	30
10.1	METHODOLOGY.....	30
10.1.1	Skill_r.....	31
10.1.2	Skill_v.....	32
10.1.3	Model Bias	32
10.1.4	Fraction Bias	32
10.1.5	Root Mean Square Error.....	33
10.1.6	Robust Highest Concentration	33
10.2	RESULTS	33
11	MODEL RESULTS FOR EXISTING REFINERY INCLUDING THE NEW 4TH HIGH PRESSURE BOILER).....	36
11.1	CRITERIA POLLUTANT CONCENTRATIONS AT DISCRETE RECEPTORS	36
11.2	ODOUR	37
12	MODEL RESULTS FOR STAGE 3	39
12.1	INDICATIVE DISPERSION CONTOURS	39
12.2	CRITERIA POLLUTANT CONCENTRATIONS AT DISCRETE RECEPTORS	40
12.2.1	Scenario 1 - 100% Gas Fuel including the Solid Liquid Calciner (SLC) for Liquor Purification	40
12.2.2	Scenario 2 - 100% Gas Fuel excluding the SLC.....	41
12.2.3	Scenario 3 - Alternate Fuel Scenario (1% Sulphur and including SLC)	42
12.2.4	Scenario 4 – Alternate Fuel Scenario (Fuel Switching to low sulphur fuel when poor dispersion conditions occur).....	43
12.3	ODOUR	44
12.4	ON-SITE AIR TOXICS CONCENTRATIONS	46
13	ASSESSMENT OF AIR QUALITY IMPACTS	47
13.1	KEY ISSUES	47
13.2	CRITERIA POLLUTANTS.....	47
13.3	ODOUR	47
13.4	PHOTOCHEMICAL SMOG POLLUTANTS INCLUDING OZONE	49
14	AN AIR QUALITY MANAGEMENT PLAN FOR THE FUTURE.....	50
15	REFERENCES.....	51
16	APPENDIX A - ODOUR BACKGROUND INFORMATION	55
	INTRODUCTION TO ODOUR ASSESSMENT	55
	ODOUR MEASUREMENT AND UNITS	55

ODOUR NUISANCE.....	56
FIDOL FACTORS.....	56
<i>Frequency</i>	57
<i>Intensity</i>	57
<i>Duration</i>	58
<i>Offensiveness</i>	59
<i>Location</i>	59
ODOUR IMPACTS IN SENSITISED COMMUNITIES	59
17 APPENDIX B – ATMOSPHERIC EMISSION PARAMETERS	63
CURRENT REFINERY WITH THE NEW 4 TH HIGH PRESSURE BOILER – POINT SOURCE EMISSION DATA	
- AVERAGE EMISSION RATES.....	63
SCENARIO 1: FUTURE PLANT: 100% GAS FUEL WITH THE SOLID LIQUID CALCINER (SLC)	68
SCENARIO 3: FUTURE PLANT: MOST LIKELY “WORST CASE” EMISSION CONDITIONS	74
SCENARIO 4: EXPANDED REFINERY: FUEL SWITCHING SCENARIO	78
FUGITIVE PARTICULATES SOURCE EMISSION DATA.....	83
18 APPENDIX C – SOURCES OF EMISSIONS DATA	86
UPGRADED (STAGE 2) FACILITY	86

LIST OF FIGURES

Figure 1: Fugitive Dust Source Prior to Improvements	15
Figure 2: Fugitive Dust Source After Initial Improvements	16
Figure 3: Annual wind rose: Gove 2002.....	18
Figure 4: Wet season wind rose: Gove 2002.	19
Figure 5: Dry season wind rose: Gove 2002.....	20
Figure 6: Gove mixing height – cumulative frequency of occurrence.....	21
Figure 7: Gove mixing height variation with time of day.....	22
Figure 8: Monthly mean rainfall for 2002 compared to climatological mean monthly rainfall at Gove.	23
Figure 9: Monthly mean temperature for 2002 compared to climatological mean monthly temperature at Gove.	23
Figure 10: Modelling methodology utilised in the study.	26
Figure 11: Pollution Rose for Drimmie from January 2003 to March 2003.....	31
Figure 12: Graphical representation of basic statistical properties for average observed and predicted SO ₂ concentrations at Marngarr.....	34
Figure 13: Comparison between observed and predicted concentrations of SO ₂ at Marngarr.	35
Figure 14: Location of Discrete Receptors	36
Figure 15: Frequency distribution for 1-hour odour concentration, Current Operations including new 4 th High Pressure Boiler	38
Figure 16: Time series odour concentration for 2002, hourly values, Galupa.....	38
Figure 17: Time series odour concentration for 2002, hourly values, Nhulunbuy	39
Figure 18: Predicted 99.5 Percentile Odour Concentration (ou) – expanded facility (100% gas).....	40
Figure 19: Frequency distribution for 1-hour odour concentration, Stage 3 Plant.	45

Figure 20: Time series odour concentration for Expanded Refinery using 2002 met data, hourly values, Galupa.....	45
Figure 21: Time series odour concentration for Expanded Refinery using 2002 met data, hourly values, Nhulunbuy	46
Figure 22: Odour source contributions	49

LIST OF TABLES

Table 1: Ambient Air Quality NEPM Goals.....	4
Table 2: Draft NEPM Air Toxics Investigation Levels	5
Table 3: Existing Alcan Gove Air Emissions Summary.....	7
Table 4: Meteorological parameters collected by Alcan Gove monitoring stations	14
Table 5: Emission Targets by Pollutant	15
Table 6: Long-term meteorological averages for Gove Airport (1944-2001).	17
Table 7: Emission source parameters used in the dispersion modelling.....	28
Table 8: Statistics for modelled and measured sulphur dioxide.	34
Table 9: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Current Operation including the 4 th High Pressure Boiler	37
Table 10: Predicted 1-hr odour concentrations, Current Operations including new 4 th High Pressure Boiler	37
Table 11: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Refinery Scenario 1.....	41
Table 12: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Refinery Scenario 2.....	42
Table 13: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Refinery Scenario 3.....	43
Table 14: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Scenario 4.....	44
Table 15: Predicted odour concentrations, Stage 3 Alcan Gove plant.....	44

1 INTRODUCTION

Pacific Air & Environment (PAE) has been commissioned by URS to assess the air quality impacts associated with expansion of Alcan's alumina refinery at Gove. The proposed expansion (Stage 3)¹ will increase the alumina production capacity from 2 million tonnes/year to 3.58 million tonnes/year. The Stage 3 expansion will include:

- ❑ Additional process steam and power generating capacity;
- ❑ One additional digestion "stage";
- ❑ Replacement of the four rotary calciners (to be kept as stand-by calciners) with two stationary bed calciners resulting in a total of three stationary bed calciners;
- ❑ One additional hydrate vacuum system;
- ❑ One solid-liquid calciner (SLC); and
- ❑ Other new equipment such as electrostatic precipitators as described in the EIS.

One of the key modifications associated with the Stage 3 expansion that will yield net benefits in air quality is the use of natural gas as the main fuel source to replace fuel oil, the current fuel type, which typically has a sulphur content of approximately 3.5%. For up to 8 days a year, gas will not be available due to maintenance of the supply pipeline. During these periods an alternative fuel with a sulphur content no more than 1% will be used. In the event that gas is delayed, emission management strategies will be employed, including switching to low sulphur fuel at times when people may be exposed to emission plumes.

Although throughput of the facility will be increased, fugitive releases of particulates are not expected to increase as additional dust control measures are to be installed.

2 GENERAL APPROACH TO THE ASSESSMENT

A typical air quality impact assessment study for an industrial development involves gathering, processing and presenting information on:

- ❑ Emission source details such as types, locations, dimensions, flow characteristics and rates of contaminant release to the atmosphere. A selection of significant or potentially significant contaminants is required, based on their expected rates of release and intrinsic potential to cause environmental harm;
- ❑ Meteorological conditions, which affect the behaviour of contaminant plumes released into the atmosphere;
- ❑ Local geographical details including topography and surface characteristics such as land use or vegetation types;
- ❑ The existing levels of selected contaminants in the receiving environment;

¹ Throughout this document, the following definitions apply:

Stage 2 plant: Any reference to the "Stage 2", or second stage plant refers to the Alcan Gove plant as will exist *after* the introduction of the fourth boiler.

Stage 3 plant: Any reference to the "Stage 3", or third stage plant refers to the Alcan Gove plant as will exist *after* the construction of the major upgrade.

- ❑ Predicted future ambient concentrations, taking into account the existing baseline conditions. The prediction of ambient (usually ground-level) concentrations requires the use of mathematical models that simulate the release and dispersion of contaminant plumes from the facility;
- ❑ A basis for determining whether predicted contaminant concentrations are acceptable. This normally involves the use of air quality guidelines prepared by the relevant regulatory authorities. In this case the relevant air quality guidelines are found in the National Environmental Protection Measure for Ambient Air Quality. These guidelines have been adopted by the NT Government. Where relevant guidelines have been developed in other jurisdictions, they are also reviewed for the purposes of comparison and to help determine air quality benchmark standards.
- ❑ Measures incorporated into the design and/or management of the proposed development to mitigate air quality impacts, and in particular to mitigate the risks of adverse impacts under abnormal operational conditions. Atypical or non-routine emission events are not normally amenable to assessment based on modelling, and their assessment focuses on design and management issues to ensure that best practice is suitably incorporated into the future plans.

For this EIS, the operational and environmental aspects of the existing refinery provide a sound basis for ‘anchoring’ the assessment of future impacts. Air quality issues associated with the existing refinery operations have been considered in the design and management of the expanded facility. Testing and monitoring data from the existing refinery enable emission sources and ambient conditions to be relatively well characterised compared to a totally new facility. Emissions from proposed new components of the refinery have been estimated using the best available data from similar processes. Predicting the impact of emissions from the refinery is based on current best practice modelling technology. Assessment of impacts is based on stringent criteria that provide for a high level of environmental and human health protection.

The key contaminants considered in this assessment are:

- ❑ Carbon monoxide (CO)
- ❑ Nitrogen dioxide (NO₂)
- ❑ Sulphur dioxide (SO₂)
- ❑ Lead
- ❑ Particles as PM₁₀ (particles less than 10 µm in aerodynamic diameter) and TSP (Total Suspended Particulates, effectively particles up to 30 µm in diameter)
- ❑ Odour
- ❑ A range of “air toxics” or “hazardous air pollutants”, which generally occur at very low ambient concentrations have been included in this assessment to ensure all practicable efforts have been made to assess the full range of potential pollutants

The selection of these contaminants is based on a consideration of relevant current and possible future air quality guidelines (see section 3), emissions characteristics and experience gained from the management of air quality at Gove and other alumina refineries.

3 AMBIENT AIR QUALITY GUIDELINES

Many regulatory authorities publish guidance documents on air quality assessment and management. These guidelines usually include ground level concentration values for specific contaminants that should normally not be exceeded in the receiving environment. Guidelines typically specify how often the quoted concentration values can be exceeded without causing unreasonable levels of impact. Typically the impacts of concern are related to human health or amenity. In some cases, the relevant impacts relate to other environmental values such as the protection of vegetation. Most guidelines aim to provide a very high level of protection against environmental harm.

The Northern Territory government has adopted the goals set down in the National Environment Protection Measure (NEPM) for Ambient Air Quality, also known as the Air NEPM, which is outlined below in section 3.1.

3.1 NEPM for Ambient Air Quality

The National Environment Protection Council (NEPC), now incorporated into the Environment Protection and Heritage Council, developed the Air NEPM in 1998. The Air NEPM refers to the so-called criteria or common air contaminants that have for many years been the core set of pollutants for air quality regulation and monitoring. The Air NEPM comprises a monitoring-based set of standards, and was not designed to be applied to 'beyond the boundary' regulation of specific industrial facilities. Compliance with the NEPM is a state and territory responsibility, and is to be demonstrated by monitoring programs that represent the exposure of relatively large population groups to ambient levels of the nominated contaminants.

Despite this specific design, some state and territory environmental authorities have adopted the NEPM goals as assessment criteria that should be complied with in all receiving environments beyond industrial site boundaries. There are some anomalies arising from this approach relating mainly to extractive industries with significant dust emissions, and the NSW EPA is currently investigating ways to re-define its PM₁₀ compliance requirements for mining activities.

The ambient air quality goals defined in the NEPM are outlined in Table 1. The goals are to be achieved by 2008. The NEPM is currently being varied to add a PM_{2.5} standard. This variation recognises that the health risks associated with exposure to PM₁₀ are driven by the finer fraction represented by PM_{2.5}.

Table 1: Ambient Air Quality NEPM Goals

Pollutant	Averaging Period	Maximum concentration (ppm)	Maximum concentration ($\mu\text{g}/\text{m}^3$)	Goal within 10 years Maximum allowable exceedences
Carbon monoxide (CO)	8 hours	9	10,000	1 day a year
Nitrogen dioxide (NO ₂)	1 hour	0.12	230	1 day a year
	1 year	0.03	60	none
Photochemical oxidants (as ozone)	1 hour	0.1	196	1 day a year
	4 hours	0.08	157	1 day a year
Sulphur dioxide (SO ₂)	1 hour	0.2	570	1 day a year
	1 day	0.08	200	1 day a year
	1 year	0.02	60	none
Lead	1 year	-	0.5	None
Particles as PM ₁₀	1 day	-	50	5 days a year

Source: NEPC 1998

Notes: Averaging periods are defined as follows:

- 1 hour clock hour average
- 4 hour rolling 4 hour average based on 1 hour averages
- 8 hour rolling 8 hour average based on 1 hour averages
- 1 day calendar day average
- 1 year calendar year average

Apart from the criteria pollutants, there has been an increasing focus on regulating a large group of contaminants known collectively as air toxics or hazardous air pollutants (HAPs). Much of the original regulatory development of air toxics took place in the US. This in turn influenced the development of the National Pollutant Inventory (NPI) in Australia, which documents the environmental releases of 90 substances, most of which are classified as air toxics.

In May 2003, NEPC released a draft NEPM for Air toxics for public consultation. The draft contains investigation levels for five common air toxics (refer to Table 2). The draft states:

“The investigation levels are established for use in assessing the significance of monitored levels of air toxics with respect to protection of human health. If the investigation levels are exceeded then some form of further investigation by the relevant jurisdiction of the cause of the exceedence is appropriate.”

Table 2: Draft NEPM Air Toxics Investigation Levels

Pollutant	Averaging period	Investigation levels (ppm)	Investigation levels (µg/m ³)	Goal
Benzene	Annual	0.003 ppm	9.55	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Benzo(a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons	Annual		0.0003	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Formaldehyde	24 hours	0.015 ppm	18.4	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Toluene	24 hours	2 ppm	7510	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Xylenes (as total of ortho, meta and para isomers)	24 hours	0.2 ppm	865	

The assessment of impacts associated with ground level concentrations of air toxics from the expanded refinery is detailed in the toxicological assessment section of the EIS.

3.2 Odour

3.2.1 Introductory comments and definitions

In attempts to quantify the odour levels that provide reasonable protection against community odour annoyance, various regulatory authorities in Australia and elsewhere have developed numerical criteria for the evaluation of odour impacts. However, no widely accepted criteria have yet been developed for the assessment of odour impacts. This reflects the difficulties of odour sampling, measurement and modelling, combined with the lack of suitable data on odour levels associated with annoyance and complaints. Assessment criteria have changed substantially over the past decade, in response to changes in the understanding of odour nuisance and odour quantification.

Recently published Australian work (Ormerod *et al.*, 2003), reflecting experience overseas (e.g., Van Harreveld, 2002) shows that often the key factor in determining odour annoyance is community perception, regardless of the numerical value of the odour concentration. That is, a community that is generally accepting of industry will experience a lower level of annoyance than a hostile and sensitised community. Clearly, odour characteristics *per se* are important, but so-called 'soft' factors

relating to attitudes, expectations and experience are extremely important in understanding the responses of communities.

Perhaps the most important question that requires addressing in planning expansions of existing facilities is to estimate the relative change in odour concentrations, and to estimate the expected impact of changes in odour concentration on perceived odour levels. For this reason, numerical odour concentration criteria are more useful in planning for new developments rather than expansions of existing plants.

Odour concentration is the strength of an odour as determined in a laboratory by dynamic olfactometry, and is related to the concentration of odour-causing chemical compounds in the air. It is expressed in “odour units” (ou).

The perceived odour strength is known as odour intensity and is explained further in Appendix A - Odour Background Information. Humans perceive odour strength in a way that is a non-linear (normally logarithmic) function of the concentration. As the concentration of an odour changes, the intensity changes much more slowly. For example, if the concentration of an odour is increased by 100%, the intensity or perceived strength may increase by only 20 or 30%. A relatively small change in odour concentration, say 10%, is essentially imperceptible. The precise relationship between odour concentration and intensity varies for different odours.

Key aspects of odour that are used in odour modelling are:

- ❑ Concentration
- ❑ Averaging time and
- ❑ Percentile value

The shorthand notation incorporating these parameters is written in the form $C_{p,t}$ where C is the concentration and the subscripts p and t refer to the percentile value and the averaging time, respectively. For example, $C_{99.5, 1\text{-hr}}$ refers to the 99.5th percentile 1-hour average concentration. If we write $C_{99.5, 1\text{-hr}} = 5 \text{ ou}$, it indicates that the 99.5th percentile 1-hour average concentration is 5 ou, meaning that for 99.5% of the hours in the year, the 1-hour average concentration does not exceed 5 ou. A corollary of this is that the 1-hour average concentration exceeds 5 ou for the remaining 0.5% of the hours in the year (i.e., 44 hours in the year).

Additional information on odour assessment can be found in Appendix A - Odour Background Information.

4 THE EXISTING REFINERY

For the purpose of this report, the refinery is defined as the Alcan Gove refinery as it will exist *after* the commissioning of the fourth high pressure boiler (currently under construction in accordance with optimisation plans that are independent of the planned expansion).

4.1 Emissions to Air

The emissions to air from the refinery are detailed in Appendix B – Atmospheric Emission Parameters, with respect to sources and specific emission parameters for a large list of pollutants. Table 3 below summarises Appendix B by listing the major emissions from each process area.

Table 3: Existing Alcan Gove Air Emissions Summary

Process Area	Release Type	Major emissions	Controls
SPS High Pressure Boilers (4 of, 3 used at any one time)	Continuous Point Source	Particulates, NO _x , SO _x , CO, VOCs, Metals	Combustion parameters
Package (Low Pressure) Boiler	Continuous Point Source	Particulates, NO _x , SO _x , CO, VOCs, Metals	Combustion parameters
Cooling Towers	Continuous Point Source	Aerosol particulates	Flow rates and maintenance scheduling
Rotary Calciners (4)	Continuous Point Source	Particulates, NO _x , SO _x , CO, VOCs, Metals	Electrostatic precipitators (ESPs)
Stationary Calciner	Continuous Point Source	Particulates, NO _x , SO _x , CO, VOCs, Metals	Electrostatic precipitators (ESPs)
Calcination Area	Fugitive	Particulates	Maintenance programme
Lime Kiln	When operating, continuous point source with black smoke emissions on 20-minute cycle of chamber changes	Particulates, NO _x , SO _x , CO, VOCs, Metals	Nil
Lime Handling	Continuous Fugitive	Particulates	Silo baghouse
Digesters (6)	Continuous Point Source	VOC's	Process flow and Pressure control systems
Ferrosilt: Desanders and process tankage.	Continuous Point Sources	VOC's	Nil
Precipitation/Hydration: Filtration, process tankage and air-entrained carry over.	Continuous Point Source	Particulates, VOC's	Nil
Evaporation: Process tankage and air-entrained carry over.	Continuous Point Source	VOC's	Process flow and pressure control systems
Exposed Areas: Residue Disposal Area, Stockpiles, Mining Area, Refinery Area	Fugitive	Particulates	Mud Stacking Surface treatment Water trucks, water conditioning of ore in dry season.
White Side: Conveyor Transfer, Alumina Loading	Fugitive	Particulates	Phased capital improvement programme-including ship loader and transfer points.

			Substantive enclosure of the conveyor
Bauxite: Conveyor Transfer, Bauxite Loading	Fugitive	Particulates	Substantive enclosure of conveyor
Fuel and Organic Liquid Storage	Periodic pseudo fugitive	VOC	Maintenance and isolation
Vehicle Exhaust	Fugitive	Particulates, NO _x , SO _x , CO, VOCs, Metals	Maximise availability of buses, maintenance scheduling.
Wheel generated dust	Fugitive	Particulates	Ongoing Capital programme to seal roads and use water trucks on unsealed sections

4.2 Emissions Estimation

4.2.1 Point Sources

The bulk of atmospheric releases with the potential to affect air quality are from point sources such as stacks. Emissions from these sources were estimated using a hierarchical “tier” system, based on the following rules:

- ❑ “First-tier” estimation techniques were used to estimate emissions of SO₂ from combustion point sources were estimated directly from measured fuel sulphur composition, measured combustion rates and known periods when high sulphur and low sulphur fuel oil was combusted. Alcan Gove supplied data from its internal “PI” system for every hour between January 2003 and April 2003. It was assumed that 100% of the fuel sulphur was released as SO₂ from combustion point sources. This is a conservative assumption as some of the SO₂ will be adsorbed onto the alumina hydrate in the calciner.
- ❑ “Second tier” estimation techniques relied on stack testing results from the ECS testing campaign (May 2003) and archives of stack testing results for the Alcan Gove site;
- ❑ “Third tier” estimation techniques used standard NPI methodology estimation techniques, and/or data provided directly from Alcan Gove.
- ❑ “Fourth tier” estimation techniques used indicative data supplied by ECS.. Fourth-tier estimation techniques were only used in estimating emissions from the digestion blow off tanks.
- ❑ “Fifth tier” estimation techniques used stack testing data for a pilot-plant process and effectively scaled-up to a production scale process as would exist in the expanded Alcan Gove refinery. Fifth-tier techniques were only used for the Liquor Purification Plant’s solid liquid calciner (SLC), where indicative emission rates were supplied by Alcan Gove and Alceng.

Details of the derivation of each emission value are provided in Appendix C – Sources of Emissions Data.

4.2.2 Fugitive Sources

Fugitive dust emissions are difficult to quantify, because of the many complex factors that interact to determine emission rates. The following main assumptions were made in modelling particulate emissions from fugitive sources:

- Particulate emissions from all fugitive emission sources at the refinery and materials handling areas were estimated. Emission sources were weighted according to the ratings listed in the Alcan Gove document “contributing sources.xls”. This spreadsheet rates all identified fugitive particulate emissions in terms of none (N), Low (L), Medium (M) and High (H). In this work, N is weighted 1, L is weighted 10, M is weighted 50 and H is weighted 100. A transfer point rated H will emit 10 times the amount of a transfer point rated N if their emissions are derived from the same NPI reported emission. This assumption effects conveying and handling of bauxite, export bauxite and alumina.
- It was assumed that emissions due to handling material occur only at transfer points and not during the conveying process.

Appendix B – Atmospheric Emission Parameters lists the modelled particulate fugitive sources for the existing and expanded refinery.

4.2.2.1 Stockpiles and exposed areas

The method used to calculate PM₁₀ emissions from stockpiles is outlined by the USEPA (1995-AP-42 13.2.5), and shown in the equation below, and takes into account the rainfall and moisture profile of the Gove Peninsula. Emissions were calculated each hour for the year 2000, based on meteorological data obtained for that period, as follows:

$$E_{PM_{10}} = \frac{k}{8784} \left\{ 58 \left[\frac{0.4 \times U \times MA}{(\ln(10/RH))} - TFV \right]^2 + 25 \left[\frac{0.4 \times U \times MA}{\ln(10/RH)} - TFV \right] \right\} \times 1000A$$

where:

$E_{PM_{10},i}$	=	Emissions of PM ₁₀ from the exposed surface <i>i</i>	(kg·hour ⁻¹)
k	=	Particle size multiplier	(-)
U	=	Average hourly wind velocity	(m·s ⁻¹)
MA	=	Maximum to average ratio	(-)
RH	=	Roughness height	(m)
TFV	=	Threshold Friction Velocity	(m·s ⁻¹)
A	=	Surface area of stockpile	(ha)

4.2.2.2 Transfer points

PM₁₀ emission rates for the transfer points were estimated using a technique from the Commonwealth Department of Environment and Heritage (2001b), using equations below.

$$E_{PM_{10}} = \sum E_{PM_{10},i}$$

$$E_{PM_{10},i} = \frac{CA \times 0.00056 \times \left(\frac{U}{2.2}\right)^{1.3} \times TP \times CF}{\left(\frac{M}{2}\right)^{1.4}}$$

where

$E_{PM_{10},i}$	=	Emissions of PM ₁₀ due to transfer of material <i>i</i>	(kg·month ⁻¹)
CA	=	Mass of material transferred	(tonnes·month ⁻¹)
U	=	Average wind speed for the month	(m·s ⁻¹)
M	=	Moisture content	(%)
TP	=	Number of transfer points with similar control type	(-)
CF	=	Control Factor	(-)

4.3 Summary of Existing Refinery Emissions

Emissions of 85 atmospheric pollutants (including odour) have been calculated for the current refinery including the new 4th high pressure boiler in order to assess potential air quality impacts. A complete list of the releases of each pollutant from each source for the upgraded (Stage 2) facility can be found in Appendix B – Atmospheric Emission Parameters. The appendix also details all the relevant stack physical parameters.

5 THE EXPANDED (STAGE 3) REFINERY

5.1 Emissions to Air

The expanded refinery will include the following additional sources:

- ❑ Additional steam and power generating capacity;
- ❑ Additional digestion capacity including a high temperature component;
- ❑ Replacement of the four rotary calciners (to be kept as stand-by calciners) with two stationary bed calciners resulting in a total of three stationary bed calciners;
- ❑ One additional hydrate vacuum system; and
- ❑ One solid-liquid calciner (SLC).

There is ongoing discussion within Alcan about the exact number of stationary bed calciners that will be included in the final plant. The configuration described above (three stationary bed calciners and

four rotary calciners on standby) is likely to conservatively overestimate emissions compared to the very latest proposed Alcan configuration: four stationary bed calciners and only one rotary calciner on standby.

5.2 Emission Estimation

Emissions from three possible scenarios of the Stage 3 expansion were estimated. They are described in the following sub-sections, together with a summary of the emissions estimation methodology used in each case.

5.2.1 Scenario 1: Future Plant: 100% Gas Fuel with the Solid Liquid Calciner (SLC)

This scenario assumes the following plant and process parameters:

- ❑ An alumina production rate of 3.8 million tonnes per year;
- ❑ Every process unit except the lime plant is fired on natural gas 100% of the time;
- ❑ The lime plant was assumed to combust a combination of waste lubricating oil and light fuel oil with a sulphur content of approximately 0.5%;
- ❑ The solid-liquid calciner (SLC) is operating at 100% of the time;
- ❑ The four rotary calcination kilns are not operating;
- ❑ Three stationary calciners with 70 metre stacks are operating at 100% of the time; and
- ❑ Four high pressure boilers in use 100% of the time.

Non-odorous emissions for this scenario were estimated on the basis of NPI emission estimation techniques and projected gas consumption rates as supplied by Alcan Gove. Emissions of odour were estimated assuming that the boilers will emit odour at approximately half the current rate (for which measurement data are available) and that other process units emit approximately the same amount of odour per unit as at present. This is a conservative assumption, as it is likely that the boilers will emit much less than half of the current emissions with the switch from fuel oil to natural gas.

Emissions from the solid-liquid calciner were estimated from data supplied by Alcan Gove based on measurements at a pilot plant.

During the operation of the expanded refinery, there may be periods where one of the stationary calciners is not available due to maintenance. In these cases, one rotary calciner will be brought into use to maintain a constant alumina production rate. The requirement for running the rotary calciner is not expected to total more than sixty days per year.

5.2.2 Scenario 2: Future Plant: 100% Gas Fuel without the Solid Liquid Calciner (SLC)

This is exactly the same as the scenario described in 5.2.1 except that the SLC is not included.

5.2.3 Scenario 3: Future Plant: most likely "worst case" emission conditions

This scenario captures the most likely worst case conditions for the operation of the expanded refinery. It is expected that there will be approximately eight non-consecutive days per year under the gas fuel scenario where gas is not available. Under this scenario, the plant will operate on “alternate fuel”. This is currently defined as a light fuel oil with a sulphur content of approximately 1%.

This scenario assumes:

- ❑ An alumina production rate of 3.8 million tonnes per year;
- ❑ Every process unit except the lime plant is fired on an “alternate fuel” for 100% of the time. The alternate fuel has a sulphur content of approximately 1%;
- ❑ The lime plant was assumed to combust a combination of waste lubricating oil and light fuel oil with a sulphur content of approximately 0.5%;
- ❑ Three rotary calciners operating at 100% of time to account for maintenance on the stationary calciners;
- ❑ Two stationary calciners, running 100% of time; and
- ❑ The solid-liquid calciner (SLC) is operating at 100% of the time.

Emissions under this scenario were estimated using estimates from the Stage 2 plant as described above, with additional estimation of SO₂ and particulates based on historical data for high sulphur and low sulphur fuel oil combustion.

5.2.4 Scenario 4: Expanded Refinery: fuel switching scenario

There is a possibility that the gas supply to the Alcan Gove plant may be delayed beyond the time of commissioning the expansion. Under this scenario, the plant may “switch” from a high sulphur fuel oil to a low sulphur fuel oil to minimise impacts of the emissions when weather conditions are not favourable. This modelling scenario has assumed that low sulphur fuel oil will be used continuously during the wet season (typically unfavourable weather conditions) and high sulphur fuel oil is used continuously during the dry season (typically favourable weather conditions). This scenario also assumes:

- ❑ An alumina production rate of 3.8 million tonnes per year;
- ❑ The lime plant burning a combination of waste lubricating oil and light fuel oil with a sulphur content of approximately 0.5%;
- ❑ Every process unit except the lime plant is fired on :
 - Fuel oil with sulphur content of 1.5% in the wet season
 - Fuel oil with sulphur content of 3.5% in the dry season;
- ❑ Three stationary calciners, running 100% of time; and
- ❑ The solid-liquid calciner (SLC) is operating at 100% of the time, and it fires 1.5% sulphur fuel oil in the wet season, 3.5% sulphur fuel oil in the dry season.

For the purpose of this modelling scenario, the wet season was defined as December to April inclusive, and the dry season as May to November inclusive.

5.3 Summary of Future Refinery Emissions

With the inclusion of a liquor purification process into the expanded facility, an additional 24 potential atmospheric pollutants have been examined, bringing the total to 106 potential pollutants. A

complete account of the estimated releases of each pollutant from each source for the existing refinery (with the inclusion of the new 4th high pressure boiler) can be found in Appendix B – Atmospheric Emission Parameters.

6 EXISTING AIR QUALITY MONITORING PROGRAM

The current ambient air quality monitoring program at Alcan Gove consists of measurements of sulphur dioxide (SO₂) and particulates (PM₁₀). Meteorological conditions are measured by both on-site and off-site weather stations. Testing of stack emissions from the major sources is conducted periodically.

6.1 Sulphur Dioxide (SO₂) Monitoring

Alcan Gove maintains a continuous SO₂ monitoring station, located near the front fence-line (southern boundary) of the main refinery site. The monitoring is conducted on site because a significant issue is the near-field grounding of plumes containing SO₂ from fuel oil burning under adverse meteorological conditions. This situation has improved in recent years since the extension of the SPS boiler stack to 90 m, but relatively high short-term SO₂ concentrations still occur on site when weather conditions are unfavourable.

During the period between January 2003 and May 2003, Alcan Gove commissioned Sigma Energy Solutions Pty Ltd to manage a real time SO₂ sampling and analysis system situated at the location of the Marngarr Medical Centre, Drimmie Head. The following parameters were measured with a 10 minute averaging time:

- ❑ Sulphur dioxide mixing ratio (parts per billion, ppb)
- ❑ Horizontal wind speed at 10 metres height (m/s)
- ❑ Wind direction at 10 metres height (degrees)

Results from the off-site SO₂ monitoring station were used to validate plume dispersion modelling results. The validation is described in detail in Section 10.

6.2 Particulate (PM₁₀) Monitoring

Alcan Gove maintains a network of six Hivol-type sampling units for PM₁₀ monitoring. Samples are collected and analysed twice a week by Alcan Gove. The Hivol units are located at various locations around the Alcan Gove site.

6.3 Meteorological Data

Alcan Gove maintains two meteorological stations. One is located inside the plant boundary near the front fence-line (southern boundary) of the main refinery site. The other is located at the residue disposal area (RDA). These meteorological stations measure ten-minute averages of the parameters listed in Table 4.

Table 4: Meteorological parameters collected by Alcan Gove monitoring stations

Parameter	Abbreviation in data file	Units
Maximum Wind Gust	WGST	Kilometres per hour (km/h)
Average Wind Speed	WSAV	Kilometres per hour (km/h)
Relative Humidity	RH	Percent (%)
Ambient Temp @ 2m	AT 2	Degrees Celsius (°C)
Temperature @ 10m	AT10	Degrees Celsius (°C)
Net Solar Radiation	NSR	Watts per meter squared (W/m ²)
Barometric Pressure	BP	Hecto Pascals (hPa)
WS/WD Sine	SIN	no units - sine of (wind speed)/(wind direction)
WS/WD Cosine	COS	no units - cosine of (wind speed)/(wind direction)
Wind Speed E/-W	WSEW	Kilometres per hour (km/h)
Wind Speed N/-S	WSNS	Kilometres per hour (km/h)
Wind Direction Vector	VECA	degrees
Wind Speed Magnitude	VECM	Kilometres per hour (km/h)
Rainfall	RAIN	Millimetres (mm)
Solar Radiation	SR	Megajoules per meter squared (MJ/m ²)

Data have been collected and archived for several years, and this archive was used in the preparation of the meteorological inputs for the dispersion modelling that has been presented in this study.

6.4 Stack Testing

Alcan Gove periodically conducts stack emission testing. The last measurement campaign was conducted in May 2003.

7 MEASURES TO CONTROL EMISSIONS

Changes to the existing refinery as a result of the expansion will incorporate the following controls to minimise atmospheric emissions:

- ❑ Enclosing of conveyors and transfer points with dust to be extracted to baghouses;
- ❑ Chutes designed to minimise dust generation;
- ❑ Installation of sampling ports to allow regular emissions testing;
- ❑ Installation of alarm systems to tighten process controls, prevent unacceptable environmental emissions and/or detect air pollution control equipment faults;
- ❑ Use of road surface treatments to prevent dust emissions during construction;
- ❑ Permanent roads and car parks to be sealed;
- ❑ Clear delineation and control of traffic areas and non-traffic areas;
- ❑ Dispersion modelling of odours and other air emissions to help identify any areas that may require investigation;
- ❑ Abatement measures in the event that investigated areas require improvement;

- ❑ Any new fugitive dust sources within and connected to calcination to be identified and controlled to eliminate dust emissions;
- ❑ Any hydrate storage to be designed and managed to prevent dust emissions;
- ❑ Calcination purging to be limited to 2 purges per month for a maximum of 120 minutes per purge except during commissioning when purging will be more frequent;
- ❑ Utilise best management practices to contaminants in cooling tower emissions; and
- ❑ SPS to run on low sulphur fuel when construction workers are exposed and utilise predictive modelling technique to anticipate fuel-switching requirement.

Specific emission targets have been set by Alcan for new emission sources and are outlined below in Table 5.

Table 5: Emission Targets by Pollutant

Pollutant	Stage 3 concentration targets
Particulates - point sources	Average concentration less than 50 mg/m ³
Particulates - fugitive sources	No significant sources of fugitive dust
CO	Average concentration less than 1000 mg/m ³
NO _x	Average concentration less than 460 mg/m ³ as NO ₂

Elimination of all significant sources of fugitive dust is a high profile initiative in the Alcan Gove Strategic Plan. Improvements over the next 5 years to conveyor transfer points and the ship loader facility are expected to result in a site-wide fugitive dust emissions reduction of around 30%. Figure 1 and Figure 2 show the relative contributions of fugitive dust sources before and after the initial improvements.

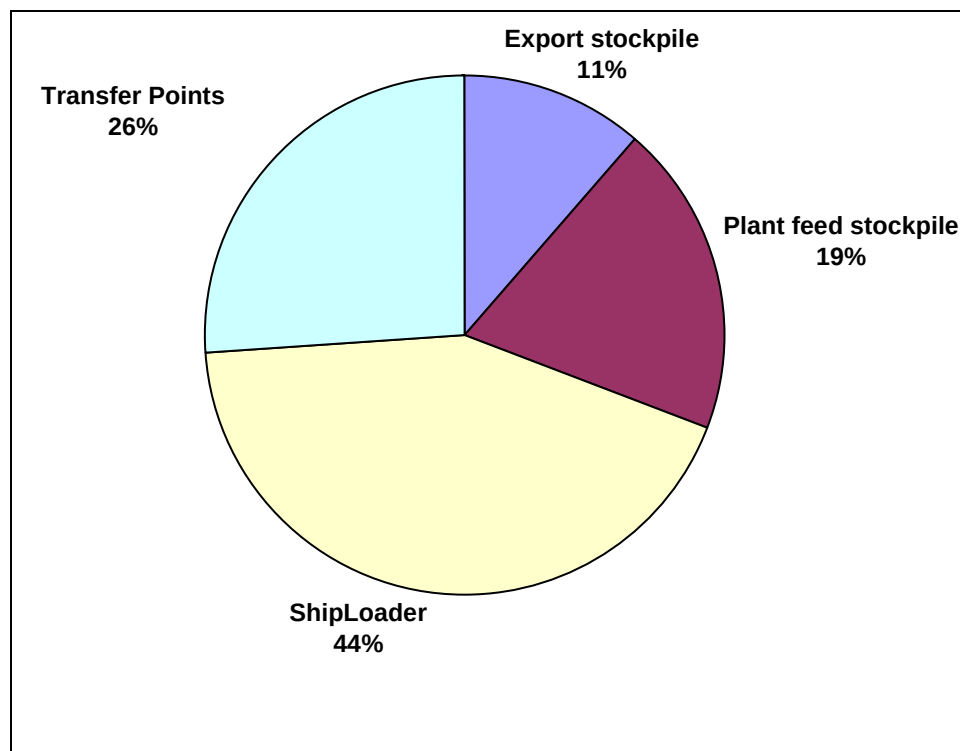


Figure 1: Fugitive Dust Source Prior to Improvements

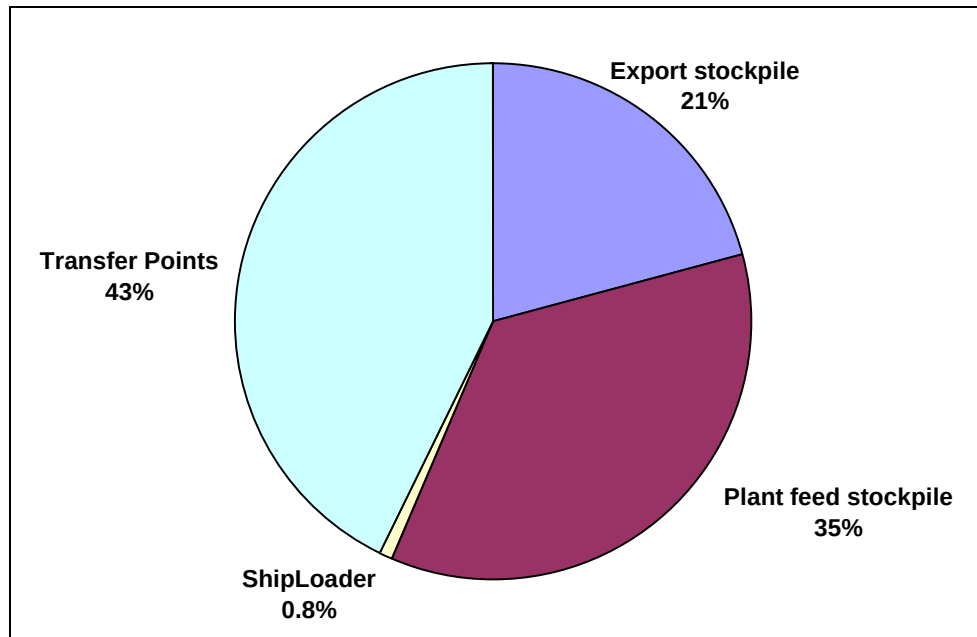


Figure 2: Fugitive Dust Source After Initial Improvements

8 METEOROLOGICAL CONDITIONS

8.1 Long-term Climatic Conditions

The Commonwealth Bureau of Meteorology has maintained a major weather station at Gove airport since 1944. The observations at this station include synoptic three-hourly surface recordings of horizontal wind speed and direction, dry bulb air temperature, dew point temperature, relative humidity, atmospheric pressure, rainfall, visibility and cloud.

Fifty-seven years of data collected at this site were analysed to provide the meteorological statistics in this section. These observations provide a long-term database of climatic information, which is adequate for planning purposes. Alcan maintains its own on-site meteorological station at the red mud disposal area (RDA), complying to Australian Standard AS 2923-1987 : *Ambient air - Guide for measurement of horizontal wind for air quality applications*.

Gove has a tropical monsoon climate with very marked seasonality in rainfall. The wet season lasts from December to April and the dry season from May to October (Table 6). The 5-month wet season accounts for over 90% of annual rainfall in a typical year. Daily maximum temperatures vary over a small range during the year, averaging 28°C in June and July and rising to an average of 33°C in November in the buildup to the wet season. Average daily minimum temperatures vary from around 19°C in August to about 25°C in December and January. The surface wind regime of the Gove region is dominated by trade winds from the southeast during the dry season. This flow is often strong and is sometimes influenced by the thermally driven sea and land breezes. During the wet season, surface winds generally reverse direction and blow frequently from the northwest. This reversal of wind combined with rainfall seasonality categorises the climate of the region as monsoonal.

Table 6: Long-term meteorological averages for Gove Airport (1944-2001).

Month	Min. Temp. (° C)	Max. Temp. (° C)	9am Windspeed (km/h)	3pm Windspeed (mm/h)	Rainfall (mm)
Jan	24.6	32.0	11.0	13.8	278.0
Feb	24.4	31.4	11.7	14.7	281.6
Mar	23.9	31.3	10.7	14.2	239.4
Apr	23.2	30.9	13.2	16.6	166.3
May	22.7	29.9	17.2	19.4	54.8
Jun	21.3	28.3	17.4	19.9	28.6
Jul	20.2	27.7	17.8	20.9	12.4
Aug	19.3	28.6	17.6	20.2	3.3
Sep	19.7	30.2	16.0	18.9	0.0
Oct	21.5	31.6	14.5	17.2	0.6
Nov	23.5	33.1	11.4	15.0	2.5
Dec	24.5	32.8	10.7	14.5	198.3
Annual	22.4	30.7	14.1	17.1	1353.0

8.2 Surface Winds

The general features of winds affecting plume dispersion are illustrated in the wind rose diagrams for annual - 2002 (Figure 3), the wet season - 2002 (Figure 4) and the dry season - 2002 (Figure 5). The wind rose summarises the measured wind statistics at 10 m height for the meteorological monitoring station at Alcan Gove. The wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points – N, NNE, NE, etc. The bar at the top of each wind rose diagram represents winds blowing from the north (i.e., northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds.

The major features of the annual wind roses are as follows:

- ❑ The predominant wind during the nocturnal hours is from the southeast;
- ❑ Winds during the afternoon are predominantly from the northeast to southeast;
- ❑ Highest speeds occur with winds from the southeast;
- ❑ Lowest speeds occur with winds from the east at night;
- ❑ Calm conditions occurred approximately 2% of the time during 2002.

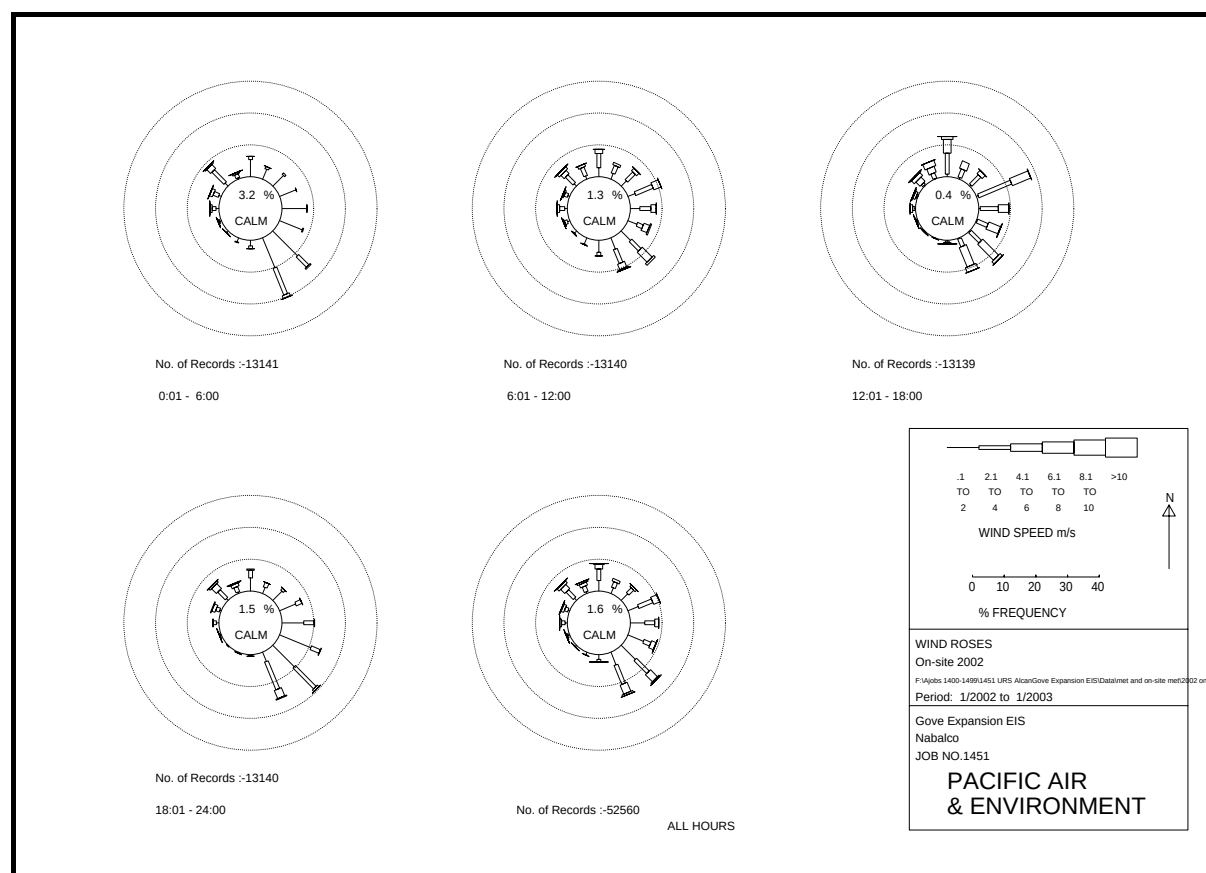


Figure 3: Annual wind rose: Gove 2002.

The major features of the wind roses during the wet season (Figure 4) may be summarised as follows:

- ❑ The predominant wind during the nocturnal hours is from the northwest;
- ❑ Winds during the afternoon are predominantly from the northwest to northeast;
- ❑ Highest speeds occur with winds from the northwest (monsoonal flow);
- ❑ Lowest speeds occur with winds from the east and southeast at night;
- ❑ Calm conditions occurred approximately 3% of the time.

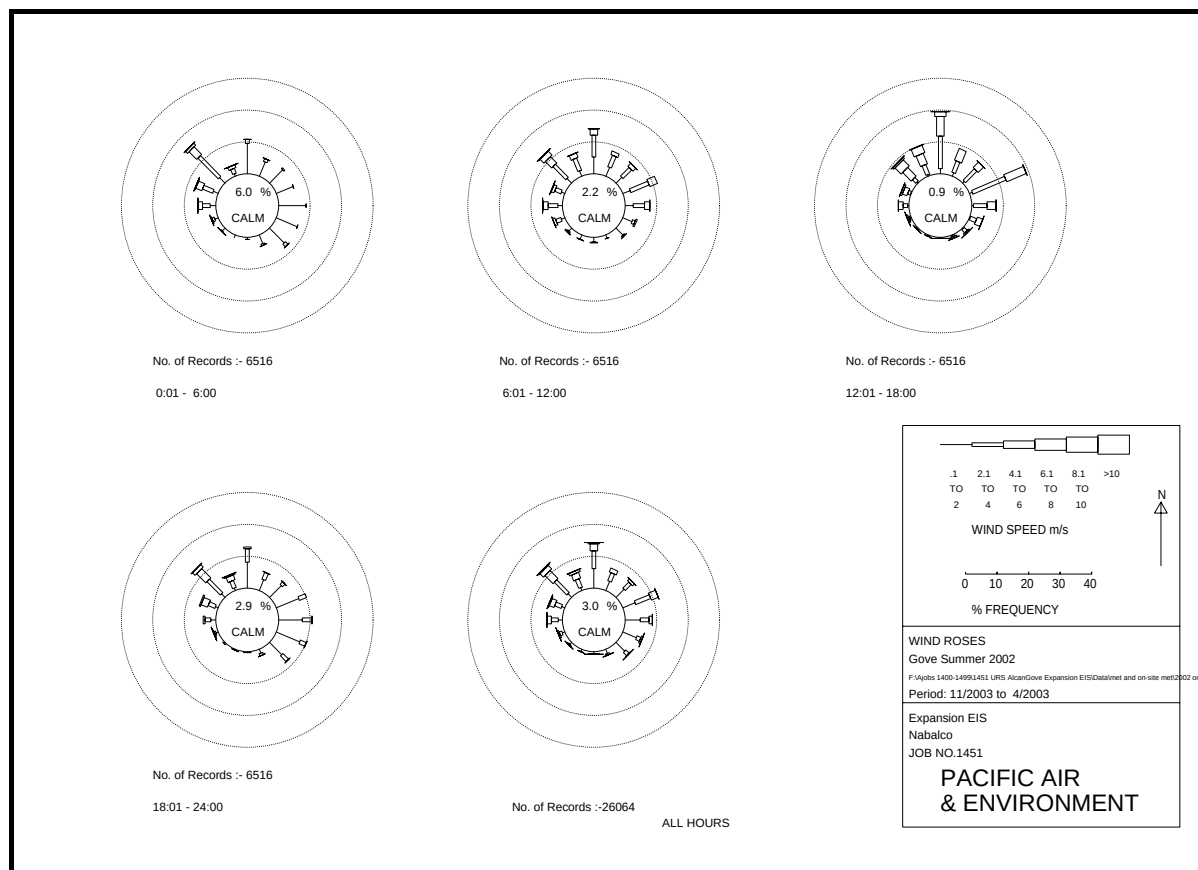


Figure 4: Wet season wind rose: Gove 2002.

The major features of the wind roses during the dry season (Figure 5) may be summarised as follows:

- ❑ The predominant wind during the nocturnal hours is from the southeast;
- ❑ Winds during the afternoon are predominantly from the southeast to northeast (trade winds);
- ❑ Highest speeds occur during the day with winds from the southeast;
- ❑ Lowest speeds occur with winds from the east and northeast at night;
- ❑ Calm conditions occurred 0.2% of the time between May and November 2002.

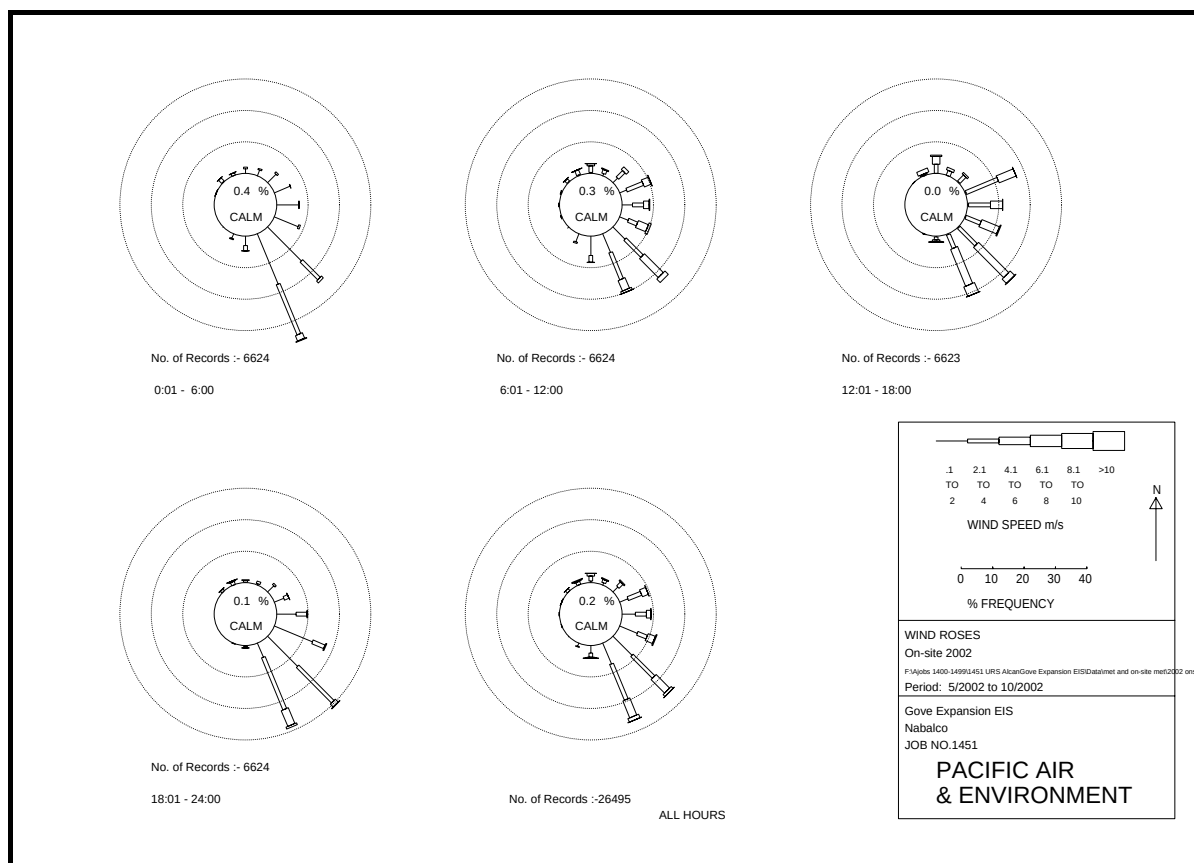


Figure 5: Dry season wind rose: Gove 2002.

8.3 Mixing Height

Mixing height is defined as the depth of the layer of air beneath an elevated temperature inversion within which pollutants are mixed by turbulence. Mixing height over land varies on a diurnal cycle driven by the flux of heat from the ground. On sunny days when the surface is heating, turbulence caused by convection grows upwards from a low height early in the day and the mixing height generally reaches a maximum height during the afternoon. At night, there is typically no turbulent mixing layer because the ground cools and does not provide convective forcing. However, strong winds, either at night or during the day, contribute to the development of a mixing layer due to mechanical turbulence effects. When the mixing height is low, it can restrict the vertical diffusion of plume material and lead to high ground level concentrations. In coastal regions, the mixing height can vary significantly over space, since water and land surfaces have different thermal and mechanical properties.

This important parameter in air pollution meteorology was calculated for Gove (2002) using a series of internal algorithms in the CALMET meteorological model (see section 9.5).

The cumulative frequency distribution of mixing heights from the 12 months' data file is shown on Figure 6 and the diurnal variation of mixing height is summarised in Figure 7.

Figure 6 indicates that 100% of mixing heights were determined to equal or exceed 50 m, and no mixing heights at Gove were calculated to exceed 2000 m. Fifty percent of mixing heights (representing mostly night-time conditions) were below 500 m, and more than 10% of mixing heights exceeded 1500 m. Approximately thirty percent of calculated mixing heights (representing the majority of day-time conditions) were between 1000 m and 2000 m.

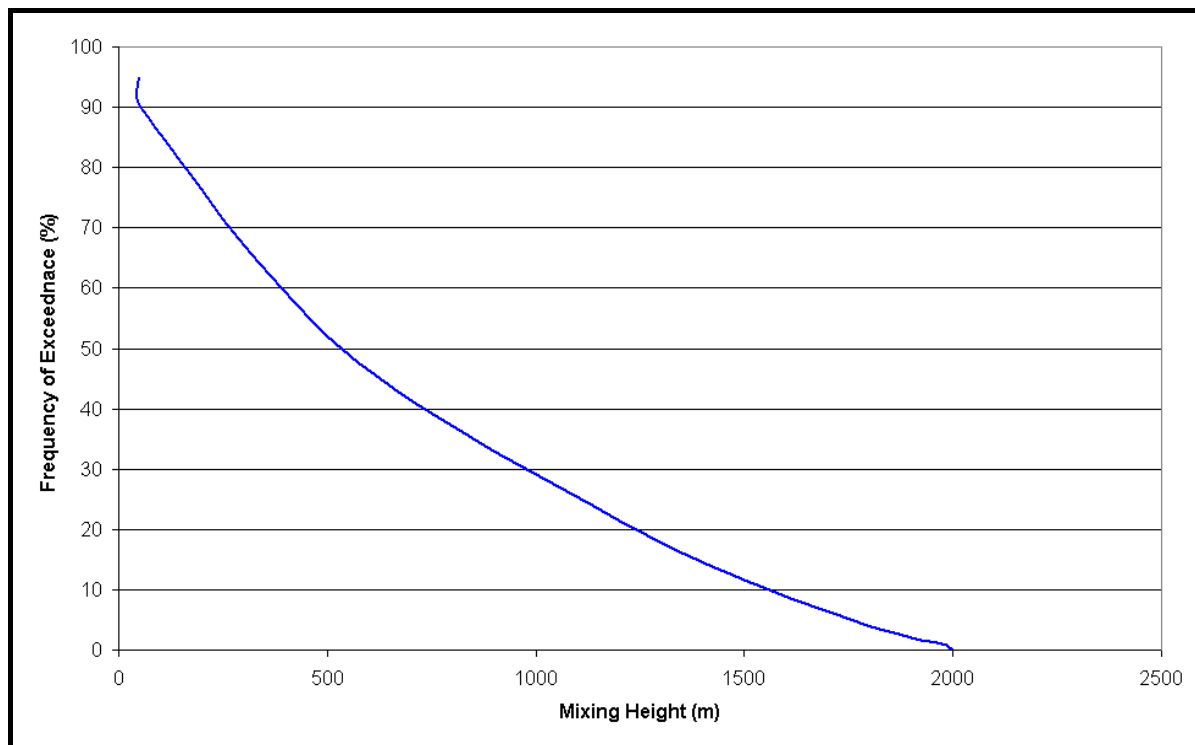


Figure 6: Gove mixing height – cumulative frequency of occurrence

The diurnal cycle of mixing height is clearly evident in Figure 7. Between midnight and 6am, mixing height is generally lower than 500 m. After sunrise, it increases to between 750 m and 2000 m. Late in the afternoon mixing height decreases rapidly after the surface heating ceases.

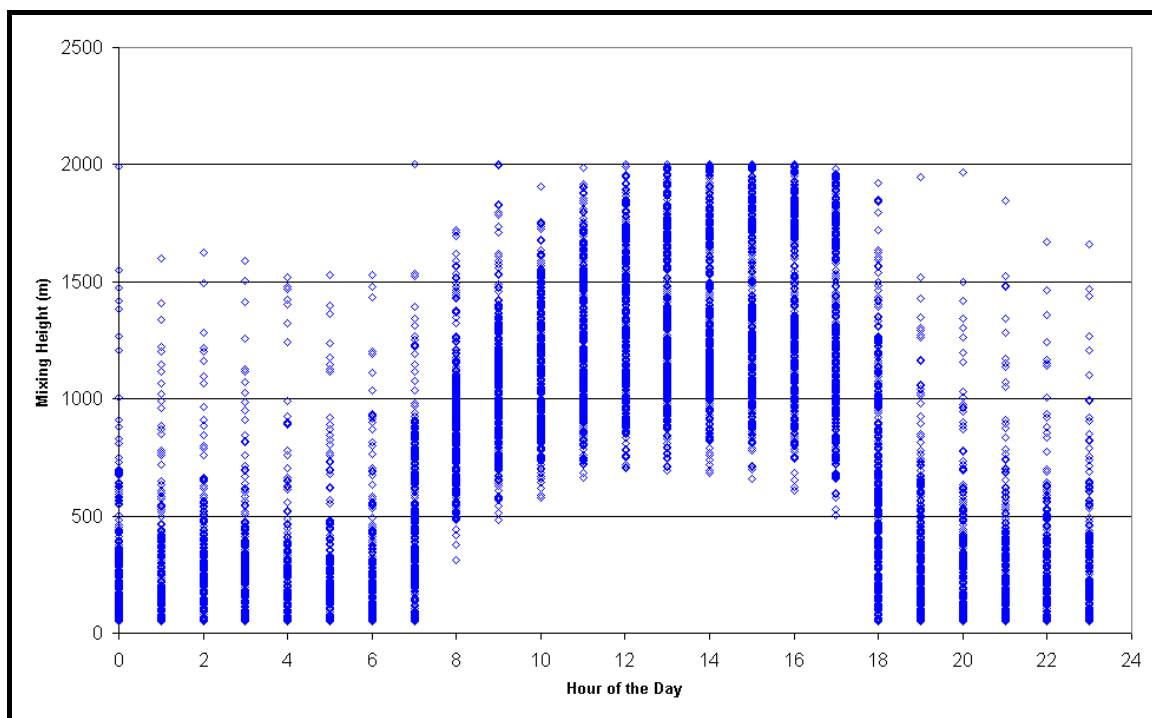


Figure 7: Gove mixing height variation with time of day

8.4 Validation of Meteorological Modelling

When using a single year of meteorological data for dispersion modelling, questions arise as to whether the year in question is representative of long-term average meteorological conditions. Selected long-term mean (57 year) parameters for Gove Airport are compared with the same parameters for January 2002 to December 2002 (Figure 8 and Figure 9). While monthly mean rainfall and wind speeds (not shown) for 2002 are significantly lower than long-term means, the monthly average temperature for 2002 is very similar to the long-term means. These results reflect the El Niño conditions that prevailed during 2002.

Although conditions in the modelled year (2002) departed from average long-term conditions, the lower wind speeds and slightly higher temperatures are likely to have resulted in less favourable conditions for dispersion of pollutants. Consequently, modelling results presented in this report are likely to represent a less favourable than average year for air quality.

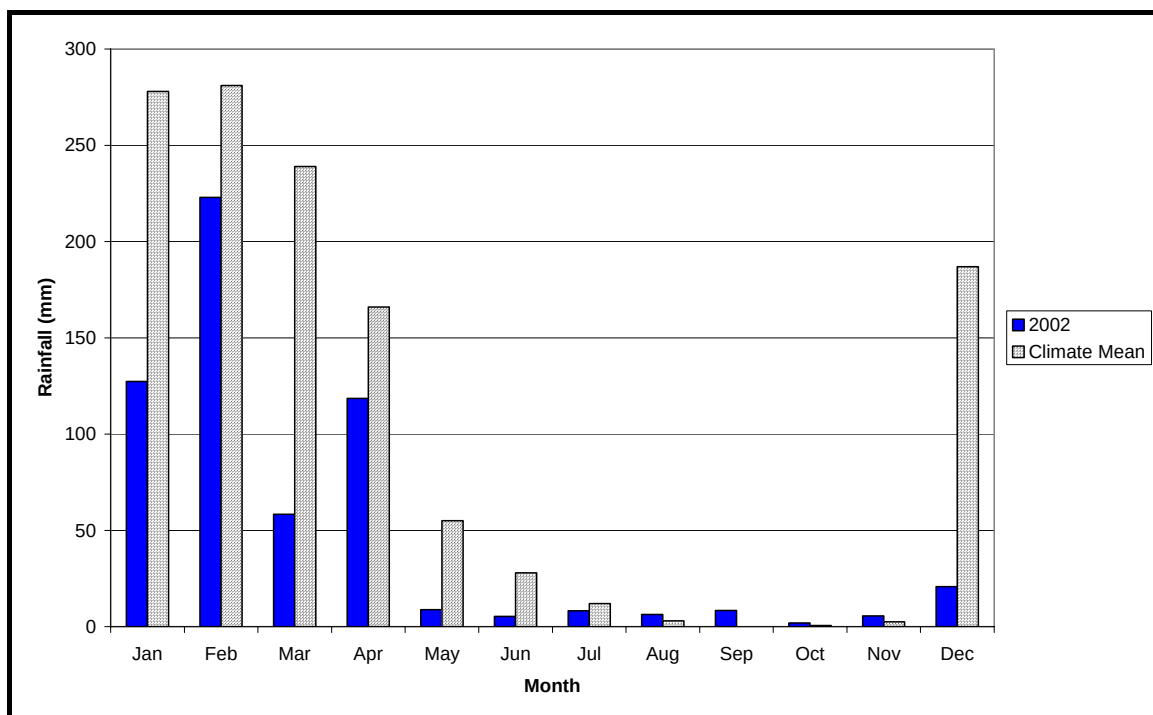


Figure 8: Monthly mean rainfall for 2002 compared to climatological mean monthly rainfall at Gove.

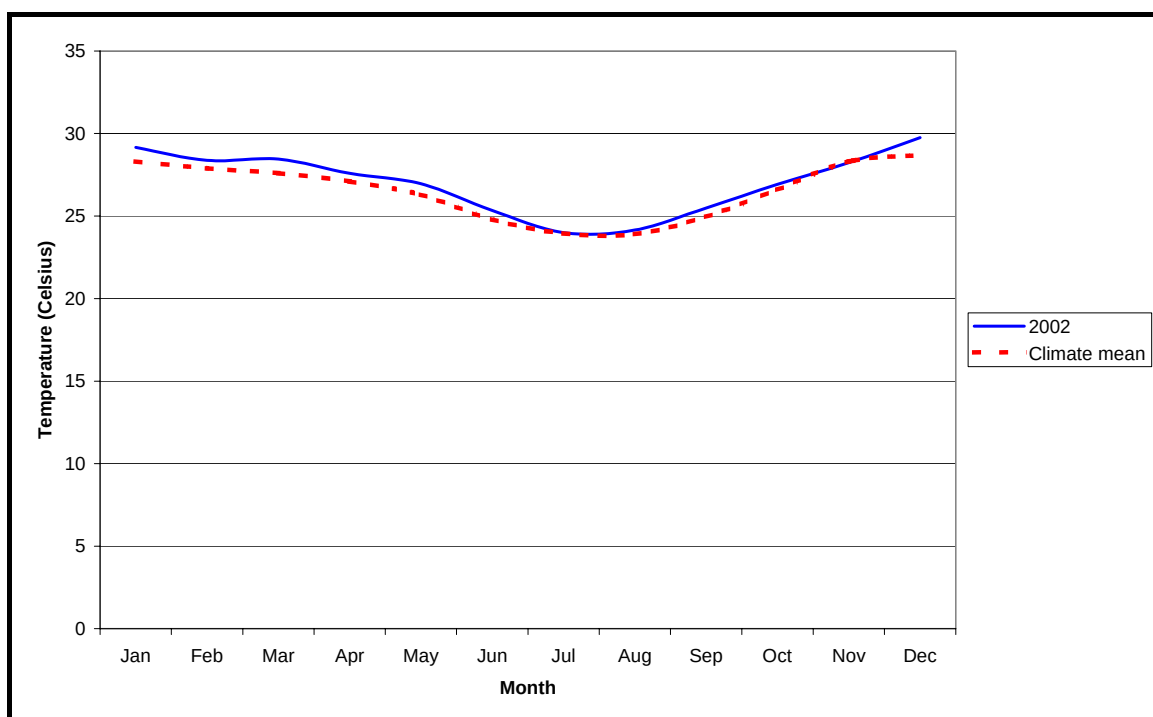


Figure 9: Monthly mean temperature for 2002 compared to climatological mean monthly temperature at Gove.

9 MODELLING METHODOLOGY

9.1 Introduction

The modelling methodology and tools for this study are outlined in the following discussion. The methodology employs current state-of-the-science tools for air quality impact assessment.

9.2 Status of Models

Plume dispersion modelling has undergone significant refinement in recent years. Steady state Gaussian plume air dispersion models such as AUSPLUME and the USEPA's ISC3, which formed the basis of air dispersion assessment for many years, are now being replaced by a generation of fully three-dimensional models, most notably CSIRO's TAPM and the USEPA's CALMET and CALPUFF. These new models incorporate many additional algorithms simulating influences which are ignored by the steady state Gaussian models but which are known to significantly impact upon plume dispersion.

The steady state Gaussian plume models adopt a relatively simple methodology. They assume that for each hour all meteorological conditions, most notably wind speed and direction, are fixed for that hour. They also assume that meteorological conditions do not vary from location to location i.e. the wind field is assumed to be constant over the modelling domain. During any particular hour under consideration, the plume from the source is assumed to travel in the direction of the wind, and disperse at a rate determined by the meteorological conditions. In the next modelled hour, the model assumes that the plume instantly changes direction to align itself with the new wind direction and the plume from the previous hour ceases to exist. In other words, all information pertaining to the previous hour of modelling is discarded. Recirculation, variable transport or variable diffusion of pollutants therefore cannot be simulated with such an approach.

The assumptions inherent in the steady state Gaussian plume dispersion models are not always valid, especially near a coastline where plume dispersion influences are often more complex. The key assumptions may be summarised as follows:

- ❑ Meteorological parameters remain constant for the period of one hour;
- ❑ Meteorological parameters remain fixed over the entire modelling domain, which often includes all regions within 10-20 km of the source. This is particularly questionable near the coastline where wind directions may vary significantly across the coastline;
- ❑ Most meteorological parameters either remain fixed with height above the ground (including wind direction and hence wind shear is ignored) or are assumed to vary according to generic formulae, which are seldom, if ever, validated for the site;
- ❑ The height of the mixing layer remains constant for the entire region. This is particularly

questionable in the vicinity of a coastline where the mixing height often varies considerably as a function of distance from the coast.

9.3 Selected Models and Methodology

The CALMET and CALPUFF models overcome the limitations of the Gaussian models. CALMET, the meteorological pre-processor for the plume dispersion model CALPUFF, calculates three-dimensional meteorological data based upon observed ground and upper level meteorological data. CALPUFF then calculates the dispersion of plumes within this three-dimensional meteorological field. Although it assumes that the meteorological conditions are constant for the period of one hour, these fields have full three-dimensional spatial variation.

The most accurate methodology currently available for environmental assessment of air quality impacts through modelling utilizes the advantages of both models. TAPM is used to simulate on-site meteorological data for regions where valid observation data are not available. These data are used as inputs to CALMET, which generates the meteorological data as input to CALPUFF. CALPUFF uses these data to evaluate the impacts of pollutants emitted from the site by generating ground level concentrations suitable for comparison with the appropriate regulatory guidelines.

The air dispersion modelling conducted for this assessment has been based on the modelling approach outlined above, which utilises the TAPM and CALMET/CALPUFF models. The following sections describe each of these models.

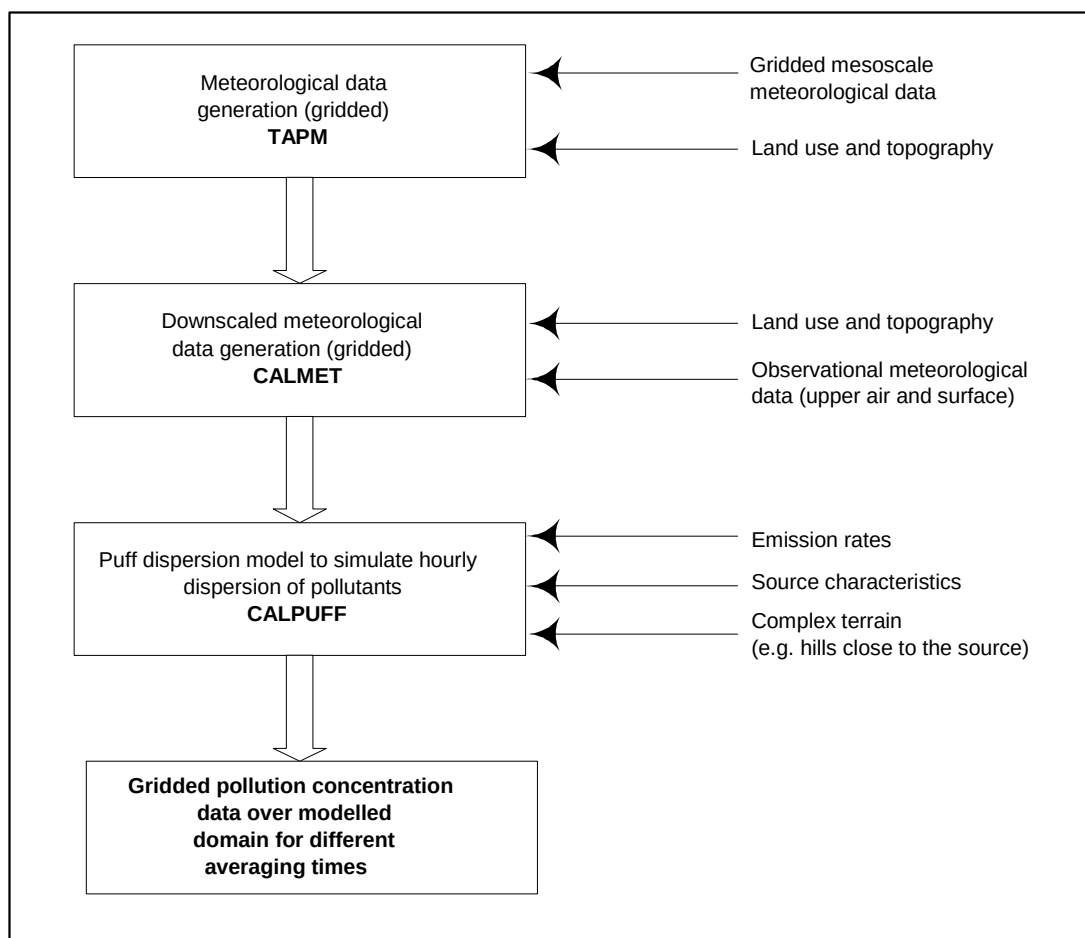


Figure 10: Modelling methodology utilised in the study.

9.4 TAPM

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research. Detailed description of the TAPM model and its performance is provided elsewhere, (Hurley, 2002a, 2002b; Hurley et al., 2002a, 2002b; Hibberd et al., 2003; Luhar & Hurley, 2003).

TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and (optionally) pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM incorporates the following databases for input to its computations:

- ❑ Gridded database of terrain heights on a longitude/latitude grid of 30 second grid spacing, (approximately 1 km). This default dataset is supplemented by finer resolution data at 9 second spacing for this study.
- ❑ Australian vegetation and soil type data at 3 minute grid spacing, (approximately 5 km).

- ❑ Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at 1 degree grid spacing, (approximately 100 km).
- ❑ Six-hourly synoptic scale analyses on a longitude/latitude grid at 0.75-degree grid spacing, (approximately 75 km), derived from the LAPS analysis data from the Bureau of Meteorology, (Puri *et al* 1998).

Initial TAPM runs showed inadequate resolution of local terrain and flow features when the standard terrain data were used, so the standard terrain database was replaced by higher-resolution (9 second) digital data generated by AUSLIG for the Roper River region.

9.5 CALMET

CALMET is a meteorological pre-processor that provides the meteorological inputs required to run the CALPUFF dispersion model (Scire *et al.*, 2000a; 2000b). It creates a fine resolution, three-dimensional meteorological field and includes a wind field generator that takes into account slope flows and terrain effects. CALMET produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables for each hour of the modelling period.

CALMET requires as input, hourly values for discrete points of:

- Dry bulb temperature;
- Wind speed;
- Wind direction;
- Cloud amount and height;
- Relative humidity;
- Surface pressure;
- Temperature and wind data from upper air sounding; and
- Land-use data.

These data were sourced from routine observational data at Gove Airport, the Alcan meteorological station at the red mud disposal area (RDA), and supplemented by data generated by TAPM. Weighting was towards the observational data. The meteorological fields generated by CALMET were then entered directly into the CALPUFF model.

9.6 CALPUFF

9.6.1 Model Description

CALPUFF (Scire *et al.*, 2000a) is a multi-layer, multi-species non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer-range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. The model employs dispersion equations based on a Gaussian distribution of pollutants across

the puff and takes into account the complex arrangement of emissions from point, area, volume, and line sources.

CALPUFF is endorsed by the US EPA, and has been used in many air quality studies in Australia.

Building downwash is a complex effect that may have significant ramifications on plume dispersion. The CALPUFF dispersion model includes built-in algorithms that treat the dispersion of the plume with respect to building downwash. The required input for the downwash algorithms is the effective building height and width for 36 sectors of wind direction for each point source. Starting at 0°, each sector accounts for a 10° arc. The Building Profile Interface Program (BPIP) was used to provide the input data to CALPUFF. The BPIP input file requires building parameters (such as heights, number of tiers and location) and stack parameters (stack height and locations). Fifty relevant buildings were used to determine building downwash in this study.

CALPUFF requires the following input data:

- ❑ Three-dimensional meteorological data output from CALMET
- ❑ Emission data, plant layout and dimensions.

9.6.2 Sources Modelled

Point emission sources included in the modelling were the SPS Boilers, Calciners, Lime Kiln, Hydrate Vacuum Exhaust, Digestion blow off and Mill vents. Relevant parameters for these sources are included in Table 7.

Table 7: Emission source parameters used in the dispersion modelling.

Source	Height	Diameter	Exit Velocity	Temperature
SPS Boilers	90	2.636	16.4	170
Calcliner 1-2	32	2.1	13.5	273
Calcliner 3-4	32	2.1	13.5	264
Station Calcliner	75	2.5	22.7	178
Lime Kiln	34.2	0.8	12.8	155
Hydrate Vacuum	30	2	9	170
Digestion Blow off 1	20	0.95	5.65	100
Digestion Blow off 2	20	0.95	5.65	100

In addition, total suspended particulates and particulate matter from stockpiles, conveyor belts and ship loading facilities were modelled.

9.7 Previous Dispersion Modelling

Prior to the availability of the advanced models used for this assessment, greater reliance was placed on simpler mathematical models and, sometimes for more complex problems, physical wind tunnel models.

In the 1990's, work was done at the refinery to overcome a localised problem of plume grounding associated mostly with emissions from the SPS Boilers. The original release height was insufficient to prevent plume grounding within the refinery site due to building downwash. This occurs when obstructions near a relatively low stack create turbulence that drags the plume lower to the ground rather than allowing it to rise unimpeded.

The refinery commissioned consultants Katestone Scientific and the advanced wind tunnel facility at Monash University to simulate dispersion from the stack and to determine a new stack height that would be sufficient to avoid the problem of building downwash. Physical modelling (i.e., using a wind tunnel) is an accurate method for predicting plume impacts associated with complex building downwash effects. The current SPS Boiler stack height of 90 m reflects the results of that detailed study.

10 VALIDATION OF DISPERSION MODEL

10.1 Methodology

Atmospheric dispersion models are mathematical simulations of reality. Consequently, it is necessary to compare these simulations with reality in order to obtain some measure of model performance. Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations. Models are reasonably reliable for estimating the magnitude of highest concentrations occurring sometime, somewhere within an area.

Both modelling and monitoring have some inherent uncertainties. According to the US-EPA, modelling introduces errors of $\pm 10 - 40\%$ in the calculations but these are deemed tolerable (US EPA, 2001), because the cost of a comprehensive monitoring programme is so expensive. There are also errors in the accuracy of monitoring and these errors increase as the monitored values approach the threshold of detectability, *i.e.* if an instrument has an accuracy of $\pm 5\%$ at span, its accuracy may decrease to $\pm 50\%$ or more near the threshold of detectability. Consequently, measured concentrations lower than 1 ppb are ignored for the validation exercise.

Pollution roses² constructed for Drimmie Head (Marngarr) (Figure 11) show that sulphur dioxide is recorded at the monitoring station for wind directions not associated with emissions from the Alcan Gove alumina refinery (*viz.* northeasterly through southwesterly). These measurements most likely reflect background concentration in the area. As the modelling has only considered emissions from the alumina refinery, concentration measurements associated with northeasterly (45°) to southwesterly (225°) have been excluded from the validation exercise. Instrumentation at the Drimmie Head (Marngarr) monitoring site was subject to daily automated calibration checks and PAE has a very high degree of confidence in the precision and accuracy of the results.

² The pollution roses show the frequency of occurrence of winds by direction and measured sulphur dioxide concentration. The bars correspond to the direction from which the wind is blowing and the length of the bar represents the frequency of occurrence of winds from that direction. The widths of the bar sections correspond to concentration categories, with the narrowest representing the lowest concentration.

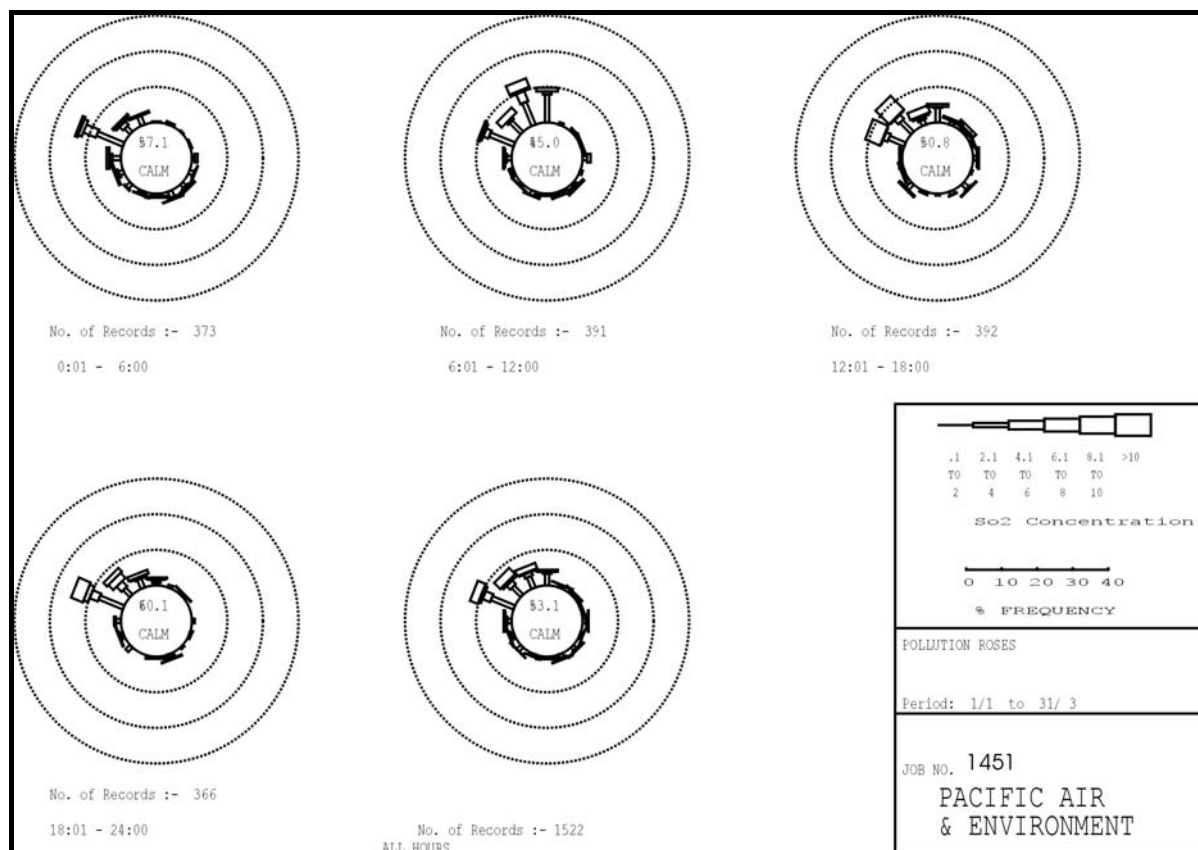


Figure 11: Pollution Rose for Drimmie from January 2003 to March 2003.

Validation was performed by comparing measured hourly-average sulphur dioxide data from the Mangarr monitoring station for 16 January 2003 to 26 March 2003, with those predicted by CALPUFF modelling.

In addition to the usual mean and standard deviations, other statistical tests have been developed to assess model performance. Statistical performance measures recommended by the Queensland EPA have been used to validate the model output data. These measures are *model bias*, *fraction bias*, *normalised mean square error*, *root mean square error* and the *coefficient of correlation*. Model performance statistics based on the recommendations of Wilmott (1981) and Pielke (1984) have also been used. These include *Skill_v* and *Skill_r* (Hurley, 2000).

10.1.1 Skill_r

The *Skill_r* test is the ratio of *RMSE* to observed standard deviation:

$$Skill_r = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^N (P_i - O_i)^2}}{O_{std}}$$

Where:

- N = the number of pairs of data
 O_i = the observed (measured) value for the i-th hour
 P_i = the predicted (modelled) value for the i-th hour
 O_{std} = the standard deviation of measured data.

A model is considered to be predicting with skill if the RMSE is less than the standard deviation of the observations ($Skill_r < 1$) (Pielke, 1984; Hurley, 2000).

10.1.2 Skill_v

$$Skill_v = \frac{P_{std}}{O_{std}}$$

Where:

- P_{std} = the standard deviation of predicted data
 O_{std} = the standard deviation of observed data.

A model is considered to be predicting with skill if the standard deviations of the predictions and observations are the same ($Skill_v = 1$) (Pielke, 1984; Hurley, 2000).

10.1.3 Model Bias

The model bias (MB) is the mean error and is given by:

$$MB = \frac{1}{n} \sum_{i=1}^n (O_i - P_i)$$

Where:

- n = the number of pairs of observed data
 O_i = the observed value for the i-th hour
 P_i = the predicted value for the i-th hour

The ideal value for the bias is zero.

10.1.4 Fraction Bias

The fraction bias (FB) is a normalised index of model performance and is expressed by:

$$FB = 2 \frac{\overline{O} - \overline{P}}{\overline{O} + \overline{P}}$$

Where:

- $\overline{O}$ = the average observed values
 $\overline{P}$ = the average predicted values

The FB varies between +2 and -2 and has an ideal value of zero. FB values of ± 0.67 correspond to a prediction within a factor of 2.

10.1.5 Root Mean Square Error

The model performance can also be measured by the root mean square error (RMSE), which is expressed by:

$$RMSE = \frac{1}{n} \left[\sum_{i=1}^n (O_i - P_i)^2 \right]^{1/2}$$

Where

- n = the number of pairs of observed data
- O_i = the observed value for the i-th hour
- P_i = the predicted value for the i-th hour

This is a measure of the gross variability of the difference of two variables. The ideal value of the RMSE is zero, and smaller values indicate greater model precision.

10.1.6 Robust Highest Concentration

The Robust Highest Concentration (RHC) statistic is preferred to the actual peak value because it mitigates the undesirable influence of unusual events, while still representing the magnitude of the maximum concentration (Hurley *et al.*, 2002).

$$RHC = C(H) + (\bar{C} - C(H)) \ln \left[\frac{3H-1}{2} \right]$$

Where

- $C(H)$ = the H^{th} highest concentration
- $\bar{C}$ = the mean of the top $H-1$ concentrations

The value of $H = 11$ is used as it is an accepted statistic for evaluation of model performance (Hanna, 1989; Hurley *et al.*, 2002).

10.2 Results

The statistics for predicted versus observed SO₂ concentrations are shown in Table 8 and Figure 12. The 3-month average model under-predicts the measured concentration at Marngarr by 38%. The modelled maximum hourly value over predicts the maximum observed (value by approximately 200%. The model over -predicts the standard deviation for hourly values by 82% (as indicated by Skill_v=1.8 in Table 8). Although the model under-predicts for the 3-month average and over predicts for the 1-hour maximum concentration, it is still generally within the $\pm 40\%$ limit for long-term concentration and the factor-of-two limit for short-term concentration. The fractional bias of

0.46 corresponds to a prediction within a factor-of-two, while a Skill_r value of 0.05 indicates a good simulation (Table 8). These errors are likely to have the following effects in the level of certainty:

- ❑ The predicted maximum hourly concentration in one year (i.e., the highest hour of 8760 hours) is likely to be an over prediction of the true hourly maximum concentration.
- ❑ The predicted three-month average concentration is likely to be an under prediction of the true 3-month average.
- ❑ The predicted long-term average (i.e., annual average) is likely to be within $\pm 40\%$ of the true long term average.

Table 8: Statistics for modelled and measured sulphur dioxide.

Test	Ideal Score	Score
Model Bias	0 ± 0.2	1.52
Fractional Bias	0 ± 0.67	0.46
RMSE	0	0.89
Skill_v	1	1.8
Skill_r	<1	0.05

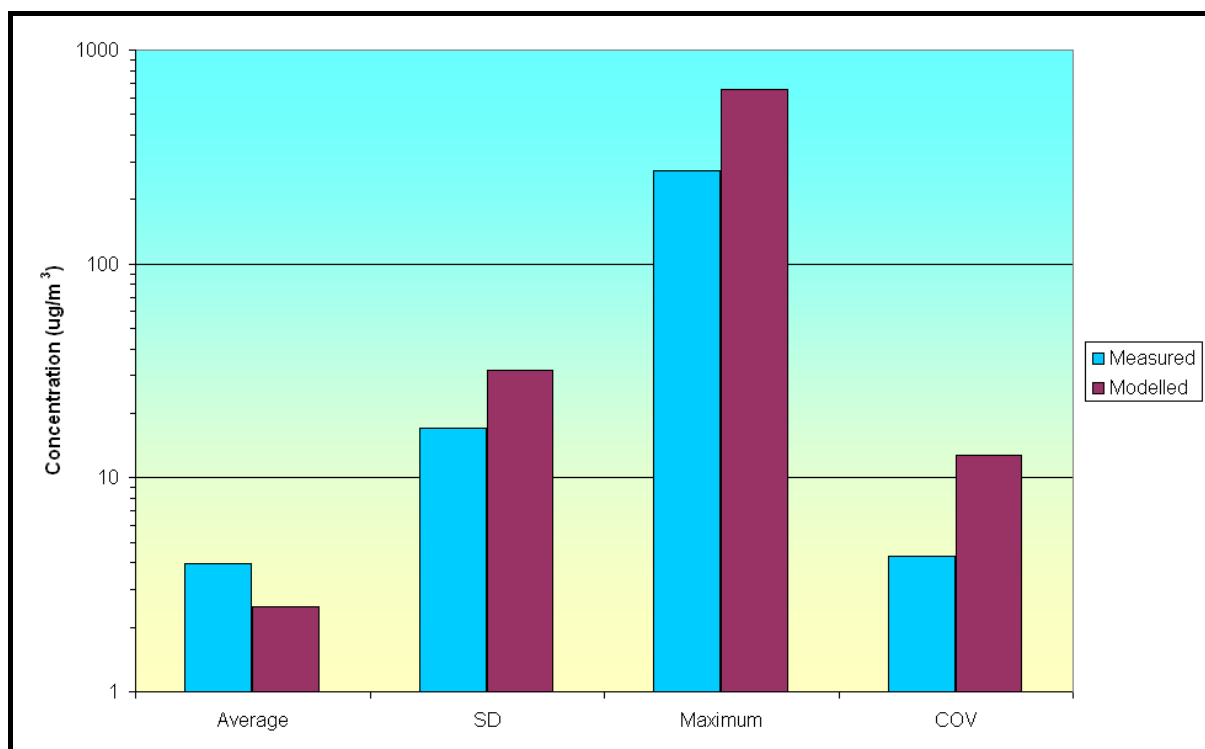


Figure 12: Graphical representation of basic statistical properties for average observed and predicted SO₂ concentrations at Marngarr

COV: Coefficient of Variation
SD: Standard Deviation

A concentration frequency distribution plot is shown in Figure 13. Both modelled and observed concentrations have the highest frequency in the 0–20 $\mu\text{g}/\text{m}^3$ class range (96% for observed and 98% for modelled). In the $> 21 \mu\text{g}/\text{m}^3$ range, observed concentrations occur slightly more frequently than modelled, but the model over-predicts maximum concentration.

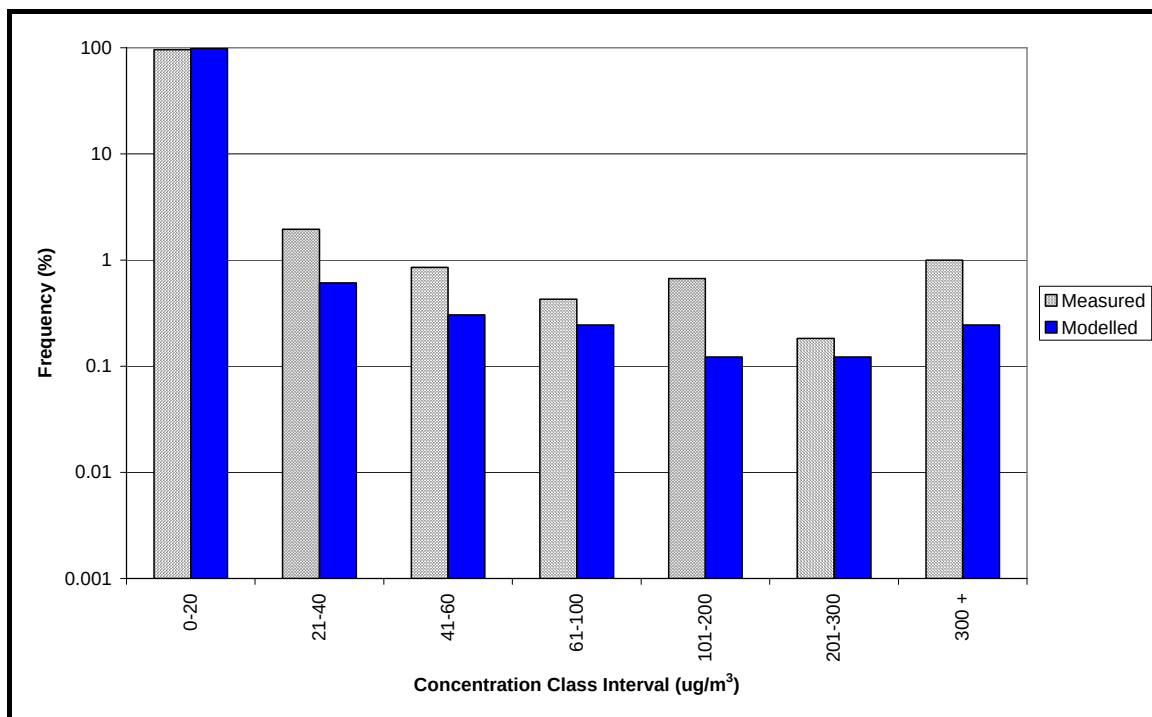


Figure 13: Comparison between observed and predicted concentrations of SO_2 at Marngarr.

Figure 13 shows that for approximately 96% of the time, SO_2 ground level concentrations at Marngarr are less than $20 \mu\text{g}/\text{m}^3$. This is very well predicted by the model. Concentrations higher than $20 \mu\text{g}/\text{m}^3$ are much less common. For example, concentrations of between 41 and $60 \mu\text{g}/\text{m}^3$ SO_2 occur less than 1% of the time.

Based on a number of statistical tests, the dispersion model generally predicts within acceptable limits (US-EPA, 2001) for SO_2 . The main areas of uncertainty are associated with variations in SO_2 emission rates and details of the often complex meteorological conditions that occur in this coastal area, particularly under seabreeze conditions.

11 MODEL RESULTS FOR EXISTING REFINERY INCLUDING THE NEW 4TH HIGH PRESSURE BOILER).

11.1 Criteria Pollutant Concentrations at Discrete Receptors

Six discrete receptors were selected for detailed dispersion modelling analysis representing the nearest populated areas. Discrete receptors were selected at:

- ❑ Galupa (R2), an Aboriginal community and the nearest offsite populated location;
- ❑ Yacht Club (R3), a recreational and residential area;(several people live permanently on yachts there)
- ❑ Marngarr (R4), an Aboriginal community;
- ❑ Wallaby Beach (R5), currently housing a small number of Alcan employees, but to be transferred to traditional owners of that land
- ❑ Nhulunbuy (R6), the nearest town; and
- ❑ West Melville Bay (R7).

The location of each discrete receptor is shown in Figure 14.

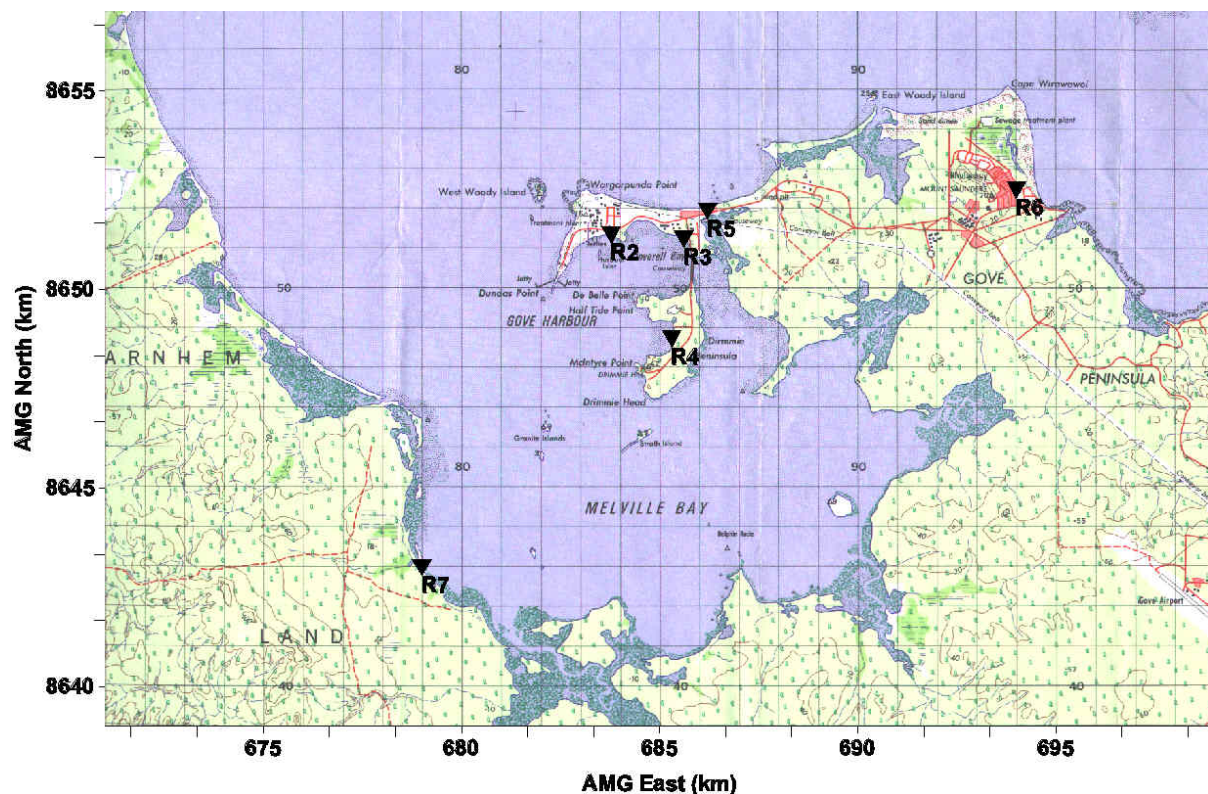


Figure 14: Location of Discrete Receptors

At each of the receptor points defined above, dispersion modelling has been used to predict the ground level concentrations of each of the 82 potential atmospheric pollutants (defined in Appendix B

– Atmospheric Emission Parameters) for the current operation including the 4th high pressure boiler. Dispersion modelling results for comparison with the Ambient Air NEPM for the current operation including the 4th high pressure boiler are given below in Table 9. Values in bold represent exceedences of the NEPM guideline.

Table 9: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Current Operation including the 4th High Pressure Boiler

Pollutant	Averaging Period	Guideline ^a (µg/m ³)	R2	R3	R4	R5	R6	R7
CO	8 hrs ^b	10 000	0.0016	0.0014	0.0033	0.0007	0.0010	0.0029
NO ₂	1 hr ^b	226	17.0	15.4	41.3	13.2	10.9	40.2
	1 yr	56	0.26	0.09	0.47	0.02	0.04	0.23
SO ₂	1 hr ^b	524	269.4	120.5	372.4	115.4	155.3	577.1
	24 hr ^b	210	80.4	45.1	148.8	26.5	40.6	131.3
	1 yr	52	1.84	0.65	4.41	0.16	0.54	3.09
Lead	1 yr	0.5	1.0E-04	4.9E-05	3.4E-05	1.7E-05	2.1E-06	1.2E-05
PM ₁₀	1 day ^c	50	42.3	31.3	26.3	28.8	4.0	10.3
Air Toxics								
Benzene	Annual	9.55	1.2E-03	2.6E-04	3.1E-04	1.0E-04	4.0E-05	2.1E-04
Benzo(a)pyrene	Annual	0.0003	1.6E-06	4.1E-07	1.0E-06	1.4E-07	6.3E-08	3.9E-07
Formaldehyde	24 hours	18.4	4.0E-02	3.9E-02	7.0E-02	2.2E-02	1.0E-02	4.1E-02
Toluene	24 hours	7510	0.13	0.06	0.05	0.05	0.01	0.02
Xylenes	24 hours	865	0.0051	0.0013	0.0010	0.0014	0.0002	0.0005

a: NEPC 1998

b: including allowance of 1 day exceedence (i.e., 2nd highest value is listed)

c: including allowance of 5 days exceedence (i.e., 6th highest value is listed)

11.2 Odour

Odour emission rates used in dispersion modelling were determined by The Odour Unit Pty Ltd after conducting odour sampling at the Alcan Gove facility in May 2003. Process-specific odour emission rates are detailed in Appendix B – Atmospheric Emission Parameters.

Dispersion modelling results showing various percentile odour concentrations for receptors R1 to R6 appear below in Table 10. Figure 15 shows the frequency distribution of 1-hour odour ground level concentration at each of the receptors, while Figure 16 and Figure 17 show a time series of hourly odour concentrations over the 12 month modelling period for Galupa and Nhulunbuy respectively.

Table 10: Predicted 1-hr odour concentrations, Current Operations including new 4th High Pressure Boiler

	Receptor					
	R2	R3	R4	R5	R6	R7
Percentile	Odour concentration (ou)					
Maximum	90	45	23	34	2.7	5.0
99.5%	73	26	13	20	0.7	1.8
99%	63	21	10	14	0.3	1.2
98%	51	14	7.1	5.1	0.09	0.7
95%	22	3.4	2.5	0.02	0.0	0.1

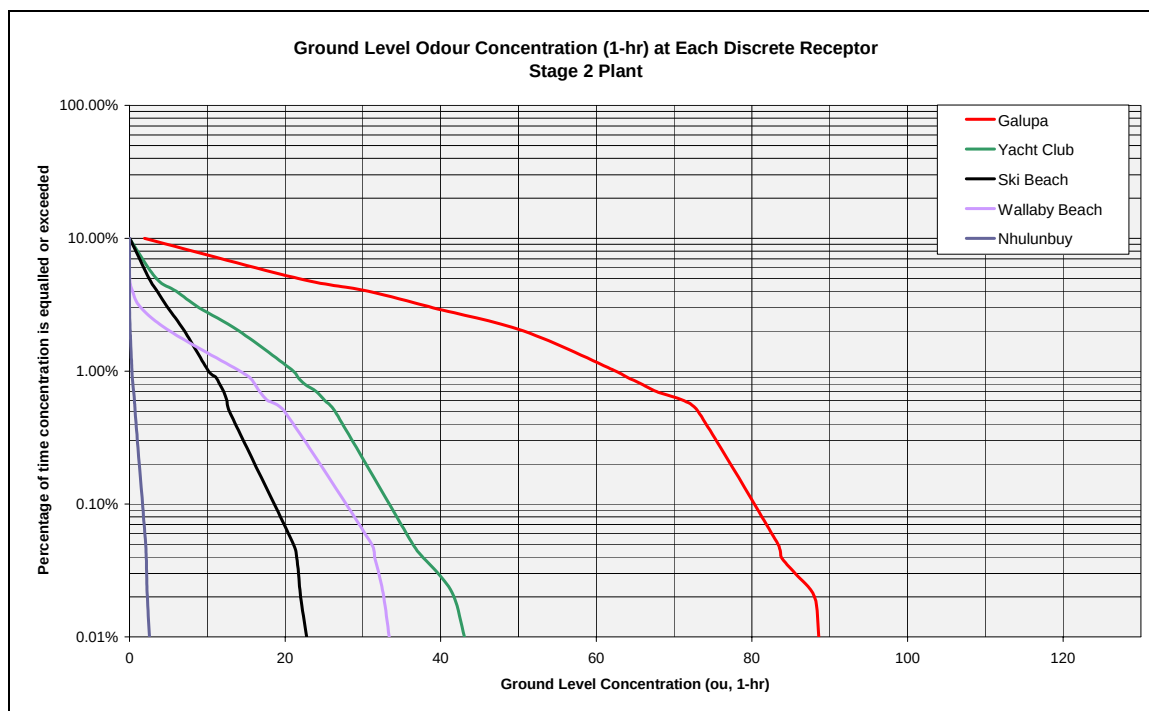


Figure 15: Frequency distribution for 1-hour odour concentration, Current Operations including new 4th High Pressure Boiler

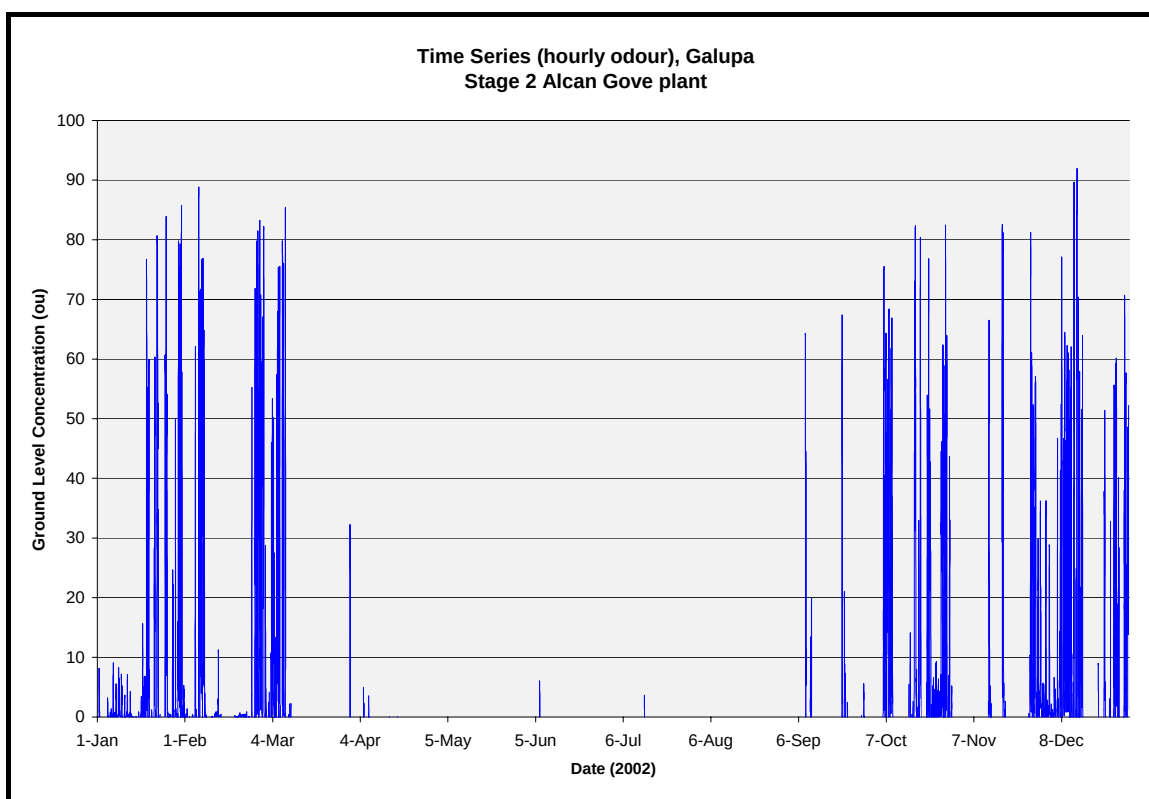


Figure 16: Time series odour concentration for 2002, hourly values, Galupa

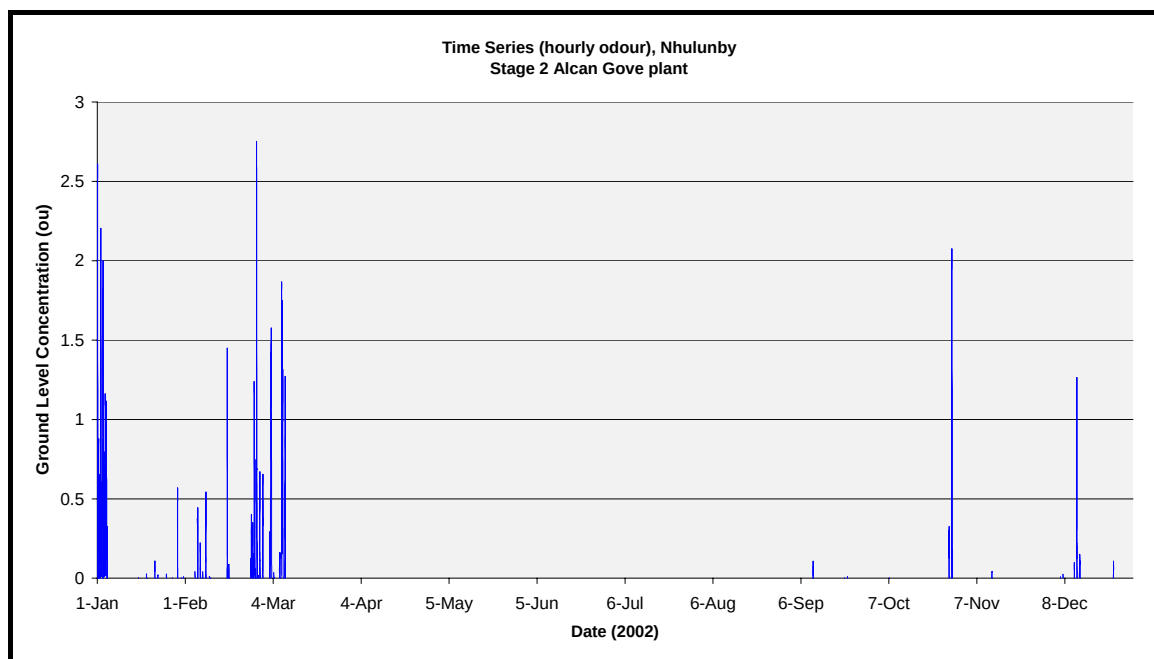


Figure 17: Time series odour concentration for 2002, hourly values, Nhulunbuy

12 MODEL RESULTS FOR STAGE 3

The air quality impacts associated with the expanded facility have been assessed based on four scenarios:

1. 100% natural gas fuel;
2. 100% natural gas fuel excluding the SLC;
3. Alternative fuel use - averaging a sulphur content of 1%; and
4. Alternative fuel use - 3.5% sulphur fuel in dry season and 1.5% sulphur fuel in wet season.

12.1 Indicative Dispersion Contours

Due to the large number of pollutants modelled for each scenario, it was not possible to display contour plots for every combination of pollutant, averaging time and scenario. Dispersion modelling of odour was conducted to provide an illustration of dispersion patterns from the existing Gove facility as this represents a combination of low and elevated sources.

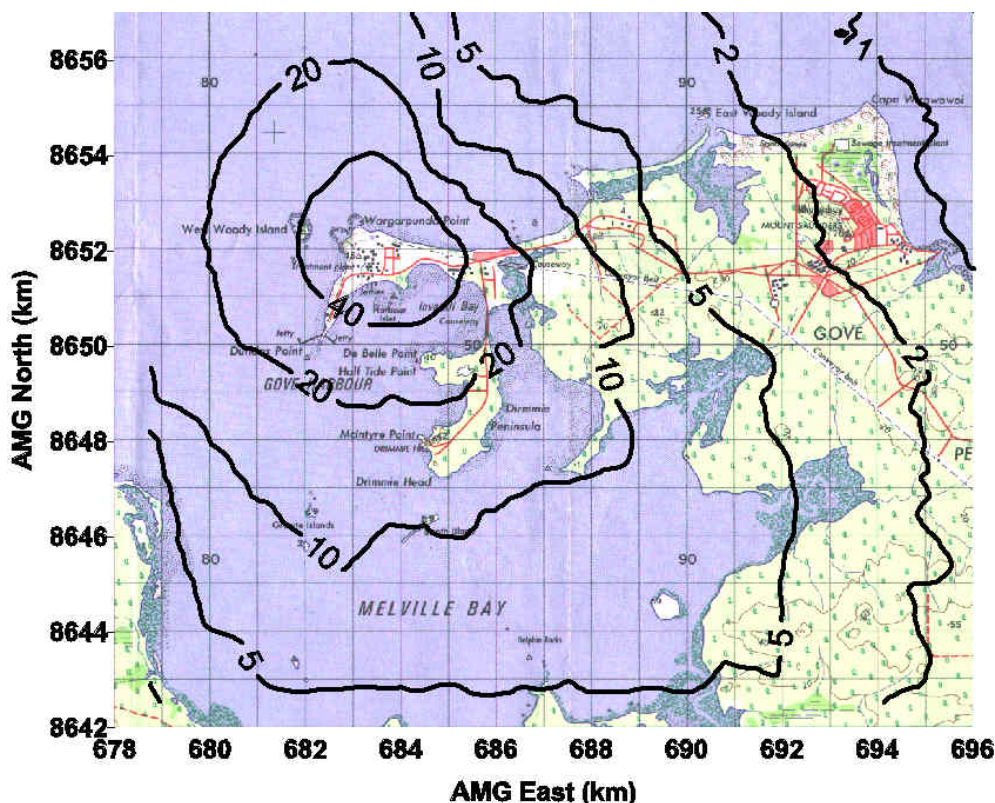


Figure 18: Predicted 99.5 Percentile Odour Concentration (ou) – expanded facility (100% gas)

12.2 Criteria Pollutant Concentrations at Discrete Receptors

12.2.1 Scenario 1 - 100% Gas Fuel including the Solid Liquid Calciner (SLC) for Liquor Purification

At each of the receptor points defined in section 11.1, dispersion modelling has been used to predict the ground level concentrations of each of the 106 potential atmospheric pollutants (defined in Appendix B – Atmospheric Emission Parameters) for the expanded refinery scenario 1.. Dispersion modelling results for comparison with the Ambient Air NEPM for the upgraded (Stage 2) facility are given below in Table 11. The tabulated values for short-term averaging periods take into account the NEPM allowance for annual exceedances (see notes b and c to Table 11).

Table 11: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Refinery Scenario 1

Pollutant	Averaging Period	Guideline ^a (µg/m ³)	R2	R3	R4	R5	R6	R7
CO	8 hrs ^b	10 000	0.0022	0.0014	0.0088	0.0011	0.0027	0.0069
NO ₂	1 hr ^b	226	12.0	10.7	51.3	8.2	12.0	38.5
	1 yr	56	0.20	0.06	0.27	0.02	0.04	0.23
SO ₂	1 hr ^b	524	20.7	28.0	17.8	16.1	2.1	6.8
	24 hr ^b	210	10.5	3.6	2.9	2.3	0.3	2.8
	1 yr	52	0.44	0.11	0.16	0.03	<0.01	0.04
Lead	1 yr	0.5	8.8E-05	4.3E-05	1.1E-05	1.6E-05	4.5E-07	1.9E-06
PM ₁₀	1 day ^c	50	45.0	32.2	10.1	26.3	0.8	1.0
Air Toxics								
Benzene	Annual	9.55	1.9E-03	4.1E-04	3.4E-04	1.6E-04	1.2E-05	7.3E-05
Benzo(a)pyrene	Annual	0.0003	0	0	0	0	0	0
Formaldehyde	24 hours	18.4	4.2E-02	2.6E-02	2.9E-02	1.6E-02	7.4E-03	1.4E-02
Toluene	24 hours	7510	0.19	0.09	0.08	0.08	0.01	0.03
Xylenes	24 hours	865	0.0077	0.0020	0.0015	0.0021	0.0002	0.0008

a: NEPC 1998

b: including allowance of 1 day exceedence (i.e., 2nd highest value is listed)

c: including allowance of 5 days exceedence (i.e., 6th highest value is listed)

12.2.2 Scenario 2 - 100% Gas Fuel excluding the SLC

At each of the receptor points defined above, dispersion modelling has been used to predict the ground level concentrations of each of the 106 potential atmospheric pollutants (defined in Appendix B – Atmospheric Emission Parameters) for the expanded refinery scenario 2. Dispersion modelling results for comparison with the Ambient Air NEPM for the current refinery with the new 4th high pressure boiler are given below in Table 12.

Table 12: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Refinery Scenario 2

Pollutant	Averaging Period	Guideline ^a (µg/m ³)	R2	R3	R4	R5	R6	R7
CO	8 hrs ^b	10 000	0.0022	0.0014	0.0087	0.0011	0.0026	0.0068
NO ₂	1 hr ^b	226	12.0	10.7	49.9	7.8	11.2	37.6
	1 yr	56	0.20	0.06	0.26	0.02	0.04	0.22
SO ₂	1 hr ^b	524	20.7	28.0	17.8	16.1	2.1	6.8
	24 hr ^b	210	10.5	3.6	2.9	2.3	0.3	2.8
	1 yr	52	0.44	0.11	0.16	0.03	0.00	0.04
Lead	1 yr	0.5	8.8E-05	4.3E-05	1.1E-05	1.5E-05	3.6E-07	1.5E-06
PM ₁₀	1 day ^c	50	45.0	32.2	10.1	26.3	0.8	1.0
Air Toxics								
Benzene	Annual	9.55	1.9E-03	4.1E-04	3.3E-04	1.6E-04	1.0E-05	6.7E-05
Benzo(a)pyrene	Annual	0.0003	0	0	0	0	0	0
Formaldehyde	24 hours	18.4	4.2E-02	2.5E-02	2.4E-02	1.5E-02	4.7E-03	1.1E-02
Toluene	24 hours	7510	0.19	0.09	0.08	0.08	0.01	0.03
Xylenes	24 hours	865	0.0077	0.0020	0.0015	0.0021	0.0002	0.0007

a: NEPC 1998

b: including allowance of 1 day exceedence

c: including allowance of 5 days exceedence

12.2.3 Scenario 3 - Alternate Fuel Scenario (1% Sulphur and including SLC)

At each of the receptor points defined above, dispersion modelling has been used to predict the ground level concentrations of each of the 106 potential atmospheric pollutants (defined in Appendix B – Atmospheric Emission Parameters) for the expanded refinery scenario 3.. Dispersion modelling results for comparison with the Ambient Air NEPM for the current refinery with the new 4th high pressure boiler are given below in Table 13.

Table 13: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Refinery Scenario 3

Pollutant	Averaging Period	Guideline ^a (µg/m ³)	R2	R3	R4	R5	R6	R7
CO	8 hrs ^b	10 000	0.0005	0.0003	0.0007	0.0002	0.0002	0.0005
NO ₂	1 hr ^b	226	7.9	10.7	20.9	6.1	5.6	17.9
	1 yr	56	0.17	0.05	0.16	0.02	0.02	0.11
SO ₂	1 hr ^b	524	21.1	24.3	229.7	41.3	56.4	199.6
	24 hr ^b	210	4.5	7.4	37.0	7.9	15.2	26.1
	1 yr	52	0.08	0.09	1.05	0.05	0.20	1.05
Lead	1 yr	0.5	9.3E-05	4.5E-05	2.3E-05	1.6E-05	2.5E-06	1.3E-05
PM ₁₀	1 day ^c	50	45.0	32.2	10.2	26.6	1.6	3.3
Air Toxics								
Benzene	Annual	9.55	1.9E-03	4.3E-04	5.8E-04	1.7E-04	5.8E-05	3.1E-04
Benzo(a)pyrene	Annual	0.0003	8.9E-06	5.0E-06	7.0E-06	1.3E-06	2.8E-07	1.8E-06
Formaldehyde	24 hours	18.4	4.2E-02	2.7E-02	3.3E-02	1.8E-02	9.9E-03	1.9E-02
Toluene	24 hours	7510	0.20	0.09	0.08	0.08	0.01	0.03
Xylenes	24 hours	865	0.0077	0.0020	0.0015	0.0021	0.0002	0.0008

a: NEPC 1998

b: including allowance of 1 day exceedance (i.e., 2nd highest value is listed)

c: including allowance of 5 days exceedance (i.e., 6th highest value is listed)

12.2.4 Scenario 4 – Alternate Fuel Scenario (Fuel Switching to low sulphur fuel when poor dispersion conditions occur)

At each of the receptor points defined above, dispersion modelling has been used to predict the ground level concentrations of each of the 106 potential atmospheric pollutants (defined in Appendix B – Atmospheric Emission Parameters) for the expanded refinery scenario 4. Dispersion modelling results for comparison with the Ambient Air NEPM for the current refinery with the new 4th high pressure boiler are given below in Table 14. Values in bold represent model predictions that exceed the NEPM guideline value.

Table 14: Predicted NEPM Defined Pollutant Concentrations at Discrete Receptors, Expanded Scenario 4

Pollutant	Averaging Period	Guideline ^a (µg/m ³)	R2	R3	R4	R5	R6	R7
CO	8 hrs ^b	10 000	0.0005	0.0003	0.0007	0.0002	0.0002	0.0005
NO ₂	1 hr ^b	226	7.9	10.7	20.9	6.1	5.6	17.9
	1 yr	56	0.17	0.05	0.16	0.02	0.02	0.11
SO ₂	1 hr ^b	524	148.8	68.7	349.6	72.4	88.4	304.4
	24 hr ^b	210	40.8	18.5	59.6	18.8	23.9	43.8
	1 yr	52	2.26	0.61	2.03	0.25	0.31	1.77
Lead	1 yr	0.5	9.3E-05	4.5E-05	2.3E-05	1.6E-05	2.5E-06	1.3E-05
PM ₁₀	1 day ^c	50	45.0	32.0	10.0	25.9	0.6	0.7
Air Toxics								
Benzene	Annual	9.55	1.9E-03	4.3E-04	5.8E-04	1.7E-04	5.8E-05	3.1E-04
Benzo(a)pyrene	Annual	0.0003	8.9E-06	5.0E-06	7.0E-06	1.3E-06	2.8E-07	1.8E-06
Formaldehyde	24 hours	18.4	4.2E-02	2.7E-02	3.3E-02	1.8E-02	9.9E-03	1.9E-02
Toluene	24 hours	7510	0.20	0.09	0.08	0.08	0.01	0.03
Xylenes	24 hours	865	0.0077	0.0020	0.0015	0.0021	0.0002	0.0008

a: NEPC 1998

b: including allowance of 1 day exceedance (i.e., 2nd highest value is listed)

c: including allowance of 5 days exceedance (i.e., 6th highest value is listed)

12.3 Odour

Odour emission rates for the expanded refinery are based on emission rates determined by The Odour Unit after conducting odour sampling at the Alcan Gove refinery in May 2003. Process specific odour emission rates are detailed in Appendix B – Atmospheric Emission Parameters.

Table 15 presents the results of odour dispersion modelling for scenario 1 of the expanded refinery (100% Gas fuel)..

Figure 19 shows the frequency distribution of 1-hour odour ground level concentration at each of the receptors, while Figure 20 and Figure 21 show a 12-month time series of hourly odour concentrations based on 2002 meteorological data for Galupa and Nhulunbuy respectively.

Table 15: Predicted odour concentrations, Stage 3 Alcan Gove plant

	Receptor					
	R2	R3	R4	R5	R6	R7
Percentile	Odour concentration (ou)					
Maximum	90	46	24	36	3.5	5.8
99.5%	73	27	15	20	1.2	1.8
99%	62	22	12	15	0.6	1.3
98%	51	16	9	7	0.2	0.9
95%	22	4	3	0.3	0.0	0.4

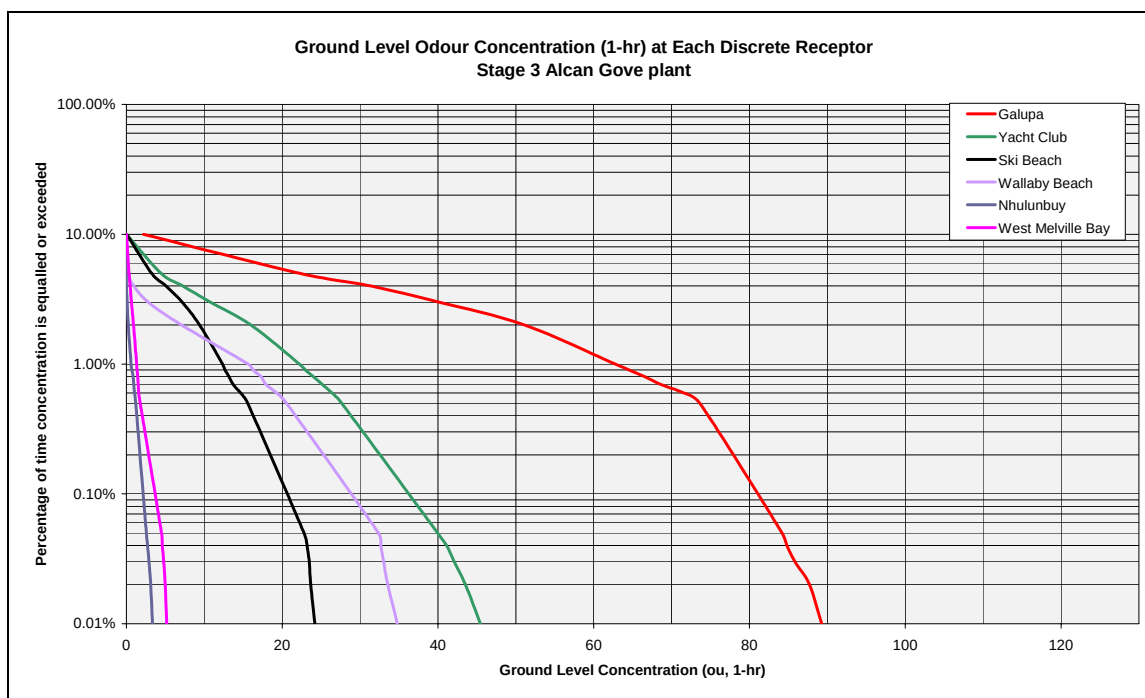


Figure 19: Frequency distribution for 1-hour odour concentration, Stage 3 Plant.

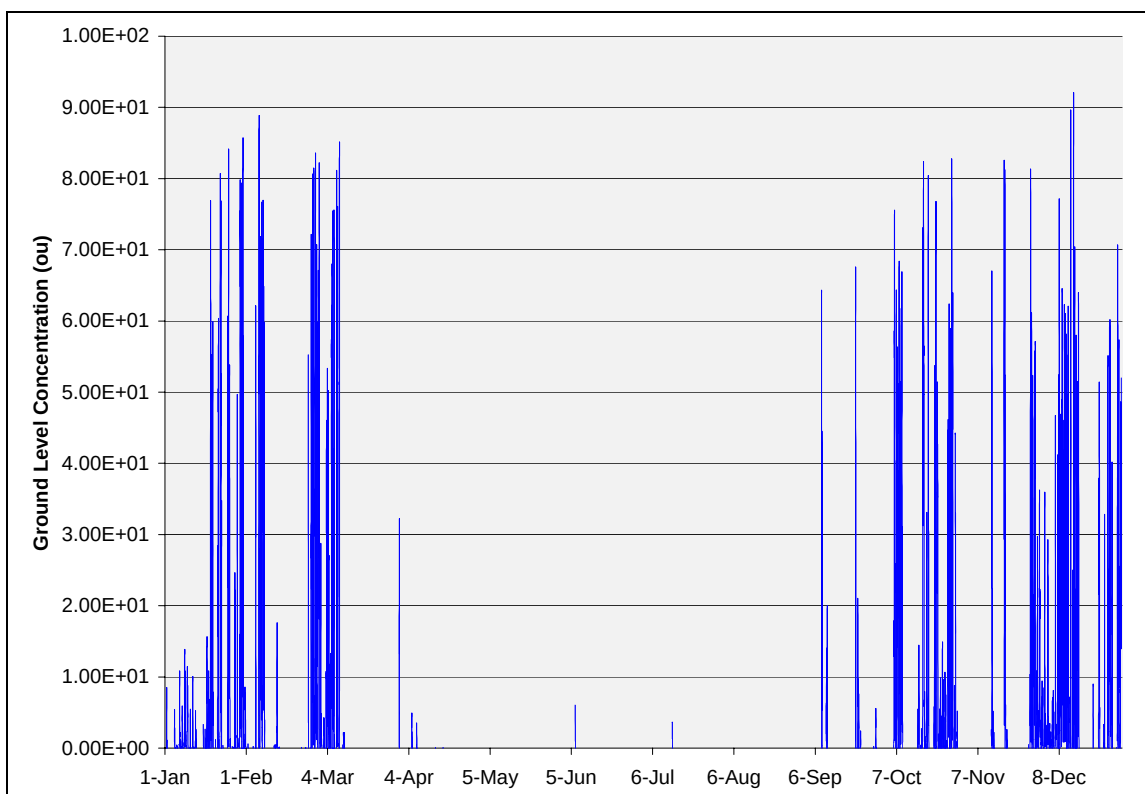


Figure 20: Time series odour concentration for Expanded Refinery using 2002 met data, hourly values, Galupa

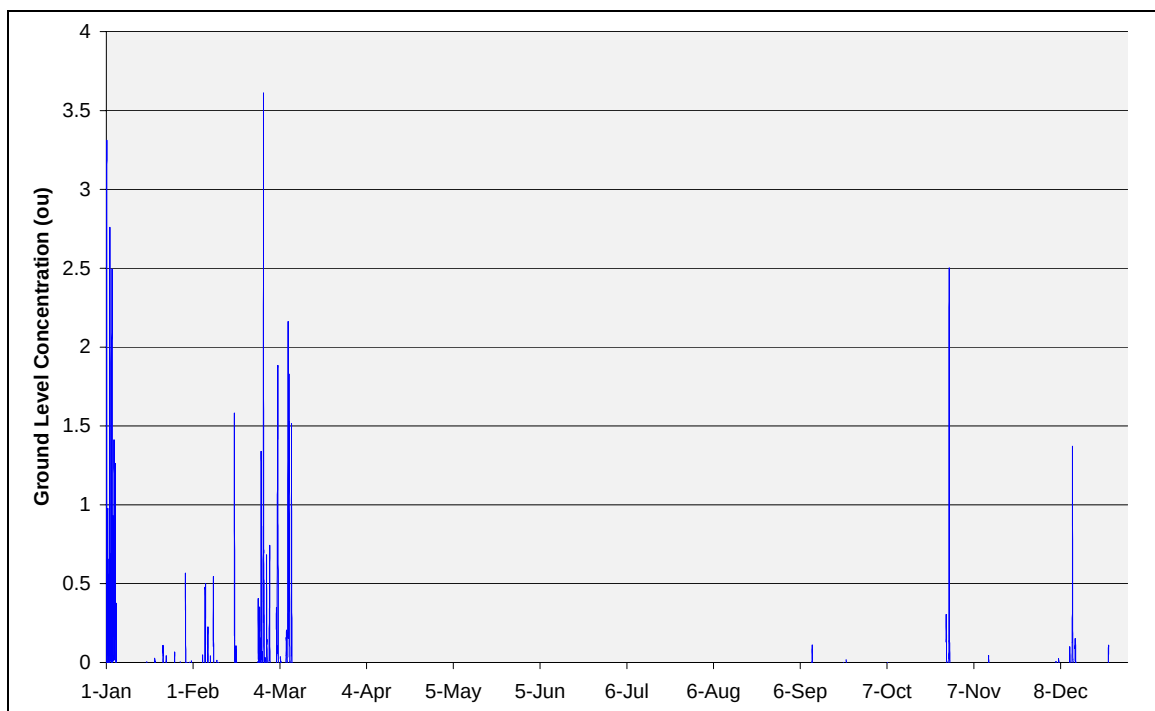


Figure 21: Time series odour concentration for Expanded Refinery using 2002 met data, hourly values, Nhulunbuy

12.4 On-site Air Toxics Concentrations

On-site air toxics concentrations have been modelled for receptor R1, the centre of Main Street.

13 ASSESSMENT OF AIR QUALITY IMPACTS

13.1 Key Issues

One of the key modifications associated with the Stage 3 expansion that will yield net benefits in air quality is the use of natural gas as the main fuel source to replace heavy fuel oil, the current fuel type, which typically has a sulphur content between 2% and 3.5%. This change in the refinery's operational condition will significantly reduce emissions from the point sources, particularly SO₂ and particulates

Although throughput of the facility will be increased, fugitive releases of particulates are not expected to increase as additional dust control measures are already in place to reduce emissions from existing sources and, as part of the expansion project, all required controls will be implemented.

13.2 Criteria Pollutants

Comparison of the dispersion modelling results for the current refinery and the three scenarios for the expanded refinery indicate that the expanded refinery will improve the atmospheric environment for the pollutants outlined in the NEPM for Ambient Air Quality. Dispersion modelling for the current refinery predicts that the NEPM guidelines will be exceeded only at West Melville Bay for SO₂ (1-hr averaging period). For the expanded refinery, the air quality in the surrounding areas will not exceed the air NEPM guidelines for criteria pollutants under any of the operational scenarios modelled. .

This assessment has been based on expected long-term emission levels. The refinery equipment specifications however, may occasionally generate higher emission levels of NO_x and PM₁₀. Depending on the timing, magnitude and duration of these higher emission events, there could be some increases in ground level concentrations above those predicted in this report. However, the maximum concentrations predicted by the model for any given point on the ground are dictated by adverse meteorological conditions that occur very rarely. Any increase in maximum concentrations would require a combination of adverse meteorology and elevated emission rates. There is expected to be a low risk of this actually occurring.

Occasional elevated emissions are not expected to be significant in terms of ambient levels. The predicted ambient NO₂ levels are less than 10% of the NEPM guideline under "normal" operating conditions. PM₁₀ levels are dominated by fugitive sources and so are less sensitive to fluctuations in process emission levels.

13.3 Odour

Emission estimation and dispersion modelling has indicated that there is likely to be a slight increase in ground level odour concentrations in most parts of the surrounding environment as a result of the

expansion of the refinery, but not enough for the difference to be noticed. (Refer to Table 10 and Table 15.)

The human response to odour is logarithmic, meaning that a significant change in the perceived odour strength (known as the odour intensity) requires quite a large change in actual odour concentration. For most odours, the relationship between odour intensity and concentration suggests that a change of at least 30-50% in concentration is necessary to produce a clearly perceptible change in intensity. At locations where a large relative change is predicted the odour concentrations (Table 15) are sufficiently low that the predicted changes will also be insignificant. For example, the increase in the 95th percentile concentration at R7 equates to a change from 0.1 to 0.4 ou, which even allowing for short-term fluctuations during the hour due to turbulence, equates to very intermittent, barely perceptible hints of odour.

However, the estimation of future odour emissions is conservative and actual levels may be significantly lower than predicted.

Odour effects are very difficult to relate back to odour concentration. It is important to note, however, that odour annoyance is very subjective and that there is the potential for communities to become desensitised or to tolerate a higher level of odour. It is an important finding of recent odour studies that appropriate odour threshold levels are very strongly dependent not only on the actual odour type and exposure levels, but also on community dynamics (Ormerod *et al.*, 2002). Community odour perception is discussed in more detail in Appendix A - Odour Background Information.

An analysis of the odour source apportionment for the Alcan Gove facility indicates that digestion and calcination are the dominant odour sources. Figure 22 shows the relative odour contributions of each process area. Although not obvious from Figure 22, (because it deals with concentration at the odour source rather than the concentration of odour outside the refinery) the ferrosilt is another source whose contribution to odour in the surrounding environment is significant due to its low release height and temperature. Any further reduction in odour emissions is therefore best addressed through consideration of these three process areas.

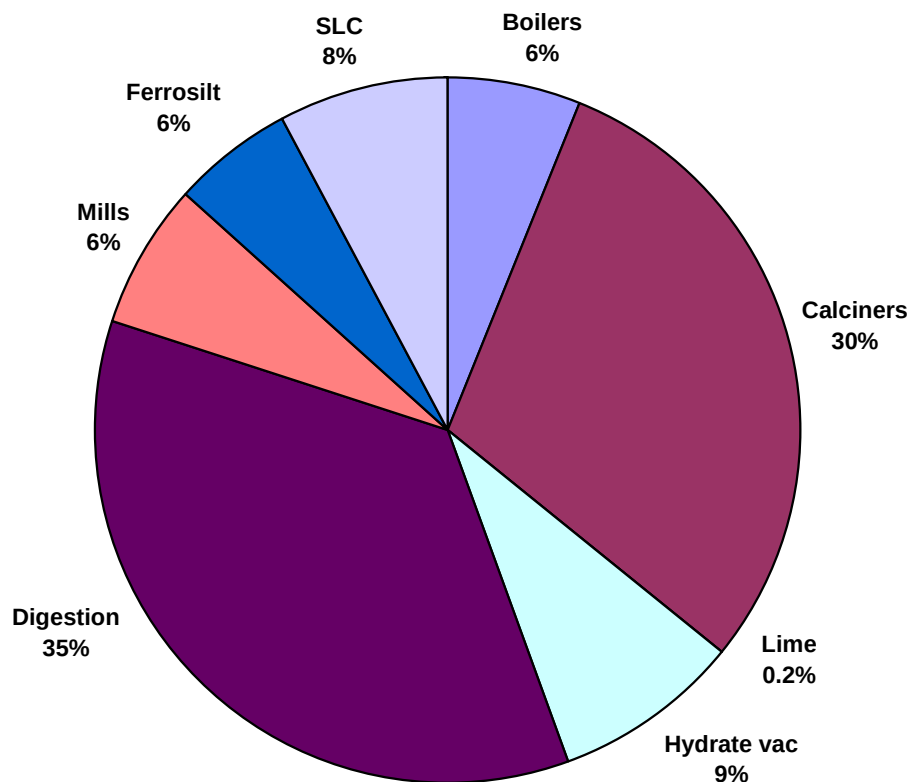


Figure 22: Odour source contributions

13.4 Photochemical smog pollutants including ozone

Photochemical smog is produced in the lower atmosphere by reactions between NO_x and a group of reactive organic gases in the presence of sunlight. Ozone is a highly oxidising gas formed in urban areas as a product of photochemical smog formation, and is a key indicator of the formation of photochemical oxidants, which can adversely affect human health, as well as other life forms and non-living materials.

As photochemical smog formation is very complex, major airshed studies are necessary to establish the relationships between these precursor emissions and resulting photochemical pollution. Ozone is the primary component of photochemical smog and is measured in ambient air quality monitoring systems as an indicator of smog presence.

The following conditions are required for the formation of photochemical smog:

- ❑ A large source of volatile organic components (typically a large motor vehicle pool, or a large oil refinery);
- ❑ A large source of nitrogen oxides (typically several large power stations, or a large motor vehicle pool);
- ❑ Relatively high temperatures;
- ❑ Relatively high solar radiation;
- ❑ Poor atmospheric mixing (for example, a temperature inversion as occurs in the Los Angeles Basin, or occasionally in the Cumberland Basin in NSW).

Photochemical smog and ozone are not an issue for either the existing or proposed Alcan Gove alumina refinery for the following reasons:

- ❑ Atmospheric mixing at the Gove Peninsula is rapid;
- ❑ There is no major source of the required volatile organic carbon species; and
- ❑ There are only, relatively minor sources of NO_x (the steam power station and the calciners at the refinery).

14 AN AIR QUALITY MANAGEMENT PLAN FOR THE FUTURE

In order to minimise the potential future air quality impacts associated with the expanded refinery, Alcan will update its air quality management plan (AQMP). The updated AQMP should include, but not be limited to, the following:

- ❑ Stack emissions monitoring: a monitoring protocol for stack emissions should be developed for regular assessment of releases to the atmosphere. This will not only ensure that management has up to date information on the atmospheric releases from the facility but will also alert operators to faulty or poorly functioning equipment.
- ❑ Ambient air quality monitoring: a monitoring protocol should be developed to assess the impacts of criteria pollutants and any relevant air toxics from the refinery in the receiving environment.
- ❑ Complaints handling: the current system (incorporated as part of the ISO 14001 Standard) should be reviewed on a regular basis and updated if necessary.
- ❑ Minimal emissions management practices: best management operating procedures should be adopted aimed at minimising the fugitive emissions (particularly particulates) such as those outlined in section 7
- ❑ Periodic reviews of operating procedures to ensure relevant best practice techniques are adopted.

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APPENDIX A

BACKGROUND ODOUR INFORMATION

16 APPENDIX A - ODOUR BACKGROUND INFORMATION

Introduction to Odour Assessment

The assessment of odour is complex, but ultimately performance criteria for industry should reflect the need to avoid odour nuisance, where nuisance is judged on the basis of reasonableness and the striking of an appropriate balance between the interests of odour emitters and the general public who may be affected by the emissions.

No odour guidelines require a complete absence of odour in the ambient air around an odour source. In other words, it is generally accepted in regulatory and legal circles that some odour can reasonably occur in sensitive areas, such as where people live, provided that this is not excessive. The question of an acceptable level of impact is an active area of research and development, and is complicated by issues such as the sensitisation of some communities to specific odours. Here sensitisation refers to a psychological process, which heightens the perception, rather than the physiological detection, of an odour.

Odour Measurement and Units

Because odour is a sensation and not a physical phenomenon, its measurement presents considerable challenges. It has been the subject of much debate and considerable development over the past few decades. The main requirement of odour measurement is to quantify the level of odour in a way that makes use of the sense of smell in a scientifically valid way.

Developments in odour measurement have led to the current preference for dynamic olfactometry. This method relies on the combination of a panel of people and an engineered system to control the delivery of odorous air and monitor the panel's responses, ultimately to produce a numerical measure of odour strength.

Dynamic olfactometry, in general terms, provides for the delivery to the panel of various mixtures of odorous air and odour-free air in way that enables the analyst to statistically determine the number of dilutions of the original sample that leads to the threshold odour concentration. This threshold occurs where statistically 50% of the panel can detect the presence of the odour, and 50% cannot, and is also referred to as the median threshold concentration.

The number of dilutions required to bring the sample of odorous air to this level is equivalent to the odour concentration, which is expressed in dilutions to threshold (D/T) or odour units (ou or OU), all of which have the same meaning. Odour concentration is also expressed as odour units per cubic metre (OU/m³). Odour units are in fact dimensionless ratios or relative concentrations, but for convenience they are sometimes used as measures of concentration.

In 2001, Australian Standard 4323.3 (AS 4323.3) was formalised, and is the basis for odour measurement now accepted by all environmental regulatory authorities. AS4323.3 refers to 'ou' as the unit of odour concentration.

Odour Nuisance

Odour has the potential to adversely affect amenity. For this reason, attempts are made to control odour emissions and the likelihood of unacceptable odour impacts is an important issue in environmental planning and management decisions.

Odour is a sensation associated with a variety of compounds which, when present in sufficiently high concentrations in the air, trigger responses in exposed individuals. Odour sensations may be pleasant or unpleasant depending principally on the nature of the substance but also on the perception of the individual.

The main effect of environmental odours is nuisance but in more serious cases, the effects may lead to feelings of nausea and headache and other symptoms that appear to be related to stress. It has been postulated that 'environmental worry' is a mechanism that helps explain the occurrence of physiological effects in people who are exposed to odorous substances at concentrations much lower than might be expected to lead to any toxic effects (Schusterman *et al.*, 1991).

Many odorous compounds are toxic at high concentrations, and in extreme cases of acute exposure, it is possible that toxic effects such as skin, eye or nose irritation will occur. Such effects are most likely to occur as a result of industrial accidents, such as the rupture of tanks containing toxic compounds, or severe upset conditions in chemical or combustion processes.

Repeated exposure to nuisance levels of odour can lead to a high level of annoyance, and the receiver may become particularly sensitive to the odour. Complaints are most likely to come from individuals who are either physiologically or psychologically sensitive to the odour, and certainly a combination of both types of sensitivity will increase the likelihood of complaint.

Responses of individuals to particular odours can be influenced by factors such as:

- ❑ state of health (for example, tolerance may be reduced if suffering a headache or a chronic illness)
- ❑ previous experience (a persistent history of odour events is likely to be met with greater hostility)
- ❑ relationship with the enterprise generating the odour. For example, if the person gains income or other benefits from the enterprise, the perception will tend to be more positive. On the other hand, if negative experiences with the enterprise have occurred, the response is likely to be much less tolerant

FIDOL Factors

Analysis of community odour exposure has identified five factors that are important in determining the potential for annoyance and complaint:

- ❑ Frequency;

- ❑ Intensity;
- ❑ Duration;
- ❑ Offensiveness, and
- ❑ Location

These are together called the FIDOL factors (NZ Ministry for Environment, 1995). Generally, the greater the frequency, intensity, duration and offensiveness of an odour the more likely it is to cause annoyance and lead to complaints.

Frequency

The frequency of odour exposure simply refers to how often odour events occur. It is a function of the variations of odour emissions over time, and of the meteorological conditions in the area around an odour source. The frequency of odour events is generally greatest in areas that are most often downwind of an odour source under conditions that lead to higher ground level concentrations.

Although the frequency of odour events is a prime determinant of the likelihood of nuisance occurring, the timing of events can also be important. There are times of the day, for example, when there may be a greater likelihood of people being exposed to any ambient odour, such as in the morning period around breakfast or around the evening mealtime. At other times, the likelihood of being away from the home, or asleep or simply inside with windows and doors shut may reduce the likelihood of being affected by odours that are present in the ambient air.

Intensity

The intensity of odour in this instance refers to an individual's perception of its strength and does not account for its character, quality, offensiveness, or hedonic tone. The hedonic tone refers to the intrinsic pleasantness or unpleasantness of an odour.

The intensity or perceived strength of an odour is related to the odour concentration, or the mass concentration of the compounds involved. However, the relationship is not direct.

For simple odours associated with single compounds, such as hydrogen sulphide, the relationship between the intensity and the mass concentration of the compound ($\mu\text{g}/\text{m}^3$) or its odour concentration (ou/m^3), has the general form of a power law or a logarithmic relationship. Thus, as the odour concentration increases, the perceived strength or intensity increases by a much smaller amount. The relationship between odour intensity and odorant concentration may be described by the Weber-Fechner law (Frechen, 1997), which is written as:

$$I = k_w \log(C_{OD})$$

where:

- I = intensity level
- k_w = Weber-Fechner coefficient

c_{OD} = odourant concentration

The detection and perception of odour usually arises from the presence of mixtures of chemical compounds, and a simple additive effect of individual odour concentrations generally does not apply. Owing to differing intensity-concentration relationships for various constituents of a complex odour, the dominant odorants giving rise to the odour's character can change with varying concentration of the odour, even though the relative concentrations of the various constituents remain the same.

This non-linear relationship is relevant when interpreting modelling results. Dispersion modelling of odour deals with odour concentration, rather than intensity.

Duration

The duration of odour events is controlled mainly by meteorological conditions, although variations in odour emissions may also be important for sources that vary in strength over short time periods. Longer duration odour events are likely to be associated with more stable meteorological conditions, which tend to be common at night and around sunrise and sunset. Somewhat persistent odour events appear to be generally more likely to cause annoyance than very brief single exposures, although this may simply reflect the general distribution of types of odour sources (which have different types of impacts). Desensitisation or habituation can occur during a substantial period of continuous exposure.

Under some circumstances, an odour 'event' may comprise intermittent, short periods of detectable odour interspersed by periods when no odour is detectable. Such behaviour is most prevalent when the odour is emitted during neutral to unstable (convective) meteorological conditions, especially when the source is elevated (e.g., a stack). The intermittent presence of the odour at downwind locations reflects the influence of atmospheric turbulence on the plume's behaviour.

In cases where the intermittency or fluctuation of the odour is a significant feature (e.g., in relation to sensory thresholds), then some means of representing the odour fluctuation statistics is important to adequately describe the relationship between odour intensity or concentration and the potential for annoyance or complaint. Various approaches are possible, and one approach currently used by the New South Wales EPA is to incorporate the concept of peak-to-mean ratios into the quantification and assessment of odour impacts.

The NSW EPA approach assumes that a basic unit of time is the 'nose-response time', which effectively is assumed to be 1 second. The mean concentration is an hourly average, which is based on the usual basic time interval of calculation in plume dispersion models. A peak value is a statistical concept only, since random variations affect the values of rare, high-end concentrations and therefore a true peak value cannot be evaluated deterministically. Thus it is necessary to express the 'peak' value within the context of a probability of occurrence. The NSW EPA's approach is to assess peak 1-second values that occur at a probability of 10^{-3} in a given hour.

Offensiveness

Offensiveness is a subjective or qualitative aspect of an odour, relating to its intrinsic pleasantness/unpleasantness or underlying quality. There is often confusion about the term, because there is a tendency to regard offensiveness and related terms (e.g. hedonic tone) as a function of the odour intensity. However, for proper evaluation of offensiveness as an intrinsic characteristic of an odour, it should be evaluated independently of intensity or concentration.

Location

Location is an essential consideration when assessing the likelihood of odour nuisance. People working within industrial environments are generally expected to be less concerned about odours than people within their home environment, or involved in recreation. There are some less straightforward situations: for example, where people travelling past odorous activities may consider the odour to be unacceptable, even though it is not impinging upon their residential property or upon some other sensitive location such as a school or hospital. This is an area that is not well resolved in terms of assessing the validity of complaints about odorous activities, but odour assessment generally places greatest emphasis and importance on odours at residential and other sensitive sites.

The detailed evaluation of the FIDOL factors requires an assessment of odour impacts over the long term. Hence, FIDOL factors cannot be used directly for a limited period of observations.

Odour Impacts in Sensitised Communities

Increasingly, it is becoming evident that certain communities can become perceptually sensitised to odours. Triggers for the sensitisation include one-off or rare, but highly adverse, events that permanently change people's perceptions about the odour. When a community displays signs of sensitisation, common features are a high level of complaints over the long term and a general distrust of those responsible for the perceived source of the odour.

In order to better understand the nature of an individual's response to odours it is helpful to understand two concepts that occur in all sensory systems: adaptation and sensitisation. Adaptation is a reduction in responsiveness (i.e. a decrease in perceived odour intensity) during or following repeated exposure. Conversely, sensitisation results in increased responsiveness during or following exposure.

Adaptation to odours can occur on either a short term or long term basis. Short-term adaptation primarily occurs as a result of odorous chemicals inducing a short refractory period during which further stimulation is limited (sometimes referred to as 'olfactory fatigue'). Long term adaptation results in more persistent reduction in response that can be measured hours or even days following exposure and can account for situations where persons who work in odorous environments cannot fully comprehend complaints from neighbours who only receive intermittent odours (Schiffman, 1998).

Individuals who are not particularly sensitive to odours may become sensitised to olfactory stimulants through acute exposure events or as a result of repeated exposure to nuisance levels of odours.

Sometimes symptoms such as headaches, nausea, throat irritations and sleeplessness are reported at exposure levels barely exceeding the odour threshold.

Shusterman, et al. (1991) suggests that a link between environmental odours and ‘environmental worry’ may help to explain apparent physiological symptoms reported in populations exposed to concentrations well below levels at which classical toxicology predicts any irritation or adverse health effect. This effect may be explained by mechanisms such as biologically intrinsic odour aversions (the concept of predictable, inherent odour response to certain stimulus), the exacerbation of underlying medical conditions (such as asthma or morning sickness) or conditioned responses (known as ‘behavioural sensitisation’).

‘Behavioural sensitization’ is well documented for cases of acute overexposure to odorous substances in the workplace. The odour may be well tolerated before acute exposure but act as a trigger for recurrent anxiety or hyperventilation symptoms afterwards. In some cases, similar involuntary responses may also be triggered by odours from other chemicals to which no known aversive conditioning has occurred.

Shusterman *et al.* (1988) concluded that far from being a neurotic process, behavioural sensitisation to odours is an adaptive or protective response with minimal, if any volitional or personality component. Similar response mechanisms have been observed within communities strongly opposed to, or affected by the siting of municipal, industrial or agricultural odour sources.

Dalton (1996, 1997) reported that beliefs about the safety of an odour can have an effect on its perception. In Dalton’s clinical studies, groups of people were exposed to odours in a test chamber. One third of test subjects (the ‘positive’ group) were told that the odour was a natural extract used by aromatherapists, another third (the ‘negative’ group’) were told the odorant was an industrial chemical which purportedly caused health effects after long exposure, while the remaining third (the ‘neutral’ group’) was told the stimulant was a common, approved stimulus for olfactometry experiments. The ‘positive’ group showed normal adaptation over the test period, that is the perceived intensity decreased over time. However, the ‘negative’ group rated the strength of the odour as increasingly greater after an exposure of 10 minutes, which was illusory as it actually remained constant over time. Overall, the negative bias group found the odours to be more irritating and had the greatest number and intensity of health symptoms, including nose, throat, and eye irritation as well as light headedness.

Symptomatic response to perceived health risks was also studied by Knasko et al. (1990) in a study of the behaviour, physical well being, and emotional state of persons in a room that supposedly contained odour but really did not. People who were told that the room contained a malodour reported a more negative mood and more symptoms of discomfort than persons told that the feigned odour was pleasant. This study, like those of Dalton, showed that cognitive expectations about odour and irritation can influence sensory perception.

A number of studies conducted in communities surrounding municipal, agricultural and industrial odour sources such as those reported by Schusterman (1992) confirm that community odour impacts can extend beyond mere nuisance and annoyance effects, producing a range of physiological symptoms including headache, nausea, eye and throat irritation, and sleep disturbance. A common

feature of many of these studies is that measured or modelled exposures to airborne toxicants report levels well below those known to cause acute symptoms by recognised toxicological mechanisms. The available evidence suggests that enhanced odour recognition can occur as a result of remembered or learned experiences.

The degree to which individual sensitisation can be influenced by community interactions (or group processes) is not well understood. However, it is postulated that community sensitisation may be 'transmitted' via normal or extraordinary communication processes. These communications may be either internal (between community members) or external (such as via media reports). Negative images (i.e. those that transmit messages of concern, dismay, distrust, adverse health impacts, etc) are likely to be more influential in increasing adverse reactions in the receiver. Thus community interactions may help explain the occurrence of localised 'hotspots' in which the occurrence of sensitised individuals may exceed the expected probability.

APPENDIX B

ATMOSPHERIC EMISSION PARAMETERS

17 APPENDIX B – ATMOSPHERIC EMISSION PARAMETERS

Current Refinery with the new 4th High Pressure Boiler – Point Source Emission Data - Average Emission Rates

Parameter	Units										
Unit ID		SPS Boilers 1-3 (a)	SPS Package Boiler	Calcn 1-2 (a)	Calcn 3-4 (a)	Station Calcn 5	Lime Kiln	Hydrate vac	Digestion blow off #1	Digestion blow off #2	Mills vent 1-3 (a)
									E63410		
Material Processed		HS/LSFO	HS/LSFO	HS/LSFO	HS/LSFO	HS/LSFO	HS/LSFO		Strong liquor		
Average Fuel consumed	tonnes/hr		0.4			7.74	0.38				
	m ³ /s		0.000113727			0.002200614	0.00010804				
density	tonnes/m ³		0.977			0.977	0.977				
Location Details											
AMG Coordinate Easting	m	683 363.2	683 363.2	683 212.0	683 185	683259.41	683 166.3	683318	683486	683546	683526
AMG Coordinate Northing	m	8 651 848.7	8 651 848.7	8 651 967.0	8 651 967.0	8652279.62	8 651 910.9	8651996	8652044	8652044	8652157
Stack Parameters											
Stack Base AHD	m	10	10	6.7	6.7	10	10	10	10	10	
Stack Height	m	90	90	32	32	75	34.2	30	20	20	
Flue Diameter	m	4.565685929	1.53	2.969848481	2.96984848	2.5	0.8	2			1.385640646
Dimensions of neighbour building	(LxWxH m)	100x90x35	100x90x35	100x35x35	100x35x35		50x35x35				
Stack Discharge Orientation		vertical	vertical	vertical	vertical	vertical	vertical				
Flow Parameters											
Flue Diameter	mm	4565.685929	1530	2969.848481	2969.84848	2499.5	800	2000	950	950	1385.640646
Velocity	m/s	16.4	17.0	13.5	13.5	22.7	12.8	9	5.65	5.65	1.25
Temperature	°C	170.0	229.5	273	264	178	155	170	100	100	150
Moisture	%v/v	11.0	17.0	34.5	34.5	40.3	8.8		97	97	

Parameter	Units										
Unit ID		SPS Boilers 1-3 (a)	SPS Package Boiler	Calcn 1-2 (a)	Calcn 3-4 (a)	Station Calcn 5	Lime Kiln	Hydrate vac	Digestion blow off #1	Digestion blow off #2	Mills vent 1-3 (a)
Flow Rate (as Discharged)	m³/min	5448.0	1900	3526	1230	3900	270		110	110	
Flow Rate (as wet NTP)	m³/min	4000.0	1100	2500	2500	2325					
Flow Rate (as dry NTP)	m³/min	3600.0	940	1545	1545	1425			1.75	1.75	
Acid Dewpoint	°C			148.2	148.2	171.0					
Static Pressure Drop	kPa										
Emissions Summary											
TSP	g/s	9.13E+01	7.67E+00	3.14E+01	3.14E+01	1.08E+00	1.58E+01	2.15E-01	2.19E-03	2.19E-03	5.00E-03
PM <10µm	g/s	9.13E+01	7.67E+00	3.14E+01	3.14E+01	1.08E+00	7.92E-01	2.17E-01			
Sulphur Dioxide	g/s	6.58E+02	1.56E+01	9.20E+01	9.20E+01	8.49E+01	3.40E-01				
H2SO4	g/s	2.92E+01	6.94E-01	1.37E+00	1.37E+00	1.26E+00	5.06E-03				
Fluoride	g/s	4.63E-02	3.79E-03	9.04E-03	9.04E-03	4.52E-03	5.00E-04				
Oxides of nitrogen (as NO2)	g/s	3.67E+01	3.76E-01	1.14E+01	1.14E+01	1.62E+00	7.00E-01				
CO	g/s	6.00E+00	2.40E+00	1.47E+00	1.47E+00	7.32E-02	7.98E-02				
TOT VOC (as n-hexane)	g/s	5.50E-02	5.00E-03	4.23E-08	4.23E-08	2.12E-08	2.35E-09	4.85E-01	3.06E-02	3.06E-02	1.45E+00
Benzene	g/s	5.50E-02	5.00E-03	6.13E-05	6.13E-05	3.07E-05	3.42E-06		1.90E-04	1.90E-04	1.71E-03
Toluene	g/s	8.80E-03	2.93E-03	1.78E-03	1.78E-03	8.88E-04	1.12E-04	2.94E-02	5.83E-03	5.83E-03	1.08E-04
Ethylbenzene	g/s								8.75E-05	8.75E-05	
Xylene	g/s	1.56E-04	5.20E-05	3.13E-05	3.13E-05	1.57E-05	1.75E-06		2.33E-04	2.33E-04	1.58E-05
dimethyldisulphide	g/s								3.21E-04	3.21E-04	
Methyl Butane	g/s								1.90E-04	1.90E-04	
2,3-Dimethylpentane	g/s								4.38E-05	4.38E-05	
Methyl Cyclopentane	g/s								1.02E-04	1.02E-04	
Hexane	g/s								2.33E-04	2.33E-04	
Cyclohexane	g/s								1.02E-04	1.02E-04	
Methylcyclohexane	g/s								2.92E-04	2.92E-04	
3-Methyl-2-butanone	g/s								8.75E-04	8.75E-04	
Aromatic - Apliphatic Hydrocarbons	g/s								1.90E-04	1.90E-04	

Parameter	Units											
Unit ID		SPS Boilers 1-3 (a)	SPS Package Boiler	Calcn 1-2 (a)	Calcn 3-4 (a)	Station Calcn 5	Lime Kiln	Hydrate vac	Digestion blow off #1	Digestion blow off #2	Mills vent 1-3 (a)	
H2S	g/s	1.40E-03	4.67E-04	1.63E-03	1.63E-03	4.67E-04	4.67E-04					
Caustic	g/s							2.79E-01			3.21E-02	
Cl (as HCl)	g/s	4.96E-01	1.65E-01	9.93E-02	9.93E-02	8.33E-03	5.53E-03					
TOTAL PAHs		1.97E-03	4.60E-04	2.59E-03	2.59E-03	1.36E-03						
Napthalene	g/s	1.35E-03	3.17E-04	1.70E-03	1.70E-03	1.17E-03					3.43E-05	
Acenaphthylene	g/s	4.00E-05	3.33E-06	6.00E-05	6.00E-05	1.53E-05					2.12E-06	
Acenaphthene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	3.17E-05					2.12E-06	
Fluorene	g/s	4.00E-05	3.50E-05	2.00E-05	2.00E-05	6.67E-05					2.12E-06	
Phenanthrene	g/s	1.60E-05	6.83E-05	3.67E-04	3.67E-04	1.53E-05					2.12E-06	
Anthracene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Fluoranthene	g/s	1.20E-04	3.33E-06	1.60E-04	1.60E-04	6.67E-06					2.12E-06	
Pyrene	g/s	4.00E-05	3.33E-06	1.00E-04	1.00E-04	6.67E-06					2.12E-06	
Benz[a]fluoranthene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Chrysene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Benz[b]fluoranthene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Benz[k]fluoranthene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Benzo[a]pyrene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Ideno[123cd]pyrene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Dibenz[ah]anthracene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
Benzo[ghi]perylene	g/s	4.00E-05	3.33E-06	2.00E-05	2.00E-05	6.67E-06					2.12E-06	
TOTAL Aldehyde/ketones												
2-Butanone	g/s							1.14E-02	7.29E-04	7.29E-04	3.13E-03	
Acetaldehyde	g/s							7.22E-03	6.27E-03	6.27E-03	1.79E-02	
Acetone	g/s	1.20E-07	0.00E+00					2.33E-02	6.56E-03	6.56E-03	2.96E-02	
Acrolein	g/s							1.14E-02				
Benzaldehyde	g/s							1.14E-02	3.50E-04	3.50E-04	4.54E-04	
Butanal	g/s							1.14E-02			1.94E-03	
Butenal	g/s							1.14E-02	4.96E-03	4.96E-03		

Parameter	Units										
Unit ID		SPS Boilers 1-3 (a)	SPS Package Boiler	Calcn 1-2 (a)	Calcn 3-4 (a)	Station Calcn 5	Lime Kiln	Hydrate vac	Digestion blow off #1	Digestion blow off #2	Mills vent 1-3 (a)
Formaldehyde	g/s	4.72E-02	1.57E-02	3.14E-02	3.14E-02	4.73E-03	5.27E-04	1.14E-02	1.90E-04	1.90E-04	
Hexaldehyde	g/s							1.14E-02			
Methacrolein	g/s							1.14E-02	5.83E-05	5.83E-05	
Pentanal	g/s							1.14E-02			2.42E-04
Propanal	g/s							1.14E-02	5.83E-04	5.83E-04	3.08E-04
Tolualdehyde	g/s							1.14E-02			
2-Pentanone	g/s							1.14E-02	6.85E-04	6.85E-04	
hexanal									1.02E-04	1.02E-04	
Isobutrylaldehyde	g/s							1.14E-02			
Polychlorinated dioxins and furans	g/s	4.41E-09	1.47E-09	8.89E-10	8.89E-10	4.44E-10	4.95E-11				
SVOCs total											
acetophenone	g/s							3.83E-04	1.46E-04	1.46E-04	1.08E-01
diethyl phtalate	g/s							2.36E-04			
Isophrone	g/s										8.35E-03
2-methyl napthalene	g/s										3.35E-02
2-picolene	g/s										3.35E-02
pyridine	g/s										3.35E-02
benzyl alcohol	g/s								4.96E-05	4.96E-05	
alkyl phenols									2.92E-04	2.92E-04	
phenols									1.46E-04	1.46E-04	
2-Cyclopenten-1-one, 2-methyl									8.75E-05	8.75E-05	
2-Cyclopenten-1-one, 3-methyl									1.02E-04	1.02E-04	
2-Cyclopenten-1-one, 3,4-dimethyl									5.83E-05	5.83E-05	
2-Cyclopenten-1-one, 2,3-dimethyl									4.38E-05	4.38E-05	
3-Hydroxy-3-methyl-2-butanone									5.83E-05	5.83E-05	
4-Hydroxy-4-methyl-2-pentanone									1.60E-03	1.60E-03	
Nonane									4.38E-04	4.38E-04	

Parameter	Units										
Unit ID		SPS Boilers 1-3 (a)	SPS Package Boiler	Calcn 1-2 (a)	Calcn 3-4 (a)	Station Calcn 5	Lime Kiln	Hydrate vac	Digestion blow off #1	Digestion blow off #2	Mills vent 1-3 (a)
TOTAL Metals	g/s	1.65E-01	1.83E-03	4.01E-02	4.01E-02	3.55E-02	1.74E-03				
Antimony & compounds	g/s	6.45E-03	7.16E-05	1.57E-03	1.57E-03	1.39E-03	6.81E-05				
Arsenic & compounds	g/s	1.62E-03	1.80E-05	3.93E-04	3.93E-04	3.48E-04	1.71E-05				
Beryllium & compounds	g/s	3.41E-05	3.79E-07	8.27E-06	8.27E-06	7.33E-06	3.60E-07				
Cadmium & compounds	g/s	4.89E-04	5.44E-06	1.19E-04	1.19E-04	1.05E-04	5.16E-06				
Chromium	g/s	1.03E-03	1.15E-05	2.51E-04	2.51E-04	2.22E-04	1.09E-05				
Chromium (VI) compounds	g/s	3.05E-04	3.39E-06	7.41E-05	7.41E-05	6.56E-05	3.22E-06				
Cobalt & compounds	g/s	7.39E-03	8.21E-05	1.79E-03	1.79E-03	1.59E-03	7.80E-05				
Copper & compounds	g/s	2.16E-03	2.40E-05	5.24E-04	5.24E-04	4.64E-04	2.28E-05				
Lead & compounds	g/s	1.85E-03	2.06E-05	4.50E-04	4.50E-04	3.98E-04	1.96E-05				
Manganese & compounds	g/s	3.68E-03	4.09E-05	8.95E-04	8.95E-04	7.92E-04	3.89E-05				
Mercury & compounds	g/s	1.39E-04	1.55E-06	3.38E-05	3.38E-05	2.99E-05	1.47E-06				
Nickel & compounds	g/s	1.03E-01	1.15E-03	2.51E-02	2.51E-02	2.22E-02	1.09E-03				
Selenium & compounds	g/s	8.39E-04	9.33E-06	2.04E-04	2.04E-04	1.80E-04	8.86E-06				
Zinc & compounds	g/s	3.57E-02	3.97E-04	8.67E-03	8.67E-03	7.68E-03	3.77E-04				
NPI Emission Factors for metals	kg/m³										
Antimony & compounds	6.30E-04										
Arsenic & compounds	1.58E-04										
Beryllium & compounds	3.33E-06										
Cadmium & compounds	4.78E-05										
Chromium	1.01E-04										
Chromium (VI) compounds	2.98E-05										
Cobalt & compounds	7.22E-04										
Copper & compounds	2.11E-04										
Lead & compounds	1.81E-04										
Manganese & compounds	3.60E-04										
Mercury & compounds	1.36E-05										
Nickel & compounds	1.01E-02										
Selenium & compounds	8.20E-05										

Parameter	Units										
Unit ID		SPS Boilers 1-3 (a)	SPS Package Boiler	Calcn 1-2 (a)	Calcn 3-4 (a)	Station Calcn 5	Lime Kiln	Hydrate vac	Digestion blow off #1	Digestion blow off #2	Mills vent 1-3 (a)
Zinc & compounds	3.49E-03										
Odour (b)	(ou.m ³ /s)	537057		290972	290972	876814	10289	188720	527096	527096	171444

a: emission rates represent the total of all units

b: additional odour emissions from ferrosilt of 252,899 ou.m³/s

c: modelled assuming four boilers all emitting at the same time

Scenario 1: Future Plant: 100% Gas Fuel with the Solid Liquid Calciner (SLC)

Scenario 2 (Future Plant: 100% Gas Fuel WITHOUT the Solid Liquid Calciner (SLC)) has exactly the same emission rates as listed below except that the SLC is not included

Unit ID	Units	SPS Boiler (1-4) ^a	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5 ^a	Hydrate vacuum exhaust 1	Hydrate vacuum exhaust 2	SLC Liquor Purification
							E63410	E63411	E63412				
Material Processed		GAS	GAS	GAS	GAS	WASTE OIL	Strong liquor	Strong liquor	Strong liquor		Pregnant Liquor	Pregnant Liquor	
Location Details													
AMG Coordinate Easting	m	683 363.2	683259.41	683265	683270	683 166.3	683486	683546	683540	683526	683318	683318	683894
AMG Coordinate Northing	m	8 651 848.7	8652279.62	8652279.62	8652279.62	8 651 910.9	8652044	8652044	8652044	8652157	8651996	8651996	8651871
Stack Parameters													
Stack Base AHD	m	10	10	10	10	10	10	10	10		10	10	6.7
Stack Height	m	90	70	70	70	34.2	20	20	20		30	30	70
Flue Diameter	m	5.272	2.4995	2.4995	2.4995	0.8	0.95	0.95	0.95	1.788854382	2	2	3.1
Dimensions of neighbour building	(LxWxH m)	100x90x35				50x35x35							
Stack Discharge Orientation		vertical	vertical	vertical	vertical	vertical							vertical

Unit ID	Units	SPS Boiler (1-4) ^a	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5 ^a	Hydrate vacuum exhaust 1	Hydrate vacuum exhaust 2	SLC Liquor Purification
Flow Parameters													
Flue Diameter	mm	5272	2499.5	2499.5	2499.5	800	950	950	950	1788.854382	2000	2000	3100
Velocity	m/s	20.0	41.0	41.0	41.0	9	5.65	5.65	5.65	1.25	9	9	15.08926504
Temperature	°C	170.0	178	178	178	155	100	100	100	150	170	170	150
Moisture	%v/v	11.0	40.3	40.3	40.3	8.8	97	97	97				24
Flow Rate (as Discharged)	m³/min		3900	3900	3900	270	110	110	110				6833.333333
Flow Rate (as wet NTP)	m³/min		2325	2325	2325								
Flow Rate (as dry NTP)	m³/min		1425	1425	1425		1.75	1.75	1.75				4416.666667
Acid Dewpoint	°C		171.0	171.0	171.0								
Static Pressure Drop	kPa												
Emissions Summary													
Total Particulates	g/s					1.58E+01	2.19E-03	2.19E-03	2.19E-03	8.33E-03	3.61E-03	3.61E-03	0.010305556
PM <10µm	g/s	2.35E+00	4.84E-01	4.84E-01	4.84E-01	7.92E-01							
Sulphur Dioxide	g/s	1.83E-01	3.78E-02	3.78E-02	3.78E-02	2.30E+00							3.02E-01
Sulphur Trioxide H2SO4	g/s												1.18E-01
Fluoride	g/s					5.97E-04							1.33E-02
Oxides of nitrogen (as NO2)	g/s	3.81E+01	8.93E+00	8.93E+00	8.93E+00	8.78E-01							3.83E+00
CO	g/s	1.87E+01	5.30E+00	5.30E+00	5.30E+00	7.98E-02					8.08E-03	8.08E-03	3.90E-01
TOT VOC (as n-hexane)	g/s	1.69E+00	2.12E-08	2.12E-08	2.12E-08	2.35E-09	3.06E-02	3.06E-02	3.06E-02	2.42E+00	4.85E-01	4.85E-01	
Benzene	g/s	6.46E-04	3.07E-05	3.07E-05	3.07E-05	3.42E-06	1.90E-04	1.90E-04	1.90E-04	2.85E-03			1.91E-03
Toluene	g/s	1.03E-03	8.88E-04	8.88E-04	8.88E-04	1.12E-04	5.83E-03	5.83E-03	5.83E-03		2.94E-02	2.94E-02	7.36E-03
Ethylbenzene	g/s						8.75E-05	8.75E-05	8.75E-05				3.75E-04
Xylene	g/s		1.57E-05	1.57E-05	1.57E-05	1.75E-06	2.33E-04	2.33E-04	2.33E-04	2.64E-05			4.27E-04
dimethyldisulphide	g/s						3.21E-04	3.21E-04	3.21E-04				2.28E-05
methyl butane	g/s						1.90E-04	1.90E-04	1.90E-04				3.75E-04
2,3 dimethyl pentane	g/s						4.38E-05	4.38E-05	4.38E-05				

Unit ID	Units	SPS Boiler (1-4) ^a	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5 ^a	Hydrate vacuum exhaust 1	Hydrate vacuum exhaust 2	SLC Liquor Purification
methyl cyclopentane	g/s						1.02E-04	1.02E-04	1.02E-04				3.75E-04
Hexane	g/s	5.58E-01					2.33E-04	2.33E-04	2.33E-04				3.75E-04
Cyclohexane	g/s	3.83E-02	4.80E-10	4.80E-10	4.80E-10		1.02E-04	1.02E-04	1.02E-04				3.75E-04
methylcylcohexane	g/s						2.92E-04	2.92E-04	2.92E-04				
3-methyl-2-butanone	g/s						8.75E-04	8.75E-04	8.75E-04				
aromaticaliphatic hydrocarbons	g/s	2.27E-02					1.90E-04	1.90E-04	1.90E-04				
H2S	g/s		4.67E-04	4.67E-04	4.67E-04	4.67E-04							5.74E-03
Caustic	g/s									5.35E-02	2.79E-01	2.79E-01	
Cl (as HCl)	g/s		8.33E-03	8.33E-03	8.33E-03	5.53E-03							1.84E-01
Total PAHs		2.13E-04	4.39E-05	4.39E-05	4.39E-05					1.10E-04	4.23E-03	4.23E-03	1.37E-03
Napthalene	g/s												
Acenaphthylene	g/s												
Acenaphthene	g/s												
Fluorene	g/s												
Phenanthrene	g/s												
Anthracene	g/s												
Fluoranthene	g/s												
Pyrene	g/s												
Benz[a]fluoranthene	g/s												
Chrysene	g/s												
Benz[b]fluoranthene	g/s												
Benz[k]fluoranthene	g/s												
Benzo[a]pyrene	g/s												
Ideno[123cd]pyrene	g/s												
Dibenz[ah]anthracene	g/s												
Benzo[ghi]perylene	g/s												
TOTAL													

Unit ID	Units	SPS Boiler (1-4) ^a	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5 ^a	Hydrate vacuum exhaust 1	Hydrate vacuum exhaust 2	SLC Liquor Purification
<i>Aldehyde/ketones</i>													
2-Butanone	g/s						7.29E-04	7.29E-04	7.29E-04	5.21E-03	1.14E-02	1.14E-02	8.10E-02
Acetaldehyde	g/s						6.27E-03	6.27E-03	6.27E-03	2.99E-02	7.22E-03	7.22E-03	6.11E-02
Acetone	g/s						6.56E-03	6.56E-03	6.56E-03	4.93E-02	2.33E-02	2.33E-02	1.69E-01
Acrolein	g/s										1.14E-02	1.14E-02	
Benzaldehyde	g/s						3.50E-04	3.50E-04	3.50E-04	7.57E-04	1.14E-02	1.14E-02	5.08E-03
Butanal	g/s									3.23E-03	1.14E-02	1.14E-02	5.15E-03
Butenal	g/s						4.96E-03	4.96E-03	4.96E-03		1.14E-02	1.14E-02	
Formaldehyde	g/s	2.35E-02	4.73E-03	4.73E-03	4.73E-03	5.27E-04	1.90E-04	1.90E-04	1.90E-04		1.14E-02	1.14E-02	3.46E-02
Hexaldehyde	g/s										1.14E-02	1.14E-02	
Methacrolein	g/s						5.83E-05	5.83E-05	5.83E-05		1.14E-02	1.14E-02	
Pentanal	g/s									4.03E-04	1.14E-02	1.14E-02	
Propanal	g/s						5.83E-04	5.83E-04	5.83E-04	5.14E-04	1.14E-02	1.14E-02	
Tolualdehyde	g/s										1.14E-02	1.14E-02	
2-Pentanone	g/s						6.85E-04	6.85E-04	6.85E-04		1.14E-02	1.14E-02	5.08E-03
Hexanal	g/s						1.02E-04	1.02E-04	1.02E-04				
Isobutrylaldehyde	g/s										1.14E-02	1.14E-02	
Polychlorinated dioxins and furans	g/s	3.67E-10	4.44E-10	4.44E-10	4.44E-10	4.95E-11							1.25E-08
<i>SVOCs total</i>													
acetophenone	g/s						1.46E-04	1.46E-04	1.46E-04	1.81E-01	3.83E-04	3.83E-04	
diethyl phtalate	g/s										2.36E-04	2.36E-04	
Isophrone	g/s									1.39E-02			
2-methyl napthalene	g/s									5.58E-02			
2-picolene	g/s									5.58E-02			
pyridine	g/s									5.58E-02			
benzyl alcohol	g/s						4.96E-05	4.96E-05	4.96E-05				
alkyl phenols	g/s						2.92E-04	2.92E-04	2.92E-04				

Unit ID	Units	SPS Boiler (1-4) ^a	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5 ^a	Hydrate vacuum exhaust 1	Hydrate vacuum exhaust 2	SLC Liquor Purification
phenols	g/s						1.46E-04	1.46E-04	1.46E-04				2.13E-02
2-Cyclopenten-1-one, 2-methyl	g/s						8.75E-05	8.75E-05	8.75E-05				
2-Cyclopenten-1-one, 3-methyl	g/s						1.02E-04	1.02E-04	1.02E-04				
2-Cyclopenten-1-one, 3,4-dimethyl	g/s						5.83E-05	5.83E-05	5.83E-05				
2-Cyclopenten-1-one, 2,3-dimethyl	g/s						4.38E-05	4.38E-05	4.38E-05				
3-Hydroxy-3-methyl-2-butanone	g/s						5.83E-05	5.83E-05	5.83E-05				
4-Hydroxy-4-methyl-2-pentanone	g/s						1.60E-03	1.60E-03	1.60E-03				
Nonane	g/s						4.38E-04	4.38E-04	4.38E-04				
<i>Metals</i>	g/s	2.02E-03	4.18E-04	4.18E-04	4.18E-04	2.79E-05							
As	g/s	6.24E-05	1.29E-05	1.29E-05	1.29E-05	8.60E-07							5.01E-05
Cd	g/s	3.37E-04	6.96E-05	6.96E-05	6.96E-05	4.66E-06							6.63E-06
Co	g/s	2.57E-05	5.30E-06	5.30E-06	5.30E-06	3.54E-07							4.49E-06
Cr	g/s												7.06667E-05
Cr (VI)	g/s	2.20E-05	4.54E-06	4.54E-06	4.54E-06	3.04E-07							3.31E-05
Cr (III)	g/s	4.11E-04	8.47E-05	8.47E-05	8.47E-05	5.67E-06							3.75E-05
Cu	g/s	2.64E-04	5.45E-05	5.45E-05	5.45E-05	3.64E-06							2.43E-04
Pb	g/s	1.76E-04	3.63E-05	3.63E-05	3.63E-05	2.43E-06							1.33E-04
Ni	g/s	6.46E-04	1.33E-04	1.33E-04	1.33E-04	8.91E-06							6.85E-05
Hg	g/s	8.07E-05	1.66E-05	1.66E-05	1.66E-05	1.11E-06							1.62E-04
<i>new for SLC stack</i>													
methanol	g/s												2.58E-03
ethanol	g/s												3.75E-04
3-methylpentane	g/s												3.75E-04
chloroform	g/s												1.84E-04
dimethyl sulfide	g/s												2.43E-05

Unit ID	Units	SPS Boiler (1-4) ^a	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5 ^a	Hydrate vacuum exhaust 1	Hydrate vacuum exhaust 2	SLC Liquor Purification
carbon disulfide	g/s												2.43E-05
aluminium (Al)	g/s												0.014133333
antimony (Sb)	g/s												4.27E-06
barium (Ba)	g/s												2.50E-03
gallium (Ga)	g/s												8.83E-06
iron (Fe)	g/s												3.46E-03
Manganese (Mn)	g/s												5.45E-04
molybdenum (Mo)	g/s												1.84E-04
thallium (Tl)	g/s												9.57E-06
vanadium (V)	g/s												4.64E-06
zinc (Zn)	g/s												1.25E-03
Odour (b)	ou.m3/s	268365	438407	438407	438407	10289	527096	527096	527096	285740	188720	188720	169560

a: emission rates represent the total of all units

b: additional odour emissions from ferrosilt of 252,899 ou.m³/s

Scenario 3: Future Plant: most likely “worst case” emission conditions

Parameter	Units														
Unit ID		SPS Boiler (1-4)	Calcn (1- 2)	Calcn (3- 4)	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5	Hydrate vacuum system exhaust 1	Hydrate vacuum system exhaust 2	SLC Liquor Purification
Alternate fuel is 1% S Fuel Oil									E63410	E63411	E63412				
Material Processed		1% S fuel oil			1% S fuel oil	1% S fuel oil	1% S fuel oil	WASTE OIL	Strong liquor	Strong liquor	Strong liquor		Pregnant Liquor	Pregnant Liquor	
Sulphur content		1	1	1	1	1	1	0.5							
Location Details															
AMG Coordinate Easting	m	683 363.2			683259.41	683265	683270	683 166.3	683486	683546	683540	683526	683318	683318	683894
AMG Coordinate Northing	m	8 651 848.7			8652279.62	8652279.62	8652279.62	8 651 910.9	8652044	8652044	8652044	8652157	8651996	8651996	8651871
Stack Parameters															
Stack Base AHD	m	10	6.7	6.7	10	10	10	10	10	10	10		10	10	6.7
Stack Height	m	90	32	32	70	70	70	34.2	20	20	20		30	30	70
Flue Diameter	m	5.272	2.969848 481	2.969848 481	2.5	2.5	2.5	0.8	0.95	0.95	0.95	1.7888543 82	2	2	3.1
Dimensions of neighbour building	(LxWxH m)	100x90x35	100x35x3 5	100x35x3 5				50x35x35							
Stack Discharge Orientation		vertical	vertical	vertical	vertical	vertical	vertical	vertical							vertical
Flow Parameters															
Flue Diameter	mm	5272	2969.848 481	2969.848 481	2499.5	2499.5	2499.5	800	950	950	950	1788.8543 82	2000	2000	3100
Velocity	m/s	20.0	23.4	23.4	41.0	41.0	41.0	9	5.65	5.65	5.65	1.25	9	9	15.08926504
Temperature	°C	170.0	273	273	178	178	178	155	100	100	100	150	170	170	150
Moisture	%v/v	11.0	34.5	34.5	40.3	40.3	40.3	8.8	97	97	97				24
Flow Rate (as Discharged)	m³/min				3900	3900	3900	270	110	110	110				6833.333333
Flow Rate (as wet NTP)	m³/min				2325	2325	2325								
Flow Rate (as dry NTP)	m³/min				1425	1425	1425		1.75	1.75	1.75				4416.666667

Acid Dewpoint	°C				171.0	171.0	171.0								
Static Pressure Drop	kPa														
Emissions Summary															
Total Particulates	g/s	4.23E+01	1.09E+01	1.09E+01	3.75E-01	3.75E-01	3.75E-01	1.58E+01	2.19E-03	2.19E-03	2.19E-03	8.33E-03	3.61E-03	3.61E-03	0.010305556
PM <10µm	g/s	4.23E+01	1.09E+01	1.09E+01	3.75E-01	3.75E-01	3.75E-01	7.92E-01							
Sulphur Dioxide	g/s	2.51E+02	2.63E+01	2.63E+01	2.43E+01	2.43E+01	2.43E+01	4.86E-02							3.02E-01
H2SO4	g/s	1.11E+01	3.91E-01	3.91E-01	3.61E-01	3.61E-01	3.61E-01	7.23E-04							1.18E-01
Fluoride	g/s	2.33E-02	9.04E-03	9.04E-03	5.35E-03	5.35E-03	5.35E-03	5.97E-04							1.33E-02
Oxides of nitrogen (as NO2)	g/s	2.04E+01	1.14E+01	1.14E+01	1.62E+00	1.62E+00	1.62E+00	8.78E-01							3.83E+00
CO	g/s	1.52E+00	1.47E+00	1.47E+00	2.00E-01	2.00E-01	2.00E-01	7.98E-02					8.08E-03	8.08E-03	3.90E-01
TOT VOC (as n-hexane)	g/s	7.33E-02	4.23E-08	4.23E-08	2.12E-08	2.12E-08	2.12E-08	2.35E-09	3.06E-02	3.06E-02	3.06E-02	2.42E+00	4.85E-01	4.85E-01	
Benzene	g/s	7.33E-02	6.13E-05	6.13E-05	3.07E-05	3.07E-05	3.07E-05	3.42E-06	1.90E-04	1.90E-04	1.90E-04	2.85E-03			1.91E-03
Toluene	g/s	1.17E-02	1.78E-03	1.78E-03	8.88E-04	8.88E-04	8.88E-04	1.12E-04	5.83E-03	5.83E-03	5.83E-03	1.81E-04	2.94E-02	2.94E-02	7.36E-03
Ethylbenzene	g/s								8.75E-05	8.75E-05	8.75E-05				3.75E-04
Xylene	g/s	2.08E-04	3.13E-05	3.13E-05	1.57E-05	1.57E-05	1.57E-05	1.75E-06	2.33E-04	2.33E-04	2.33E-04	2.64E-05			4.27E-04
dimethyldisulphide	g/s								3.21E-04	3.21E-04	3.21E-04				2.28E-05
methyl butane	g/s								1.90E-04	1.90E-04	1.90E-04				3.75E-04
2,3 dimethyl pentane	g/s								4.38E-05	4.38E-05	4.38E-05				
methyl cyclopentane	g/s								1.02E-04	1.02E-04	1.02E-04				3.75E-04
Hexane	g/s								2.33E-04	2.33E-04	2.33E-04				3.75E-04
Cyclohexane	g/s								1.02E-04	1.02E-04	1.02E-04				3.75E-04
methylcylcohexane	g/s								2.92E-04	2.92E-04	2.92E-04				
3-methyl-2-butanone	g/s								8.75E-04	8.75E-04	8.75E-04				
aromaticaliphatic hydrocarbons	g/s								1.90E-04	1.90E-04	1.90E-04				
H2S	g/s	1.87E-03	1.63E-03	1.63E-03	4.67E-04	4.67E-04	4.67E-04	4.67E-04							5.74E-03
Caustic	g/s											5.35E-02	2.79E-01	2.79E-01	
Cl (as HCl)	g/s	6.61E-01	9.93E-02	9.93E-02	8.33E-03	8.33E-03	8.33E-03	5.53E-03							1.84E-01
Total PAHs		2.67E-03	2.59E-03	2.59E-03	1.37E-03	1.37E-03	1.37E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-04	4.23E-03	4.23E-03	1.37E-03
Napthalene	g/s	1.80E-03	1.70E-03	1.70E-03	1.17E-03	1.17E-03	1.17E-03					5.71E-05	2.82E-03	2.82E-03	6.48E-04
Acenaphthylene	g/s	5.33E-05	6.00E-05	6.00E-05	1.53E-05	1.53E-05	1.53E-05					3.53E-06	9.39E-05	9.39E-05	2.21E-05
Acenaphthene	g/s	5.33E-05	2.00E-05	2.00E-05	3.17E-05	3.17E-05	3.17E-05					3.53E-06	9.39E-05	9.39E-05	5.96E-06
Fluorene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-05	6.67E-05	6.67E-05					3.53E-06	9.39E-05	9.39E-05	4.71E-05

Phenanthrene	g/s	2.13E-05	3.67E-04	3.67E-04	1.53E-05	1.53E-05	1.53E-05					3.53E-06	9.39E-05	9.39E-05	2.65E-04
Anthracene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	2.58E-05
Fluoranthene	g/s	1.60E-04	1.60E-04	1.60E-04	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	1.18E-04
Pyrene	g/s	5.33E-05	1.00E-04	1.00E-04	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	1.03E-04
Benz[a]fluoranthene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	2.06E-05
Chrysene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	9.57E-05
Benz[b]fluoranthene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	5.82E-06
Benz[k]fluoranthene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	7.21E-06
Benzo[a]pyrene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.31E-06
Ideno[123cd]pyrene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.83E-07
Dibenz[ah]anthracene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.53E-07
Benzo[ghi]perylene	g/s	5.33E-05			6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.53E-07
<i>TOTAL</i>															
<i>Aldehyde/ketones</i>															
2-Butanone	g/s								7.29E-04	7.29E-04	7.29E-04	5.21E-03	1.14E-02	1.14E-02	8.10E-02
Acetaldehyde	g/s								6.27E-03	6.27E-03	6.27E-03	2.99E-02	7.22E-03	7.22E-03	6.11E-02
Acetone	g/s	1.60E-07							6.56E-03	6.56E-03	6.56E-03	4.93E-02	2.33E-02	2.33E-02	1.69E-01
Acrolein	g/s												1.14E-02	1.14E-02	
Benzaldehyde	g/s								3.50E-04	3.50E-04	3.50E-04	7.57E-04	1.14E-02	1.14E-02	5.08E-03
Butanal	g/s											3.23E-03	1.14E-02	1.14E-02	5.15E-03
Butenal	g/s								4.96E-03	4.96E-03	4.96E-03		1.14E-02	1.14E-02	
Formaldehyde	g/s	6.29E-02	3.14E-02	3.14E-02	4.73E-03	4.73E-03	4.73E-03	5.27E-04	1.90E-04	1.90E-04	1.90E-04		1.14E-02	1.14E-02	3.46E-02
Hexaldehyde	g/s												1.14E-02	1.14E-02	
Methacrolein	g/s								5.83E-05	5.83E-05	5.83E-05		1.14E-02	1.14E-02	
Pentanal	g/s											4.03E-04	1.14E-02	1.14E-02	
Propanal	g/s								5.83E-04	5.83E-04	5.83E-04	5.14E-04	1.14E-02	1.14E-02	
Tolualdehyde	g/s												1.14E-02	1.14E-02	
2-Pentanone	g/s								6.85E-04	6.85E-04	6.85E-04		1.14E-02	1.14E-02	5.08E-03
Hexanal	g/s								1.02E-04	1.02E-04	1.02E-04				
Isobutrylaldehyde	g/s												1.14E-02	1.14E-02	
Polychlorinated dioxins and furans	g/s	5.88E-09	8.89E-10	8.89E-10	4.44E-10	4.44E-10	4.44E-10	4.95E-11							1.25E-08
<i>SVOCs total</i>															
acetophenone	g/s								1.46E-04	1.46E-04	1.46E-04	1.81E-01	3.83E-04	3.83E-04	
diethyl phtalate	g/s												2.36E-04	2.36E-04	

Isophrone	g/s											1.39E-02			
2-methyl naphthalene	g/s											5.58E-02			
2-picoline	g/s											5.58E-02			
pyridine	g/s											5.58E-02			
benzyl alcohol	g/s							4.96E-05	4.96E-05	4.96E-05					
alkyl phenols	g/s							2.92E-04	2.92E-04	2.92E-04					
phenols	g/s							1.46E-04	1.46E-04	1.46E-04					2.13E-02
2-Cyclopenten-1-one, 2-methyl	g/s							8.75E-05	8.75E-05	8.75E-05					
2-Cyclopenten-1-one, 3-methyl	g/s							1.02E-04	1.02E-04	1.02E-04					
2-Cyclopenten-1-one, 3,4-dimethyl	g/s							5.83E-05	5.83E-05	5.83E-05					
2-Cyclopenten-1-one, 2,3-dimethyl	g/s							4.38E-05	4.38E-05	4.38E-05					
3-Hydroxy-3-methyl- 2-butanone	g/s							5.83E-05	5.83E-05	5.83E-05					
4-Hydroxy-4-methyl- 2-pentanone	g/s							1.60E-03	1.60E-03	1.60E-03					
Nonane	g/s							4.38E-04	4.38E-04	4.38E-04					
<i>Total Metals</i>		2.20E-01			3.55E-02	3.55E-02	3.55E-02	1.74E-03							
Antimony & compounds	g/s	8.60E-03			1.39E-03	1.39E-03	1.39E-03	6.81E-05							
Arsenic & compounds	g/s	2.16E-03			3.48E-04	3.48E-04	3.48E-04	1.71E-05							5.00556E-05
Beryllium & compounds	g/s	4.54E-05			7.33E-06	7.33E-06	7.33E-06	3.60E-07							
Cadmium & compounds	g/s	6.52E-04			1.05E-04	1.05E-04	1.05E-04	5.16E-06							0.000006625
Chromium	g/s	1.38E-03			2.22E-04	2.22E-04	2.22E-04	1.09E-05							7.06667E-05
Chromium (VI) compounds	g/s	4.07E-04			6.56E-05	6.56E-05	6.56E-05	3.22E-06							0.000033125
Cobalt & compounds	g/s	9.85E-03			1.59E-03	1.59E-03	1.59E-03	7.80E-05							6.29E-06
Copper & compounds	g/s	2.88E-03			4.64E-04	4.64E-04	4.64E-04	2.28E-05							0.000242917
Lead & compounds	g/s	2.47E-03			3.98E-04	3.98E-04	3.98E-04	1.96E-05							0.0001325
Manganese & compounds	g/s	4.91E-03			7.92E-04	7.92E-04	7.92E-04	3.89E-05							
Mercury & compounds	g/s	1.86E-04			2.99E-05	2.99E-05	2.99E-05	1.47E-06							0.000161944
Nickel & compounds	g/s	1.38E-01			2.22E-02	2.22E-02	2.22E-02	1.09E-03							6.84583E-05
Selenium & compounds	g/s	1.12E-03			1.80E-04	1.80E-04	1.80E-04	8.86E-06							
Zinc & compounds	g/s	4.76E-02			7.68E-03	7.68E-03	7.68E-03	3.77E-04							

<i>new for SLC stack</i>															
methanol	g/s														2.58E-03
ethanol	g/s														3.75E-04
3-methylpentane	g/s														3.75E-04
chloroform	g/s														0.000184028
dimethyl sulfide	g/s														2.42917E-05
carbon disulfide	g/s														2.42917E-05
aluminium (Al)	g/s														0.014133333
antimony (Sb)	g/s														4.26944E-06
barium (Ba)	g/s														0.002502778
gallium (Ga)	g/s														8.83333E-06
iron (Fe)	g/s														0.003459722
Manganese (Mn)	g/s														0.000544722
molybdenum (Mo)	g/s														0.000184028
thallium (Tl)	g/s														9.56944E-06
vanadium (V)	g/s														4.6375E-06
zinc (Zn)	g/s														0.001251389

Scenario 4: Expanded Refinery: fuel switching scenario

The emission rates below are for 1.5% S fuel oil. Modelling takes into account emissions for high sulphur fuel oil (3.5% S) during the dry season period.

Parameter	Units														
Unit ID		SPS Boiler (1-4)	Calcn (1- 2)	Calcn (3- 4)	Station Calcn 1	Station Calcn 2	Station Calcn 3	Lime Kiln	Digestion blow off #1	Digestion blow off #2	Digestion blow off #3	Mills vent 1-5	Hydrate vacuum system exhaust 1	Hydrate vacuum system exhaust 2	SLC Liquor Purification
Alternate fuel is 1.5% S Fuel Oil									E63410	E63411	E63412				
Material Processed		1% S fuel oil			1% S fuel oil	1% S fuel oil	1% S fuel oil	WASTE OIL	Strong liquor	Strong liquor	Strong liquor		Pregnant Liquor	Pregnant Liquor	
Sulphur content		1.5	1.5	1.5	1.5	1.5	1.5	0.75							
Location Details															
AMG Coordinate Easting	m	683 363.2			683259.41	683265	683270	683 166.3	683486	683546	683540	683526	683318	683318	683894

AMG Coordinate Northing	m	8 651 848.7			8652279.62	8652279.62	8652279.62	8 651 910.9	8652044	8652044	8652044	8652157	8651996	8651996	8651871
Stack Parameters															
Stack Base AHD	m	10	6.7	6.7	10	10	10	10	10	10	10		10	10	6.7
Stack Height	m	90	32	32	70	70	70	34.2	20	20	20		30	30	70
Flue Diameter	m	5.272	2.969848 481	2.969848 481	2.5	2.5	2.5	0.8	0.95	0.95	0.95	1.7888543 82	2	2	3.1
Dimensions of neighbour building	(LxWxH m)	100x90x35	100x35x35	100x35x35				50x35x35							
Stack Discharge Orientation		vertical	vertical	vertical	vertical	vertical	vertical	vertical							vertical
Flow Parameters															
Flue Diameter	mm	5272	2969.848 481	2969.848 481	2499.5	2499.5	2499.5	800	950	950	950	1788.8543 82	2000	2000	3100
Velocity	m/s	20.0	23.4	23.4	41.0	41.0	41.0	9	5.65	5.65	5.65	1.25	9	9	15.08926504
Temperature	°C	170.0	273	273	178	178	178	155	100	100	100	150	170	170	150
Moisture	%v/v	11.0	34.5	34.5	40.3	40.3	40.3	8.8	97	97	97				24
Flow Rate (as Discharged)	m³/min				3900	3900	3900	270	110	110	110				6833.333333
Flow Rate (as wet NTP)	m³/min				2325	2325	2325								
Flow Rate (as dry NTP)	m³/min				1425	1425	1425		1.75	1.75	1.75				4416.666667
Acid Dewpoint	°C				171.0	171.0	171.0								
Static Pressure Drop	kPa														
Emissions Summary															
Total Particulates	g/s	5.81E+01	1.50E+01	1.50E+01	5.16E-01	5.16E-01	5.16E-01	1.58E+01	2.19E-03	2.19E-03	2.19E-03	8.33E-03	3.61E-03	3.61E-03	0.010305556
PM <10µm	g/s	5.81E+01	1.50E+01	1.50E+01	5.16E-01	5.16E-01	5.16E-01	7.92E-01							
Sulphur Dioxide	g/s	3.76E+02	3.94E+01	3.94E+01	3.64E+01	3.64E+01	3.64E+01	7.29E-02							3.02E-01
H2SO4	g/s	1.67E+01	5.87E-01	5.87E-01	5.41E-01	5.41E-01	5.41E-01	1.08E-03							1.18E-01
Fluoride	g/s	2.33E-02	9.04E-03	9.04E-03	5.35E-03	5.35E-03	5.35E-03	5.97E-04							1.33E-02
Oxides of nitrogen (as NO2)	g/s	2.04E+01	1.14E+01	1.14E+01	1.62E+00	1.62E+00	1.62E+00	8.78E-01							3.83E+00
CO	g/s	1.52E+00	1.47E+00	1.47E+00	2.00E-01	2.00E-01	2.00E-01	7.98E-02					8.08E-03	8.08E-03	3.90E-01
TOT VOC (as n-hexane)	g/s	7.33E-02	4.23E-08	4.23E-08	2.12E-08	2.12E-08	2.12E-08	2.35E-09	3.06E-02	3.06E-02	3.06E-02	2.42E+00	4.85E-01	4.85E-01	
Benzene	g/s	7.33E-02	6.13E-05	6.13E-05	3.07E-05	3.07E-05	3.07E-05	3.42E-06	1.90E-04	1.90E-04	1.90E-04	2.85E-03			1.91E-03

Toluene	g/s	1.17E-02	1.78E-03	1.78E-03	8.88E-04	8.88E-04	8.88E-04	1.12E-04	5.83E-03	5.83E-03	5.83E-03	1.81E-04	2.94E-02	2.94E-02	7.36E-03
Ethylbenzene	g/s								8.75E-05	8.75E-05	8.75E-05				3.75E-04
Xylene	g/s	2.08E-04	3.13E-05	3.13E-05	1.57E-05	1.57E-05	1.57E-05	1.75E-06	2.33E-04	2.33E-04	2.33E-04	2.64E-05			4.27E-04
dimethyldisulphide	g/s								3.21E-04	3.21E-04	3.21E-04				2.28E-05
methyl butane	g/s								1.90E-04	1.90E-04	1.90E-04				3.75E-04
2,3 dimethyl pentane	g/s								4.38E-05	4.38E-05	4.38E-05				
methyl cyclopentane	g/s								1.02E-04	1.02E-04	1.02E-04				3.75E-04
Hexane	g/s								2.33E-04	2.33E-04	2.33E-04				3.75E-04
Cyclohexane	g/s								1.02E-04	1.02E-04	1.02E-04				3.75E-04
methylcylcohexane	g/s								2.92E-04	2.92E-04	2.92E-04				
3-methyl-2-butanone	g/s								8.75E-04	8.75E-04	8.75E-04				
aromaticaliphatic hydrocarbons	g/s								1.90E-04	1.90E-04	1.90E-04				
H2S	g/s	1.87E-03	1.63E-03	1.63E-03	4.67E-04	4.67E-04	4.67E-04	4.67E-04							5.74E-03
Caustic	g/s											5.35E-02	2.79E-01	2.79E-01	
Cl (as HCl)	g/s	6.61E-01	9.93E-02	9.93E-02	8.33E-03	8.33E-03	8.33E-03	5.53E-03							1.84E-01
Total PAHs		2.67E-03	2.59E-03	2.59E-03	1.37E-03	1.37E-03	1.37E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-04	4.23E-03	4.23E-03	1.37E-03
Napthalene	g/s	1.80E-03	1.70E-03	1.70E-03	1.17E-03	1.17E-03	1.17E-03					5.71E-05	2.82E-03	2.82E-03	6.48E-04
Acenaphthylene	g/s	5.33E-05	6.00E-05	6.00E-05	1.53E-05	1.53E-05	1.53E-05					3.53E-06	9.39E-05	9.39E-05	2.21E-05
Acenaphthene	g/s	5.33E-05	2.00E-05	2.00E-05	3.17E-05	3.17E-05	3.17E-05					3.53E-06	9.39E-05	9.39E-05	5.96E-06
Fluorene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-05	6.67E-05	6.67E-05					3.53E-06	9.39E-05	9.39E-05	4.71E-05
Phenanthrene	g/s	2.13E-05	3.67E-04	3.67E-04	1.53E-05	1.53E-05	1.53E-05					3.53E-06	9.39E-05	9.39E-05	2.65E-04
Anthracene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	2.58E-05
Fluoranthene	g/s	1.60E-04	1.60E-04	1.60E-04	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	1.18E-04
Pyrene	g/s	5.33E-05	1.00E-04	1.00E-04	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	1.03E-04
Benz[a]fluoranthene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	2.06E-05
Chrysene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	9.57E-05
Benz[b]fluoranthene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	5.82E-06
Benz[k]fluoranthene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	7.21E-06
Benzo[a]pyrene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.31E-06
Ideno[123cd]pyrene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.83E-07
Dibenz[ah]anthracene	g/s	5.33E-05	2.00E-05	2.00E-05	6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.53E-07
Benzo[ghi]perylene	g/s	5.33E-05			6.67E-06	6.67E-06	6.67E-06					3.53E-06	9.39E-05	9.39E-05	3.53E-07
TOTAL															

Aldehyde/ketones															
2-Butanone	g/s								7.29E-04	7.29E-04	7.29E-04	5.21E-03	1.14E-02	1.14E-02	8.10E-02
Acetaldehyde	g/s								6.27E-03	6.27E-03	6.27E-03	2.99E-02	7.22E-03	7.22E-03	6.11E-02
Acetone	g/s	1.60E-07							6.56E-03	6.56E-03	6.56E-03	4.93E-02	2.33E-02	2.33E-02	1.69E-01
Acrolein	g/s												1.14E-02	1.14E-02	
Benzaldehyde	g/s								3.50E-04	3.50E-04	3.50E-04	7.57E-04	1.14E-02	1.14E-02	5.08E-03
Butanal	g/s											3.23E-03	1.14E-02	1.14E-02	5.15E-03
Butenal	g/s								4.96E-03	4.96E-03	4.96E-03		1.14E-02	1.14E-02	
Formaldehyde	g/s	6.29E-02	3.14E-02	3.14E-02	4.73E-03	4.73E-03	4.73E-03	5.27E-04	1.90E-04	1.90E-04	1.90E-04		1.14E-02	1.14E-02	3.46E-02
Hexaldehyde	g/s												1.14E-02	1.14E-02	
Methacrolein	g/s								5.83E-05	5.83E-05	5.83E-05		1.14E-02	1.14E-02	
Pentanal	g/s											4.03E-04	1.14E-02	1.14E-02	
Propanal	g/s								5.83E-04	5.83E-04	5.83E-04	5.14E-04	1.14E-02	1.14E-02	
Tolualdehyde	g/s												1.14E-02	1.14E-02	
2-Pentanone	g/s								6.85E-04	6.85E-04	6.85E-04		1.14E-02	1.14E-02	5.08E-03
Hexanal	g/s								1.02E-04	1.02E-04	1.02E-04				
Isobutrylaldehyde	g/s												1.14E-02	1.14E-02	
Polychlorinated dioxins and furans	g/s	5.88E-09	8.89E-10	8.89E-10	4.44E-10	4.44E-10	4.44E-10	4.95E-11							1.25E-08
SVOCs total															
acetophenone	g/s								1.46E-04	1.46E-04	1.46E-04	1.81E-01	3.83E-04	3.83E-04	
diethyl phthalate	g/s												2.36E-04	2.36E-04	
Isophrone	g/s											1.39E-02			
2-methyl napthalene	g/s											5.58E-02			
2-picoline	g/s											5.58E-02			
pyridine	g/s											5.58E-02			
benzyl alcohol	g/s								4.96E-05	4.96E-05	4.96E-05				
alkyl phenols	g/s								2.92E-04	2.92E-04	2.92E-04				
phenols	g/s								1.46E-04	1.46E-04	1.46E-04				2.13E-02
2-Cyclopenten-1-one, 2-methyl	g/s								8.75E-05	8.75E-05	8.75E-05				
2-Cyclopenten-1-one, 3-methyl	g/s								1.02E-04	1.02E-04	1.02E-04				
2-Cyclopenten-1-one, 3,4-dimethyl	g/s								5.83E-05	5.83E-05	5.83E-05				

2-Cyclopenten-1-one, 2,3-dimethyl	g/s								4.38E-05	4.38E-05	4.38E-05				
3-Hydroxy-3-methyl-2-butanone	g/s								5.83E-05	5.83E-05	5.83E-05				
4-Hydroxy-4-methyl-2-pentanone	g/s								1.60E-03	1.60E-03	1.60E-03				
Nonane	g/s								4.38E-04	4.38E-04	4.38E-04				
Total Metals		2.20E-01			3.55E-02	3.55E-02	3.55E-02	1.74E-03							
Antimony & compounds	g/s	8.60E-03			1.39E-03	1.39E-03	1.39E-03	6.81E-05							
Arsenic & compounds	g/s	2.16E-03			3.48E-04	3.48E-04	3.48E-04	1.71E-05							5.00556E-05
Beryllium & compounds	g/s	4.54E-05			7.33E-06	7.33E-06	7.33E-06	3.60E-07							
Cadmium & compounds	g/s	6.52E-04			1.05E-04	1.05E-04	1.05E-04	5.16E-06							0.000006625
Chromium	g/s	1.38E-03			2.22E-04	2.22E-04	2.22E-04	1.09E-05							7.06667E-05
Chromium (VI) compounds	g/s	4.07E-04			6.56E-05	6.56E-05	6.56E-05	3.22E-06							0.000033125
Cobalt & compounds	g/s	9.85E-03			1.59E-03	1.59E-03	1.59E-03	7.80E-05							6.29E-06
Copper & compounds	g/s	2.88E-03			4.64E-04	4.64E-04	4.64E-04	2.28E-05							0.000242917
Lead & compounds	g/s	2.47E-03			3.98E-04	3.98E-04	3.98E-04	1.96E-05							0.0001325
Manganese & compounds	g/s	4.91E-03			7.92E-04	7.92E-04	7.92E-04	3.89E-05							
Mercury & compounds	g/s	1.86E-04			2.99E-05	2.99E-05	2.99E-05	1.47E-06							0.000161944
Nickel & compounds	g/s	1.38E-01			2.22E-02	2.22E-02	2.22E-02	1.09E-03							6.84583E-05
Selenium & compounds	g/s	1.12E-03			1.80E-04	1.80E-04	1.80E-04	8.86E-06							
Zinc & compounds	g/s	4.76E-02			7.68E-03	7.68E-03	7.68E-03	3.77E-04							
new for SLC stack															
methanol	g/s														2.58E-03
ethanol	g/s														3.75E-04
3-methylpentane	g/s														3.75E-04
chloroform	g/s														0.000184028
dimethyl sulfide	g/s														2.42917E-05
carbon disulfide	g/s														2.42917E-05
aluminium (Al)	g/s														0.014133333

antimony (Sb)	g/s																	4.26944E-06
barium (Ba)	g/s																	0.002502778
gallium (Ga)	g/s																	8.83333E-06
iron (Fe)	g/s																	0.003459722
Manganese (Mn)	g/s																	0.000544722
molybdenum (Mo)	g/s																	0.000184028
thallium (Tl)	g/s																	9.56944E-06
vanadium (V)	g/s																	4.6375E-06
zinc (Zn)	g/s																	0.001251389

Fugitive Particulates Source Emission Data

Existing Plant					Speciated Metals														
		TSP	PM10		Antimony	As	Beryllium	Cd	Cr	Co	Cu	Pb	Mn	Hg	Ni	Se	Zn	B	F
	Type	g/s	g/s		g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s
Export stockpile	Area	2.4E+01	1.3E+01																
Plant feed stockpile	Area	4.0E+01	2.6E+01		8.0E-06	6.6E-04	1.6E-05	1.0E-04	7.2E-03	5.0E-04	6.2E-04	2.3E-04	3.8E-03	1.2E-06	1.2E-04	2.4E-04	7.3E-04	4.8E-04	2.6E-02
TS1	Vol.	4.0E+00	1.6E+00		8.0E-07	6.6E-05	1.6E-06	1.0E-05	7.2E-04	5.0E-05	6.2E-05	2.3E-05	3.8E-04	1.2E-07	1.2E-05	2.4E-05	7.3E-05	4.8E-05	2.6E-03
TS2	Vol.	9.5E+00	3.8E+00		1.9E-06	1.6E-04	3.8E-06	2.5E-05	1.7E-03	1.2E-04	1.5E-04	5.4E-05	9.0E-04	2.9E-07	2.9E-05	5.7E-05	1.7E-04	1.1E-04	6.2E-03
TS3	Vol.	4.0E+00	1.6E+00		8.0E-07	6.6E-05	1.6E-06	1.0E-05	7.2E-04	5.0E-05	6.2E-05	2.3E-05	3.8E-04	1.2E-07	1.2E-05	2.4E-05	7.3E-05	4.8E-05	2.6E-03
TS4	Vol.	8.9E+00	3.6E+00		1.8E-06	1.5E-04	3.6E-06	2.3E-05	1.6E-03	1.1E-04	1.4E-04	5.1E-05	8.4E-04	2.7E-07	2.7E-05	5.3E-05	1.6E-04	1.1E-04	5.7E-03
TS5	Vol.	8.9E+00	3.6E+00		1.8E-06	1.5E-04	3.6E-06	2.3E-05	1.6E-03	1.1E-04	1.4E-04	5.1E-05	8.4E-04	2.7E-07	2.7E-05	5.3E-05	1.6E-04	1.1E-04	5.7E-03
TS6	Vol.	8.9E+00	3.6E+00		1.8E-06	1.5E-04	3.6E-06	2.3E-05	1.6E-03	1.1E-04	1.4E-04	5.1E-05	8.4E-04	2.7E-07	2.7E-05	5.3E-05	1.6E-04	1.1E-04	5.7E-03
Ship Loader	Vol.	8.9E+01	3.6E+01		1.8E-05	1.5E-03	3.6E-05	2.3E-04	1.6E-02	1.1E-03	1.4E-03	5.1E-04	8.4E-03	2.7E-06	2.7E-04	5.3E-04	1.6E-03	1.1E-03	5.7E-02
TS7	Vol.	9.5E+00	3.8E+00		1.9E-06	1.6E-04	3.8E-06	2.5E-05	1.7E-03	1.2E-04	1.5E-04	5.4E-05	9.0E-04	2.9E-07	2.9E-05	5.7E-05	1.7E-04	1.1E-04	6.2E-03

Expanded Refinery																			
Export stockpile	Area	2.4E+01	1.3E+01																
Plant feed stockpile	Area	4.0E+01	2.6E+01		8.0E-06	6.6E-04	1.6E-05	1.0E-04	7.2E-03	5.0E-04	6.2E-04	2.3E-04	3.8E-03	1.2E-06	1.2E-04	2.4E-04	7.3E-04	4.8E-04	2.6E-02
TS1	Vol.	3.6E+00	1.4E+00		7.2E-07	6.0E-05	1.4E-06	9.4E-06	6.4E-04	4.5E-05	5.5E-05	2.1E-05	3.4E-04	1.1E-07	1.1E-05	2.2E-05	6.6E-05	4.3E-05	2.3E-03
TS2	Vol.	8.6E+00	3.4E+00		1.7E-06	1.4E-04	3.4E-06	2.2E-05	1.5E-03	1.1E-04	1.3E-04	4.9E-05	8.1E-04	2.6E-07	2.6E-05	5.2E-05	1.6E-04	1.0E-04	5.5E-03
TS3	Vol.	3.6E+00	1.4E+00		7.2E-07	6.0E-05	1.4E-06	9.4E-06	6.4E-04	4.5E-05	5.5E-05	2.1E-05	3.4E-04	1.1E-07	1.1E-05	2.2E-05	6.6E-05	4.3E-05	2.3E-03
TS4	Vol.	8.0E+00	3.2E+00		1.6E-06	1.3E-04	3.2E-06	2.1E-05	1.4E-03	1.0E-04	1.2E-04	4.6E-05	7.5E-04	2.4E-07	2.4E-05	4.8E-05	1.5E-04	9.6E-05	5.2E-03
TS5	Vol.	8.0E+00	3.2E+00		1.6E-06	1.3E-04	3.2E-06	2.1E-05	1.4E-03	1.0E-04	1.2E-04	4.6E-05	7.5E-04	2.4E-07	2.4E-05	4.8E-05	1.5E-04	9.6E-05	5.2E-03
TS6	Vol.	8.0E+00	3.2E+00		1.6E-06	1.3E-04	3.2E-06	2.1E-05	1.4E-03	1.0E-04	1.2E-04	4.6E-05	7.5E-04	2.4E-07	2.4E-05	4.8E-05	1.5E-04	9.6E-05	5.2E-03
Ship Loader	Vol.	8.9E-01	3.6E-01		1.8E-07	1.5E-05	3.6E-07	2.3E-06	1.6E-04	1.1E-05	1.4E-05	5.1E-06	8.4E-05	2.7E-08	2.7E-06	5.3E-06	1.6E-05	1.1E-05	5.7E-04
TS7	Vol.	8.6E+00	3.4E+00		1.7E-06	1.4E-04	3.4E-06	2.2E-05	1.5E-03	1.1E-04	1.3E-04	4.9E-05	8.1E-04	2.6E-07	2.6E-05	5.2E-05	1.6E-04	1.0E-04	5.5E-03

APPENDIX C

SOURCE OF EMISSION DATA

18 APPENDIX C – SOURCES OF EMISSIONS DATA

Upgraded (Stage 2) facility

Emission codes:

- A Measured by ECS 2003
- B Estimated from measured total particulate measurement
- C Direct, real time measurement (Based on hourly fuel consumption data and fuel sulphur from Alcan Gove PI system)
- D Estimated from SO₂ emission
- E Stack testing measurement (2000)
- F Stack testing measurement (2000) but based on detection limit
- G Estimated using NPI estimation methodology and supplied by Alcan Gove
- H Measured by ECS 2003 based on detection limit
- I Estimated from data supplied by ECS
- J Measured by The Odour Unit 2003

Emission data for the Solid Liquid Calciner was supplied by Alceng and was based on emission testing of an SLC pilot plant.

	Boiler	Package Boiler	Rotary Calciner	Stationary Calciner	Lime Kiln	Hydrate vacuum exhaust	Mills Vent	Digestion blow off
Emission / Source								
Total Particulates	A	E	A	A	A	A	A	I
PM <10µm	B	E	A	B	B			
Sulphur Dioxide	G	G	G	G	G			
H ₂ SO ₄	G	G	G	G	G			
Fluoride	G	G	G	G	G			
Oxides of nitrogen (as NO ₂)	G	G	G	G	G			

Emission / Source	Boiler	Package Boiler	Rotary Calciner	Stationary Calciner	Lime Kiln	Hydrate vacuum exhaust	Mills Vent	Digestion blow off
CO	G	G	G	G	G			
VOC (as n-hexane)	E	E	G	G	G	A	A	I
Benzene	E	E	G	G	G		A	I
Toluene	G	G	G	G	G	A	A	I
Ethylbenzene								I
Xylene	G	G	G	G	G		A	I
dimethyldisulphide								I
methylbutane								I
2,3 dimethylpentane								I
methyl cyclopentane								I
Hexane								I
Cyclohexane								I
Methylcyclohexane								I
3-Methyl-2-butanone								I
Aromatic - Apliphatic Hydrocarbons								I
H2S					G			
Caustic						A	A	
Cl (as HCl)	G	G	G	A	G			
PAHs								
Napthalene	F	F	F	F			A	
Acenaphthylene	F	F	F	F				
Acenaphthene	F	F	F	F				
Fluorene	F	F	F	F				
Phenanthrene	F	F	F	F				
Anthracene	F	F	F	F				
Fluoranthene	F	F	F	F				
Pyrene	F	F	F	F				
Benz[a]fluoranthene	F	F	F	F				
Chrysene	F	F	F	F				
Benz[b]fluoranthene	F	F	F	F				
Benz[k]fluoranthene	F	F	F	F				

Emission / Source	Boiler	Package Boiler	Rotary Calciner	Stationary Calciner	Lime Kiln	Hydrate vacuum exhaust	Mills Vent	Digestion blow off
Benzo[a]pyrene	F	F	F	F				
Ideno[123cd]pyrene	F	F	F	F				
Dibenz[ah]anthracene	F	F	F	F				
Benzo[ghi]perylene	F	F	F	F				
Carbonyls								
2-Butanone						H	A	I
Acetaldehyde						A	A	I
Acetone	G					A	A	I
Acrolein						H	H	
Benzaldehyde						H	A	I
Butanal						H	A	
Butenal						H	H	I
Formaldehyde	G	G	G	G	G	H	H	I
Hexaldehyde						H	H	
Methacrolein						H	H	I
Pentanal						H	A	
Propanal						H	A	I
Tolualdehyde						H	H	
2-Pentanone						H	H	I
Hexanal								I
Isobutrylaldehyde						H	H	
Polychlorinated dioxins and furans	G	G	G	G	G			
SVOCs total								
acetophenone								I
diethyl phtalate								
Isophrone								
2-methyl napthalene								
2-picolene								

Emission / Source	Boiler	Package Boiler	Rotary Calciner	Stationary Calciner	Lime Kiln	Hydrate vacuum exhaust	Mills Vent	Digestion blow off
pyridine								
benzyl alcohol								I
alkyl phenols								I
phenols								I
2-Cyclopenten-1-one, 2-methyl								I
2-Cyclopenten-1-one, 3-methyl								I
2-Cyclopenten-1-one, 3,4-dimethyl								I
2-Cyclopenten-1-one, 2,3-dimethyl								I
3-Hydroxy-3-methyl-2-butanone								I
4-Hydroxy-4-methyl-2-pentanone								I
Nonane								I
Metals								
As	G	G	G	G	G			
Cd	G	G	G	G	G			
Co	G	G	G	G	G			
Cr	G	G	G	G	G			
Cr (VI)	G	G	G	G	G			
Cr (III)	G	G	G	G	G			
Cu	G	G	G	G	G			
Pb	G	G	G	G	G			
Ni	G	G	G	G	G			
Hg	G	G	G	G	G			
Odour	J		J	J	J	J	J	J