# Report

## Air Quality and Greenhouse Gas Assessment for the McArthur River Mine Phase 3 Development Project

5 JANUARY 2012

Prepared for

METSERVE Pty Ltd

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42626795

URS

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# Introduction

URS Corporation has been commissioned to undertake an air quality and greenhouse gas assessment for the Phase 3 Development Project Environmental Impact Statement (EIS) at McArthur River Mine (MRM). MET Serve Pty Ltd is the Project Manager of the EIS on behalf of Xstrata Zinc, who has 100% ownership of McArthur River Mine Pty Ltd.

## 1.1 Project Background

The McArthur River Mine (MRM) is located in the Northern Territory (NT), approximately half way between Darwin and Mount Isa. MRM is located approximately 60 kilometres south-west of the township of Borroloola, 120 kilometres south of the Bing Bong loading facility on the Gulf of Carpentaria and 900 kilometres south-east of Darwin in the Gulf Region of the Northern Territory in Australia (Figure 1-1).


**Figure 1-1 MRM location**

MRM is a major operation developing one of the largest known sedimentary stratiform zinc-lead-silver deposits. It has a current mine life of 21 years (concluding 2027) extracting 2.5 million tonnes of ore per annum. After extraction and processing of the ore onsite, the product zinc concentrate is then transported by truck to Bing Bong port along the existing sealed highway, before being loaded into barges in the Gulf of Carpentaria where it is transferred to awaiting cargo vessels.

# 1 Introduction

Xstrata has plans to undertake the third phase of development for the mine which will increase the mine life by 9 years to 2036, with a mining rate of approximately 5 million tonnes per annum. To achieve this increase, the open cut pit will be expanded by doubling the width, and by doubling the depth. Proposed major changes to the mine are detailed in Table 1-1.

**Table 1-1 Overview of proposed changes to the MRM**

| Item | Current Approved Project | Proposed MRM Phase 3 Development Project |
|---|---|---|
| Resource | 53 million tonnes Reserve | Likely mining reserve of 115 million tonnes total |
| Mine Life | Until 2027 | Until 2036 |
| Mining Method | Open pit mine using conventional drilling, blasting, loading and haulage methods | No change |
| Open Pit Dimensions | Length – 1500 metres<br>Width – 800 metres<br>Depth – 210 meters<br>Overall footprint – 103 hectares | Length – 1750 metres<br>Width – 1500 metres<br>Depth – 420 meters<br>Overall footprint – 205 hectares<br>(within the existing approved bunding area) |
| Mining Rate Capacity | 2.5 million tonnes of ore per annum | Approximately 5 million tonnes of ore per annum |
| Waste Rock | Stored on surface in overburden emplacement facility (OEF)- capacity 185 Mt | Stored on surface in existing and new overburden emplacement facilities – an additional 500Mt |
| Processing | Flotation process producing concentrate (46% Zn concentrate grade) | No Change in method. Upgrade of processing capacity. |
| Power | Gas fired turbines producing 20 MW. Fired with natural gas deliver to site via a pipeline from Daly Waters | Gas power station upgrade to a total of 45-50 MW |
| Product | 360,000 dmt/y of lead-zinc-silver concentrate (166,000 tonnes of zinc in concentrate) | 800,000 dmt/y of lead-zinc-silver concentrate (368,000 tonnes of zinc in concentrate) |
| Transport | Concentrate trucked 115 km to Bing Bong Port, transferred to barge, then offshore loading onto ships | No change in method.<br>Approximate doubling of concentrate volume trucked to Bing Bong Port for shipment (up from 9 truck movements per day to 18) |
| Water Management | Bore fields water supply (if required)<br>Mine water collected and utilised in the process<br>Emergency discharge licence in place | To continue.<br>Existing water management structures to be upgraded<br>No diversions necessary |
| Workforce | 440 permanent staff and contractors | Construction workforce peak –900<br>Approximately 550 permanent staff and contractors |

Figure 1-2 shows the current mine, and the proposed expansion works.

## 1 Introduction

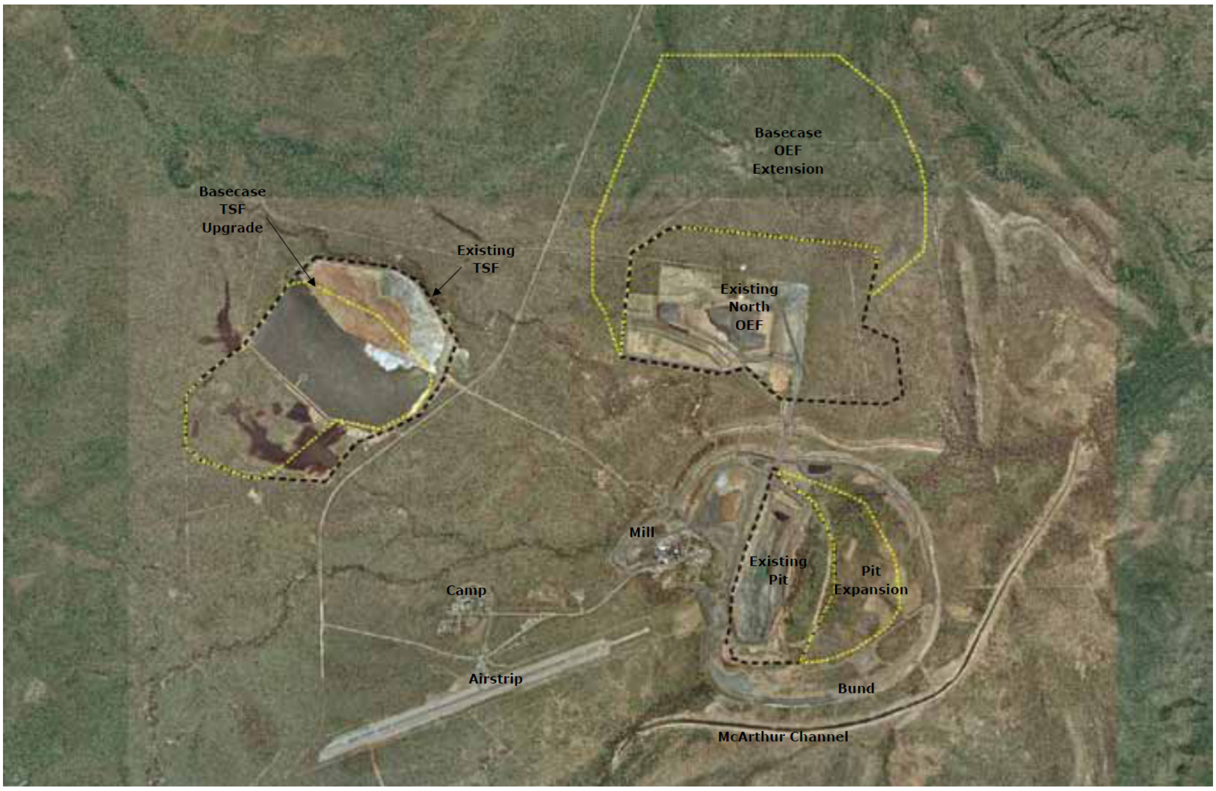



**Figure 1-2 Existing and Proposed MRM**

Xstrata have triggered the Environmental Impact Statement (EIS) process under the NT legislation, requiring for emissions to atmosphere to be assessed against the air quality legislation, and GHG emissions to be calculated.

This report does not consider impacts of plume rise from the proposed power station on potential aviation safety.

## 1.2 Assessment Methodology Overview

### 1.2.1 Air Quality

Emissions from the Project are generated primarily from activities that move overburden, and move and process ore. The main emission of concern is particulates, and to a lesser extent, emissions associated with the power station.

Dust particles emitted to the atmosphere may be characterised by particle size according to the legislative assessment requirements of the Project Goals for air quality. These are:

- Particulate matter less than 50 micrometres (µm) in aerodynamic diameter - Total suspended particulates (TSP);
- Particulate matter less than 10 µm in aerodynamic diameter ($PM_{10}$); and
- Particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$).

$PM_{10}$has the potential to enter the human respiratory system, whilst particles between 10 µm and 50 µm in aerodynamic diameter are related to nuisance dust through deposition on property.

# 1 Introduction

The emissions and impacts of dust from mine-related activities considered in this assessment are related to:

- Deposition of TSP;
- Ambient concentrations of TSP, $PM_{10}$; and $PM_{2.5}$.

The main emissions of metals from the site will be lead and zinc, which are a component of the fugitive dust emissions from the mining and crushing operations. Exposures to elevated levels of lead can give rise to a range of toxic effects. Zinc, however, is an essential trace element in the diet of all living organisms from bacteria to humans. However, either too little zinc or too much zinc can be harmful to human health.

Emissions of trace metals to atmosphere from mine-related activities considered in this assessment include:

- Lead; and
- Zinc.

Emissions to atmosphere that result from the power station include the following species:

- Nitrogen dioxide ($NO_2$);
- Carbon Monoxide (CO);
- Sulphur Dioxide ($SO_2$); and
- Volatile Organic Compounds (VOCs), such as formaldehyde ($CH_2O$)

In order to consider the effects of VOCs emitted from the power station, formaldehyde has been selected for further assessment. This is considered to be a conservative approach as the emission rate for formaldehyde is relatively high, whilst the ambient concentration standard set for the protection of human health is low compared to other species.

Emissions from vehicles result in elevated concentrations of these species in the area surrounding the road. At locations beyond approximately 200 m from the road centreline, ambient concentrations return to background levels (DMRB, 2007). Due to the proximity of the sensitive receptors to the Project and the number of vehicle movements, these species are not considered to be emitted in sufficient quantities to impact significantly on air quality at these locations. Therefore, air quality impacts associated with, $NO_2$, PM, and VOCs from vehicular emissions have not been considered further.

The assessment considers the impacts on air quality by predicting future ground level concentrations, and rates of deposition of dust, at sensitive receptors of emissions from the Project. Predictions have been undertaken for the following years of the Project in order to represent the main phases of development through to mine closure:

- Year 2011 (base case);
- Year 2015;
- Year 2025;
- Year 2030; and
- Year 2035

Although the mine life will run to 2036, the final year of assessment for emissions at the end of this period has been selected as 2035 because mining is predicted to decline in 2036.

# 1 Introduction

To predict ambient concentrations of emitted species, an inventory of emissions and simulated meteorological fields were developed and used as inputs into the US EPA approved atmospheric dispersion modelling software package CALPUFF.

The detailed emissions inventory for dust emissions from the Project was developed using information provided by the proponent, in conjunction with emission factors from both the Australian National Pollutant Inventory (NPI) emission estimation technique manual (EETM) and US EPA AP-42 emission estimation manual.

Site-specific meteorological fields were developed for 2009 using a combination of meteorological data for the McArthur River Mine Airport (located at the Project site), the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) prognostic meteorological model The Air Pollution Model (TAPM), and the US EPA approved meteorological model CALMET.

A comparison between predicted ground-level concentrations of dust associated with the Project and regulatory ambient air quality objectives at identified receptor locations have been presented in this report.

Whilst predicted ground level concentrations at sensitive receptor locations are presented in tabular form for all years modelled, contour plots are presented for years 2015 and 2025 as predictions for these years were identified as representing worst-case impacts.

### 1.2.2 Greenhouse Gas

Emissions of greenhouse gases from the proposed Project will be generated primarily from electricity generation and fuel use. This assessment has calculated the scope 1 and scope 2 emissions in accordance with the National Greenhouse and Energy Reporting Act 2007, and has considered the following greenhouse gases:

- Carbon dioxide ($CO_2$);
- Methane ($CH_4$); and
- Nitrous Oxide ($N_2O$).

In addition, an assessment of the lost carbon sink capacity due to clearing has also been undertaken using the Australian Government's Department of Climate Change FullCAM Carbon Accounting Model.

The predicted emissions have been presented as a percentage of Australian and Northern Territory emissions for 2009, and as a percentage of non-energy Australian mining.

# Project Description

The mine follows a simple process to access the ore, process it, and transport it to the port of Bing Bong. This process involves:

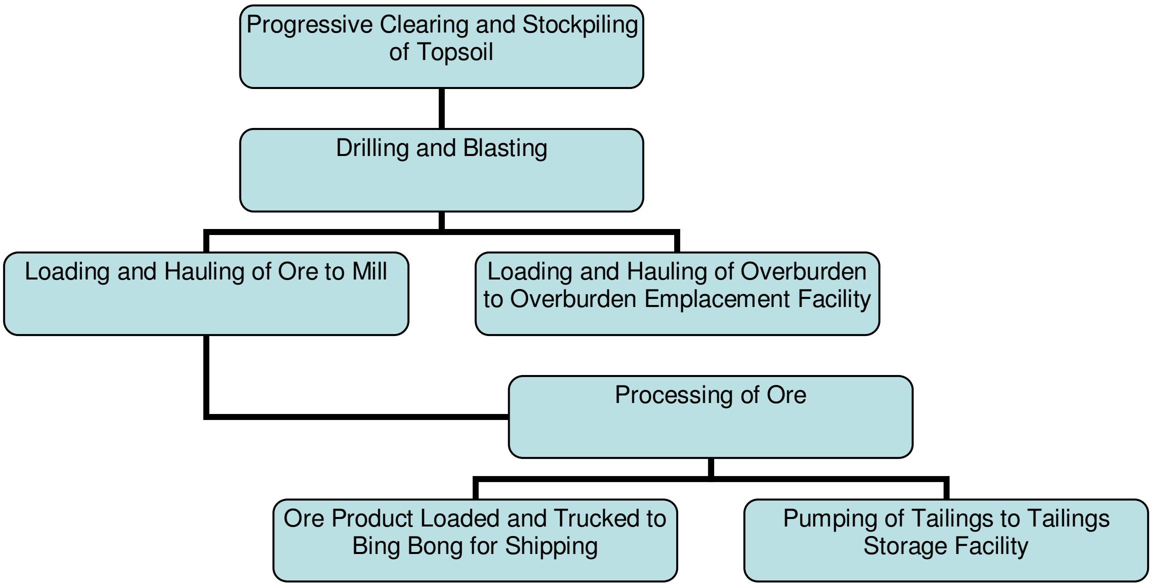



**Figure 2-1 MRM Process Flowchart**

The mine is currently approved to process 2.5 million tonnes of ore per annum, and the proposed expansion is to increase this to approximately 5 million tonnes per annum. While the process of extracting the ore and processing it at the mill essentially won't change, the physical characteristics of the mine will. The pit will be expanded to double the size (depth, width and footprint), and the capacity of the overburden emplacement facility (OEF) will be substantially increased from 185Mt to 685Mt by both increasing the existing OEF, and creating a new OEF.

Product will continue to be trucked approximately 115km from the mine to the Bing Bong Port, the number of trucks will approximately double from 9 truck movements per day up to 18.

In order to facilitate these increases, the existing power arrangements will also require adjustment. It is predicted at total of 45-50 MW will be required, up from the current gas fired turbines producing 20 MW. In order to deliver this power requirement, two options are being considered:

- Option 1 – augment existing power station by adding sufficient capacity to meet forecast demand:
  - 3 x Solar Taurus T-7001 (existing);
  - 3 x Solar Centaur T-4500 (existing);
  - 1 x Caterpillar 3516 gas engine (existing); and
  - 14 x J620 Spark Ignition Gas Engines (Proposed).
- Option 2 – replace existing power station with new generators:
  - 16 x J620 Spark Ignition Gas Engines (Proposed); and
  - 2 x Caterpillar 3516B HD diesel generators for emergency operation and for mill start operation.

## 2 Project Description

It should be noted that the additional plant to be used for option 1 and option 2 have not yet been finalised. The engines used in this assessment have representative emissions for the class of engines being considered for each option.

# Legislative Framework

## 3.1 Air Quality

### 3.1.1 Introduction

The Northern Territory (NT) Minister for Natural Resources, Environment and Heritage has determined that the proposed development requires formal assessment under the NT Environmental Assessment Act 1982, at the level of an Environmental Impact Statement (EIS).

The Northern Territory Government issued Guidelines for the Preparation of an EIS in August 2011, which require the proponent to:

- describe the quantity and sources of greenhouse gas emissions caused by the project and any actions to mitigate or offset emissions;
- describe the sources of dust emissions and particulate matter caused by the mining, processing and transport from the McArthur River Mine;
- demonstrate that zinc and lead laden dust mitigation measures at the mine site will ensure that an increase in production will not cause environmental contamination or health issues; and
- demonstrate that monitoring of dust emissions at mine site and Bing Bong Port will measure effectiveness of mitigation measures.

With relation to the power station upgrade, the proponent is required to provide an estimate of the greenhouse gases that will be produced over the life of the mine from power production.

As NT does not have specific air quality legislation, other criteria have been used to determine the environmental goals of the project with regard to air quality. In selecting these, the following sources (listed in order of priority) have been used:

- National Environment Protection Measure for Ambient Air Quality (the 'Air NEPM');
- Australian state legislation; and
- Other international criteria.

### 3.1.2 National Environment Protection Council

The National Environment Protection Council (NEPC) comprises environment ministers from the Australian Government and each state and territory taking a cooperative approach to the management of environmental issues in Australia. The purpose of NEPC is to ensure that:

- Australians enjoy the benefit of equivalent protection from air, water or soil pollution and from noise wherever they live, and
- business decisions are not distorted and markets are not fragmented by variations in major environment protection initiatives between member governments.

NEPC has powers to make National Environment Protection Measures (NEPMs) on:

- ambient air quality
- ambient marine, estuarine and fresh water quality
- the protection of amenity in relation to noise (but only if differences in environmental requirements relating to noise would have an adverse effect on national markets for goods and services)
- general guidelines for the assessment of site contamination
- environmental impacts associated with hazardous wastes
- the re-use and recycling of used materials

## 3 Legislative Framework

- motor vehicle noise and emissions (in consultation with the National Transport Commission)

Regarding air quality, two NEPMs exist; the Ambient Air Quality NEPM establishes ambient air quality standards and monitoring and reporting protocols for listed air pollutants, and the Air Toxics NEPM establishes procedures to collect information regarding certain hazardous air pollutants in order to develop national standards by 2012.

In the absence of Northern Territory air quality legislation, the Ambient Air Quality NEPM standards have been adopted. Where the NEPM does not provide a standard for a pollutant associated with this project, standards have been adopted from other states of Australia.

### *Ambient Air Quality NEPM*

The Ambient Air Quality NEPM provides the following standards for emissions applicable for the MRM expansion project:

- Particles as $PM_{10}$;
- Particles as $PM_{2.5}$;
- Nitrogen dioxide;
- Sulphur Dioxide;
- Carbon Monoxide; and
- Lead.

Table 3-1 provides the relevant standards and goals.

**Table 3-1 Ambient Air Quality NEPM: Standards and Goal for Pollutants**

| Pollutant | Averaging Period | Maximum Concentration | Goal within 10 years, Maximum allowable exceedances |
|---|---|---|---|
| Particles as PM10 | 1 day | 50 µg/$m^3$ | 5 days a year |
| Particles as PM2.5* | 1 day | 25 µg/$m^3$ | Goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of a review of this Measure scheduled to commence 2005 |
| | 1 year | 8 µg/$m^3$ | |
| Nitrogen dioxide | 1 hour | 0.12 ppm (225 µg/$m^3$) | 1 day a year |
| | 1 year | 0.03 ppm (56 µg/$m^3$) | none |
| Sulfur dioxide | 1 hour | 0.20 ppm (522 µg/$m^3$) | 1 day a year |
| | 1 day | 0.08 ppm (208 µg/$m^3$) | 1 day a year |
| | 1 year | 0.02 ppm (52 µg/$m^3$) | None |
| Carbon monoxide | 8 hours | 9.0 ppm (10 mg/$m^3$) | 1 day a year |
| Lead | 1 year | 0.50 µg/$m^3$ | None |
| Note *- Particles as $PM_{2.5}$ is an advisory reporting standard | | | |

### *Air Toxics NEPM*

The Air Toxics NEPM provides a standard for the ambient concentration of formaldehyde. This is a monitoring investigation level, which means the concentration of an air toxic which if exceeded requires an appropriate form of further investigation and evaluation. The choice of this goal is conservative as these are levels of air pollution below which lifetime exposure, or exposure for a given averaging time, does not constitute a significant health risk. If these limits are exceeded in the short-term it does not mean that adverse health effects automatically occur.

| Pollutant | Averaging Period | Maximum Concentration |
|---|---|---|
| Formaldehyde | 24 hours | 0.0 ppm (54 µg/$m^3$ at 0K) |

### 3.1.3 Other Applicable Standards and Goals

Emissions of the following species are expected to increase with the expansion of the MRM and do not have standards or goals outlined in NEPMs:

- TSP
- Zinc
- Dust Deposition

The Queensland Department of Environment and Resource Management (DERM) has legislated a standard for emissions of TSP. This is detailed below.

**Table 3-2 Queensland DERM Standard for TSP**

| Indicator | Environmental Value | Objective (µg/m³) | Period |
|---|---|---|---|
| TSP | Health and wellbeing | 90 | 1 year |

The New South Wales Department of Environment Climate Change and Water (DECCW) has legislated standards for dust deposition. These are detailed below.

**Table 3-3 New South Wales DECCW Standards for Dust Deposition**

| Indicator | Environmental Value | Objective | Period |
|---|---|---|---|
| Dust Deposition | Nuisance | 4 grams/$m^2$/month | Monthly (total) |
| | Nuisance | 2 grams/$m^2$/month | Monthly (increase) |

The Ontario Ministry of the Environment (MOE) has legislated a standard for emissions of Zinc as particulate. This is detailed below.

**Table 3-4 Ontario MOE Standard for Zinc**

| Indicator | Environmental Value | Objective (µg/m³) | Period |
|---|---|---|---|
| Zinc | Health and wellbeing | 120 | 24 hour |

The criteria selected above are all set for the protection of human health. Further criteria for the protection of ecosystems have been considered, although no rare or endangered flora have been identified at or near the site and no endangered or vulnerable fauna have been identified in the area affected by the development. As noted above, areas of standing water and rehabilitation areas represent the most sensitive ecosystems in the vicinity.

Queensland DERM has standards for nitrogen dioxide and sulphur dioxide for the protection of the health and biodiversity of ecosystems, as shown below.

**Table 3-5 Queensland DERM Standard for the Protection of Ecosystems**

| Indicator | Environmental Value | Objective (µg/m³) | Period |
|---|---|---|---|
| Nitrogen dioxide | Ecosystems | 33 | 1 year |
| Sulfur dioxide | Ecosystems | 22 | 1 year |

### 3.1.4 Project Goals

The Project Goals adopted for each of the applicable pollutants are included in Table 3-6.

**Table 3-6 Summary of Project Goals for applicable pollutants**

| Pollutant | Averaging Period | Project Goal | Jurisdiction |
|---|---|---|---|
| TSP | 1 year | 90 µg/m$^3$ | QLD DERM |
| $PM_{10}$ | 1 day | 50 µg/m$^3$ (exceedances allowed 5 days per year) | Air NEPM |
| $PM_{2.5}$* | 1 day | 25 µg/m$^3$ | Air NEPM |
| | 1 year | 8 µg/m$^3$ | Air NEPM |
| $NO_2$ | 1 hour | 225 µg/m$^3$ (exceedence allowed 1 day per year) | Air NEPM |
| | 1 year | 56 µg/m$^3$ | Air NEPM |
| | 1 year | 33 µg/m$^3$ (ecosystems only) | QLD DERM |
| $SO_2$ | 1 hour | 522 µg/m$^3$ (exceedence allowed 1 day per year) | Air NEPM |
| | 1 day | 208 µg/m$^3$ (exceedence allowed 1 day per year) | Air NEPM |
| | 1 year | 52 µg/m$^3$ | Air NEPM |
| | 1 year | 22 µg/m$^3$ (ecosystems only) | QLD DERM |
| CO | 8 hours | 10 mg/m$^3$ (exceedence allowed 1 day per year) | Air NEPM |
| Formaldehyde | 24 hours | 0.04 ppm (49 µg/m$^3$ at 298K) | Air Toxics NEPM |
| Lead | 1 year | 0.50 µg/m$^3$ | Air NEPM |
| Zinc | 1 day | 120 µg/m$^3$ | Ontario MOE |
| Dust Deposition | 1 year (total) | 4 g/m$^2$/month | NSW DECCW |
| | 1 year (increase) | 2 g/m$^2$/month | NSW DECCW |

* Goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of a review of this Measure scheduled to commence 2005

## 3.2 Greenhouse Gas

### 3.2.1 International Policy

In 1997, the United Nations Framework Convention on Climate Change (UNFCC) produced the Kyoto Protocol aimed at limiting the greenhouse gas (GHG) emissions of countries that ratified the protocol (United Nations, 1997). The Kyoto Protocol entered into force in 2005, and was designed to work by setting limits to individual mandatory GHG emission targets using the ratifying country's 1990 GHG emissions as their baseline.

The Kyoto Protocol sets out three flexibility mechanisms to allow GHG targets to be met:

- The Clean Development Mechanism;
- Joint Implementation; and
- International Emissions Trading.

These three mechanisms effectively allow GHG reductions to be made at the point where the marginal cost of that reduction is lower. An industrialised country sponsoring a GHG reduction project in a developing country can claim that reduction towards its Kyoto Protocol target and those GHG reductions can be traded.

Australia ratified the Kyoto Protocol in December 2007 and has committed to meeting its Kyoto Protocol target of 108% of 1990 emissions by 2012.

### 3.2.2 Australian Policy

The Australian policy on climate change was released in July 2007 and is managed by the Commonwealth Government Department of Climate Change and Energy Efficiency (DCCEE). The policy sets out the Commonwealth Government's focus on reducing GHG emissions, encouraging the development of low emissions and emission reduction technology climate change adaptation, and setting national policies and response to climate change within a global context.

On 24 February 2011, the Prime Minister, Julia Gillard, announced a climate change framework outlining the broad architecture for a carbon price mechanism, which has been considered by the Multi-Party Climate Change Committee (DCCEE, 2011). The proposed mechanism has been agreed to by members of the Committee.

The proposal focuses on the high level architecture, sectoral coverage, international linking arrangements and potential progression to emissions trading. It outlines a two-stage plan for a carbon price mechanism commencing in July 2012 with a fixed price period for three to five years before transition to an emissions trading scheme.

Further detailed discussions are required in relation to a starting carbon price for the mechanism; assistance arrangements for households, communities and industry; and support for low emissions technology and innovation. The architecture also allows for consideration of other design options such as phased coverage and an intensity-based allocation scheme for the electricity sector.

#### *Garnaut Review*

The Commonwealth Government commissioned the Garnaut Climate Change Review (Garnaut Review) as an independent study to examine the impacts, challenges and opportunities of climate change for Australia. The Garnaut Review's final report was released on 30 September 2008 (Garnaut, 2008). The Garnaut Review considered the potential impacts that climate change will have on Australia's environment and economy, and proposed medium- to long-term policies and policy frameworks to improve the prospects for sustainable prosperity.

# 3 Legislative Framework

### *Clean Energy Future*

In July 2011, the Australian Government announced the plan for a Clean Energy Future (CEF) which has four key elements (Department of Climate Change and Energy Efficiency, DCCEE, 2011[1]):

- Putting a price on carbon pollution;
- Promoting innovation and investment in renewable energy;
- Improving energy efficiency;
- Creating opportunities in the land sector to cut pollution.

The plan will operate in two phases: a fixed price phase commencing July 2012 and a floating price phase commencing July 2015. Carbon permits will be required to be submitted by entities that emit more than 25,000 t $CO_2$-e. The mechanism by which the CEF will be implemented will be The Clean Energy Legislative Package. The draft legislative package was recently available for public comment and changes to the legislation will occur prior to submission to parliament. The requirements associated with the project, however, cannot be established until legislation is passed.

The CEF is supported by the National Greenhouse and Energy Reporting Act 2007 (NGER) which establishes a national framework for Australian corporations to report greenhouse gas emissions, reductions, removals and offsets, and energy consumption and production. It is designed to provide robust data as a foundation to the CEF.

### *National Greenhouse and Energy Reporting Act 2007 (NGER Act)*

The *National Greenhouse and Energy Reporting Act 2007* (NGER Act) established a national framework for Australian corporations to report GHG emissions, reduction removals and offsets, and energy consumption and production.

From 1 July 2008, corporations have been required to register and report if:

- They control facilities that emit 25 kilotonnes or more of GHG ($CO_2$ equivalent), or produce/consume 100 terajoules or more of energy; or
- Their corporate group emits 125 kilotonnes or more GHG ($CO_2$ equivalent), or produces/consumes 500 terajoules or more of energy.

### *Energy Efficiency Opportunities (EEO)*

The Commonwealth Government's Energy Efficiency Opportunities (EEO) program came into effect in July 2006, and mandates large energy users (over 0.5 petajoules [PJ] of energy consumption per year) to participate in the program. The objective of this program is to drive ongoing improvements in energy consumption amongst large users. Businesses are required to identify, evaluate and report publicly on cost-effective energy saving opportunities.

The EEO program is designed to result in:

- Improved identification and uptake of cost-effective energy efficiency opportunities;
- Improved productivity and reduced GHG emissions; and
- Greater scrutiny of energy use by large energy consumers.

The EEO program will be incorporated into the National Framework for Energy Efficiency.

[1] http://www.climatechange.gov.au/reporting

# 3 Legislative Framework

As the sole Proponent of the Project, and a large energy user, the Proponent is a mandatory participant, and triggers the reporting requirements under the EEO program. Consequently, the minimum requirements of the scheme will need to be met by the Project.

As the EEO program's Assessment Framework takes a whole-of-business approach to assessing energy use and energy saving opportunities, the framework involves corporations looking at the many factors influencing energy use. These factors include leadership, management and policy; the accuracy and quality of data and analysis; the skills and perspectives of a wide range of people; decision making; and communication outcomes. Participants are expected to meet minimum requirements in each of these areas.

# Environmental Values

The environmental values of the air environment to be enhanced or protected are:

- The qualities that make the air environment suitable for the life, health and wellbeing of humans,; and
- The aesthetic environment.

The following sections address the climate and meteorology, the existing air quality and sensitive receptor locations.

## 4.1 Climate and Meteorology

This section provides a brief summary of climate, rainfall patterns, humidity, air temperature and wind in the region of the Project. Two monitoring sites have been chosen to represent the region of the project;

- The McArthur River Mine Bureau of Meteorology (BOM) monitoring station, located at the MRM airport represents the mine site region of the project. Particulars of this station include:
  - 014704 MacArthur River Mine
  - Commenced 1968, records ongoing
  - Location: 16.44 Degrees South, 136.08 Degrees East
  - Elevation 40 m
  - Records hourly
- The Centre Island monitoring station is the closest BOM monitoring station to Bing Bong, and is considered representative of the port region of the project. Particulars of this station are:
  - 014703 Centre Island
  - Commenced 1968, records ongoing
  - Location: 15.74 Degrees South, 136.82 Degrees East
  - Elevation 12m
  - Records every three hours

Data regarding mixing height and stability class is not recorded at either of these monitoring stations. In order to present this information for the MRM (section 4.1.5), outputs from the meteorological modelling has been adopted. Details of the meteorological modelling are provided in section 5.

### 4.1.1 Climate

The McArthur River region experiences a tropical monsoonal climate with two seasons: the wet season which lasts from December to March; and the generally dry conditions which last for the remainder of the year. The main climatic hazard in the region is the occurrence of tropical cyclones which may produce flooding, wind damage and high seas. The El Nino Southern Oscillation phenomenon, a global system of atmospheric and oceanic interactions, can also have a significant effect on year-to-year weather variability, including the timing and amount of wet season rainfall.

### 4.1.2 Temperature

Ambient temperature at MRM has an annual mean daily maximum of 35 ºC and annual mean daily minimum of 20 ºC (Figure 4-1). The mean annual temperatures for 9 am and 3 pm are 26 ºC and 33 ºC respectively. The maximum temperature recorded occurred in December 1990 and was 46 ºC.

# 4 Environmental Values

June and July are the coolest months; however mean minimum temperatures are still mild with minimum 9 am and 3 pm temperatures of 20 ºC and 29 ºC respectively.

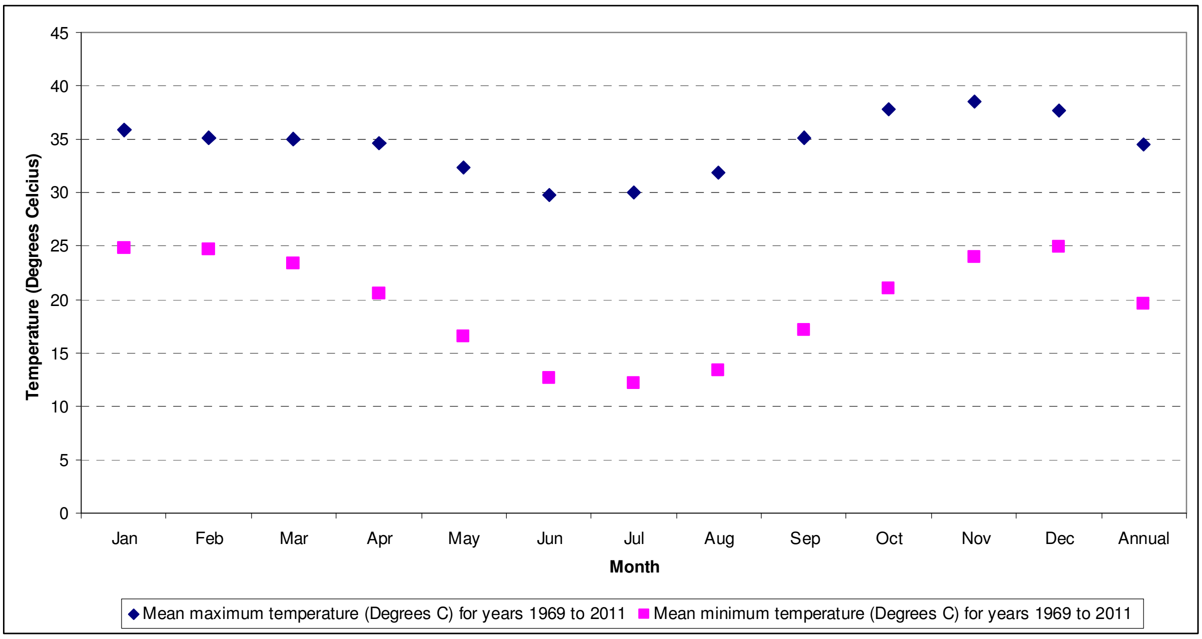



**Figure 4-1 BOM MRM Temperature Statistics (1969 to 2011)**

At Centre Island, the mean daily maximum temperature is 35 ºC and annual mean daily minimum of 24 ºC (Figure 4-2).

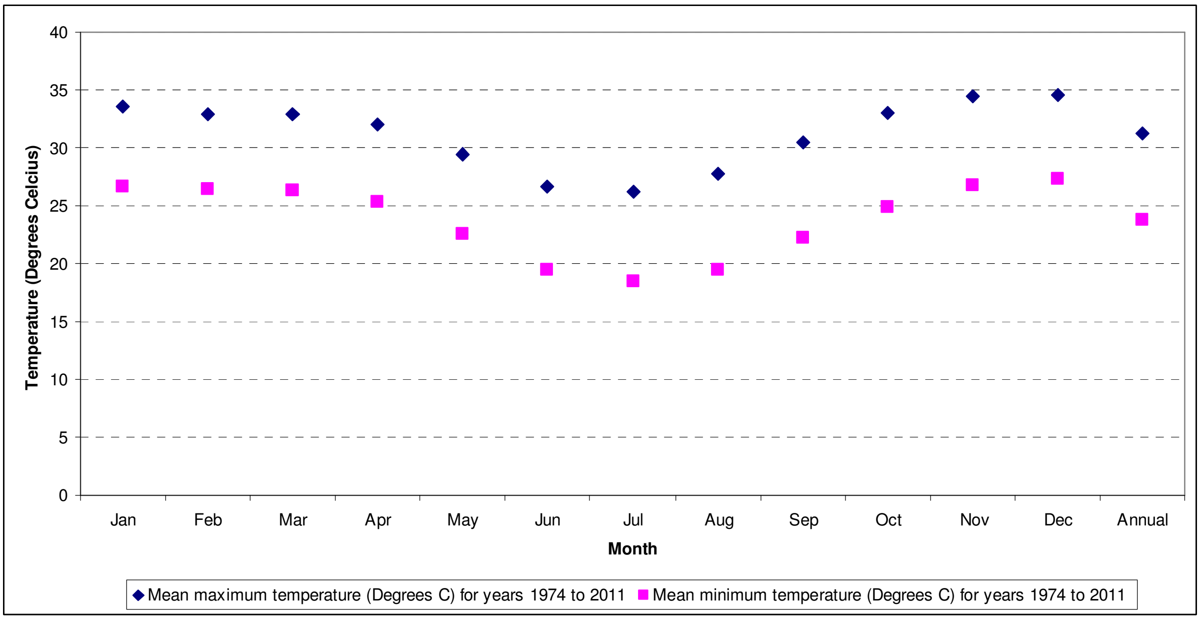



**Figure 4-2 BOM Centre Island Temperature Statistics (1974 to 2011)**

### 4.1.3 Rainfall and Humidity

Monthly mean rainfall values for the period of record 1968 to April 2011 and monthly mean humidity percentages for 9am and 3 pm from the MRM monitoring site are provided in Figure 4-3. The data indicate a mean annual rainfall of 793 mm, with approximately 85% of rainfall occurring in the wet season (December to March).

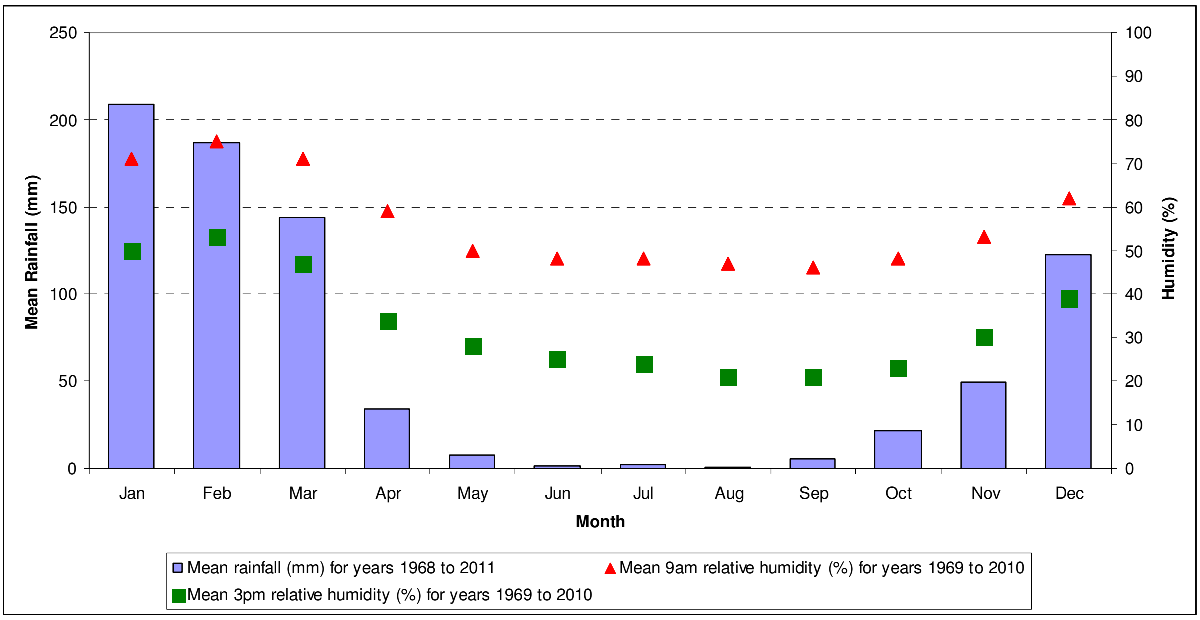



**Figure 4-3 BOM MRM Rainfall and Humidity Statistics (1968/9 to 2011)**

The 9am and 3pm annual mean relative humidity percentages for the period of records between 1969 and April 2011 are 57% and 33% respectively.

Rainfall at Centre Island follows a similar pattern, however there is a higher annual rainfall reported for this area of 1069 mm (Figure 4-4). Humidity is generally higher, corresponding to the coastal location of the monitoring site.

# 4 Environmental Values

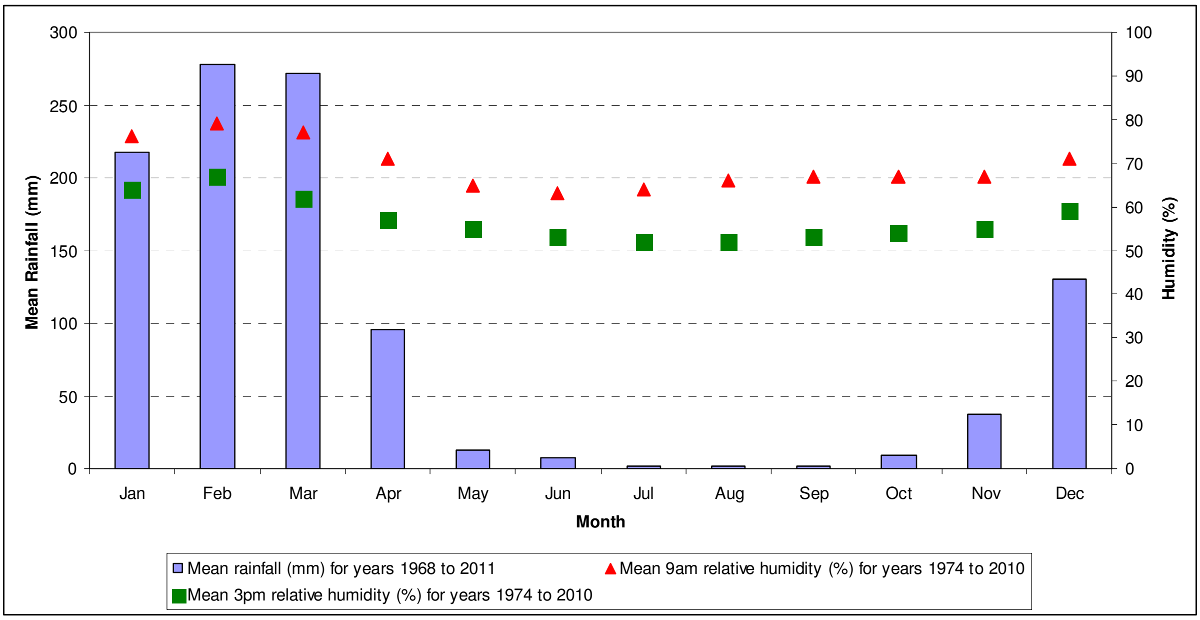


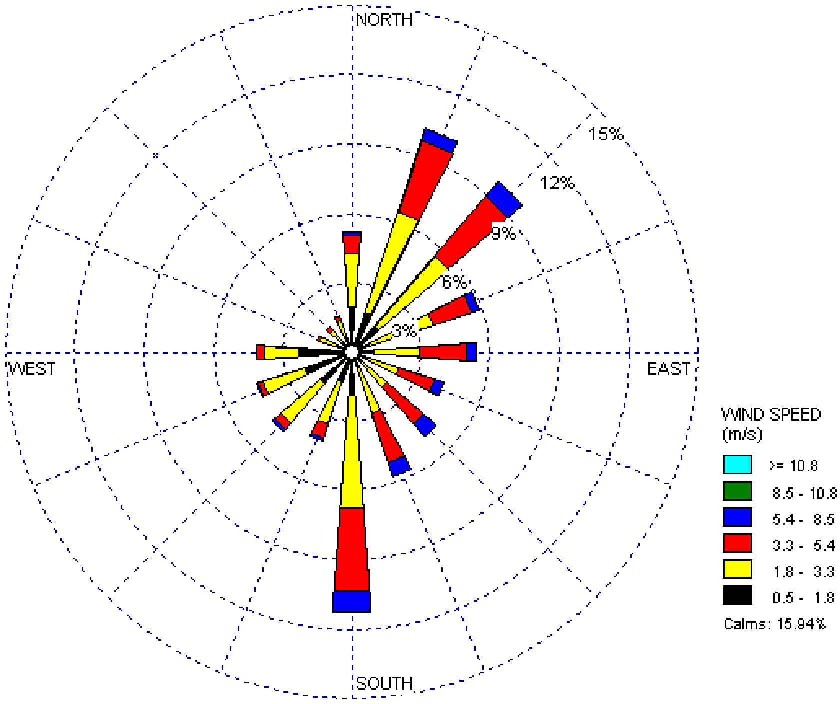

**Figure 4-4 BOM Centre Island Rainfall and Humidity Statistics (1968/74 to 2011)**

### 4.1.4 Wind Speed and Direction

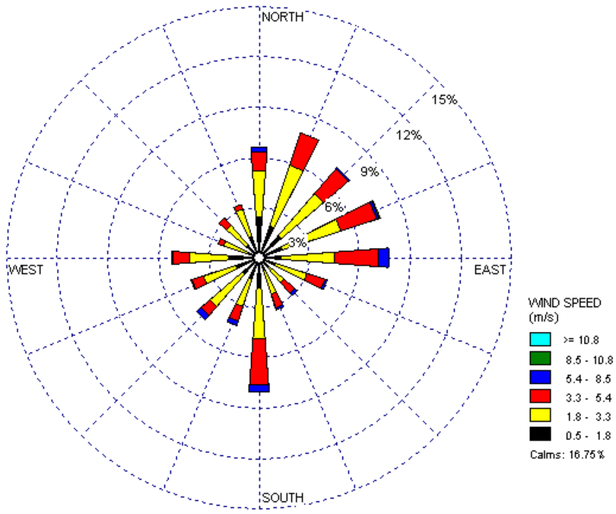
Figure 4-5 provides wind roses for the annual and seasonal periods at the MRM. The site has a north-east prevailing wind throughout the year, with a strong southerly particularly through the dry season (April to November). The wet season, December to March, is characterised by slightly lighter winds which are less dominated by any particular direction.

Time of day wind roses provided in Appendix A show mornings for MRM (Figure A-1) are generally calm with a southerly picking up during daylight hours. In the afternoons, winds are generally stronger but are prone to originating anywhere from the south through east and from the north-east. Winds in the evenings are dominated by north-north-easterlies, with occasional southerlies.

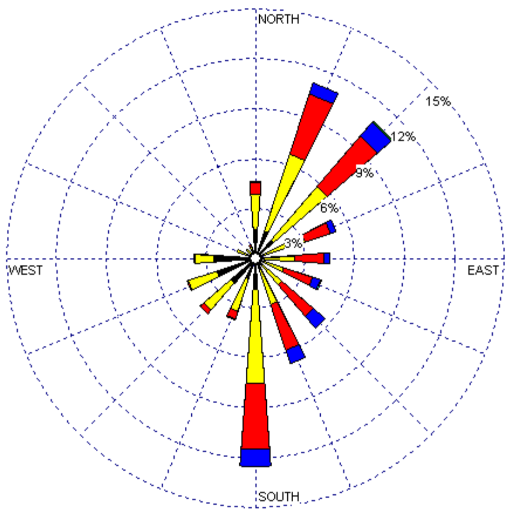
# 4 Environmental Values




Annual




Dec to Mar, Wet Season




Apr to Nov, Dry Season

**Figure 4-5 BOM MRM Annual and Seasonal Wind Roses**

When the annual wind rose for MRM is overlain at the monitoring site location on the topography (Figure 4-6), it can be seen that the winds are significantly influenced by the surrounding terrain. Mornings typically have a southerly as the air drains from the surrounding ridges down into the floodplain and toward the ocean (to the north-east). In the afternoons the cycle is reversed, with flows coming up the valley toward the ridge tops. This results in the annual wind rose being dominated by north/north-easterly and southerly wind patterns.

# 4 Environmental Values

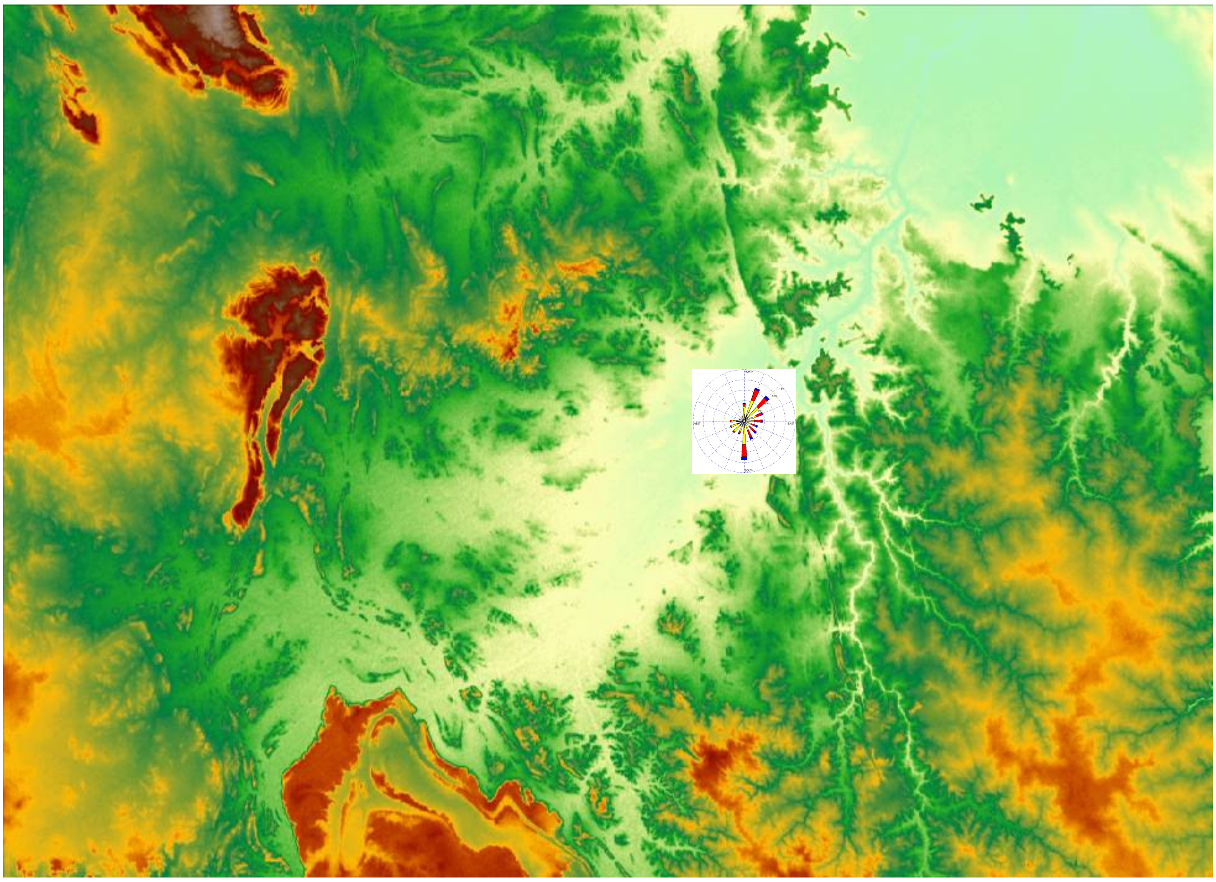
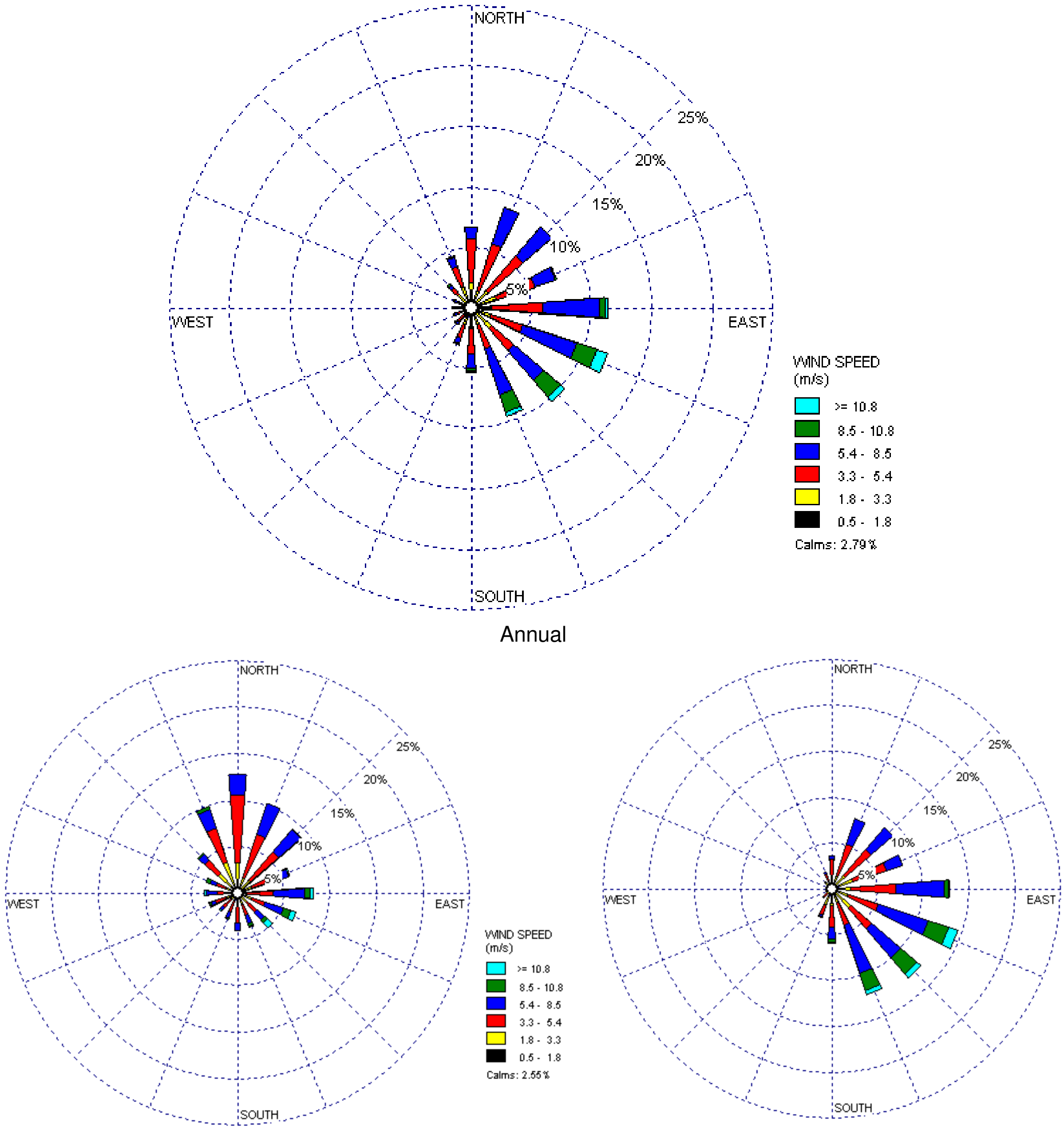


**Figure 4-6 MRM Annual Wind Rose overlayed on the Surrounding Topography**

At Centre Island, annual winds are generally from the south-east, with occurrences from the north-east. Wet season (December to March) winds are predominantly from the northern sector with occasional winds from the east and south-east. Winds during the dry season (April to November) are predominantly from the south-east. Throughout the whole year winds from the south-east are generally stronger than from any other direction.

Winds during the night (Figure A-2) are strong with prevailing directions from the north through east. During daylight hours, winds continue to be strong but are dominated from the south-east.

# 4 Environmental Values




Dec to Mar, Wet Season

Apr to Nov, Dry Season

**Figure 4-7 BOM Centre Island Annual and Seasonal Wind Roses (CALMET, 2009)**

### 4.1.5 Mixing Height

The meteorological data generated by CALMET was analysed for estimates of mixing height. Figure 4-8 presents the mixing height box and whisker plots by hour of the day. At night, the mixing height is very low, mostly close to the model lower limit of 50m (above the surface level), and the air is very stable. The mixing height rises sharply after sunrise and often reaches to about 1,500m to 2,000m or higher in the afternoon.

Mixing height is the maximum height that rapid vertical mixing takes place in the atmosphere unless the plume has enough heat or velocity to break through; it essentially acts as a lid prevent further dispersion above that height.

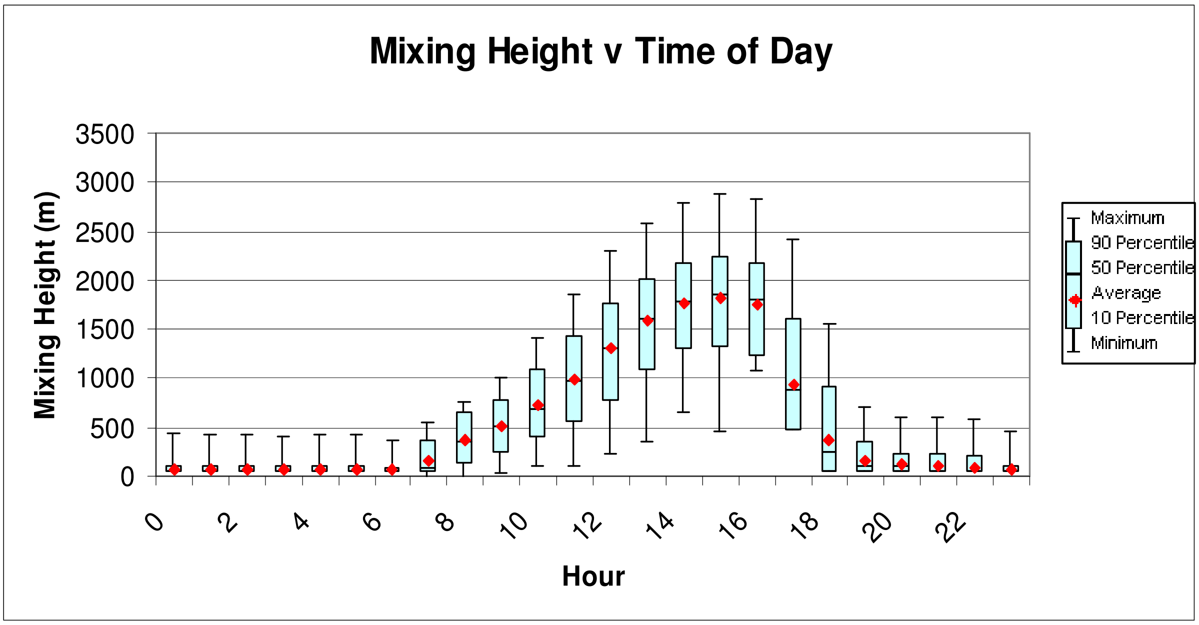



**Figure 4-8 Mixing Height by Time and the Day for the MRM (CALMET, 2009)**

### 4.1.6 Stability Class

Stability of the atmosphere is determined by a combination of horizontal turbulence caused by the wind and vertical turbulence caused by the solar heating of the ground surface. Stability cannot be measured directly; instead it must be inferred from available data, either measured or model-generated data.

The Pasquill-Gifford scale defines stability on a scale from A to G, with stability class A being the least stable, occurring during strong daytime sun, and stability class G being the most stable condition, occurring during low wind speeds at night. For any given wind speed the stability category may be characterised by two or three categories depending on the time of day and the amount of cloud present.

In air quality models such as TAPM, the stability classes F and G are combined. Stability class data for 2009 have been summarised using the modelled data generated by TAPM and CALMET (Figure 4-9). This showed that for the MRM site stability class F occurred most frequently (43%) in 2009, indicating that the dominant conditions were moderately stable. This occurs when surface wind speeds are 3m/s or less during cloudy nights.

In atmospheric dispersion modelling, F class corresponds to the lowest dispersion rates.

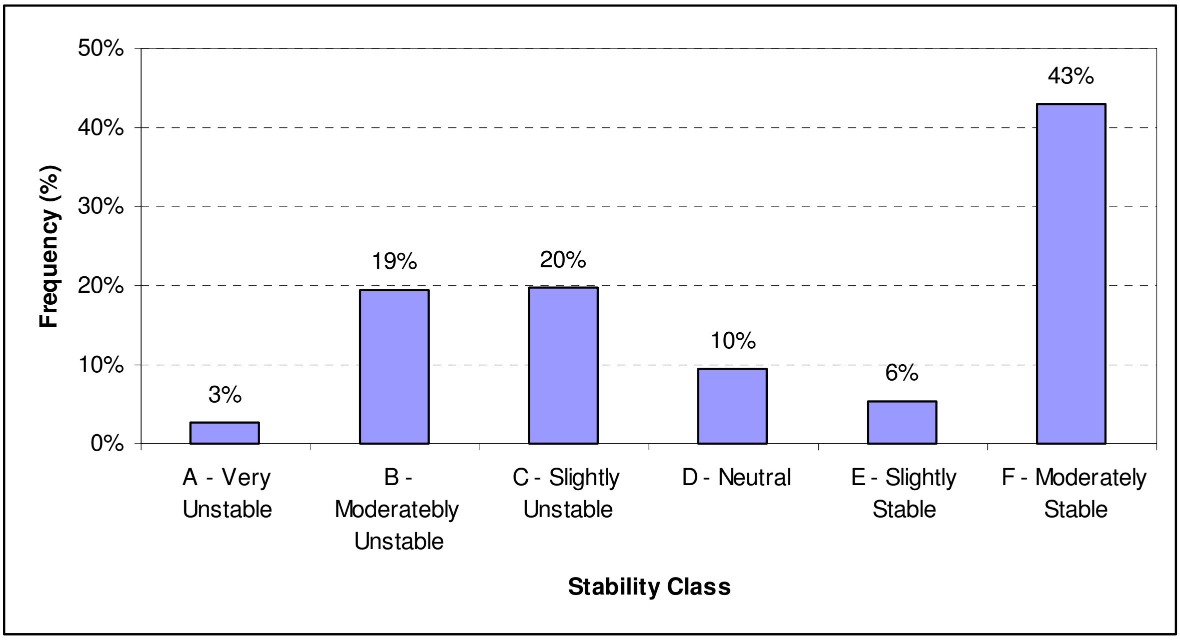



**Figure 4-9 Frequency of Stability Class for the MRM (CALMET, 2009)**

## 4.2 Existing Air Quality

### 4.2.1 McArthur River

The McArthur River Mine is located in a predominantly rural area subject to few anthropogenic emission sources other than the existing mine. Natural sources such as dust storms and bush fires also influence the local air quality.

The township of Borroloola is located approximately 60km to the north-west of the mine, but no monitoring data are available for this location. In the absence of other major sources of air pollution, the baseline environment is expected to be similar to that at the mine. However, given the separation distance and infrequent south-westerly winds, the influence of the mine operations on air quality at Borroloola is considered to be negligible.

#### *Depositional Dust*

Due to the fine-grained nature of the ore body and in particular the concentrate, the generation of dust is one of the environmental aspects closely managed at MRM. The monitoring program established at the mine has the objective to monitor potential contaminated particulate matter (dust particles) arising from MRM activities. The monitoring procedures adhere to AS3580.2003.

Depositional dust gauges; located strategically around the mine (to capture fugitive dust sources and prevailing wind conditions), are mounted on stands approximately two metres high. Depositional dusts sampled undergo laboratory analysis on a monthly basis. Parameters analysed are:

- Total Insoluble Matter (TIM); and
- Total Pb, Zn.

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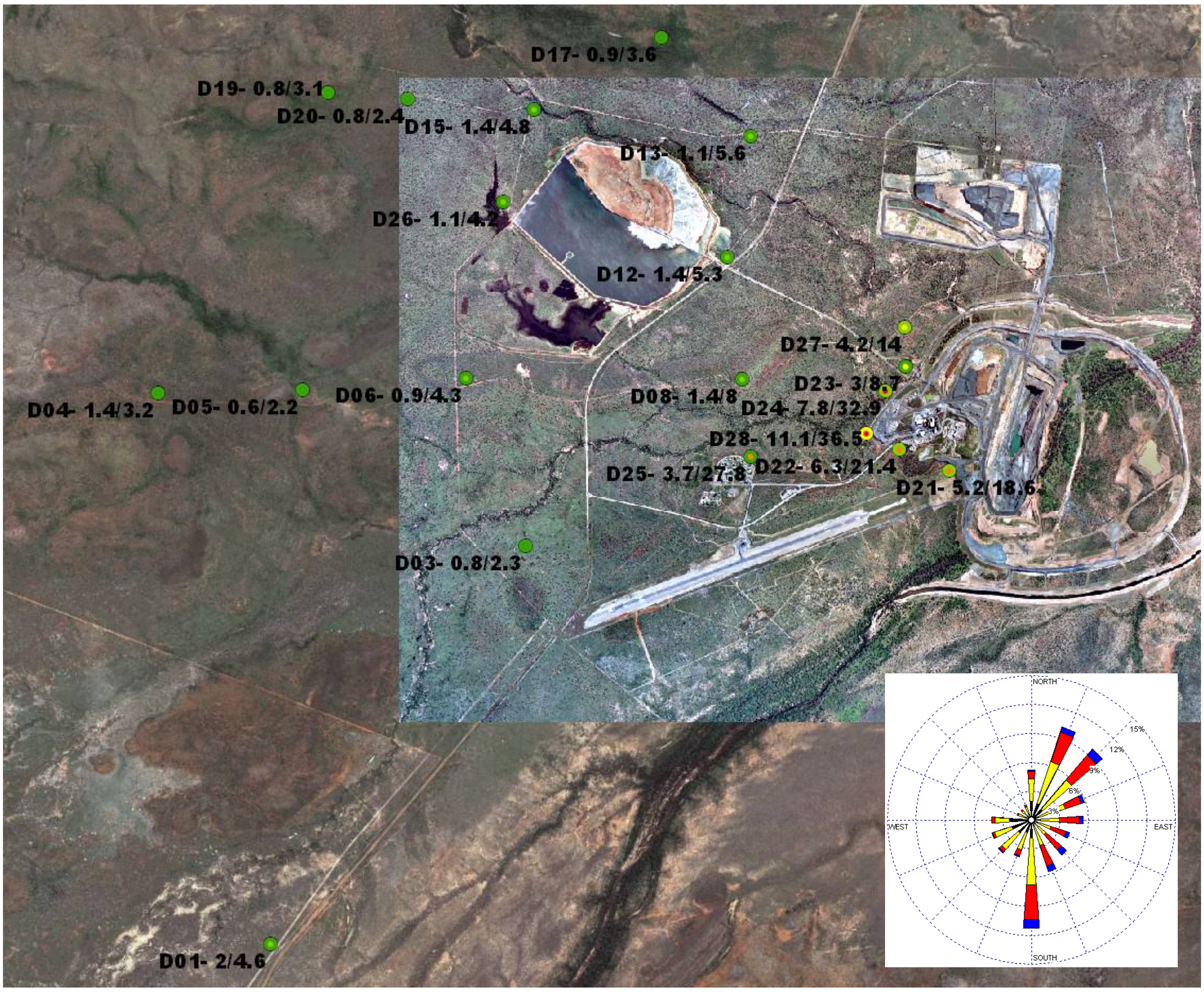
The project goal for dust deposition (represented as TIM) is no greater than 4 g/m$^2$/month cumulative (background plus project related emissions).

Appendix B provides the 2009/2010 dust monitoring locations and data statistics. Figure 4-10 provides a graphical summary.




<table>
<tr><td>Maximum Monthly Dust Deposition Result (g/m2/month)<br>2.200000 - 4.000000<br>4.000001 - 8.000000<br>8.000001 - 16.000000<br>16.000001 - 32.000000<br>32.000001 - 36.500000</td><td>Average Monthly Dust Deposition Result (g/m2/month)<br>0.600000 - 4.000000<br>4.000001 - 8.000000<br>8.000001 - 16.000000<br>16.000001 - 32.000000<br>32.000001 - 36.000000</td></tr>
<tr><td colspan="2"><u>Labelling Code</u><br>“D##” Sample Point Location Name<br>“#/#” Average Result at Sample Point / Maximum Result at Sample Point (g/m2/month)</td></tr>
</table>

**Figure 4-10 Depositional dust monitoring summary at MRM**

Figure 4-10 shows the current mining activities are generally within the project goals. The larger circles represent the average monthly dust deposition, and with the exception of sites in the immediate

## 4 Environmental Values

vicinity of the Mill and pit, are under the 4 g/m$^2$/month guideline. The smaller circles represent the maximum monthly dust deposition result. While these exceed the guideline further afield from the Mill and pit, these levels achieve the guideline within the monitoring network.

### *Other Existing Air Quality Parameters*

No other monitoring is currently undertaken for ambient air quality. While there are emissions from the power station and mine vehicles, there are no other industrial or urban developments in the vicinity of the mine and therefore, background concentrations of pollutants such as $SO_2$, $NO_x$, CO and metals are expected to be minor and hence they have not been monitored.

There are two NEPM monitoring sites located in Darwin which monitor for $PM_{10}$ and $PM_{2.5}$. These sites were determined not to be suitable to be used as representative background concentrations, as these have been established to provide a representative measure of air quality experienced by the general population of the Darwin/Palmerston region (NT Government, 2009). McArthur River Mine is situated in a regional area where background air quality would not be influenced by anthropogenic influences.

### 4.2.2 Bing Bong Port

Dust deposition levels are monitored at Bing Bong, using five dust monitoring sites. The collected dust samples are analysed for zinc and lead concentrations as well as total insoluble solids.

Five strategically positioned dust gauges mounted on stands are currently established. The locations of the depositional dust monitoring sites at Bing Bong Port are shown in Figure 4-11.

**Figure 4-11 Location of Bing Bong Dust Monitoring Sites**

Generally, dust levels (total solids) are low to moderate and are normally below levels that would be expected to give rise to complaints in more populated areas. Long term data for TIM points to consistently high records at BBD4 in relation to other dust monitoring sites located around the Bing Bong Port facility (Figure 4-12). BBD4 is located on the dredge spoil area that has little vegetation cover hence, the conditions create the probability of higher than site average dust levels. Importantly, the concentrations of metals at BBD4 were comparably lower than most other Bing Bong sites.

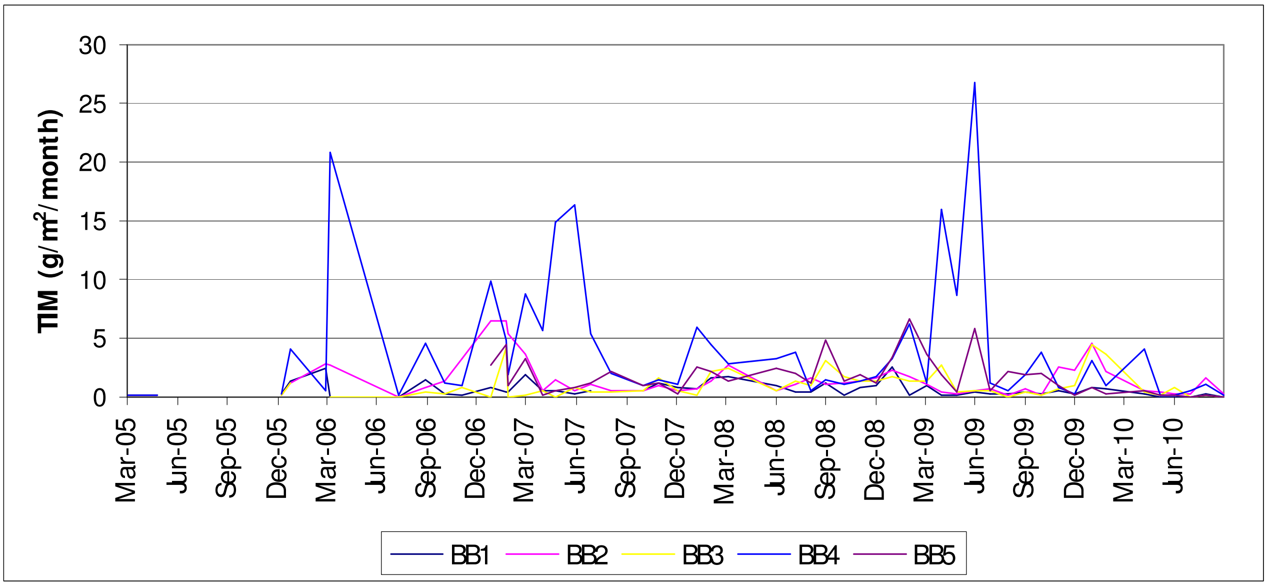



**Figure 4-12 Long Term TIM data for Bing Bong dust monitoring Sites**

Dust at Bing Bong sites showed greatest concentration of metals, both lead and zinc, at BBD2 located to the west of the bulk carrier hardstand (Figure 3-145; Figure 3-146). The predominant wind direction during the dry season is the main transport mechanism for any fugitive material from the storage area and loading process.

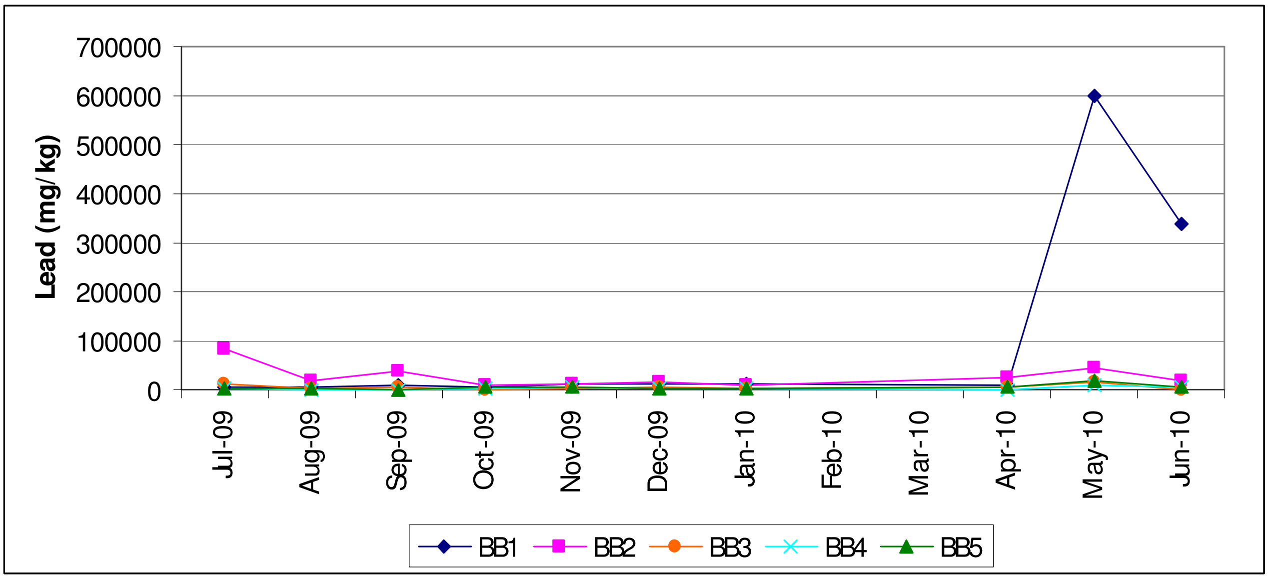



**Figure 4-13 2009/10 Lead Concentrations Recorded at Bing Bong Dust Monitoring Sites**

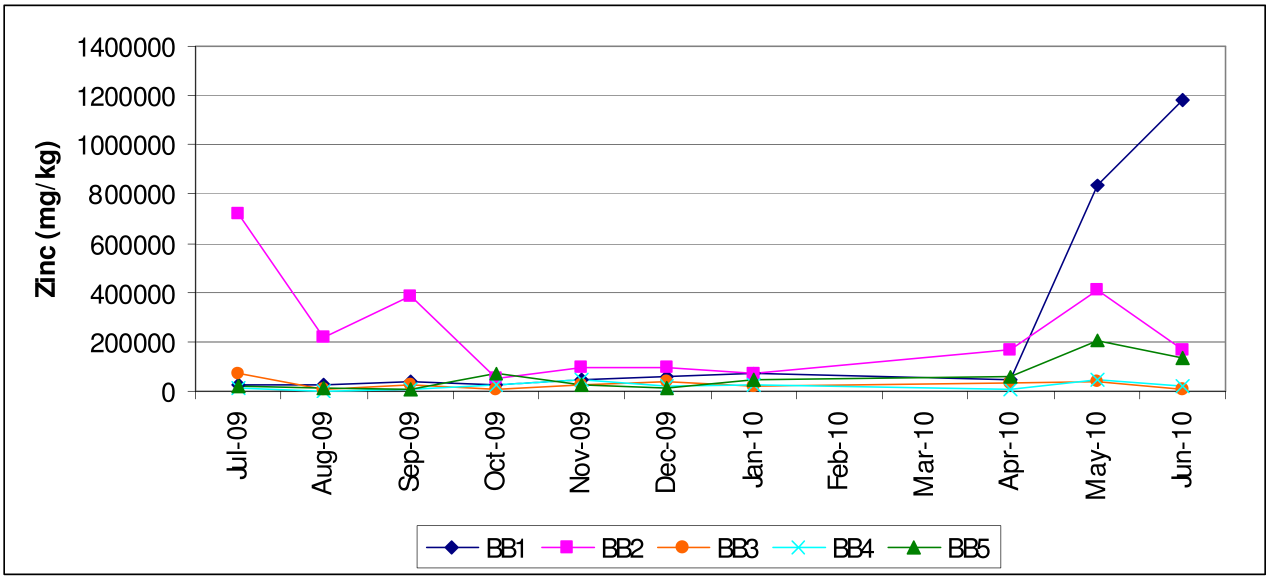



**Figure 4-14 Zinc Concentrations Recorded at Bing Bong Dust Monitoring Sites**

No other monitoring is currently undertaken at Bing Bong for ambient air quality.

## 4.3 Sensitive Receptor Locations

The MRM is located approximately 60 km south-west of the township of Borroloola, the closest township to the mine. Consequently there are no sensitive human receptors within the model domain except for a project related receptor being the mine accommodation village.

The mine accommodation village is located within the boundary of the mine, approximately 1,500m from the existing power station, and 2,000m from the open cut pit.

# 4 Environmental Values

The area surrounding the mine site can be described as flat, open woodland, which is not considered sensitive, except for areas of riverine forest and managed rehabilitation areas. In addition, any areas of standing water (likely only in the wet season) in the old river channel resulting from its diversion may be more sensitive to increased deposition of dust containing zinc and lead. Further evaporative concentration of these metals would be expected in such water bodies.

# Air Quality Assessment Methodology

## 5.1 Sources of Air Emissions

Dust emission sources associated with the McArthur River Mine Expansion Project include (but may not be limited to):

- Graders;
- Scrapers;
- Dozers operating on overburden and ore;
- Blasting;
- Front end loading (FEL) of material to trucks;
- Excavators and shovels;
- Truck dumping of material;
- Loading and unloading of stockpiles;
- Transport of material (overburden, ore, topsoil);
- Wind erosion from
  - The ore stockpiling area,
  - Exposed surfaces, and
  - Overburden stockpile;
- Mill; and
- Power station.

In addition, the power station has also been identified to emit $NO_x$ and minor quantities of $SO_2$, CO and VOCs (such as formaldehyde).

## 5.2 Emissions Estimation

### 5.2.1 Particulate Matter Inventories

Particulate matter emissions from the proposed expanded project have been estimated based on mine plans and activity data provided by MET Serve, emission factors provided in the National Pollutant Inventory (NPI) and the Emission Estimation Technique (EET) Manuals. The emission factors contained in the NPI EET manuals have been developed from measurements of emissions from other operational mines in Australia and the United States during typical operations.

The NPI EET Manual for Mining (NPI, 2001) has been used to provide data to estimate the amount of TSP and $PM_{10}$ emitted from the various activities on a mine site, based on the amount of ore and overburden material mined as provided by the Proponent. Site-specific parameters were used to derive emission factors for trucks on unpaved roads, excavators, shovels, graders, dozers and blasting. Detail of these calculations is provided in Appendix C.

Reductions in emissions have been calculated based on the following assumptions:

## 5 Air Quality Assessment Methodology

**Table 5-1 Reductions of Inventory Emissions Achieved through Controls at Sources**

| Source | Reduction Type | Reduction Achieved (%) |
|---|---|---|
| Haul Roads and Ramps | Level 2 watering (greater than 2 $l/m^2/hr$) | 75% |
| Inpit- Loading | Inpit Sheltering | 50%- TSP, 5% PM10 |
| Wind Erosion- Pit | Inpit Sheltering | 50%- TSP, 5% PM10 |
| Wind Erosion- Overburden Stockpiles | Watering | 50% |
| Wind Erosion- Ore Stockpiles | Watering | 50% |
| Mill- Various Emission Points in Process | Sealed<br>Hooded<br>Windbreaks<br>Hooded with fabric filters<br>Water Sprays | 100%<br>75%<br>30%<br>83%<br>50% |

Where more than one control is applied to an emission source, the reduction is considered cumulative. For example, an emission point in the Mill which is both hooded and has water sprays would have 87.5% reduction (75% reduction from the hood, plus 50% reduction of the remaining 25% (12.5%) from the water sprays).

Windbreaks are proposed for the crushing and grinding points, upwind of the worker accommodation. As the reduction in emission resulting from this mitigation will be dependent on wind direction, it has not been included in the inventory calculations that are presented below. However, as it is expected to be effective in reducing particulate concentrations at the closest sensitive receptors, its effect has been included in the dispersion modelling results presented in Section 6, but is not represented in the contour plots shown in Appendix E.

### *TSP*

The inventory for TSP has been generated using the NPI EET Manual for Mining (NPI, 2001) based on the amount of ore and overburden material mined and other information as provided by the Proponent.

**Table 5-2 TSP Inventory (kg per year)**

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Mining | Vegetation Clearing and Soil Removal | 40,563 | 49,343 | 25,458 | 9,920 | 9,028 |
| | Drill and Blasting | 71,970 | 71,970 | 71,970 | 71,970 | 71,970 |
| | Inpit- Loading | 11,109 | 16,224 | 21,574 | 10,211 | 9,640 |
| | Overburden Emplacement Facility | 164,057 | 339,960 | 646,561 | 49,109 | 20,314 |
| | ROM stockpiles- Mill | 20,719 | 63,909 | 63,059 | 61,456 | 53,223 |
| Roads | Topsoil to stockpiles | 36,734 | 47,192 | - | - | - |
| | Overburden to OEF | 264,945 | 683,819 | 1,184,070 | 78,813 | 26,174 |
| | ROM to Mill | 30,787 | 131,095 | 103,808 | 123,814 | 107,228 |
| Wind | Exposed Surfaces | 684 | 627 | 661 | 634 | 271 |

## 5 Air Quality Assessment Methodology

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Erosion | Overburden Stockpiles | 430 | 2,541 | 1,883 | 726 | 1,200 |
| | Ore Stockpiles | 612 | 2,331 | 2,331 | 2,331 | 2,331 |
| Mill | Mill | 325,686 | 990,468 | 971,567 | 946,401 | 816,317 |
| **Total** | | **968,296** | **2,399,478** | **3,092,942** | **1,355,386** | **1,117,695** |

### *$PM_{10}$*

The inventory for $PM_{10}$ has been generated using the NPI EET Manual for Mining (NPI, 2001) based on the amount of ore and overburden material mined and other information as provided by the Proponent.

**Table 5-3 $PM_{10}$ Inventory (kg per year)**

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Mining | Vegetation Clearing and Soil Removal | 14,367 | 18,332 | 9,562 | 2,964 | 2,565 |
| | Drill and Blasting | 37,577 | 37,577 | 37,577 | 37,577 | 37,577 |
| | Inpit- Loading | 4,968 | 8,490 | 12,936 | 3,968 | 3,454 |
| | Overburden Emplacement Facility | 58,171 | 120,599 | 230,464 | 16,377 | 6,059 |
| | ROM stockpiles- Mill | 7,496 | 23,122 | 22,814 | 22,234 | 19,256 |
| Roads | Topsoil to stockpiles | 7,591 | 9,796 | - | - | - |
| | Overburden to OEF | 54,944 | 142,689 | 246,790 | 16,426 | 5,455 |
| | ROM to Mill | 6,523 | 27,840 | 22,052 | 26,271 | 22,751 |
| Wind Erosion | Exposed Surfaces | 650 | 596 | 628 | 603 | 257 |
| | Overburden Stockpiles | 215 | 1,270 | 942 | 363 | 600 |
| | Ore Stockpiles | 306 | 1,165 | 1,165 | 1,165 | 1,165 |
| Mill | Mill | 43,510 | 132,321 | 129,796 | 126,434 | 109,055 |
| **Total** | | **236,318** | **523,798** | **714,725** | **254,382** | **208,195** |

### *$PM_{2.5}$*

Dust emitted from an emission source consists of a range of particle sizes that are dependent on the source characteristics. Dust from overburden and ore handling operations is generated using mechanical means, and thus the majority of dust emitted from the mine consists of larger-sized particles (i.e. greater than $PM_{2.5}$) when compared with PM generated during combustion processes which contain more ultrafine particles. Dust from roads can be finer than that generated by material handling due to the repeated pulverising of PM into smaller fragments and the resultant creation of fine particles which can easily become airborne.

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Studies conducted by the Midwest Research Institute[2] into a wide-range of dust generating activities for the purposes for developing emission factors for the US EPA, have resulted in proposed $PM_{2.5}$ to $PM_{10}$ ratios as outlined in Table 5-4.

**Table 5-4 Midwest Research Institute's Proposed $PM_{2.5}$ to $PM_{10}$ Ratios**

| Source Category | $PM_{2.5}/PM_{10}$ Ratio |
|---|---|
| Paved Roads | 0.15 |
| Unpaved Roads | 0.1 |
| Construction and Demolition | 0.1 |
| Aggregate handling and Storage piles | 0.1 (traffic), 0.15 (transfer) |
| Industrial wind erosion | 0.15 |
| Agricultural tilling | 0.2 |
| Open area wind erosion | 0.15 |

In the absence of additional information, it has been assumed that $PM_{2.5}$ concentrations resulting from Project activities are equal to a conservative 25% of $PM_{10}$ concentrations from the Project.

As particles move away from a source, the larger particles with greater mass will deposit first, with smaller lower mass particles able to be transported further. The ratio between $PM_{10}$ and $PM_{2.5}$ therefore changes with distance from the source. For this reason, the fraction of $PM_{10}$ to $PM_{2.5}$ has been applied to the inventory, and $PM_{2.5}$ has been modelled as a unique emission type with unique behavioural characteristics. This approach is expected to over predict the results at the sensitive receptors as the fraction of $PM_{2.5}$ is considered conservative.

**Table 5-5 $PM_{2.5}$ Inventory (kg per year)**

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Mining | Vegetation Clearing and Soil Removal | 3,592 | 4,583 | 2,390 | 741 | 641 |
| | Drill and Blasting | 9,394 | 9,394 | 9,394 | 9,394 | 9,394 |
| | Inpit- Loading | 1,242 | 2,123 | 3,234 | 992 | 864 |
| | Overburden Emplacement Facility | 14,543 | 30,150 | 57,616 | 4,094 | 1,515 |
| | ROM stockpiles- Mill | 1,874 | 5,780 | 5,703 | 5,559 | 4,814 |
| Roads | Topsoil to stockpiles | 1,898 | 2,449 | - | - | - |
| | Overburden to OEF | 13,736 | 35,672 | 61,697 | 4,107 | 1,364 |
| | ROM to Mill | 1,631 | 6,960 | 5,513 | 6,568 | 5,688 |
| Wind Erosion | Exposed Surfaces | 162 | 149 | 157 | 151 | 64 |
| | Overburden Stockpiles | 54 | 318 | 235 | 91 | 150 |
| | Ore Stockpiles | 76 | 291 | 291 | 291 | 291 |
| Mill | Mill | 10,877 | 33,080 | 32,449 | 31,608 | 27,264 |
| **Total** | | **59,080** | **130,949** | **178,681** | **63,596** | **52,049** |

[2] C. Cowherd & D. Ono (2005) *Proposed revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors.* http://www.epa.gov/ttn/chief/conference/ei15/session14/cowherd_pres.pdf

## 5 Air Quality Assessment Methodology

### *Lead and Zinc*

Analysis of the dust deposition collected at the existing mine and data regarding waste rock and ore feed compositions has been used to characterise the fraction of lead and zinc in the TSP generated by different emission sources across the mine.

Table 5-6 provides the percentages of the TSP for lead and zinc. These have been applied to the TSP inventory to generate the lead and zinc inventories, provided in Table 5-7 and Table 5-8.

**Table 5-6 Percentages of TSP for Lead and Zinc for Various Emission Sources**

| Emission Source | Lead | Zinc |
|---|---|---|
| Ore Feed | 4.3% | 9.8% |
| Concentrate | 10.4% | 46% |
| Tailings | 1.2% | 7.29% |
| Waste Rock | 0.15% | 0.49% |
| Haul Roads | 0.009% | 0.059% |

**Table 5-7 Lead Inventory (kg Lead per year)**

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Mining | Vegetation Clearing and Soil Removal | 63 | 76 | 39 | 15 | 14 |
| | Drill and Blasting | 1,679 | 1,679 | 1,679 | 1,679 | 1,679 |
| | Inpit- Loading | 478 | 698 | 928 | 439 | 415 |
| | Overburden Emplacement Facility | 253 | 525 | 998 | 76 | 31 |
| | ROM stockpiles- Mill | 891 | 2,748 | 2,712 | 2,643 | 2,289 |
| Roads | All road and ramps | 30 | 78 | 116 | 18 | 12 |
| Wind Erosion | Exposed Surfaces | 29 | 27 | 28 | 27 | 12 |
| | Overburden Stockpiles | 1 | 4 | 3 | 1 | 2 |
| | Ore Stockpiles | 26 | 100 | 100 | 100 | 100 |
| Mill | Mill | 14,004 | 42,590 | 41,777 | 40,695 | 35,102 |
| **Total** | | **17,454** | **48,524** | **48,380** | **45,694** | **39,655** |

**Table 5-8 Zinc Inventory (kg Zinc per year)**

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Mining | Vegetation Clearing and Soil Removal | 198 | 241 | 124 | 48 | 44 |
| | Drill and Blasting | 3,873 | 3,873 | 3,873 | 3,873 | 3,873 |
| | Inpit- Loading | 1,089 | 1,590 | 2,114 | 1,001 | 945 |
| | Overburden Emplacement Facility | 801 | 1,660 | 3,157 | 240 | 99 |
| | ROM stockpiles- Mill | 2,030 | 6,263 | 6,180 | 6,023 | 5,216 |
| Roads | All road and ramps | 196 | 509 | 760 | 120 | 79 |

| Group | Source | 2011 | 2015 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| Wind Erosion | Exposed Surfaces | 67 | 61 | 65 | 62 | 27 |
| | Overburden Stockpiles | 2 | 12 | 9 | 4 | 6 |
| | Ore Stockpiles | 60 | 228 | 228 | 228 | 228 |
| Mill | Mill | 31,917 | 97,066 | 95,214 | 92,747 | 79,999 |
| **Total** | | **40,234** | **111,504** | **111,724** | **104,346** | **90,516** |

Lead and Zinc is considered as a proportion of total TSP, as opposed to a particular fraction size range with the total TSP (like how $PM_{2.5}$ was considered in relation to $PM_{10}$). As such, Lead and Zinc have not been independently modelled, but the results for each of the emission sources have been scaled based on the relevant fraction of Lead or Zinc for each particular emission source. This is considered to be a conservative assumption as particles larger than $PM_{10}$ do not have the potential to enter the respiratory system and, therefore, are unlikely to affect human health.

### 5.2.2 Power Station Inventories

As discussed in Section 2, there are two options being considered for increasing the supply of electricity to the site to meet demand. This includes an augmentation option and a new power station option. With the augmentation option, the existing facility would be maintained and new generators would be added to the site.

The following tables outline the configurations of the options, the parameters for each of the emission points, and the operation scenarios modelled as likely average and peak loads.

**Table 5-9 Equipment Inventory**

| Scenario | Solar Centaur | Solar Taurus | Jenbacher | Caterpillar |
|---|---|---|---|---|
| Equipment Description | 3.5 MW Gas Turbine | 5.7 MW Gas Turbine | 3.3 MW Gas Engine | 2.0 MW Diesel Engine |
| Existing Plant | 3 | 3 | - | 1 |
| Augmentation of Existing Plant | 3 | 3 | 14 | 1 |
| New Plant | - | - | 16 | 2 |

**Table 5-10 Stack Parameters**

| Parameter | Solar Centaur | Solar Taurus | Jenbacher | Caterpillar |
|---|---|---|---|---|
| Height (m) | 10 | 12 | 12.5 | 5 |
| Diameter (m) | 1.3 | 1.45 | 0.6 | 0.44 |
| Temperature (ºC) | 120 | 120 | 365 | 554 |
| Velocity (m/s) | 20 | 21 | 34 | 49 |

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**Table 5-11 Emission Rates (g/s)**

| Substance | Solar Centaur | Solar Taurus | Jenbacher | Caterpillar |
|---|---|---|---|---|
| $NO_x$ (as $NO_2$) | 4.7 | 5.3 | 2.0 | 6.7 |
| CO | 0.48 | 0.54 | 0.0 | 1.2 |
| $SO_2$ | 0.04 | 0.05 | 0.02 | 0.002 |
| $PM_{10}$ | 0.04 | 0.06 | 0.04 | 0.06 |
| formaldehyde | - | - | 0.2 | - |

**Table 5-12 Operation Scenarios Modelled**

| Substance | Solar Centaur | Solar Taurus | Jenbacher | Caterpillar |
|---|---|---|---|---|
| Augmentation of Existing Plant (Peak Load) | 3 | 3 | 8 | - |
| Augmentation of Existing Plant (Average Load) | - | - | 14 | - |
| New Plant (Mill Start) | - | - | 15 | 1 |
| New Plant (Average Load) | - | - | 14 | - |

See Appendix C for a discussion on the configuration of the existing power station compared to previous studies.

### *$NO_x$ to $NO_2$ Conversion*

The prediction of ground-level concentrations of $NO_2$ has been conducted by modelling the total emission rate in grams per second for $NO_X$ from each source, with the results scaled by an empirical nitric oxide/nitrogen dioxide conversion ratio. The Ministry for the Environment's Good Practice Guide for Assessing Discharges to Air from Industry (2008) outlines the process by which to estimate this conversion. This outlines three levels of assessment:

1. Assume complete conversion of $NO_x$ to $NO_2$. This is highly conservative.
2. Use the Ozone Limiting Method. This assumes that all available ozone in the atmosphere is converted to $NO_2$. This is also conservative, and it requires measured ozone background levels.
3. Site specific modelling.

An assessment of the NT air quality network 2000-2001 data by the NT Government (NT Government, 2009) identified that ozone was not a cause for concern in the Darwin/Palmerstone conurbation when assessed against the NEPM standards. As a result, ozone is not measured in Darwin, and is also not measured in regional areas. Consequently, the information required to follow the second and third levels of assessment is not measured. However, the Guide details that for most combustion sources (e.g. power stations, and vehicle emissions) the value of 10% $NO_2$ in $NO_x$ in discharged emissions is usually considered sufficient, and a further conversion of 10% is considered a conservative estimate.

For this study a conservative ratio of 20% conversion of the $NO_X$ to $NO_2$ has been applied.

# 5 Air Quality Assessment Methodology

### Ranking of Power Station Emissions

In order to develop a better understanding of the potential for adverse environmental impacts from the power station, and to aid in the prioritisation of possible mitigation options, a ranking methodology was developed and applied to the power station emissions inventory.

The objective of the ranking exercise was to identify the key emitted species associated with the power station. If modelling determined the top ranking species met the criteria, then no further modelling of other power station emissions would be undertaken.

It is important to note that the relative mass emission rate (such as g/s) of species from the same source (for example) may not accurately reflect the relative potential of each emission to result in adverse environmental impacts. A small amount of a substance with higher toxicity may be associated with a higher risk of adverse impact at a given receptor location when compared with the emission of larger amounts of a less toxic species.

Therefore, in order to assess the relative potential for environmental harm of emissions of different species, consideration of relevant ambient air criteria is required. By scaling the mass emissions by the relevant criteria, the resulting ratio can be compared against a similar ratio for all other species. The individual emitted species are then ranked according to these ratios from highest (rank 1) to lowest (rank N).

This ranking process is demonstrated by the following example:

- Consider the emission of two species, A and B, for a source such that:
  - Emission of species A = 1000 g/min
  - Emission of species B = 10 g/min
- The adopted ambient criteria for species A and B are:
  - Criterion for species A = 100 Wg/m3
  - Criterion for species B = 0.1 Wg/m3
- Then the ratio of the mass emission rate to the relevant ambient criterion is given by:
  - Ratio for species A = 10
  - Ratio for species B = 100
- As the ratio for species B is greater than that for species A, the ranking for these two species with respect to environmental risk would be assigned as:
  - Rank for species A = 2
  - Rank for species B = 1

The ranking was undertaken for each of the power station options, which resulted in the same ranking of species for each option. The ranking for the augmentation of the existing plant, peak load is provided below, and found that $NO_2$ has the greatest potential to exceed on the annual criteria than the other emitted species.

**Table 5-13 Ranking for the Augmentation of the Existing Plant, Peak Load**

| Species | Emission Rate (g/s) | Averaging Period | Criteria (μg/m³) | Ratio | Rank |
|---|---|---|---|---|---|
| $NO_2$ | 46.3 | Annual | 22* | 2.1 | 1 |
| CO | 3.14 | 8 hrs | 10 | 0.31 | 2 |
| $NO_2$ | 46.3 | 1 hr | 225 | 0.21 | 3 |
| $CH_2O$ | 1.7 | 1 day | 49 | 0.03 | 4 |
| $SO_2$ | 0.46 | Annual | 33* | 0.01 | 5 |
| $SO_2$ | 0.46 | 1 day | 208 | 0.002 | 6 |
| $SO_2$ | 0.46 | 1 hr | 522 | 0.0008 | 7 |

* values set for the protection of ecosystems

Based on these results, the emissions of CO and $SO_2$ will not be modelled unless the $NO_2$ results show exceedences of the project goals.

## 5.3 Dispersion Modelling

A brief overview of the methodology for meteorological modelling using TAPM and CALMET and atmospheric dispersion using CALPUFF is provided. A more detailed description is included in Appendix D.

### 5.3.1 Meteorological Modelling Methodology

Atmospheric dispersion modelling using CALPUFF requires detailed data on surface and upper air meteorology in the model domain. CALMET was used to generate three-dimensional wind fields from inputs of surface and upper air data. Surface data was sourced from the McArthur Rive Mine airport meteorological monitoring site (BOM) (see Section 4.1), and upper data was generated using The Air Pollution Model (TAPM).

Details of the meteorological modelling is provided in Appendix D.1.

### 5.3.2 Dispersion Modelling Methodology

The dispersion model CALPUFF was used to simulate the dispersion of species emitted from specified sources through a three dimensional domain over time using the meteorological characteristics developed in Section 5.3.1, with the results measured both over a grid, and at discrete receptors.

In order to be able to determine percentage contributions of the different sources to the concentrations predicted at the receptors, each emission source was run as a separate model. The results of the all the models for each species were then summed to produce the final total result.

#### *Modelled Species*

Species modelled included TSP (including dust deposition, lead and zinc), $PM_{10}$, $PM_{2.5}$, and $NO_x$ as $NO_2$.

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### Emission Sources

The locations of particulate emission sources modelled for operational year 2015 are presented in Figure 5-1. Additional figures indicating the location of modelled particulate emission sources for other modelled years and the power station options are presented in Appendix D.2.

Emission sources were characterised in order for CALPUFF to accurately predict how the release of the emissions would occur and then disperse. Appendix D.2 provides a description of how the sources were characterised.

### Receptor Locations

As discussed in Section 4.3, the accommodation village is the only identified receptor. The accommodation village has been represented in the modelling as five discrete receptors at the following coordinates and locations:

**Table 5-14 Receptor Coordinates**

| Receptor Number | X (km) | Y (km) |
|---|---|---|
| Receptor 1 | 614.4887 | 8182.144 |
| Receptor 2 | 614.7325 | 8182.161 |
| Receptor 3 | 614.6506 | 8182.293 |
| Receptor 4 | 614.5544 | 8182.453 |
| Receptor 5 | 614.8441 | 8182.404 |

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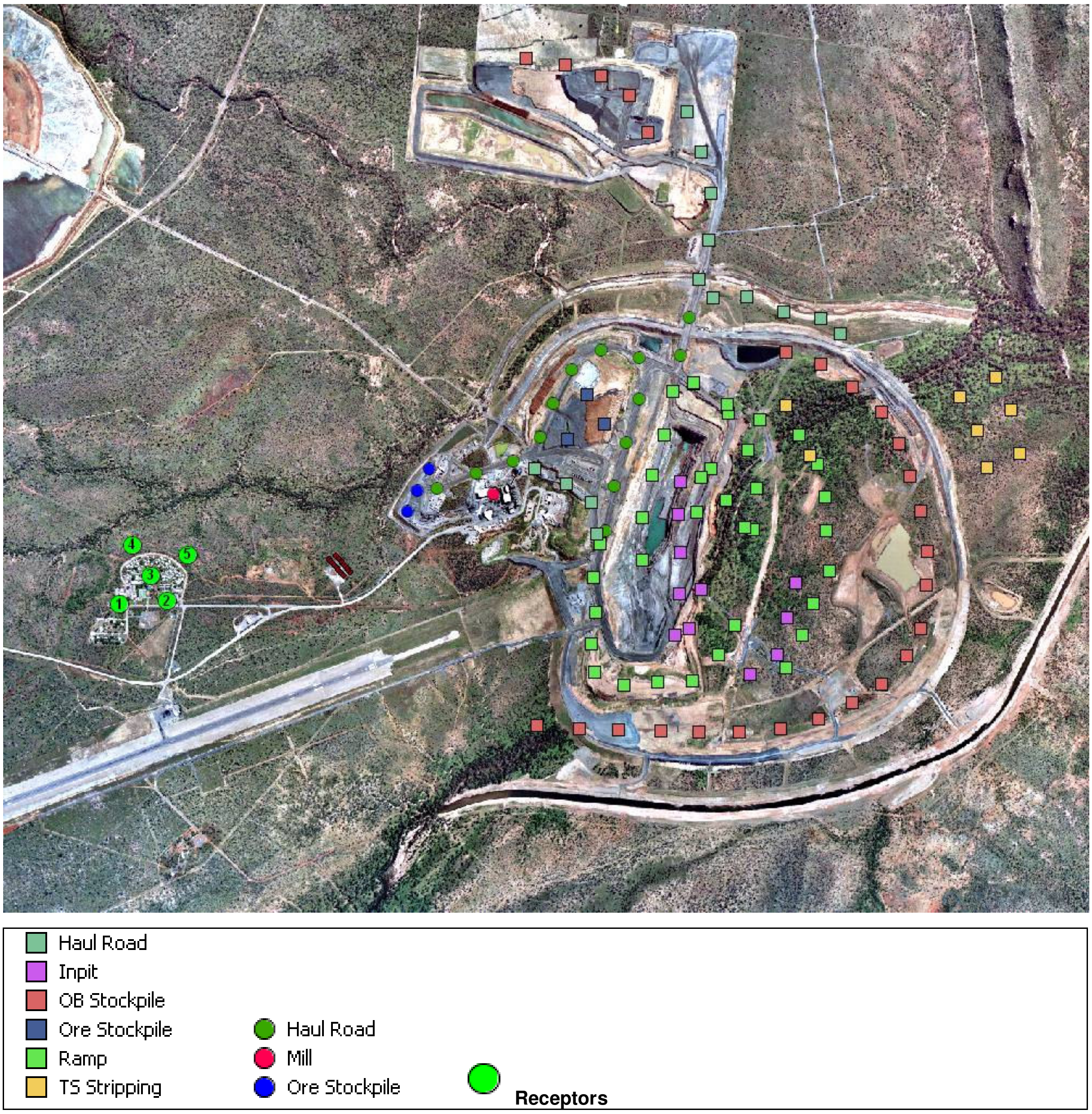


**Figure 5-1 Location of Emission Sources for Year 2015**

## 5 Air Quality Assessment Methodology


**Figure 5-2 Receptor Locations**

### 5.3.3 Limitations of Dispersion Modelling

#### *General Limitations*

Modelling of complex physical systems is based on the use of numerical techniques to solve a set of governing equations. In general, the more complicated the system modelled, the more parameterisations (or approximations) are required in order to solve these equations; particularly in relation to the representation of sub-grid scale processes. Thus, there are inherently a number of 'tuneable' parameters that are required as input into the models. Model developers often suggest default values for these parameters which may be based on observational data, laboratory experiments or professional experience. Depending on the scale of the mine, assessing the sensitivity of model results to input data and/or the value of tuneable parameters can be prohibitive, either in terms of computational requirements, timeframes for completion of the assessment and/or budgetary constraints.

Validation is a critical component to both model development and application. Rarely however does a suitable data set exist with which to conduct a detailed, statistically meaningful model validation study. The CALPUFF dispersion model has been developed to estimate the impact of emissions from a range of source types including: point sources (tall and short stacks), buoyant line sources (aluminium smelters), buoyant area sources (i.e. forest fires), area sources and volume sources. Model validation exercises have tended to focus on the impacts of emissions from point sources (i.e. stacks). Non-buoyant line sources such as haul roads are not explicitly included as a source type in CALPUFF. Instead, these types of sources are typically represented as a series of volume sources whose separation distance is taken as a function of the minimum distance to the nearest receptor. This follows the simulated line source methodology used in regulatory approved dispersion model AUSPLUME developed by the EPA Victoria. Model validation of low level emissions of pollutants (such as dust generated by large-scale mining activities) is additionally complicated by the near-surface release of emissions, the mobility of emission sources and the variability in the locale of activities (such as blasting events).

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The inability to accurately predict the minimum mixing height is another limiting factor of dispersion modelling and is particularly important when dealing with low level, non-buoyant (or low buoyancy) emission sources such as those present on a mine.

Further limitations in dispersion modelling are the uncertainties relating to the precision and applicability of input data, and the lack of observational data with which to validate the predicted concentrations.

### *Project Specific Limitations*

This assessment relies on the completeness, accuracy and/or representativeness of a number of input data sets including:

- McArthur River Mine Expansion Project information used to develop the inventory;
- Regulatory supplied ambient air and meteorological monitoring data;
- Client and supplied monitoring data;
- NPI emission factors; and
- Non site-specific default parameters used in the development of the emission factors.

Other limitations of the assessment include (but may not be limited to):

- The accuracy of the characterisation of the background environment;
- The sensitivity of the dispersion modelling results to model input parameters such as surface roughness and albedo; and
- The accuracy of the modelled meteorological fields incorporated into the dispersion model.

# Dispersion Modelling Results

Predicted concentrations from the dispersion modelling have been analysed at discrete receptor locations in the locality of the Mine and across the region through the use of contour plots.

## 6.1 Interpretation of Results

When reviewing dispersion model outputs, it is important to interpret the results presented in the context of the limitations outlined in Section 5.3.3. In particular, the limitations associated with validating the relevance and applicability of both the model input data sets and model output should be considered.

Dispersion modelling should be regarded as a tool for the identification of potential air quality issues within the study region. However, the confirmation of a model-predicted impact (either adverse or beneficial) can only be definitively assessed by the detailed comparison against observational data.

Other minor comments noted include:

- The software graphics package ARCMAP has been used in this assessment to develop the regional contour plots. Contouring techniques involve the interpolation of results onto a grid which is a source of spatial uncertainty. The results presented in tabular form are extracted directly from model output and are thus a better representation of predicted impacts at receptor locations.
- Tabulated results are reported to the nearest whole number. However, this suggests a level of accuracy of model predictions which is not realisable, nor verifiable. Reporting (for example) a concentration of 24 $\mu g/m^3$ implies an accuracy of ±1 $\mu g/m^3$. Quantifying the uncertainty in the results presented is in general, not undertaken for the reasons discussed in Section 5.3.3.

Results presented in the following sections include the Project-related incremental contribution to ground level concentrations of dust at receptor locations.

## 6.2 Results

Predicted ground level concentrations at sensitive receptor locations are presented in this section in tabular form for all years modelled. Contour plots for years 2011 (base case), 2015, 2025, 2030, and 2035 are included as Appendix E.

Due to the lack of site-specific data, estimates of background concentrations are considered to be uncertain. A discussion regarding this is presented in Section 4.2.1. Results presented in this section have therefore been presented as project contribution only.

As discussed above, the receptor results presented here include the anticipated mitigation benefit of windbreaks located upwind of the crushing and grinding points at the mill.

# 6 Dispersion Modelling Results

### 6.2.1 TSP

**Table 6-1 Annual Average Concentrations of TSP at Receptors (µg/m$^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| **Annual Average Concentrations (µg/m$^3$)** | | | | | |
| Year 2011 | 6 | 8 | 7 | 5 | 7 |
| Year 2015 | 14 | 18 | 15 | 11 | 15 |
| Year 2025 | 15 | 20 | 17 | 13 | 18 |
| Year 2030 | 10 | 13 | 11 | 7 | 11 |
| Year 2035 | 8 | 11 | 9 | 6 | 9 |
| **Project Goal** | | | **90** | | |
| **Percentage of Project Goal** | | | | | |
| Year 2011 | 7% | 9% | 8% | 5% | 7% |
| Year 2015 | 15% | 20% | 17% | 12% | 17% |
| Year 2025 | 17% | 22% | 19% | 14% | 19% |
| Year 2030 | 11% | 15% | 12% | 8% | 12% |
| Year 2035 | 9% | 12% | 10% | 7% | 10% |

**Table 6-2 Year 2015 Contributions of Sources to each Receptor**

| Source | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| Haul Roads | 19% | 18% | 19% | 21% | 20% |
| Inpit activities | 1% | 1% | 1% | 1% | 1% |
| Blasting | 0% | 0% | 0% | 0% | 0% |
| Inpit wind erosion | 0% | 0% | 0% | 0% | 0% |
| Mill | 48% | 51% | 49% | 44% | 47% |
| OB stockpile activities | 9% | 7% | 8% | 9% | 7% |
| OB stockpile wind erosion | 0% | 0% | 0% | 0% | 0% |
| Ore stockpile activities | 4% | 4% | 4% | 3% | 3% |
| Ore stockpile wind erosion | 0% | 0% | 0% | 0% | 0% |
| Ramps | 19% | 18% | 19% | 22% | 21% |
| Clearing/Topsoil removal | 0% | 0% | 0% | 0% | 0% |

### 6.2.2 $PM_{10}$

**Table 6-3 5th Highest Daily Average Concentrations of $PM_{10}$ at Receptors ($\mu g/m^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| **5th Highest Daily Average Concentrations ($\mu g/m^3$)** | | | | | |
| Year 2011 | 6 | 7 | 7 | 5 | 6 |
| Year 2015 | 34 | 39 | 39 | 30 | 36 |
| Year 2025 | 40 | 48 | 40 | 27 | 36 |
| Year 2030 | 17 | 20 | 17 | 11 | 14 |
| Year 2035 | 14 | 16 | 17 | 12 | 14 |
| **Project Goal** | | | | | |
| **Percentage of Project Goal** | | | | | |
| Year 2011 | 12% | 14% | 13% | 9% | 11% |
| Year 2015 | 68% | 79% | 77% | 59% | 71% |
| Year 2025 | 79% | 96% | 80% | 55% | 72% |
| Year 2030 | 33% | 39% | 34% | 21% | 28% |
| Year 2035 | 28% | 33% | 33% | 24% | 29% |

**Table 6-4 Year 2015 Contributions of Sources to each Receptor**

| Source | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| Haul Roads | 9% | 8% | 9% | 9% | 9% |
| Inpit activities | 2% | 2% | 2% | 2% | 2% |
| Blasting | 0% | 0% | 0% | 0% | 0% |
| Inpit wind erosion | 0% | 0% | 0% | 0% | 0% |
| Mill | 34% | 35% | 34% | 30% | 32% |
| OB stockpile activities | 17% | 17% | 17% | 16% | 15% |
| OB stockpile wind erosion | 0% | 0% | 0% | 0% | 0% |
| Ore stockpile activities | 6% | 6% | 6% | 5% | 5% |
| Ore stockpile wind erosion | 0% | 0% | 0% | 0% | 0% |
| Ramps | 30% | 30% | 30% | 35% | 34% |
| Clearing/Topsoil removal | 3% | 2% | 2% | 3% | 3% |

### 6.2.3 $PM_{2.5}$

**Table 6-5 Maximum Daily Average Concentrations of $PM_{2.5}$ at Receptors ($\mu g/m^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| **Highest Daily Average Concentrations ($\mu g/m^3$)** | | | | | |
| Year 2011 | 4 | 4 | 4 | 3 | 4 |
| Year 2015 | 12 | 13 | 13 | 10 | 12 |
| Year 2025 | 11 | 13 | 13 | 12 | 13 |
| Year 2030 | 6 | 6 | 6 | 5 | 6 |
| Year 2035 | 5 | 5 | 5 | 4 | 5 |
| **Project Goal** | **25** | | | | |
| **Percentage of Project Goal** | | | | | |
| Year 2011 | 15% | 17% | 16% | 13% | 15% |
| Year 2015 | 47% | 52% | 50% | 41% | 47% |
| Year 2025 | 46% | 52% | 52% | 46% | 52% |
| Year 2030 | 22% | 26% | 26% | 20% | 23% |
| Year 2035 | 19% | 21% | 21% | 17% | 19% |

**Table 6-6 Annual Average Concentrations of $PM_{2.5}$ at Receptors ($\mu g/m^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| **Annual Average Concentrations ($\mu g/m^3$)** | | | | | |
| Year 2011 | 1 | 1 | 1 | 1 | 1 |
| Year 2015 | 3 | 3 | 3 | 2 | 3 |
| Year 2025 | 3 | 4 | 4 | 3 | 3 |
| Year 2030 | 1 | 2 | 1 | 1 | 1 |
| Year 2035 | 1 | 1 | 1 | 1 | 1 |
| **Project Goal** | **8** | | | | |
| **Percentage of Project Goal** | | | | | |
| Year 2011 | 15% | 18% | 17% | 13% | 16% |
| Year 2015 | 36% | 43% | 39% | 31% | 37% |
| Year 2025 | 40% | 48% | 44% | 36% | 44% |
| Year 2030 | 17% | 20% | 18% | 13% | 17% |
| Year 2035 | 14% | 17% | 15% | 11% | 14% |

### 6.2.4 Lead

**Table 6-7 Annual Average Concentrations of Lead at Receptors (µg/m$^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| Annual Average Concentrations (µg/m$^3$) | | | | | |
| Year 2011 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Year 2015 | 0.3 | 0.4 | 0.3 | 0.2 | 0.3 |
| Year 2025 | 0.3 | 0.4 | 0.3 | 0.2 | 0.3 |
| Year 2030 | 0.3 | 0.4 | 0.3 | 0.2 | 0.3 |
| Year 2035 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 |
| **Project Goal** | | | **0.5** | | |
| **Percentage of Project Goal** | | | | | |
| Year 2011 | 21% | 30% | 25% | 17% | 25% |
| Year 2015 | 59% | 81% | 68% | 45% | 65% |
| Year 2025 | 58% | 79% | 67% | 45% | 65% |
| Year 2030 | 56% | 76% | 64% | 43% | 62% |
| Year 2035 | 48% | 66% | 55% | 37% | 54% |

### 6.2.5 Zinc

**Table 6-8 Maximum Daily Average Concentrations of Zinc at Receptors (µg/m$^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| Annual Average Concentrations (µg/m$^3$) | | | | | |
| Year 2011 | 2 | 3 | 3 | 2 | 2 |
| Year 2015 | 6 | 7 | 7 | 6 | 7 |
| Year 2025 | 6 | 7 | 7 | 6 | 7 |
| Year 2030 | 6 | 7 | 7 | 5 | 7 |
| Year 2035 | 5 | 6 | 6 | 5 | 6 |
| **Project Goal** | | | **120** | | |
| **Percentage of Project Goal** | | | | | |
| Year 2011 | 2% | 2% | 2% | 2% | 2% |
| Year 2015 | 5% | 6% | 6% | 5% | 6% |
| Year 2025 | 5% | 6% | 6% | 5% | 6% |
| Year 2030 | 5% | 6% | 6% | 5% | 6% |
| Year 2035 | 4% | 5% | 5% | 4% | 5% |

### 6.2.6 Dust Deposition

The modelling results predicted there would be no impact from dust deposition at the receptor locations. Given the distance of the receptors from the sources, and that dust is primarily made up of larger particles which by nature settle quickly and thereby near the source due to the weight of the particle, these results are considered appropriate.

### 6.2.7 Nitrogen Dioxide

Four scenarios were examined in modelling of the power station as detailed in Section 5.2.2, these included:

- Augmentation of the existing facility- average load
- Augmentation of the existing facility- peak load
- New power station- average load
- New power station- peak load

The hourly maximum and annual average results of the four scenarios are included in Table 6-9 and Table 6-10 respectively.

**Table 6-9 $NO_2$ Maximum Hourly Concentrations at Receptors (µg/m$^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| **Hourly Maximum Concentrations (µg/m$^3$)** | | | | | |
| Aug- average load | 59 | 64 | 111 | 105 | 110 |
| Aug- peak load | 147 | 151 | 106 | 74 | 94 |
| New- average load | 204 | 188 | 204 | 132 | 161 |
| New- peak load | 221 | 199 | 218 | 147 | 177 |
| **Project Goal** | | | **225** | | |
| **Percentage of Project Goal** | | | | | |
| Aug- average load | 26% | 29% | 49% | 46% | 49% |
| Aug- peak load | 65% | 67% | 47% | 33% | 42% |
| New- average load | 91% | 84% | 91% | 59% | 71% |
| New- peak load | 98% | 89% | 97% | 65% | 79% |

## 6 Dispersion Modelling Results

**Table 6-10 $NO_2$ Annual Average Concentrations at Receptors (µg/m$^3$)**

| | Receptor 1 | Receptor 2 | Receptor 3 | Receptor 4 | Receptor 5 |
|---|---|---|---|---|---|
| **Annual Average Concentrations (µg/m$^3$)** | | | | | |
| Aug- average load | 1 | 1 | 1 | 1 | 1 |
| Aug- peak load | 1 | 1 | 1 | 1 | 1 |
| New- average load | 1 | 2 | 1 | 1 | 2 |
| New- peak load | 2 | 3 | 2 | 2 | 2 |
| **Project Goal** | | | **56** | | |
| **Percentage of Project Goal** | | | | | |
| Aug- average load | 1% | 1% | 1% | 1% | 1% |
| Aug- peak load | 2% | 2% | 2% | 2% | 2% |
| New- average load | 2% | 3% | 3% | 2% | 3% |
| New- peak load | 3% | 5% | 4% | 3% | 4% |

Appendix E Figure 31 shows the effect of power station emissions on annual average concentrations of $NO_2$. The maximum effect on riverine forest areas is 1-2 µg/m$^3$, which is not considered significant. Therefore, no impact on flora and fauna in these areas is expected.

The scenarios presented are considered worst case with the results of the model at the mine camp being under the project goals. Improvements to the scenarios could be achieved through:

- Fewer and cleaner turbines;
- Taller stacks; and/or
- Situation of a new power station further from the mine camp.

### 6.2.8 Bing Bong Port

Concentrate will continue to be exported via the port at Bing Bong in the same way that is used for the current operations; however the volume of concentrate will increase accordingly. Fugitive dust from the concentrate will be minimised by the material's moisture content of approximately 12%.

It is understood that further dust mitigation measures will be installed at Bing Bong Port. These include a Wet Scrubber dust extraction system to the concentrate shed. The system will generate a negative airflow that will contain any airborne dust in the shed. The dust extraction system is then wet filtered. In addition, fast opening / closing doors will be installed on the unload ramps so that concentrate transfer out of the road trains can occur with the main doors closed.

Taking into account the proposed upgrades to must mitigation, no significant adverse impacts on local air quality at Bing Bong are anticipated as a result of the proposed expansion.

Exhaust emissions from the delivery trucks and the barges will be minimised through appropriate tuning and maintenance and would not be expected to significantly impact on local air quality.

# Air Quality Monitoring Program

## 7.1 Dust Deposition

The existing monitoring programme at the mine site and Bing Bong Port will be maintained. Consideration should be given to including representative rehabilitation areas where new planting will take place in the monitoring programme in the future. Environmental objectives for such monitoring sites should be developed with guidance from a suitably qualified ecologist or ecotoxicologist.

It is considered that the continuity of the data record will be more valuable than any adjustment to the existing monitoring locations or procedures.

The dust collected in the gauges will continue to be analysed for lead and zinc concentrations.

The results of the monitoring program will be used to provide an indication of the effectiveness of the dust control measures being implemented at the mine site.

Deposition of zinc and lead to areas of standing water during the wet season has been identified as a potential impact. If any sensitive flora or fauna are found to be supported by this habitat, then the water quality monitoring programme should be expanded to incorporate representative sites. However, no action considered necessary at this time.

## 7.2 $PM_{10}$

Monitoring for $PM_{10}$ should be undertaken at the mine camp to evaluate the effectiveness of controls in place at the mine and, in particular, at the grinding and crushing points. Regular visual observations of wind breaks installed at these points should be undertaken, with note made of approximate wind speed and direction, to ensure that they are functioning correctly.

## 7.3 Nitrogen Dioxide

Given the potential for nitrogen dioxide emissions from the power station to affect workers at the mine camp, continuous ambient monitoring for nitrogen dioxide should be undertaken alongside the particulate monitoring to confirm that ambient standards are being met. Continuous emissions monitoring (CEMS) is not considered necessary.

## 7.4 Meteorology

Monitoring of wind speed, wind direction, rainfall and temperature should continue to be undertaken at the airfield. This data should be logged on an hourly basis and the anemometer should be regularly calibrated and maintained to ensure acceptable data quality.

# Greenhouse Gas Assessment Methodology

## 8.1 Accounting and Reporting Principles

This inventory follows the accounting and reporting principles detailed in the National Greenhouse and Energy Reporting System Measurement Technical Guidelines (Technical Guideline), July 2011 (DCCEE, 2011). The inventory is also in accordance with the NT Environmental Impact Assessment Guide for Greenhouse Gas Emissions and Climate Change (2010).

The main principles of the Technical Guidelines (DCCEE, 2011) are described below:

- Transparency – emission estimates must be documented and verifiable;
- Comparability – emission estimates using a particular method and produced by a registered corporation in an industry sector must be comparable with emissions estimates produced by similar corporations in that industry sector using the same method and consistent with the emission estimates published by the DCCEE in the National Greenhouse Accounts;
- Accuracy – having regard to the availability of reasonable resources by a registered corporation and the requirements of the guideline, uncertainties in emission estimates must be minimised and any estimates must neither be over nor under estimates of the true values at a 95% confidence level; and
- Completeness – all identifiable emission sources within the energy, industrial process and waste sectors as identified by the National Inventory Report must be accounted for.

## 8.2 Inventory Boundaries

In preparing a GHG Assessment, there are two forms of boundaries to be specified:

- organisational boundaries; and
- operational boundaries.

The project proponent is McArthur River Mining Pty Ltd. MRM Pty Ltd is a company wholly-owned by a global mining ground Xstrata Zinc and is the operator of the McArthur River Mine. It constitutes the organisational boundary of the mine. The operational boundary is delineated by the physical mine area comprising seven mineral leases, and includes all the GHG emissions controlled or influenced by the Project. The GHG emissions that are outside the control or influence of the Project, such as the processing of the iron ore into a product, lie outside this boundary.

The operational boundary for the GHG assessment includes both direct and indirect emissions from the Project. The Technical Guidelines further define direct and indirect emissions through the concept of emission scope as follows:

- Scope 1: Direct GHG emissions. Emissions released from a facility as a direct result of the activities of the facility. For example:
  - Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; and
  - Emissions from on-site power generators.
- Scope 2: Indirect GHG emissions. Scope 2 emissions are activities that generate electricity, heating, cooling or steam that is consumed by the facility but do not form part of the facility. They occur principally at electricity generators as a result of electricity consumption at another facility. They are recorded principally as a measure of what might happen to national emissions as a result of the consumption of electricity from facilities.

MRM has a power station located onsite to generate electricity for the project. Ordinarily this would be considered scope 1, however for this project it is considered scope 2 as the power station is operated by a third party with electricity sold back to the project.

## 8.3 Calculation Approach

Data from the following sources have been utilised in the formation of the inventory:

- Spreadsheet provided by MET Serve “MM Summary 38.xls” detailing:
  - Diesel oil usage
  - Explosives
  - Ore mined
- Spreadsheet provided by MET Serve “McArthurRiverNPIDatasheet2008-09.xls” detailing:
  - Proportion of diesel usage as mobile vs. stationary
- Document provided by MET Serve “MRM EIS Project Description Draft 14 June 2011.pdf” detailing:
  - Electricity requirements
- AutoCAD Plans detailing topsoil stripping areas for each year of the project, provided by MET Serve
- 2006 PER Inventory providing site specific electricity emissions factor
- Document provided by MET Serve “MRM NGERs Report 2010.pdf”, used to confirm GHG from electricity calculations

### 8.3.1 Emission Factors

Direct measurement of GHG at the emission source provides the most accurate and precise assessment of GHG emissions. When this data is not available it is usual to adopt the Method 1 emission factors from the National Greenhouse Accounts (NGA) Factors workbook (DCCEE, 2011). For the purposes of this assessment, emission factors have been adopted from DCCEE (2011).

The emission factors for each of the main GHGs used in this report are presented in Table 8-1. Note that the emission factors are presented in terms of equivalent $CO_2$, which takes into account the global warming potential of each of the gases relative to carbon dioxide. Results presented below are also expressed in this unit.

**Table 8-1 Emission Factors used in the formation of the MRM Project Greenhouse Gas (GHG) Inventory**

| Type | Emission Factor | | | | Energy Content | | Source* |
|---|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | Unit | Factor | Unit | |
| **Scope 1** | | | | | | | |
| Diesel- Stationary Energy | 69.2 | 0.1 | 0.2 | Kg $CO_2$-e/GJ | 38.6 | GJ/kL | Table 2.4.2A |
| Diesel- Mobile Energy | 69.2 | 0.2 | 0.5 | Kg $CO_2$-e/GJ | 38.6 | GJ/kL | Table 2.4.2B |
| **Scope 2** | | | | | | | |
| Natural Gas distributed in a pipeline | 51.2 | 0.1 | 0.03 | Kg $CO_2$-e/GJ | 3.93E-02 | GJ/$m^3$ | Table 2.3.2A |

Note *- Source is the DCCEE (2011)

An estimate of the loss of carbon sink capacity of vegetation due to clearing has also been undertaken.

*FullCAM* Version 3.0, released with the National Carbon Accounting Toolbox Version 1.0, accounts for carbon stock changes associated with land use and management. The FullCAM Data Builder allows users to access the data archives of the National Carbon Accounting System and build models for individual site and management practices. This tool has been used to generate an emission factor for the capacity of the vegetation and soil types on the project site to store carbon, or lost capacity if the site were cleared. The emission factor derived for the site to represent lost carbon sink capacity due to clearing was 181.08 t/ha/yr. Appendix F provides a description of the tool and inputs to derive the emission factor.

### 8.3.2 Materiality

Materiality is a concept used in accounting and auditing to minimise time spent verifying amounts and figures that do not impact a company's accounts or inventory in a material way. The exact materiality threshold used in GHG emissions accounting and auditing is subjective and dependent on the context of the site and the features of the inventory. Depending on the context, the materiality threshold can be expressed as:

1. a percentage of a company's total inventory;
2. a specific amount of GHG emissions; or
3. a combination of 1 and 2.

All emissions that are found within the boundary are included in the inventory unless they are excluded on materiality grounds. Information is considered to be material if, by its inclusion or exclusion, it can be seen to influence any decisions or actions taken by users. A material discrepancy is an error (for example, from an oversight, omission or miscalculation) that results in a reported quantity or statement being significantly different from the true value or meaning.

Within this report, emissions are assumed to be immaterial if they are likely to account for less than 5% of the overall emissions profile. In calculating the GHG emissions for the project, all sources of GHG emissions where adequate data was provided have been included.

### 8.3.3 Aggregation

Aggregation refers to the combining of several inventories, typically of different sites or operations, into an overall inventory. This report is specific to the Project and does not contain an aggregated inventory of all the Proponent's GHG emissions.

### 8.3.4 Uncertainty Analysis

A measure of the uncertainty for Scope 1 emissions within the inventory is a standard part of a GHG inventory as indicated by the Technical Guidelines (DCCEE, 2011). Uncertainties associated with the GHG inventory are either related to scientific uncertainty or estimation uncertainty.

Analysing and quantifying scientific uncertainty is extremely problematic as it often involves, for example, estimating uncertainty in the global warming potential values; and as a consequence, an estimate of scientific uncertainty is beyond the capacity of this inventory.

Estimation uncertainty can be classified further into two types: model uncertainty and parameter uncertainty. Model uncertainty refers to the uncertainty associated with mathematical equations used to calculate the emissions. This is also beyond the scope of the inventory.

Parameter uncertainties within this inventory can be divided into two parts:

- uncertainty relating to activity data; and
- uncertainty relating to emission factors.

Activity uncertainties relate to measured quantities, including:

- production;
- consumption; and
- monitored data.

Emission factor uncertainty considers the conversion from measured activities to GHG emissions.

#### *Fuel Combustion*

Following the process outlined in the Technical Guidelines (DCCEE, 2011), an uncertainty level for fuel is determined by a combination of uncertainties associated with the energy content factor, $CO_2$ emission factor and the quantity of fuel.

The Technical Guidelines (DCCEE, 2011) provide standard uncertainties for diesel and natural gas distributed in a pipeline for the energy content factor and emission factor, see Table 8-2.

**Table 8-2 Standard Uncertainties for Diesel and Natural Gas distributed in a pipeline (DCCEE, 2011, Section 8.6)**

| Fuel Combusted | Energy Content Uncertainty Level (%) | $CO_2$ Emission Factor Uncertainty Level (%) |
|---|---|---|
| Diesel Oil | 2 | 2 |
| Natural gas if distributed in a pipeline | 4 | 4 |

For the estimation of the quantity of fuel, the Technical Guidelines (DCCEE, 2011) provide an uncertainty level based on the method used to make the estimation. The levels of uncertainty for the method of estimation of the quantity of fuel have been outlined in Table 8-3. For this assessment, Criteria BBB has been adopted as this assessment is based on estimated requirements for the proposed project.

**Table 8-3 Level of Uncertainty for the method of estimation of the quantity of fuel**

| Criterion Letter | Criterion | Uncertainty Level (%) |
|---|---|---|
| A | The amount of the fuel delivered for the facility during the year as evidenced by invoices or delivery records issued by the vendor of the fuel. | 1.5 |
| AA | Indirect measurement at the point of consumption, based on the amount of fuel delivered for the facility and adjusted for changes in stock. | 1.5 |
| AAA | Direct measurement at the point of consumption, based on the amount of fuel combusted as estimated by measurement equipment that complies with specified standards. | 1.5 |
| BBB | Simplified measurement of consumption. | 7.5 |

Table 8-4 outlines the uncertainties and how they have been derived.

**Table 8-4 Uncertainties for Fuel Combustion**

| Parameter | Diesel Uncertainty (%) | Natural Gas Uncertainty (%) |
|---|---|---|
| Energy Content Factor | 2 | 4 |
| Emission Factor | 2 | 4 |
| Quantity of Fuel Combusted | 7.5 | 7.5 |

Per Section 8.11 (1) of the Technical Guidelines (DCCEE, 2011), the aggregated uncertainty for fuel combustion is calculated by:

$$D = \pm\sqrt{A^2 + B^2 + C^2}$$

where:

- D is the aggregated uncertainty for the emission source (%);
- A is the uncertainty associated with the emissions factor for the source (%);
- B is the uncertainty associated with the energy content factor for the source (%); and
- C is the uncertainty associated with the activity data for the source (%).

Using the methodology detailed in the Technical Guidelines (DCCEE, 2011), an aggregated uncertainty level of ± 8% has been calculated for diesel, and ± 9.4% for natural gas. This includes the uncertainty level for the emission factor, energy content factor, and the activity data.

In Section 8.1 it was described that a confidence level of 95% (± 5% uncertainty level) was considered acceptable. The Technical Guidelines (DCCEE, 2011) were developed to calculate the GHG emissions associated with an existing facility for the previous year of operation for reporting to the Australian Government. While this standard has been applied in calculating the emissions of the proposed project, the assessment is expected less accurate as it is derived from predictions rather than actual usage over the life of the project.

# Greenhouse Gas Results and Management

## 9.1 Scope 1 and 2 Emission Summary

The GHG Scope 1 and 2 emission sources from the Project that are included in this inventory are:

- Diesel combustion in vehicles (Scope 1);
- Diesel combustion for stationary energy (i.e. pumps) (Scope 1);
- Carbon Sink Capacity Loss (Scope 1); and
- Electricity consumption (Scope 2).

Emissions from other sources, such as waste-to-landfill and use of oil, grease and acetylene, as considered to be not material to the inventory. This has been confirmed through a review of NGERS (National Greenhouse and Energy Reporting) data supplied by MRM.

The Scope 1 and 2 emissions for the Project are summaries in Table 9-1. The average annual emissions from the Project are presented, as well as the total GHG emissions over the Life of Mine (LOM).

These data are shown in terms of tonnes of $CO_2$-e, which includes the contribution of other relevant GHGs ($CH_4$ and $N_2O$). However, these gases represent only 0.1% of the total inventory and are not presented separately.

**Table 9-1 Estimated GHG Emissions for the MRM Project**

| Scope | Source | Minimum Emissions (t CO2-e/yr) | Maximum Emissions (t CO2-e/yr) | Average Emissions (t CO2-e/yr) | LOM Emissions (t CO2-e/yr) |
|---|---|---|---|---|---|
| 1 | Diesel Combustion (transport) | 791 | 4,128 | 2,252 | 58,543 |
| 1 | Diesel combustion (stationary) | 19,099 | 99,634 | 54,351 | 1,413,114 |
| 1 | Carbon Sink Capacity Loss | - | 26,383 | 5,926 | 154,067 |
| | Annual Scope 1[1] | 19,890 | 128,459 | 62,528 | 1,625,724 |
| 2 | Electricity consumption | 107,535 | 215,070 | 202,662 | 5,269,215 |
| | Annual Scopes 1 and 2[2] | 145,317 | 343,529 | 265,190 | 6,894,939 |

[1] This row indicates the minimum, maximum, average and life of mine emissions of all the totalled Scope 1 emissions and hence will not equal the total of the Scope 1 emissions included in this table.

[2] This row indicates the minimum, maximum, average and life of mine emissions of all the totalled Scopes 1 and 2 emissions and hence will not equal the total of the Scopes 1 and 2 emissions included in this table.

The GHG emissions presented are based on current predictions regarding the mine's future operations, diesel and electricity consumption. GHG emissions from explosives have not been calculated as there is no emission rate in the Technical Guideline (DCCEE, 2011) specifically for explosives. Screening calculations to estimate the approximate contribution of explosives to the inventory were carried out and this source was found to be not material.

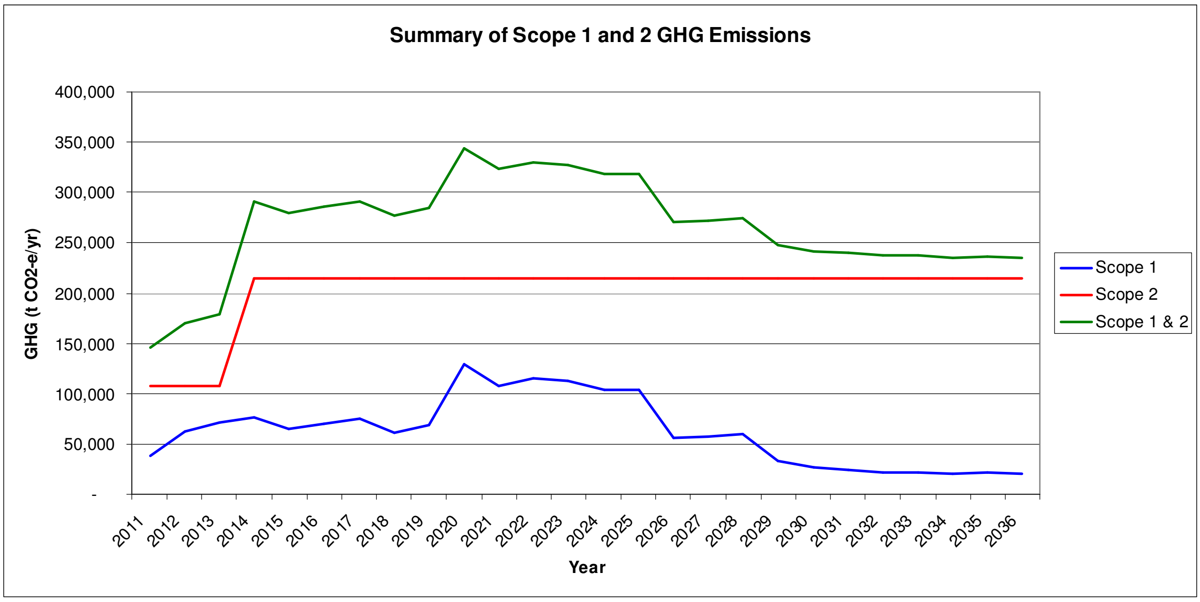
Figure 9-1 shows the estimated GHG emissions for the Scope 1 and Scope 2 emissions throughout the life of the Project.

Analysis of the annual GHG inventory for all Scope 1 and Scope 2 emissions shows the GHG emissions continue to increase with the clearing of vegetation works that are to occur for expansion of the pit and new overburden stockpile. Once these construction activities are completed (including the increased diesel use from trucking of the associated overburden), the GHG emissions for the project slightly reduce and become steady for the remainder of the project. It should be noted that the loss of carbon sink capacity is not considered cumulative (AGO, 2005), i.e. once an area is cleared any regrowth is considered as a negative carbon emission (i.e. it reduces the overall emissions). The largest GHG emissions are predicted to occur in Year 2020.

Scope 2 emissions far exceed Scope 1 emissions throughout the life of the mine.

The Project will be obliged to report under the NGER Act given that emissions for the Project's Scope 1 and Scope 2 emissions will exceed the 25,000 tonne $CO_2$-e threshold.

**Figure 9-1 Total of Scope 1 and 2 GHG Emissions (tonnes CO2-e)**




### 9.1.1 Performance Measures

The performance of the GHG emissions efficiency can be measured as emissions intensity. Emissions intensity is defined as tonnes $CO_2$-e per tonne of product.

The emissions intensity of the Project based on Scope 1 and 2 emissions ranges from 0.01 to 0.02 tonnes $CO_2$-e per tonne of product ore once operations are in full production, averaging 0.02 tonnes $CO_2$-e per tonne of product ore.

### 9.1.2 Emissions Comparison

The Australian National Greenhouse Accounts National Inventory by Economic Sector 2009 (DCCEE, 2011a) is the latest available national account of Australia's GHG emissions. The National GHG Inventory has been prepared in accordance with the Revised 1996 and 2006 Intergovernmental Panel on Climate Change (IPCC) Objectives for National GHG inventories (IPCC, 2007).

A comparison between the project's maximum year of emissions, and the 2009 inventories for Australia, Northern Territory, and the Mining non-energy sector including and excluding land use and land use change (LULUCF) total are provided in Table 9-2.

**Table 9-2 Comparison of Australian and Project GHG Emissions**

| Inventory | Total Emissions (Mt $CO_2$-e) | Maximum Project Emissions (Mt $CO_2$-e) | Maximum Project Contribution (%) |
|---|---|---|---|
| 2009 Aus (incl LULUCF) | 549.9 | 0.34 | 0.1 % |
| 2009 Aus (excl LULUCF) | 418.3 | 0.32 | 0.1 % |
| 2009 NT (incl LULUCF) | 11.6 | 0.34 | 3.0 % |
| 2009 NT (excl LULUCF) | 10.6 | 0.32 | 3.0 % |
| 2009 Aus Mining Non-Energy (incl LULUCF, Scope 1 only) | 7.4 | 0.24 | 3.2 % |

The maximum contribution of the Project to any of these inventories is 3.2%. This contribution is not considered to be materially relevant.

## 9.2 Management

Xstrata Zinc Australia metallurgical operations are powered primarily by electricity while the main source of energy in their mining operations is diesel used to run the mining fleet.

## 9.3 Commitment

Xstrata recognises that greenhouse gases, released by fossil fuel consumption related to these energy sources and other sources, contribute to climate change. The future potential impacts of climate change, including increased regulation, higher energy costs and physical impacts such as drought and flooding, present a risk to operations. Xstrata supports coordinated, global action to reduce greenhouse gas emissions.

Xstrata Zinc Australia has a series of targets including, GHG emissions targets, which they score themselves against each year in their Sustainability Report (Xstrata Zinc, 2010). Provided in Table 9-3 are the 2010 targets, their scores for that year, and the 2011 targets. Xstrata has not achieved a targeted reduction in total energy consumption with instead an increase experienced. This was due to the change in operations from an underground mine to an open cut pit in 2006. The result was also impacted by revisions to the reporting system used to track on-site electricity generation in line with evolving National Greenhouse and Energy Report Act 2007 requirements. Xstrata has met its other targets of a reduction in energy intensity, and compliance with the requirements of NGERs.

## 9 Greenhouse Gas Results and Management

**Table 9-3 GHG Emissions 2010 Scorecard and 2011 Targets**

| 2010 Target | 2010 Performance | 2011 Target |
|---|---|---|
| 5% reduction in the intensity of direct GHG emissions (per tonne of final product/ore milled) over 2005 performance by 2010 | Not Achieved. This was due to the change in operations since 2005 from underground to open pit since 2006 which requires greater fuel consumption. | 3% reduction in GHG direct emissions intensity over 2010 performance by 2012 |
| 1% reduction in energy intensity (per tonne of final product/ore milled) over 2007 performance by 2012 (0.6) | Achieved, (actual was 0.1) | 1% reduction in energy intensity (per tonne of final product/ore milled) over 2007 performance by 2012 |
| Comply with requirements under the NGERS, Energy Efficiency Opportunities Act 2006 | Achieved | • Report monthly on NGERS requirements and track performance according to targets set by CBU<br>• Continue to develop Energy Efficiency Opportunities and report annually<br>• Report on cost savings associated with GHG or energy efficiency projects on an annual basis |

Xstrata Holdings Pty Ltd is registered in accordance with the National Greenhouse and Energy Report Act 2007. The annual report was submitted to Federal Government in October 2010. Xstrata Mount Isa Mines, Bowen Coke and MRM activities are reported as part of the Xstrata Holdings Pty Ltd submission.

### 9.3.1 Project Requirements

This Project will operate in accordance with the following climate change policies: Clean Energy Future (CEF), Energy Efficiency Opportunities (EEO), and National Greenhouse and Energy Reporting (NGER), as described above.

### 9.3.2 Electricity Generation

While the use of diesel, other fuels and explosives in open pit mining produce GHG, the main source of GHG at MRM is electricity generation. While electricity generation is the highest contributor, the power station at MRM is natural gas-fired, which is one of the most GHG efficient fuels for generating electricity.

A variety of options are being considered to accommodate the increased electricity requirement with the expansion of the mine. These options are considering more efficient technology, so greater electricity can be generated for each tonne of $CO_2$-e emitted. This assessment has not accounted for these potential efficiencies.

### 9.3.3 Greenhouse Gas Minimisation Measures

MRM has already implemented a number of energy efficiency measures to reduce emissions of GHGs, including:

- Replacing sand with ceramic media in the primary grinding mills;
- Replacing diesel powered light towers with mains connected LEDs at the mine;

- Timers to control lighting across the site; and
- Driver simulation softwarwe for bulldozers and loaders instead of using equipment.

Future projects directly related to the current Project (the new crushing plant in particular) are expected to include:

- Improved materials for more efficient road maintenance; and
- Reduced rehandling off screening plant and reduced transport of purchased materials.

In addition, the following measures have been proposed:

- New crib room to reduce truck travel distance;
- New more efficient water pump;
- Use of a solar powered pump to pump water to a holding tank for irrigation, replacing diesel plant;
- Replace sodium lights with LEDs across the site.

### 9.3.4 Offsetting Carbon Emissions

The GHG inventory presented in this report accounts for the loss of carbon sink capacity of vegetation due to clearing. However, MRM also has in place a rehabilitation programme, which will offset this by providing new vegetation to sequester carbon dioxide from the atmosphere. In 2010, 60 ha of land were rehabilitated, compared to 15 ha in 2009. This included planting of 40,000 native species seedlings. Growth and establishment of forest through the continuation of the rehabilitation programme represents a significant opportunity to offset emissions from the project directly within the NT.

Further offsetting of emissions is likely to be accomplished in accordance with the Clean Energy Future legislation. This will include carbon trading during the floating price phase (due to commence in 2015) where international permits such as certified emissions reduction units under the Kyoto Protocol Clean Development Mechanism and emission reduction units under the Kyoto Protocol Joint Implementation arrangements may be used for up to 50% of an organisation's carbon liabilities under the legislation.

### 9.3.5 Greenhouse Challenge Program

Xstrata Zinc Australia intends to become a signatory to the Greenhouse Challenge Program, and accordingly will improve reporting on emissions management. The Greenhouse Challenge is a voluntary program coordinated by the AGO, aimed at reducing the greenhouse gas emissions of organisations.

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# Conclusion

Xstrata proposes to undertake a third phase of development at MRM to increase the mine life by 9 years to 2036, with a mining rate of approximately 5 million tonnes per annum. To achieve this increase, the open cut pit will be expanded by doubling the width, and by doubling the depth. In addition, the power station capacity will be increased from 20 MW to 45-50 MW.

This report has considered the potential air quality and greenhouse gas impacts of this expansion in the context of NT, Commonwealth and international guidance. Impacts on local air quality were assessed for emissions from the mine and power station using the CALPUFF model. All defined project goals were predicted to be achieved. Greenhouse gas emissions were quantified and found to be not material in the context of current national, state and sectoral emissions.

It is proposed that the existing programme of monitoring for dust deposition, lead and zinc at MRM and Bing Bong Port is continued, and supplemented with monitoring for nitrogen dioxide and $PM_{10}$

Additional dust controls being put in place at Bing Bong Port are anticipated to ensure that there is no additional impact as a result of the additional concentrate throughput.

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# Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of MET Serve Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 4 April 2011.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between May and September 2011 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

A

# Appendix A Wind Roses

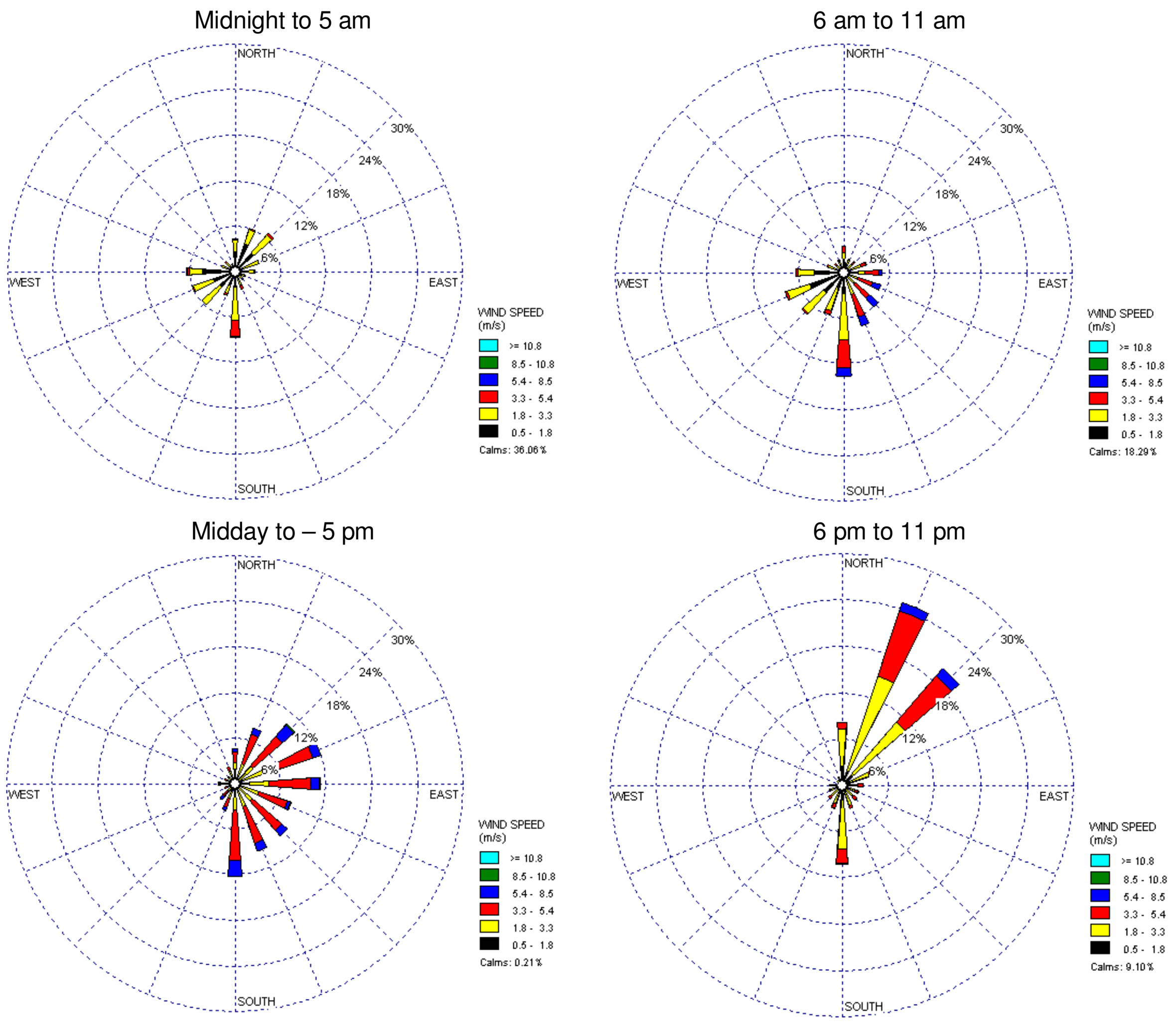


**Figure A-1 BOM MRM Time of Day Wind Roses**

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## Appendix A

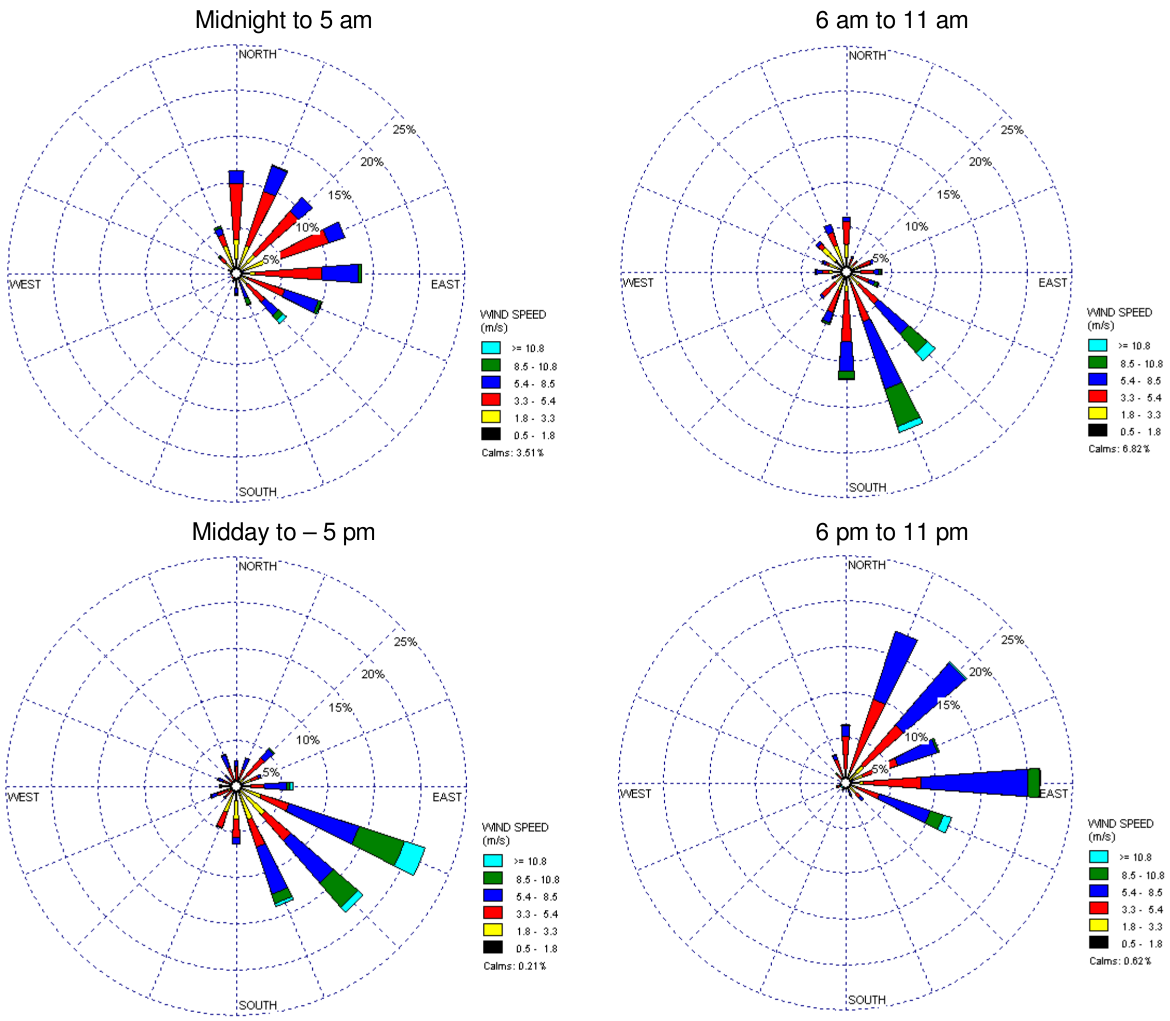


**Figure A-2 BOM Centre Island Time of Day Wind Roses**

B

# Appendix B Dust Deposition Summary

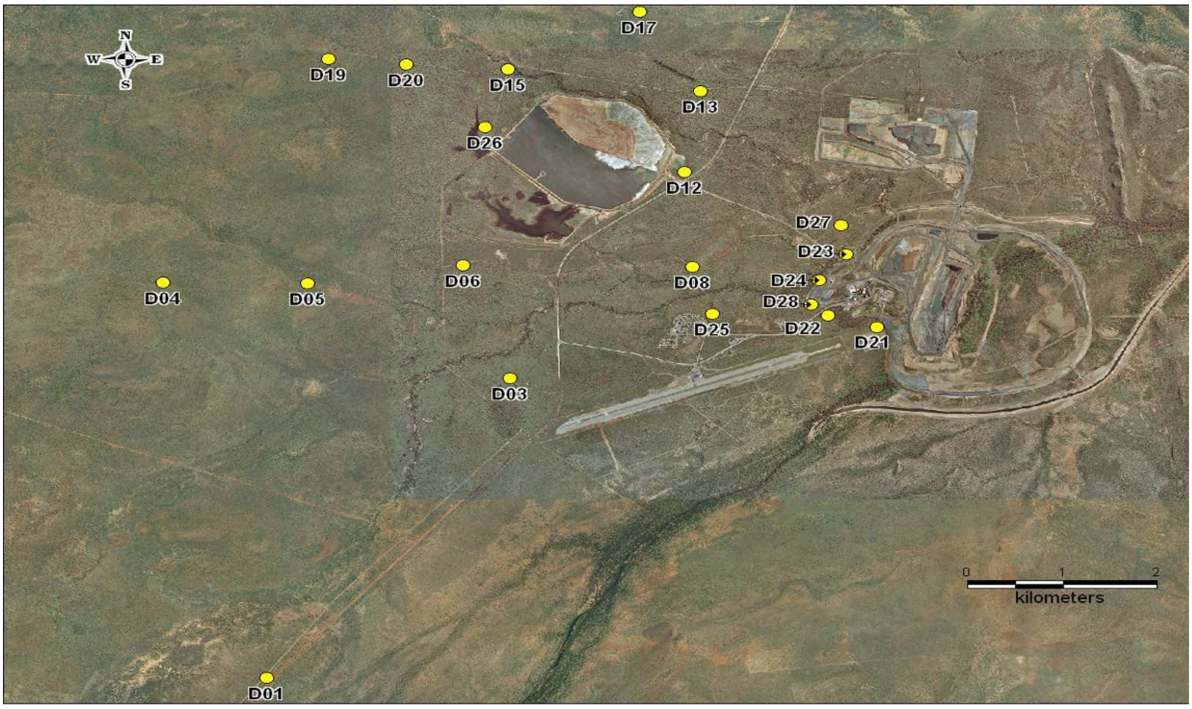


**Figure B-3 Dust Deposition Monitoring Locations at McArthur River Mine**

**Table B-1 Summary of Dust Deposition Monitoring Results at McArthur River Mine**

| Unit | Site | TIM (g/m²/month) | Pb (mg/kg) | Zn (mg/kg) | Site | TIM (g/m²/month) | Pb (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Mean | D01 | 2.0 | 7851.4 | 21310.5 | D19 | 0.8 | 4086.7 | 13289.8 |
| Min | | 0.3 | 2780.0 | 30.0 | | 0.0 | 330.0 | 100.0 |
| Max | | 4.6 | 19296.2 | 53255.1 | | 3.1 | 16818.2 | 66279.1 |
| Mean | D03 | 0.8 | 6905.8 | 14588.2 | D20 | 0.8 | 6155.0 | 12587.0 |
| Min | | 0.1 | 250.0 | 230.0 | | 0.1 | 1223.0 | 780.0 |
| Max | | 2.3 | 23863.6 | 47000.0 | | 2.4 | 25932.2 | 45000.0 |
| Mean | D04 | 1.4 | 1260.0 | 1070.0 | D21 | 5.2 | 3168.3 | 8206.2 |
| Min | | 0.3 | 1260.0 | 1070.0 | | 0.4 | 40.0 | 80.0 |
| Max | | 3.2 | 1260.0 | 1070.0 | | 18.6 | 10670.0 | 32009.9 |
| Mean | D05 | 0.6 | 5072.4 | 15370.5 | D22 | 6.3 | 19868.5 | 42398.6 |
| Min | | 0.0 | 1180.0 | 1010.0 | | 0.1 | 310.0 | 460.0 |
| Max | | 2.2 | 13750.0 | 38235.3 | | 21.4 | 45400.6 | 131176.5 |
| Mean | D06 | 0.9 | 5082.8 | 13163.9 | D23 | 3.0 | 9337.6 | 23400.0 |
| Min | | 0.0 | 0.0 | 0.0 | | 0.2 | 40.0 | 40.0 |
| Max | | 4.3 | 16100.0 | 39200.0 | | 8.7 | 23430.4 | 57182.0 |
| Mean | D08 | 1.4 | 2974.7 | 8434.5 | D24 | 7.8 | 21527.6 | 43496.7 |
| Min | | 0.0 | 0.0 | 0.0 | | 0.1 | 170.0 | 160.0 |
| Max | | 4.3 | 16100.0 | 39200.0 | | 32.9 | 143000.0 | 345000.0 |

# Appendix B

| Unit | Site | TIM ($g/m^2/month$) | Pb (mg/kg) | Zn (mg/kg) | Site | TIM ($g/m^2/month$) | Pb (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Mean | D12 | 1.4 | 3663.4 | 7484.0 | D25 | 3.7 | 6939.6 | 18975.7 |
| Min | | 0.0 | 0.0 | 0.0 | | 0.1 | 0.0 | 0.0 |
| Max | | 5.3 | 22413.8 | 25775.9 | | 27.8 | 29864.9 | 57162.2 |
| Mean | D13 | 1.1 | 4574.3 | 8715.3 | D26 | 1.1 | 6768.5 | 14915.9 |
| Min | | 0.1 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| Max | | 5.6 | 23700.0 | 31250.0 | | 4.2 | 66666.7 | 166666.7 |
| Mean | D15 | 1.4 | 4709.9 | 7425.5 | D27 | 4.2 | 2867.9 | 6855.1 |
| Min | | 0.1 | 170.0 | 100.0 | | 0.7 | 0.0 | 0.0 |
| Max | | 4.8 | 27000.0 | 60000.0 | | 14.0 | 5600.0 | 16000.0 |
| Mean | D17 | 0.9 | 5261.9 | 16578.8 | D28 | 11.1 | 25763.3 | 61695.2 |
| Min | | 0.0 | 420.0 | 290.0 | | 0.1 | 160.0 | 360.0 |
| Max | | 3.6 | 21600.0 | 93600.0 | | 36.5 | 209000.0 | 990000.0 |

C

# Appendix C Emission Estimation Methodology

## C.1 Particulate Matter Emissions Estimation

The quantity of emissions of particulates from the Project cannot be determined from direct measurement as the proposed expansion is not yet operational. The activities that are proposed to occur across the McArthur River Mine, and the resulting emissions, have been summarised and described by emission factors.

Particulate emissions from the Project have been estimated based on mine plans and activity data provided by MET Serve, in conjunction with emission factors provided in the National Pollutant Inventory (NPI) Emission Estimation Technique (EET) Manuals. The emission factors contained in the NPI EET manuals have been developed from measurements of particulate emissions from other operational mines in Australia and the United States during typical operations.

The following summarises the emission factors adopted and the input parameters used to estimate the amount of TSP and $PM_{10}$ emitted from the various activities proposed.

In some instances there is both an equation provided so the emission factor can be calculated based on site specific information, and also a default emission factor which has been developed from a range of mines. In all these cases the site specific emission factor has been calculated and used, even if it is higher than the default provided.

### C.1.1 Activities Described by Emission Factors

The following table summarises the emission factors that have been used to describe the proposed emission sources at the site, and the source of the factor. Where a default emission factor has been used, this line is shaded.

**Table C-2 Emissions Factors used to Described the Proposed Project Emission Sources**

| Activity | Material | Unit | TSP EF | PM10 EF | Source |
|---|---|---|---|---|---|
| Excavators/Shovels/FEL | Overburden | kg/t | 0.000373 | 0.000176 | NPI Mining |
| Excavators/Shovels/FEL | ROM | kg/t | 0.000373 | 0.000176 | NPI Mining |
| Bulldozer | Other than coal | kg/h | 1.199 | 0.186 | NPI Mining |
| Trucks Dumping | Overburden | kg/t | 0.012 | 0.0043 | NPI Mining |
| Drilling | | kg/hole | 0.59 | 0.31 | NPI Mining |
| Blasting | Overburden | kg/blast | 148.27 | 77.10 | NPI Mining |
| Blasting | ROM | kg/blast | 343 | 178.6 | NPI Mining |
| WGD- unpaved roads | Overburden- full | kg/VKT | 4.19 | 0.84 | NPI Mining |
| WGD- unpaved roads | Overburden- empty | kg/VKT | 2.75 | 0.60 | NPI Mining |
| WGD- unpaved roads | ROM- full | kg/VKT | 3.81 | 0.78 | NPI Mining |
| WGD- unpaved roads | ROM- empty | kg/VKT | 2.49 | 0.56 | NPI Mining |
| WGD- unpaved roads | Product- full | kg/VKT | 3.81 | 0.78 | NPI Mining |
| WGD- unpaved roads | Product- empty | kg/VKT | 2.49 | 0.56 | NPI Mining |
| Graders | | kg/VKT | 0.19 | 0.08 | NPI Mining |
| Loading Stockpiles | | kg/t | 0.004 | 0.0017 | NPI Mining |
| Unloading Stockpiles | | kg/t | 0.03 | 0.013 | NPI Mining |
| Misc Transfer Point | ROM | kg/t | 0.000373 | 0.000176 | NPI Mining |
| Misc Transfer Point | Product | kg/t | 0.001345 | 0.000636 | NPI Mining |

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| Activity | Material | Unit | TSP EF | PM10 EF | Source |
|---|---|---|---|---|---|
| Wind Erosion | Stockpiles- OB | kg/ha/yr | 32.2 | 16.1 | SKM 2005 |
| Wind Erosion | Stockpiles- Ore | kg/ha/yr | 157.0 | 78.5 | SKM 2005 |
| Wind Erosion | Exposed Surfaces | kg/ha/yr | 48.3 | 24.2 | SKM 2005 |
| Crushing- Primary | Low moisture ore (<4%) | kg/Mg | 0.2 | 0.02 | AP42.11.24 |
| Crushing- Primary | High moisture ore (>4%) | kg/Mg | 0.01 | 0.004 | AP42.11.24 |
| Crushing- Secondary | Low moisture ore (<4%) | kg/Mg | 0.6 | 0.02 | AP42.11.24 |
| Crushing- Secondary | High moisture ore (>4%) | kg/Mg | 0.03 | 0.012 | AP42.11.24 |
| Crushing- Tertiary | Low moisture ore (<4%) | kg/Mg | 1.4 | 0.08 | AP42.11.24 |
| Crushing- Tertiary | High moisture ore (>4%) | kg/Mg | 0.03 | 0.01 | AP42.11.24 |
| Screening | Low moisture ore (<4%) | kg/Mg | 0.0125 | 0.0043 | AP42.11.19.2 |

Note- shaded lines represent where default emission factors have been adopted

### C.1.2 Input Parameters for Site Specific Emission Factors

The following information has been used to calculate the site specific emission factors:

**Table C-3 Site Specific Emission Factor Input Parameters**

| Description | Material | Value | Unit | Symbol | Source |
|---|---|---|---|---|---|
| Mean Wind Speed | NA | 2.4 | m/s | U | CALMET data |
| Depth of blast holes | Overburden | 17.5 | m | D | Project Description |
| | Ore Insitu | 9 | m | D | Project Description |
| Silt Content | Overburden | 2 | % | s | Expansion 2 EIS |
| | Road | 3 | % | s | Expansion 2 EIS |
| | Product | 3 | % | s | Expansion 2 EIS |
| | ROM | 3 | % | s | Expansion 2 EIS |
| Mean Vehicle Speed | Grader | 5 | Km/h | S | Previous Studies |
| Moisture Content | Overburden | 5 | % | M | Expansion 2 EIS |
| | Road | 2 | % | M | Expansion 2 EIS |
| | Product | 2 | % | M | Expansion 2 EIS |
| | ROM | 5 | % | M | MRM NPI Reporting 2010 |
| Area blasted | Overburden | 10,000 | $m^2$ | A | Project Description |
| | Ore Insitu | 6,400 | $m^2$ | A | Project Description |
| Vehicle gross mass | Overburden full | 384 | t | W | Online Spec- Cat793 (220t) |
| | Overburden empty | 166 | t | W | Online Spec- Cat793 (220t) |
| | ROM full | 317.5 | t | W | Online Spec- Cat789 (175t) |
| | ROM empty | 135.7 | t | W | Online Spec- Cat789 (175t) |
| | Product full | 317.5 | t | W | Online Spec- Cat789 (175t) |
| | Product empty | 135.7 | t | W | Online Spec- Cat789 (175t) |
| Days rainfall >0.25mm | NA | 58 | count | p | CALMET data |
| Wind Speed >5.4m at mean height of stockpile | Overburden | 0.4 | % | f | CALMET data |
| | Product | 1.3 | % | f | CALMET data |
| | Exposed areas | 0.4 | % | f | CALMET data |

### C.1.3 Site Specific Emission Factor Equations

The following equations have been used to calculate the site specific emission factors. Wind Speed dependant emission factors are discussed in Appendix Section C.1.4.

#### *Excavators/shovels/front end loaders (FEL)*

Dust emissions from loading of trucks using excavators, shovels or front-end loaders were estimated using the following NPI equation:

$$EF = k \times 0.0016 \times (\frac{U}{2.2})^{1.3} (\frac{M}{2})^{-1.4} \qquad kg/t$$

Where:

- $k$ = 0.74 for TSP and 0.35 for $PM_{10}$
- $U$ = mean wind speed (m/s)
- $M$ = moisture content of overburden or ore (%)

#### *Bulldozers*

Dust emissions from the use of bulldozers was estimated using the following NPI equation:

For TSP, the following NPI equation was used

$$EF = 2.6 \frac{s^{1.2}}{M^{1.3}} \qquad kg/h$$

For $PM_{10}$, the following NPI equation was used

$$EF = 0.34 \frac{s^{1.5}}{M^{1.4}} \qquad kg/h$$

Where:

- $s$ = silt content (%)
- $M$ = moisture content (%)

#### *Blasting*

Dust emissions from blasting was estimated using the following NPI equation:

For TSP, the following NPI equation was used

$$EF = 344 \times A^{0.8} \times M^{-1.9} \times D^{-1.8} \qquad kg/blast$$

Where:

- $A$ = area blasted in $m^2$
- $M$ = moisture content of material blasted (%)
- $D$ = depth of blast holes in meters

For PM10, the value calculated for TSP is multiplied by 0.52

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### Wheel generated dust

The following NPI formula was used to estimate wheel generated dust:

$$EF = k \times (\frac{s}{12})^{A} \times (\frac{W}{3})^{B} \div (\frac{M}{0.2})^{C} \qquad kg / VKT$$

Where:

- $k$ = 2.82 for TSP and 0.733 for $PM_{10}$
- $s$ = silt content in %
- $W$ = vehicle gross mass in tonnes
- $M$ = Moisture content % (of road surface)
- $A$ = 0.8
- $B$ = 0.5 for TSP and 0.4 for $PM_{10}$
- $C$ = 0.4 for TSP and 0.3 for $PM_{10}$

### Graders

The following NPI formulas have been used to estimate grader dust emission:

$$EF = 0.0034 S^{2.5} \qquad kg / VKT \qquad \text{for TSP}$$

$$EF = 0.0034 S^{2.0} \qquad kg / VKT \qquad \text{for } PM_{10}$$

Where:

- $S$ = mean vehicle speed in km/h (5 km/h)
- VKT = vehicle kilometres travelled

### Miscellaneous Transfer points

For conveyor belt transfer points, the following NPI formula has been used:

$$EF = k 0.0016 (\frac{U}{2.2})^{1.3} (\frac{M}{2})^{-1.4} \qquad kg / t$$

Where:

- $U$ = mean wind speed (m/s)
- $M$ = material moisture content (%)
- $k$ = 0.74 for TSP and 0.35 for $PM_{10}$

## C.1.4 Wind Speed Dependant Emissions

### Introduction

In an evaluation of fugitive particulate matter emission estimation techniques, Sinclair Knight Mertz (SKM) (2005) recommended not using the current default emission factors in the NPI Mining Manual (2001), which are a constant value of 0.4 kg/ha/h for TSP and 0.2 kg/ha/hr for $PM_{10}$, as crucial environmental factors such as wind and surface wetness are not considered. SKM (2005) suggested retaining the current NPI equation, presented here as Equation 1, to account for the climate variations across Australia while recognising the uncertainty and indicative nature of the NPI equation.

$$E = 1.9(\frac{s}{1.5})365(\frac{365-p}{235})(\frac{f}{15})$$

Where:

- s is the silt content (%);
- f is the percentage of time that wind speed is greater than 5.4 m/s at the mean height of the stock pile; and
- p is the number of days when rainfall is greater than 0.25 mm.

The equation above is used in the revised modelling of the impacts of dust emissions from the Project to provide an estimate for the annual total emissions of particulates associated with wind erosion. The local meteorological data was then used to distribute the total annual emissions equally to those hours for which the wind speed is greater than a critical wind speed using the methodology outlined in the following sections.

### *Wind Erosion for Stockpiles*

The NPI Mining Manual (2001) suggests the use of *Equation 1* to calculate annual dust emission from active coal stockpiles. *Equation 1* is for estimating emissions for total suspended particles (TSP). Emissions of $PM_{10}$ are estimated from TSP using a $PM_{10}$ to TSP ratio of 0.5. *Equation 1* represents the annual total emissions.

The following equation (SKM, 2005, Eq 5.14) was then used to distribute the total annual emissions into hourly emissions

$$F = ku^3(1-\frac{u^2}{u_0^2}) \text{ when } u > u_0 \text{, otherwise F = 0}$$

Where:

- k is a calculated constant;
- u is hourly average wind speed at root mean square height of the stockpile (m); and
- $u_0$ is a wind speed threshold velocity.

The critical wind speed $u_0$ is calculated based on a critical wind speed of 5.4 m/s at the root mean square height of the stockpile, corrected to 10 m based on logarithmic wind speed profile as shown in this equation.

$$u_0 = 5.4\ln(\frac{10-z_0}{z-z_0})$$

Where:

- z is the root mean square height of a stockpile (m)
- $z_0$ is the surface roughness (0.05 m)

The constant k is used to normalise the annual total of the power law relationship to the annual emissions calculated. In practice, this constant is calculated after the sum of the power law is calculated. The result is a wind speed dependent emission rate that increases in accordance with the power law, whilst agreeing with the annual emissions.

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### *Wind Erosion for Exposed Areas*

The methodology for the development of wind speed dependent dust emissions for exposed areas is identical to that for stockpiles with a critical wind speed of 5.4 m/s at 10 m height used in *Equation 2*.

### *Input Parameters*

The input parameters used to calculate the wind erosion emission factors is provided in Table C-4.

**Table C-4 Summary of Parameters used to Calculate Wind Erosion Emission Factors**

| Parameter | Units | ROM Stockpile | Overburden Stockpiles | Exposed Areas |
|---|---|---|---|---|
| Source height | m | 5 | 3 | 3 |
| Wind speed at source height | m/s | 5.4 | 5.4 | 5.4 |
| Critical wind speed @ 10m | m/s | 6.2 | 7 | 7 |
| Hours over critical wind speed | % | 1.3 | 0.4 | 0.4 |
| Silt content | % | 3 | 2 | 3 |
| F (kg/ha/year) | kg/ha/year | 156 | 32 | 48 |
| k | - | 0.2E-.2 | 4.9E-.3 | 0.0 |

## C.2 Power Station Configuration

Information provided for preparation of the power station parameters for modelling for each of the scenarios being investigated was very limited. Consequently many of the parameters have been generated on assumptions.

### C.2.1 Existing Power Station

Details provided on the existing power station included the model of the turbines/engines, and the advise to utilise the parameters used in the 2006 PER for the McArthur River Mine Open Cut Project. Upon examination of the 2006 inventory, it became apparent it was based on little known information and broad assumptions generally based around the parameters of the gas being used as fuel.

Having this time received the models of the turbines and engines, the assumptions previously made have been refined and in some instances changed, with more likely parameters being modelled.

Known information includes:

- There are 3 Solar Centaur turbines
- There are 3 Solar Taurus turbines
- There is 1 Caterpillar Diesel Engine

The following table outlines the 2006 PER modelling parameters against the 2011 modelling parameters.

**Table C-5 2006 PER Modelling Parameters Compared to 2011 Modelling Parameters for the Existing Power Station**

| Parameter | 2006 PER Modelling Parameters | 2011 EIS Modelling Parameters | | |
|---|---|---|---|---|
| Turbine Type | Unknown | Solar Centaur | Solar Taurus | Caterpillar Diesel |
| Number of Turbines | 1 | 3 | 3 | 1 |
| Stack Diameter (m) | 3.5 | 1.3 | 1.45 | 0.44 |
| Exhaust Temperature (ºC) | 605 | 120 | 120 | 554 |
| Exit Velocity (m/s) | 16.7 | 20 | 21 | 49 |
| Stack Height m | 23 | 10 | 12 | 5 |
| **Emission rate per turbine/engine (kg/hr)** | | | | |
| $NO_x$ (as $NO_2$) | 50.3 | 16.9 | 19.25 | 7.35 |
| $SO_2$ | 0.5 | 0.14 | 0.20 | 0.08 |
| CO | 11.5 | 1.71 | 1.95 | 0.04 |
| $PM_{10}$ | 2.0 | 0.14 | 0.20 | 0.14 |

As can be seen, the parameters have changed significantly. In order to model the worst case scenario for the 2011 EIS, it has been assumed that all turbines and engines will run at all times.

## C.2.2 Proposed Project Scenarios

Two scenarios have been identified in order to represent options being considered for increasing the capacity of electricity supply to the site. This information was provided in an options paper, “MRM Power Upgrade- Air Emissions and Noise Modeling Input Data”, Rev 1, July 2011.

As discussed in the options paper, power station expansion options are still being investigated for the Phase 3 mine development, and as such, the options presented were developed to encompass worst-case scenarios.

# Appendix D Modelling Methodology – Additional Details

## D.1 Meteorological Modelling

Dispersion modelling using CALPUFF requires detailed data on surface and upper air meteorology in the model domain. Surface and upper air data are incorporated to the meteorological pre-processor CALMET to develop a three dimensional grid of meteorology for the model domain.

The McArthur River Mine Bureau of Meteorology (BOM) monitoring station located onsite at the McArthur River Airport provides surface air meteorological measurements with sufficient frequency for inclusion in CALMET. In order to generate upper air meteorological measurements, The Air Pollution Model (TAPM) was used.

Meteorological modelling using CALMET was therefore undertaken in a two stage process:

- TAPM modelling to derive an upper air dataset;
- CALMET modelling incorporating:
  - Surface observations from McArthur River Mine airport; and
  - Upper air dataset from TAPM.

### D.1.1 TAPM Observation Generation

The Air Pollution Model (TAPM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is a prognostic model which may be used to predict three-dimensional meteorological data and the atmospheric concentration of emissions.

TAPM predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations.

Additionally, the TAPM model may assimilate actual local wind observations so that they can be included in a model solution. The wind speed and direction observations are used to weight the predicted solution towards the observed values. This function of accounting for actual meteorological observations within the region of interest is referred to as data assimilation. Data from the Bureau of Meteorology's (BOM) McArthur River Mine Airport Meteorological Station for 2009 were assimilated into TAPM in order to provide improved results for the meteorological parameters in the vicinity of the study site.

TAPM was set up for the region around the MRM Project to simulate wind flows around the location to a 1 km resolution. The table below details the parameters used in the meteorological modelling for this assessment.

**Table D-6 TAPM Model Parameters**

| Parameter | Value |
|---|---|
| Number of grids (spacing) | 5 (30 km, 10 km, 3 km, 1 km, 300 m) |
| Number of grid points | 25 x 25 x 25 |
| Year of analysis | 2009 |
| Centre of analysis | 615655m E, 8181899 m N (UTM zone 53) |
| Data Assimilation | McArthur River Mine Airport Meteorological Station (BOM) |

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TAPM has limitations which are a result of the necessity to simplify many of the processes within the atmosphere, subgrid-scale parameterisation and the application of boundary conditions. The earth curvature is not included in TAPM and hence any weather phenomena resulting from earth curvature are not represented. TAPM uses climate average sea-surface temperature and hence may not adequately simulate land and/or sea breezes.

### D.1.2 CALMET Meteorological Modelling

CALMET is a meteorological model that is used to generate gridded three-dimensional wind fields from observational meteorological measurements. It allows treatment of local terrain effects on wind flows with calculation of convergence/divergence parameters. It also calculates atmospheric mixing height and stability conditions caused by differential heating and cooling of the land surface depending on the angle and intensity of the solar insolation, in conjunction with the amount of cloud cover present. The TAPM output data files were used as direct inputs to the CALMET meteorological model by extracting the modelled data at the centre of the grid for the surface and upper air data files. CALMET outputs hourly atmospheric parameters such as wind speed and direction (three-dimensional), mixing height and stability class. The outputs from CALMET were used as inputs to the dispersion model CALPUFF.

The CALMET model parameters specified for this project are presented below.

**Table D-7 CALMET Model Parameters**

| **Parameter** | **Value** |
|---|---|
| Grid Spacing | 0.25 km |
| Number of grid points | 120 x 120 x 12 |
| Vertical levels; | 0, 20, 30, 40, 50, 70, 90, 100, 250, 500, 1000, 1500 and 2000m. |
| Year of analysis | 2009 |
| Grid Origin | 599.75 km E, 8166.4 km N |
| Data Assimilation | Surface Data from McArthur River Mine Meteorological Station (BOM)<br>Surface and Upper Air data from centre of TAPM grid<br>Landuse from USGS Landsat database<br>Terrain from Shuttle Ray Topography Missions |

The CALMET model domain is of sufficient size to include all mining activities and the receptors that may be affected by the proposed mining operations. The CALMET model features enhanced treatment of terrain effects around the site and allows the wind fields to be influenced by the differential heating of the land surface depending on the angle of the sun. Its non steady-state formulation also allows the wind fields to travel around or over obstacles such hills, depending on the strength of the wind and to recirculate emissions within the model domain as the prevailing wind directions change through the day. CALMET calculates parameters such as mixing height and stability class that are used in the model to determine the dispersion conditions for every hour of the year.

The limitations associated with the use of CALMET are related to sub-grid scale parameterisation, grid resolution, domain sizes and boundary conditions. For example, sub-grid scale terrain effects may not be fully captured and the minimum mixing height of 50 m used in the modelling may vary in the project area, depending on the weather condition.

## D.2 Dispersion Model Setup

### D.2.1 Model Setup

The model domain was set to reflect the meteorological domain, with the area being 40km by 40km, and grid points at spacing of 0.25 km.

The computation domain was reduced to an area from grid point 20, 20 to grid point 100, 100. The sample grid was reduced again to an area from grid point 26, 26 to grid point 94, 94. No nesting factor was applied.

### D.2.2 Source Types and Locations

The selection of source type to represent an air emission source is matched by the nature of the dust generating activities and release. The source type options in CALPUFF are point, area, volume and lines. Volume sources have been used for dispersion modelling of all sources of particulates from the site which best represent the scale of the activities conducted on open-cut mines. Activities such as excavating of ore or dropping of overburden from a excavator bucket result in the instantaneous creation of a cloud of dust, which is clearly visible from the edge of an operating open-cut pit.

Likewise, the plume of dust that is generated by a truck moving on unpaved roads is mixed in the wake of the vehicle to form a visible dust cloud that rises above the vehicle height. The volume source is the most representative of the nature of these activities, as it accounts for the dispersion of an amount of dust that is will mixed in the air immediately at the source.

For the power station a point source was adopted as this allows appropriate characterisation of the nature of a buoyant plume; with velocity and temperature being some of the parameters classified for a point source.

The sensitive receptor locations are at some distance from the mining activities (approximately 1km from the Mill). This separation of the sources and receptors lessens the influence of the initial source type selection, and results should be relatively independent of this selection.

Source emission parameters, such as the height of release and the initial spread of the plume from each release point, were estimated from data provided by the MET Serve on the height of sources and the source types. These data have been used to derive the source height and initial spread of the plume, used in the dispersion modelling setup, as noted in Table D-8.

The location of each source was derived from the mine plans that was developed for the project. Haul roads were modelled as individual volume sources spread along the haul routes at approximately 200 m intervals. The emissions for each road section were determined form the number of vehicle movements on the section and the distance travelled for the return journey.

Sources that are located in the pit, including excavators and blasting, were modelled as volume sources. For modelling of typical operations from the mine, the source locations were spread out along the pit base at 200m intervals, with emission rates corresponding to the appropriate pit activities.

Activities at the Mill such as dumping and stockpile movements were modelled as one volume source located at the centre of the Mill.

The power station was modelled as a series of stacks for each turbine/engine, with building downwash effects incorporated.

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**Table D-8 Source Height and Initial Horizontal and Vertical Spread of Plumes as used in Dispersion Modelling**

| Source Type | Emission Description | Source Height Above Ground Level (m) | Initial Horizontal Spread (m) | Initial Vertical Spread (m) |
|---|---|---|---|---|
| Inpit | Constant- excavators, truck loading, drilling of holes for blasting | 5 | Distance between volume sources / 2.15 | 1.16 |
| | Time Varying- blasting | 15 | 23.3 | 13.95 |
| | Wind Speed Dependent- wind erosion of exposed areas | 3m / 2= 1.5 | Distance between volume sources / 2.15 | 0.7 |
| Stockpiles | Constant- Unloading of trucks, dozers | 2.5 | Distance between volume sources / 2.15 | Effective height/4.3 |
| | Wind Speed Dependant- wind erosion on stockpiles | OB SP- 1.5<br>Ore SP- 2.5 | Distance between volume sources / 2.15 | OB SP- 0.7<br>Ore SP- 1.16 |
| Haul Roads/Ramps | Constant- truck movements | 5 | Distance between volume sources / 2.15 | 2.3 |
| Topsoil Stripping | Constant- Topsoil stripping | 5 | Distance between volume sources / 2.15 | 1.2 |
| Mill | Constant- processing at the Mill | 5 | 46.5 | 4.65 |

### *Particulate Matter Source Locations*

The following figures show the particulate matter sources for years 2011, 2025, 2030 and 2035. Locations of sources for year 2015 are shown in Section 5.3.2.

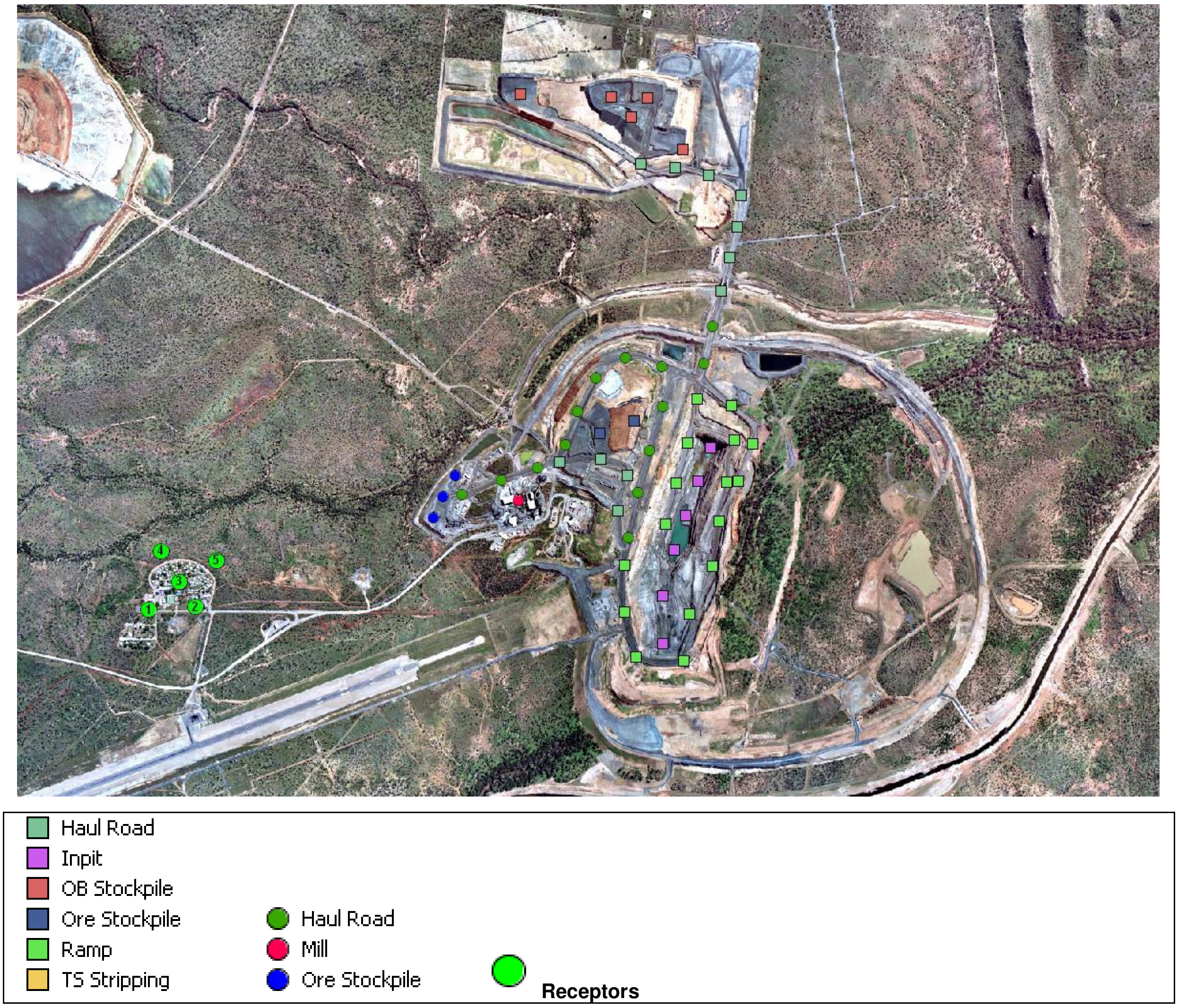


**Figure D-4 2011 Particulate Matter Source Locations**

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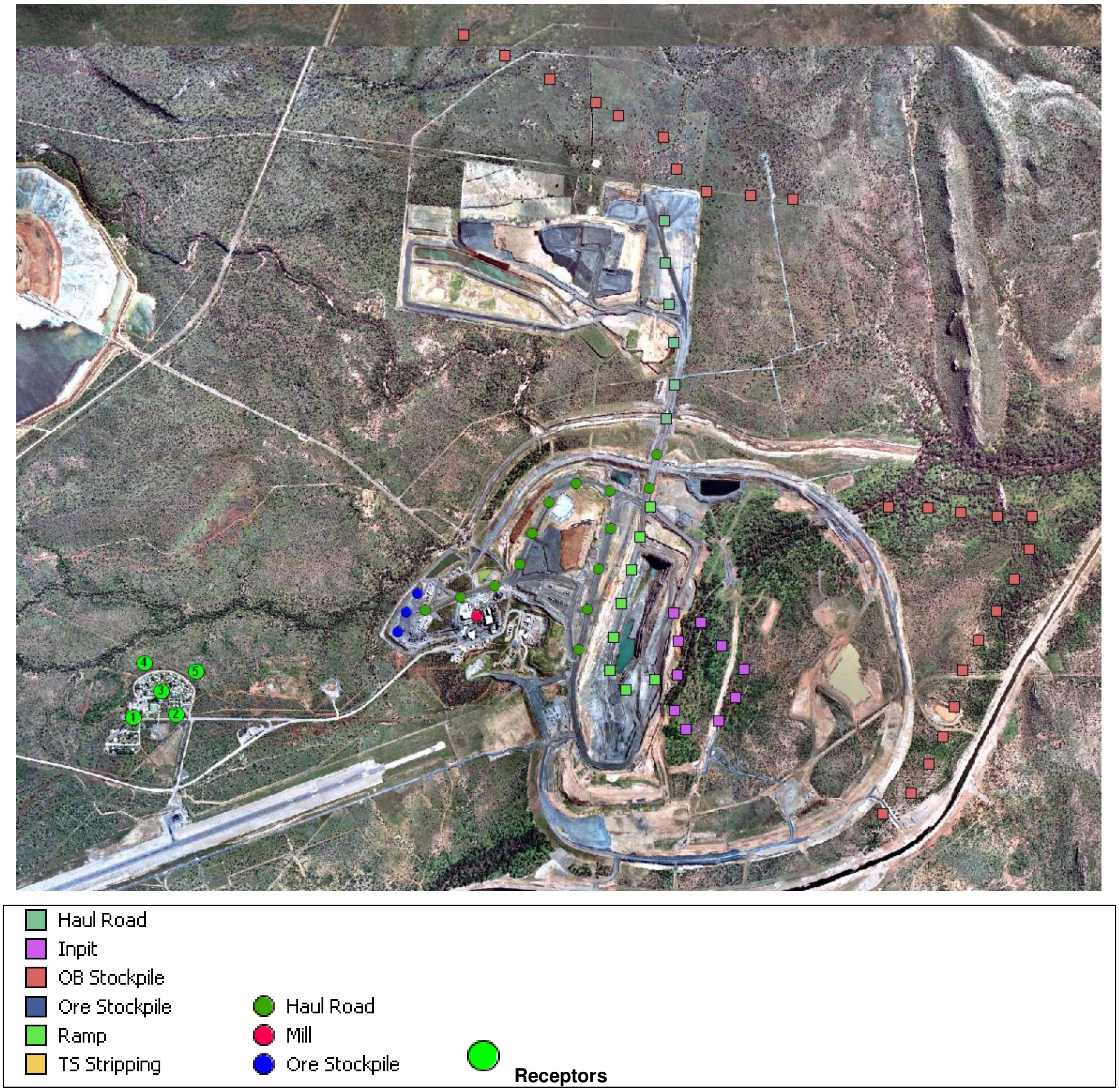


**Figure D-5 2025 Particulate Matter Source Locations**

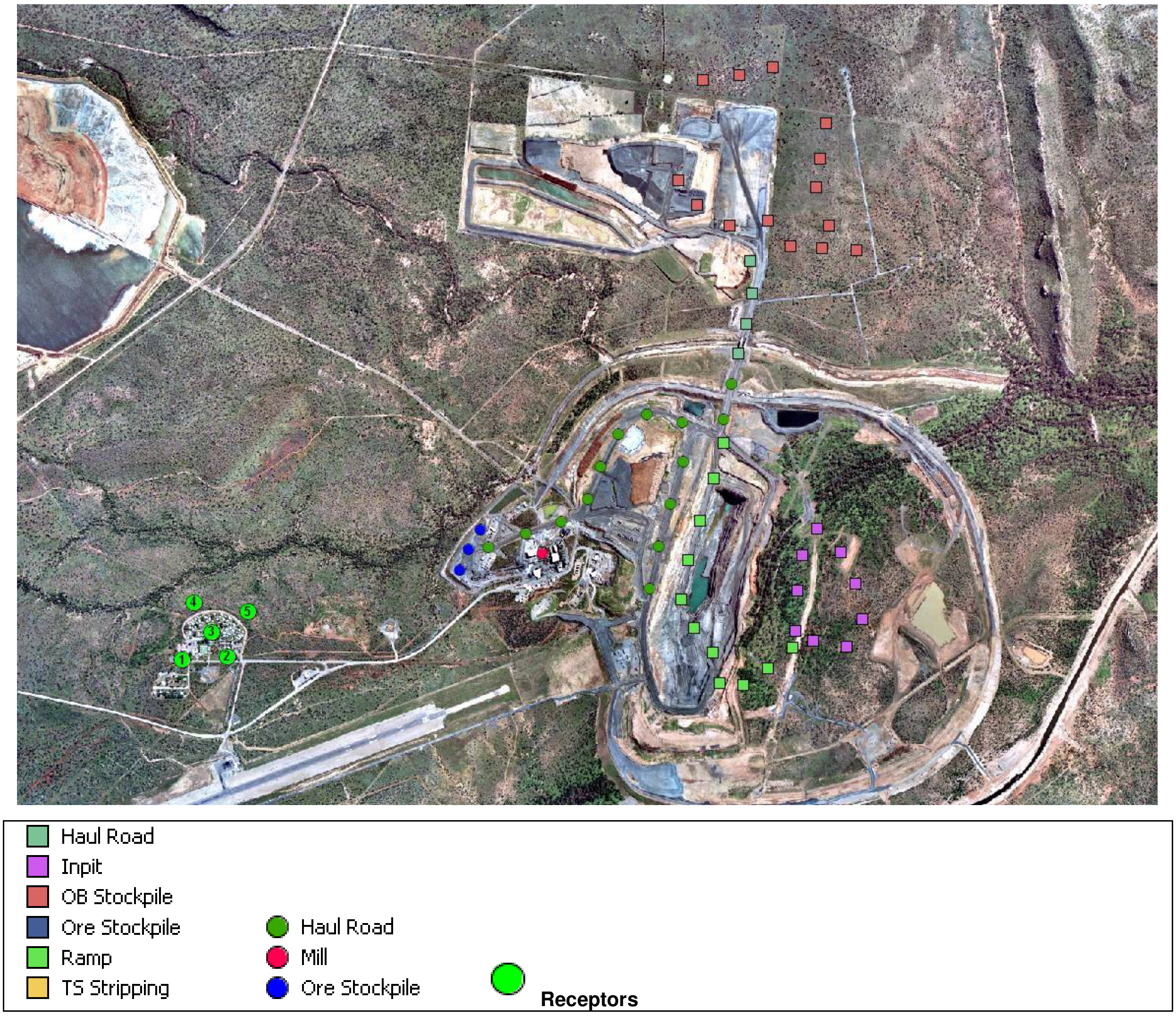


**Figure D-6 2030 Particulate Matter Source Locations**

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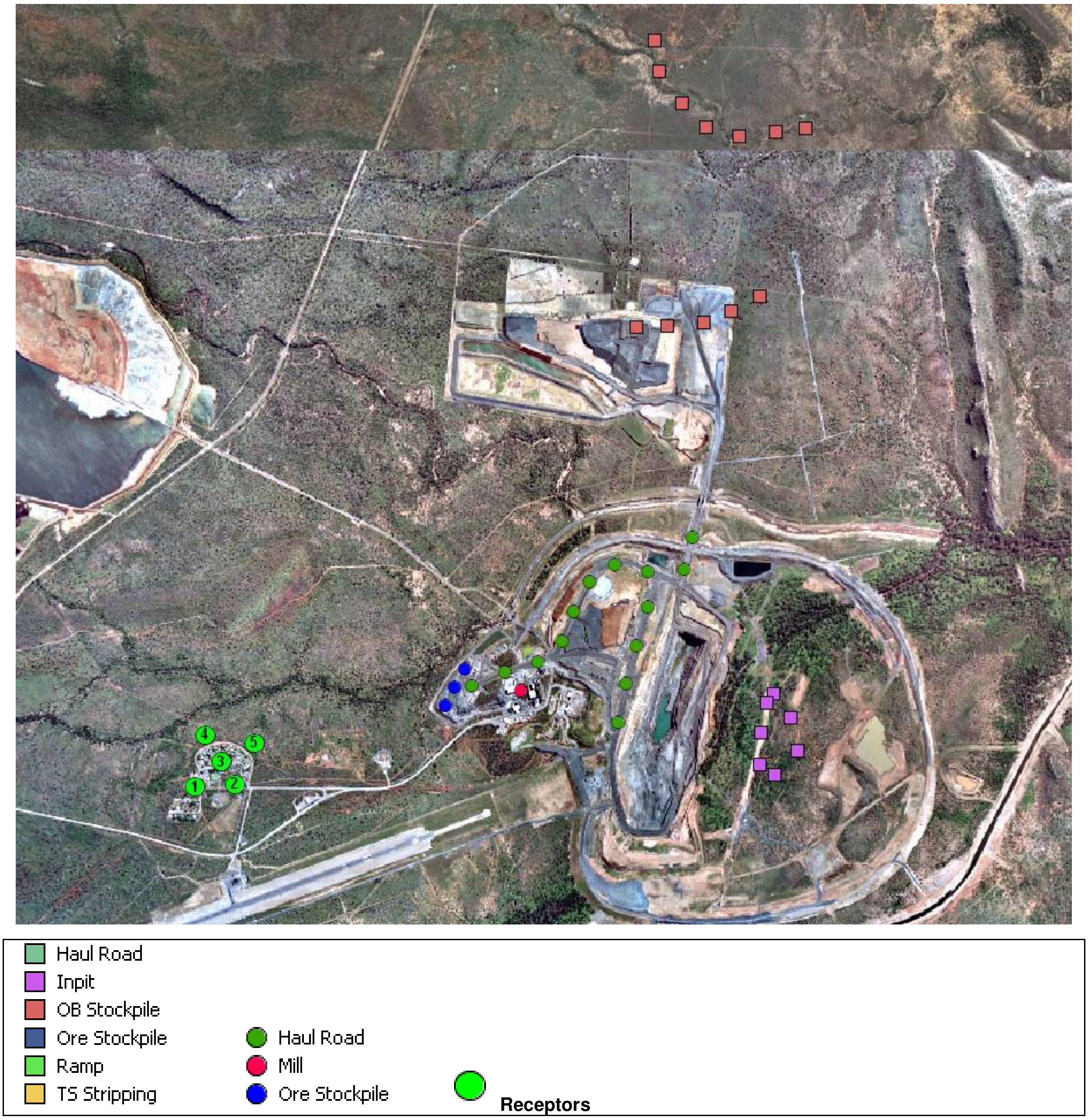


**Figure D-7 2035 Particulate Matter Source Locations**

### *Power Station Source Locations*

The following figure provides the existing and proposed stack locations for the two power station options.

| | |
|---|---|
| Existing Power Station | New Power Station |
| Augmentation to Existing Power Station | Receptors |

**Figure D-8 Power Station Source Locations**

### D.2.3 Particle Size Distributions

In CALPUFF, the particle size distribution is described in terms of:

- Geometric mass mean diameter; and
- Geometric standard deviation.

These parameters describe the average particle size based on mass within the size fraction, and the distribution of other size fractions within the particle type. The way the particle behaves in the model is driven by these characteristics, including the deposition rate as the particles disperse away from the source.

This assessment used the particle size distributions shown in table as a typical distribution for the modelled particulate matter emissions.

**Table D-9 Particle Size Distributions**

| Emission Type | Geometric Mass Mean Diameter (µm) | Geometric Standard Deviation (µm) |
|---|---|---|
| TSP (particles less than 30 µm) | 20.0 | 1.24 |
| $PM_{10}$ (particles less than 10 µm) | 5.0 | 1.24 |
| $PM_{2.5}$ (particles less than 2.5 µm) | 1.0 | 0 |