Rasp Mine, Broken Hill
Air Quality Assessment

Prepared for:
Broken Hill Operations Pty Ltd

On behalf of:
CBH Resources Ltd

Prepared by:
ENVIRON Australia Pty Ltd

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Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

ENVIRON Australia Pty Ltd (ENVIRON) has been commissioned by Broken Hill Operations Pty Ltd (BHOP), a wholly owned subsidiary of CBH Resources Limited (CBH) to undertake an air quality assessment for the expansion of the Rasp Mine located on Consolidated Mining Lease 7 (CML7) in Broken Hill, NSW.

BHOP proposes to mine the Western Mineralisation and Centenary Mineralisation and Main Lode Pillars, zinc-lead-silver masses within the Project Area. Mining will take place over 15 years including one year to construct the processing plant, one year to complete closure activities and an estimated 13 years for extraction of ore from underground mining, at a maximum rate of 750,000tpa (along with approximately 250,000 tpa of waste rock).

The air quality assessment conducted for the Rasp Project focussed on emissions of total suspended particulates (TSP), particulate matter less than 10 microns and 2.5 microns in aerodynamic diameter (PM_{10} and $PM_{2.5}$ respectively), dust deposition and a range of individual metals/metalloids.

Proposed Dust Management

In view of the proposed Project's proximity to sensitive receptors, combined with the potential impacts associated with the production of the lead and zinc concentrates, BHOP have committed to best practice dust controls for the duration of the Project. Such practices include:

- Extensive sealing of haul routes;
- Application of chemical dust suppression for unsealed roads, ROM stockpile and exposed areas;
- Full enclosure for crushing operations venting under negative pressure to a baghourse and enclosure of potentially dust generating conveyors and transfer points;
- Installation of real-time air quality monitoring to assist in the active management of emissions;
- Application of water spray systems with added chemical dust suppressant and wind breaks (where applicable) across other key areas of operation, including tailings storage facilities (both during construction and operation), ROM stockpile area, exposed areas and assorted construction and ancillary surface activities; and
- Installation of a vehicle wash facility.

Existing Air Quality Environment

The local region surrounding the Rasp Project site was reviewed to identify surrounding sources that may contribute pollutants to the local air shed. Additionally, historic observational data for notable dust storm activity was resourced from the Bureau of Meteorology. On the basis of the scale and nature of the surrounding particulate-generating activities, it is considered that the wind-generated suspension of particulate matter, such as dust storm events, is the likely dominant influence on baseline air quality for the Broken Hill area.

Air quality monitoring data for the area was resourced from a number of sources including:

- 24-hour average TSP concentrations recorded by BHOP at the Rasp Project site between May 2007 and January 2010;
- Monthly dust deposition levels from a network of dust deposition gauges maintained by BHOP about the Rasp Project site;
- Measured lead content in BHOP-recorded TSP and dust deposition samples; and
- 24-hour average PM_{10} concentrations recorded by Bemax Resources Limited between January 2010 at the Broken Hill Mineral Separation Plant, 4 km to the west-southwest of the Rasp Project site.

No monitoring data for ambient $PM_{2.5}$ or metals (excluding lead) were available for the Broken Hill region.

Emissions Inventory

In order to conduct dispersion modelling for the key aspects of the Rasp Project, the following scenarios were developed:

- Project Construction phase; and
- Project Operational phase under maximum production.

Additionally, in order to provide a partial estimate of baseline metal concentration/deposition, simulations were undertaken for the existing free areas assuming the implementation of future controls with a control efficiency of 80% (conservative estimate based on manufacturers recommendation of 90 to 95% efficiency).

Emissions from all key construction and operational sources of particulate matter were estimated based on published US-EPA AP-42 literature. Where applicable, emission reduction factors were applied to account for the proposed best practice dust management techniques.

Air Quality Assessment

Dispersion simulations were undertaken and results analysed for TSP, PM_{10}, $PM_{2.5}$ and a range of heavy metal concentrations and dust deposition. Simulations were also undertaken for gaseous emissions from the planned ventilation shaft to be situated in the Little Kintore Pit during the operation phase.

Dispersion modelling of particulate emissions from the Rasp Project was conducted utilising the US-EPA regulatory model AERMOD for two complete calendar years, 2008 and 2009. Local meteorological conditions recorded at the nearby Bureau of Meteorology Broken Hill

Airport automatic weather station were integrated into the dispersion modelling process. To assess the performance of the Rasp Project, dispersion modelling predictions for a range of local sensitive receptor locations will be compared with relevant NSW Department of Environment, Climate Change and Water (DECCW) assessment criteria.

Suspended Particulate Concentrations

Predicted incremental concentrations of TSP, PM_{10} and $PM_{2.5}$ are below the applicable NSW DECCW assessment criteria for both construction and operational phases of the Rasp Project for 24-hour and annual average concentrations.

Application of the recorded PM_{10} concentrations for the Broken Hill area indicated that the cumulative impact of the Rasp Project and ambient concentrations could result in the exceedance of the DECCW criterion of 50 µg/m^3 for 24-hour average PM_{10}. However, review of the ambient PM_{10} monitoring data suggested that ambient concentrations would be in exceedance of the DECCW criterion approximately 35 days per year, without the inclusion of the Rasp Project.

Analysis of the concurrent AERMOD-predicted and measured 24-hour average PM_{10} concentrations throughout 2008 and 2009 indicated that, in addition to the existing exceedances within the PM_{10} dataset, the DECCW criterion would be exceeded an additional one and two times at the two closest sensitive receptors over the entire 2008 and 2009 modelling period respectively. Furthermore, analysis of the frequency of the predicted incremental 24-hour average PM_{10} concentrations indicated that the likely hood that incremental concentrations of PM_{10} would cause an additional exceedance of the 24-hour average DECCW criterion is low.

Dust Deposition

Predicted annual average monthly dust deposition levels were predicted for both modelling scenarios. The predicted incremental increase in dust deposition across both modelled years is below the NSW DECCW incremental criterion of 2 g/m^2/month at all surrounding sensitive receptors. It is expected that the cumulative dust deposition criterion of 4 g/m^2/month will be exceeded, however it is noted that, based on provided monitoring data, the existing dust deposition levels in the Broken Hill area range between 3.3 and 7.2 g/m^2/month, likely due to the arid setting of the region.

Heavy Metal Concentrations

Predicted concentrations of assorted metals satisfied the relevant NSW DECCW assessment criteria at all surrounding sensitive receptors for both construction and operational phases of the Rasp Project.

Mitigation and Monitoring Recommendations

Mitigation

Mitigation of emissions from the Project has already largely been addressed by the commitments made by BHOP to implement best practice control technologies and techniques. Given that the modelling results indicate that the prime source of dust for the

Project is that generated by wind erosion from the existing free areas about the Rasp Project site, it is recommended that the focussed control of wind erosion from existing free areas about the Rasp Project site through the addition of chemical dust suppressants should be viewed as a priority in controlling emission from the site.

Air Quality Monitoring

A number of key recommendations in respect to air quality monitoring have been made within the air quality assessment, including the following:

- Routine source based measurements to be conducted by BHOP (road silt loading, control technology performance, etc);
- Establishment of realtime air quality monitoring for PM_{10} at key surrounding receptors;
- Additional dust deposition monitoring locations established away from the Rasp Project to provide a more robust indication of typical background levels for Broken Hill.
- Continuation of the sampling of lead in TSP and dust deposition monitoring samples, along with the analysis of additional metals covered in this study; and
- The review and amendment of the Air Quality Management Plan aligned to the proposed changes and recommendations.

1 Introduction

ENVIRON Australia Pty Ltd (ENVIRON) has been commissioned by Broken Hill Operations Pty Ltd (BHOP), a wholly owned subsidiary of CBH Resources Limited (CBH) to undertake an air quality assessment for the expansion of the Rasp Mine located on Consolidated Mining Lease 7 (CML7) in Broken Hill, NSW. The Rasp Mine Project is hereafter termed “the Project”, with the mine lease area termed “the Project Area”.

BHOP proposes to mine the Western Mineralisation and Centenary Mineralisation and Main Lode Pillars, zinc-lead-silver masses within the Project Area. Mining will take place over 15 years including one year to construct the processing plant, one year to complete closure activities and an estimated 13 years for extraction of ore from underground mining, at a maximum rate of 750,000tpa (along with approximately 250,000 tpa of waste rock).

BHOP is seeking approval from the Department of Planning (DoP) for the re-establishment of full scale mining and processing operations under Part 3A of the *Environmental Planning and Assessment Act 1979*. A project application and preliminary environmental assessment was lodged with DoP in 2007; updated Director General’s Requirements (DGRs) were issued on 29 March 2009. The DGRs, as they relate to air quality, state that the Environmental Assessment must include*:*

> *An assessment of all potential airborne lead and dust emissions from construction, traffic movements, open exposed areas including tailings dams, materials processing and handling, transfer points, mine exhaust, loading facilities, etc.*
>
> *A lead monitoring program based on current best practice with respect to monitoring impacts of off-site lead exposures on the community.*

The DGRs additionally reference the following policies and guidelines with respect to air quality:

- Protection of the Environment Operations (Clean Air) Regulation, 2002
- Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DECCW, 2005); and
- Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DECCW, 2007).

1.1 Project Scope for Air Quality Assessment Purposes

The scope of study of the air quality assessment includes four main components, namely:

(i) Baseline environment characterisation, specifically the selection of pertinent air quality criteria to use in the assessment, identification of sensitive receptors, and the description of the prevailing meteorology and air quality based on available data.

(ii) Air quality assessment of the construction and operation stages of the Project, including the establishment of an emissions inventory, air dispersion modelling to predict resultant air pollution levels, and assessment of such on the basis of the air quality criteria selected.

(iii) Recommendation of management measures to reduce atmospheric emission potentials and air quality monitoring to track ambient air pollutant concentrations during the life of the Project.

(iv) Modelling and provision of air quality related inputs for the Health Risk Assessment (HRA) to be undertaken for the Rasp Mine by Toxikos Pty Ltd (Toxikos). ENVIRON consulted with Toxikos to identify all inputs required for the Health Risk Assessment prior to the initiation of modelling.

Given the location of the Rasp Mine, the mining to be undertaken and recommendations by government agencies, best practice dust controls have been identified and, to the extent practicable, integrated into the Project proposal. These dust controls are comprehensively documented in this report. The air quality assessment was conducted for the Project with all the proposed controls assumed to be in place. No assessment of unmitigated or partially mitigated operations was undertaken.

Air pollutants evaluated in the assessment include suspended particulate matter, dust deposition and a range of metals/metalloids including lead, zinc, cadmium, mercury, nickel, arsenic and manganese. Within this assessment, suspended particulates are characterised and assessed as three size fractions; total suspended particulate (TSP), and particulate less than or equal to 10 and 2.5 microns in aerodynamic diameter (PM_{10} and $PM_{2.5}$ respectively). Airborne concentrations and deposition rates of metals/metalloids are determined based on measured content in the particulate matter.

Suspended particulate concentrations, dust deposition rates and suspended metal/metalloid concentrations are evaluated based on identified air quality criteria including impact assessment criteria specified by DECCW (2005) and inhalation reference concentrations obtained from widely-referenced health risk information sources (e.g. World Health Organisation, US Integrated Risk Information System or IRIS).

Suspended particulate concentrations and metal/metalloid concentrations and deposition rates were provided to Toxikos to facilitate a multi-pathway Health Risk Assessment (HRA). The HRA should be referred to for a completed understanding of the potential health risks associated with the Project.

1.2 Report Outline

An overview of the Project is given in **Section 2**, with a description provided of the surrounding land-use and the locations of the nearest sensitive receptors. **Section 3** comprises a detailed description of the dust management measures proposed for implementation during the construction and operation stages of the Project.

Air quality criteria selected for the evaluation of predicted air pollutant concentrations and deposition rates are presented in **Section 4**. Existing air quality in the vicinity of the Project is discussed in **Section 5** and an overview provided of the prevailing dispersion meteorology in **Section 6**.

The emissions inventory compiled for the construction and operation stages of the Project is documented in **Section 7**, with the air dispersion modelling methodology and results presented in **Section 8.**

Section 9 documents the results from the air quality impact assessment, with mitigation and monitoring recommendation given in **Section 10.**

2 Project Overview

The following section provides an overview of key aspects of the Project as they relate to air quality. A more complete project description is contained within the body of the Environmental Assessment.

2.1 Project Summary

BHOP proposes to mine the Western Mineralisation, Centenary Mineralisation and Main Lode Pillars, zinc-lead-silver masses. Mining will take place over 15 years including one year to construct the processing plant, an estimated 13 years for extraction of ore from underground mining, and one year for closure.

Ore excavated during mining operations will be processed by an on-site crushing and flotation plant designed to produce high quality lead and zinc concentrates, which will be dispatched by rail for smelting and/or shipping to market.

For a short period during construction of the processing plant, ore will be crushed, stockpiled and transported off site for mineral processing.

Key components of the Project are (**Figure 1**):

- expansion of underground mining;
- surface ventilation fan;
- explosives magazine;
- Run-of-Mine (ROM) pad;
- processing plant;
- concentrate loading and transport system;
- mine back fill plant;
- tailings storage facilities (TSF1 and TSF2);
- evaporation and collection ponds;
- haul roads and access corridors; and
- offices, workshops and other supporting facilities (change house, control rooms, stores, vehicle wash facility, power distribution system and core yard).

Key Project information is summarised in **Table 1**.

Table 1 – Key Project Information

Component	Proposed
Mine life	15 years (includes 1 year of construction and 1 year of closure activities)
Tenement status	Consolidated Mining Lease (CML) 7 – Incorporates the Rasp Mine.
Approval period	15 years comprising construction, underground mining and processing operations and closure activities.
Mining methodology	Underground mining using various methods including long hole, benching, modified Avoca and, room and pillar or up-hole retreat.
Mining rate and total production	750 000 tonnes per annum (tpa) ore. Total production over life of Project: Approximately 8,450,000 t ore
Waste rock disposal	Underground: Backfill and rehabilitation at closure Surface: Inert material to be used for road repair and bunding and rehabilitation at closure.
Processing methodology	Crushing, grinding, flotation, thickening and filtration at on-site processing facilities.
Processing rates	250 tonnes per hour (tph) in crushing plant and 93.8 tph in grinding plant.
Concentrate production	Lead: 44,000 tpa (concentrate 73% Pb and 985 g/t Ag) Zinc: 8,000 tpa (concentrate 50% Zn)
Tailings disposal	Fine tailings disposal (approximately 320,000 tpa):- - TSF1 existing on-site Tailings Storage Facility (TSF) (10 m raise), and - TSF2 Blackwood Pit Coarse tailings disposal (approximately 320,000 tpa) as underground stope back fill.
Services	Extensions to existing substations, water lines and phone lines. New 22kV overhead powerlines to be constructed.
External roads	No changes to external road network.
Water supply	Potable / treated water 9 ML/pa Raw untreated water 139 ML/pa Reclaimed / recycled water 300 ML/pa
Employment numbers	Construction and commissioning: 107 Full Production: 143

Table 1 – Key Project Information	
Component	**Proposed**
Hours of operation	Construction: 7 days per week, 7am to 7pm. Underground Operations: 7 days per week, 24 hours per day Processing Plant: Crushing and screening - 7 days per week, 7am to 7pm. Shunting 7 days per week, 7am to 6pm. Activities not listed above – 7 days per week, 24 hours per day.

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FIGURE 1: Key Operational Components of the Project

Figure

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Construction of the Project will coincide with concurrent ancillary surface mining activities comprising the crushing, stockpiling and off-site transport of 120,000 tpa of ore as described in **Section 2.2**. The operations stage of the Project, which will include on-site crushing, screening, grinding, flotation, filtering and concentrate loading into rail wagons for off site transport, is outlined in **Section 2.3**.

2.2 Construction and Ancillary Surface Mining Activities

Equipment used during construction will include 50 t truck mounted cranes, mobile cranes, light vehicles, delivery trucks (semis and rigid), concrete agitators (as required), elevating work platforms, earth moving equipment and a variety of smaller hand held tooling (e.g. welders, grinders, saws, etc). Construction of infrastructure will be short term in duration with an expected construction period of up to twelve months.

During the construction phase, there is proposed to be some concurrent ancillary surface mining activities, comprising the crushing, stockpiling and transport of 120,000 tpa ore to the CBH Endeavour Mine for processing, as documented in **Section 2.2.3**.

2.2.1 Construction Stages

The Project will require the construction of civil type infrastructure and will be conducted in the following stages:

- Stage 1 – Preconstruction;
- Stage 2 – Construction; and
- Stage 3 – Commissioning.

From a dust generation perspective, the construction phase represents the most significant of these phases requiring further evaluation.

The general construction stage involves the excavation of foundations and footings, placement of reinforced concrete, the erection of various structures (many prefabricated off-site) and the refurbishment of some existing buildings. The key activities include:

- excavation of free digging waste rock materials for major footings, foundations (e.g. ore bin) and permanent service lines (e.g. trenches);
- placement of reinforced concrete such as raft foundations for ball mills, crushers, conveyors, etc;
- installation of processing plant including crushers, storage bins, conveyors, grinding mills, flotation cells and thickening tanks;
- installation of pumps, pipe work and wiring throughout the processing facility;
- installation of an additional 22 kV line, substations and associated supply lines and water header and containment tanks;
- laying of new rail lines to concentrate filtration plant and installation of an indexing system to move wagons through the concentrate loading area;

- refurbishment and internal upgrade of existing buildings (no demolition) for offices, workshops, stores/warehouse and similar;
- decommissioning of temporary buildings (portables);
- construction of the enclosed concentrate filtration plant, reagent store and associated containment structures;
- installation of primary ventilation fans, fan evasee (diffuser) and associated noise reduction infrastructure;
- tailings storage facility (TSF) embankment construction; and
- works for surface water management.

2.2.2 TSF Embankment Construction

TSF1 is located centrally within CML7 and is adjacent to Eyre Street. At TSF1, tailings from the Project will be deposited over historic tailings.

The historic TSF was constructed using remnant tailings with a starter embankment of approximately 2 m to 3 m in height and was progressively raised using the upstream construction method in raises of 2 m to 3 m. The upper surface of the historic TSF has been covered with a nominal 0.5 m thick layer of slag and waste rock has been placed over the sides of the TSF embankment.

The proposal is to raise the existing TSF from 322 mRL to 332 mRL with waste rock as the embankment material using the centreline raise method. It is not proposed to remove the current layer of slag on the surface of the TSF.

The TSF1 embankment will require the construction of a 6 m high starter embankment followed by a subsequent 4 m high raise. The embankment will be constructed to the full footprint of the proposed final embankment, avoiding the need to construct the raise on freshly deposited tailings. The design allows for a minimum of 1 m freeboard.

Waste rock has been chosen as the construction material for the embankments as it has fewer fines and is readily available adjacent to the facility.

Prior to embankment construction, approximately 45,000 m^3 of waste rock will be required to construct a buttress at the toe of the slope. This will ensure the integrity of the wall and will involve approximately 2,200 truck movements and take less than one month. Approximately 190,000 m^3 of waste rock will then be required for construction of the embankments. The Stage 1 starter embankment will take approximately three months to construct and require around 9,500 truck movements. Stage 2, a 4 m lift, will take approximately two months to construct with an estimated 2,500 truck movements.

2.2.3 Ancillary Surface Mining Activities

During construction underground operations will restricted to the mining of the Main Lode Pillars. Mining will be accessed via the Rasp Decline. A ventilation circuit will draw fresh air via the Rasp Decline and will be exhausted through Delprat Shaft. The ventilation circuit will utilise a combination of development fans and underground booster fans and will not require a primary surface ventilation fan to be installed.

During construction ore will be crushed prior to transporting off-site for mineral processing. The crushed ore will be loaded into trucks which will be covered and washed prior to leaving site and transported to the CBH Endeavor Mine near Cobar.

Ore will be transferred from the base of the Kintore Pit to a temporary ROM stockpile located within a gully to the north-west of Mt Hebbard. It is estimated this will require 16 truck movements per day, occurring 7 days per week, 7am to 6pm.

Ore will then be loaded to a mobile crusher using an excavator, with the mobile crusher crushing to 115 mm, with an average daily throughput of 500 t/day, at a maximum capacity of 200 t/hour (8am to 5pm weekdays).

A finished product ore stockpile 15 m by 20 m and 7.5 m in height is to be located at the exit to the mobile crusher. Finished product ore will be loaded into 50 t trucks using a front end loader (FEL), between 7am to 6pm.

It is estimated that 21 truck movements will be required per day to transfer product ore off-site, occurring between 7am to 6pm weekdays.

2.3 Expanded Operations Phase

2.3.1 Underground Mining

The expanded underground operations will involve the mining of the Western Mineralisation, Centenary Mineralisation in addition to the Main Lode Pillars.

All excavations will be of a stable design with no block cave operations and with back fill being placed in subsequent voids as a key control of subsidence and caving. Drill and blast will be the primary method used to break the ore into a size range which is less than 800 mm.

Underground mining will be accessed by the existing portal located in the northern end of the Kintore Pit (**Figure 1**). Mining of the Western and Centenary Mineralisation will predominately occur at depths 200 m below surface while some mining of the Main Lode Pillars may occur at depths of less than 100 m below surface. Drives will be developed from the decline and lead to production areas where stopes will be developed using conventional drill and blast methods. Ore and waste will be excavated using load haul dump equipment and transported to loading points where mine trucks will transport ore to the ROM pad via the northwest haul road. Waste will predominately be used in underground back fill operations with some waste rock being retained and stored in the Kintore Pit for closure activities.

Stope voids will be back filled with a combination of back fill materials including waste rock and deslimed tailings by the back fill plant. This will minimise rock stress build-up, stabilise the void and maximise ore recovery.

The anticipated production schedule throughout underground operations is presented in **Table 2**.

Table 2 – Production Schedule (Operational Phase)

Year	Planned Production (t ROM)	Zinc Concentrate		Lead Concentrate		
		Production (t)	Zn content (Approx. %)	Production (t)	Pb content (Approx. %)	Ag Content (Approx. g/t)
1	450,000	55,000	49.3	30,000	73.5	1000
2	475,000	56,000	49.3	31,000	73.5	1000
3	475,000	56,000	49.3	31,000	73.5	1000
4	525,000	62,000	49.2	33,000	73.5	950
5	600,000	70,000	49.1	36,500	73.4	950
6	675,000	78,500	49.1	40,000	73.3	925
7 onwards	750,000	87,000	49.1	43,500	73.3	925

2.3.2 Mining Ventilation

A primary ventilation circuit will be constructed within the underground mine to draw air through the mine clearing exhaust fumes, dust and heat (including blasting) resulting from the mining operations and promoting fresh air intake.

Fresh air will enter the mine via the decline and the existing Delprat Shaft and travel through the mine, getting pushed and pulled by various fans underground.

Exhaust or return air will leave via the existing Little Kintore Shaft. This process will be assured by twin 450 kW centrifugal fans located at the top of the Little Kintore Shaft. This site was selected as it is approximately central to the Project Area and away from the mining lease boundaries and surrounding neighbours.

2.3.3 Ore Transportation

Ore extracted during underground operations will be transported by haul trucks to the ROM pad via the haul road located to the west of the Kintore Pit.

This haul road is being reinstated around the northwest side of the Pit to aid in the management of potential noise and dust issues.

2.3.4 Waste Rock

The volume of waste rock to be extracted during mining is estimated at 250,000 tpa from underground development.

Waste rock from underground mining will be deposited in underground voids as they become available. Where there are no voids available the waste rock will be:

- placed in underground drives waiting for a void to become available; or
- stored in Kintore Pit awaiting back-loading into underground voids upon availability.

Towards the end of the mine life inert waste rock will be retained and stored in the Kintore Pit to be available for closure and rehabilitation activities. Testing of the waste rock from the pit and underground will identify inert material suitable for civil works and rehabilitation.

2.3.5 Mineral Processing

Once the processing plant is commissioned the ore will be processed on-site to produce zinc and lead concentrates which will be transported from site via covered rail wagons to Port Pirie and / or Newcastle. The plant design capacity is 750,000 tpa of ore based on a throughput of 93 tph. The processing method is representative of commercial practices at existing zinc / lead ore processing plants and is considered to be industry standard.

Processing of ore excavated during underground operations will include:

- ore crushing and screening;
- wet grinding;
- zinc and lead flotation;
- zinc and lead concentrate thickening and filtration;
- reagent mixing, storage and distribution; and
- concentrate loading.

2.3.6 Crushing

The crushing plant will operate on day shift (7am to 7pm) only.

A three stage primary, secondary and tertiary, crushing and screening process will reduce the ore from rocks as large as 800 mm to a size suitable for grinding, roughly comparable to that of gravel (less than 16 mm).

Crushed ore will be loaded from the ore stockpile into the 150 t capacity ore bin using a FEL before being stored in a 2,250 t capacity enclosed fine ore bin prior to transfer to the enclosed grinding mills.

2.3.7 Grinding and Flotation

All processes from grinding onwards are wet processes that require the ore to be mixed with water and as such there is not a significant potential for dust generation.

The grinding circuit will consist of primary and secondary ball mills. The grinding and classification circuit will operate 24 hours per day, 7 days per week. The ore feed for the grinding circuit will be reclaimed from the fine ore bin via conveyor.

2.3.8 Concentrate Thickening, Filtration, Storage and Dispatch

Zinc and lead slurry from the floatation circuit will be dewatered in a process of thickening and filtration to produce a concentrated product. The thickened zinc and lead concentrates will be filtered to reduce the concentrate moisture content to around 9 percent moisture (filter cake). After filtering, the filter cake will be discharged directly to the rail wagons, located below the filter presses.

The process is designed as a continuous process from slurry - to concentrate feed - to rail wagons. A storage area has been designated, as a contingency, in the event of breakdowns or if rail wagons are not available. Concentrate will be stored in sealed containers and located in the existing No 4 Shaft change-house. This eliminates double handling which could cause additional dust generation.

2.3.9 Concentrate Loading

The rail infrastructure runs parallel to the lease on the western side of the Project Area. A spur line runs into the lease and stops at No. 7 Shaft. It is proposed to refurbish and re-establish the rail siding between No.7 Shaft and the old mill building to allow rail wagons onto the Project Area to transport concentrate from the facility.

Concentrates (131,000 tpa) at a moisture content of around 9 percent will be loaded into rail wagons which will be covered to prevent dispersal of the concentrate in the form of dust during transport to a smelter or export port facility located at Port Pirie and / or Newcastle.

Loading of the rail wagons will take place in an enclosed building with rubber curtains at each end to permit thoroughfare by the wagons. All wagons will pass through a wash facility prior to leaving site to remove any potential concentrate spillage.

2.3.10 Tailings Disposal

The waste stream from ore processing (tailings) will be thickened and separated by cycloning to produce two waste streams. The coarser stream will be redirected underground to back fill mine voids and stopes.

The tailings from the processing plant will be pumped from the plant to the back fill plant located near the Delprat Shaft. The tailings will be transported to the back fill plant by way of pipes on surface placed within a purpose built containment structure (trench or bund) which will protect the line from damage and contain the tailings in the event of a rupture.

The back fill plant will consist of cyclones to split the tailings feed. The coarser underflow stream from the cyclones will be mixed with suitable materials and redirected underground to use as stope fill. The finer overflow (slimes) will be directed to a high rate thickener, allowing thickened slimes to be sent to the TSF1 or TSF2.

The finer stream will be pumped to the existing tailings storage facility, a conventional paddock style facility (TSF1) for containment and settling and, once this is filled to free-board capacity, tailings will be deposited in the disused Blackwood Pit (TSF2).

In the early stages of the Project, prior to the development of sufficient underground void capacity, the total tailings stream will report to TSF1. When in full production fifty percent of tailings will be directed underground via boreholes and fill lines to mined voids for use as back fill and fifty percent will be deposited in the two separate surface storage facilities. The storage characteristics for each TSF are outlined in **Table 3**.

Table 3 – Tailings Storage Characteristics

Characteristic	TSF1	TSF2
Crest Height	322 mRL to 332 mRL.	295.5 mRL.
Rate of rise	Varies, approximately 2.5 m per year 1 x 6m and 1 x 4m wall lift.	Varies, approximately 3 m per year No walls – subsurface void.
Tailings storage area	4.97 ha south cell 5.28 ha north cell	Varies such that it increases with depth of tailings – approx 10 ha.
Total freeboard required	Operation freeboard 1 m.	Minimum of 1 m freeboard.
Capacity	970,000 t	3,120,000 t
Life	4.25 years	8.75 years

TSF1 Lift to historic tailings storage facility

As documented previously, TSF1 is located centrally within the Project Area adjacent to Eyre Street with deposition occurring over a historic tailings dam which has been covered with slag (see **Section 2.2.2**).

Tailings will be deposited in TSF1 as a slurry with a moisture content of around 50 percent, deposition will occur through a ring main with spigots located at approximately 25 m (adjusted for actual tailings size distribution) intervals around the perimeter of the embankment. Discharge from each spigot would be rotated to ensure deposition is evenly distributed around the facility and deposition would be switched between the two cells to maximise drainage and consolidation of the tailings. It is expected that tailings will be cycled between the two cells over a one to two week period.

The decant dam is located over waste rock storages to the north of TSF1 in an area of proposed borrow for the embankment rockfill. A sump will be formed to facilitate pumping of water from the dam for the dust management spray system and also potentially for the process plant. Waste rock has been chosen as the construction material for the embankments as it has fewer fines and is readily available adjacent to the facility.

The tailings surface is likely to initially be a slurry, changing slowly over a few days to wet then moist tailings. The length of wet beach is expected to extend from the active spigot to the opposite side of the cell.

It is anticipated that when deposition to the active cell is complete (i.e. the tailings deposition is switched and the inactive cell becomes the active cell) it will take between 7 to 14 days for the material within this cell to become dried out to a condition where it is spadeable (Pers. Comm. Fred Gassner, Golder Associates).

Details of the proposed dust management for the Tailings Storage Facilities are provided in **Section 3.2.1**.

Following completion of tailings disposal to the cells, a final covering of chemical dust suppressant will be placed over each cell. Irrigation sprays will remain *in situ* to allow additional application of chemical dust suppressant or water as required to prevent dust generation whilst the tailings dry sufficiently to allow inert waste rock to be placed over the top of the cells. On completion of TSF1 tailings will be deposited in TSF2.

TSF2 Blackwood Pit

Blackwood Pit is located to the north east of the existing tailings facility and will form TSF2 as part of the tailings storage strategy. The depth of the pit varies from about 40 m at the western end to about 70 m at the eastern end.

Review of geological data covering the eastern end of the mining lease indicate there is potentially 630,000 tonnes of minable remnant ore remaining in the Blackwood Pit area. BHOP proposes to use TSF1 for tailings disposal initially to allow detailed investigation into the potential remnant ore located beneath the Pit. (Recovery of remnant ore from the Blackwood Pit does not form part of the Project assessed.)

The proposal is to deposit tailings into Blackwood Pit from the 260 mRL to 295.5 mRL by pumping tailings into the bottom of the Pit.

At the cessation of tailings disposition in TSF2, a final covering of inert wast rock will be placed over the top of the tailings to avoid the potential for dust generation as they stabilise and consolidate.

The same dust management measures as outlined for TSF1 are intended to be applied for TSF2, the details of which are documented in **Section 3.2.1**.

2.4 Site Layout

The Project Area is occupied by historical mine workings and associated buildings and infrastructure. The site layout is unique in that there are several surface exclusion zones within the CML7 lease as well as several other occupiers conducting businesses within CML7. These include:

- Broken Earth Café;
- Miners Memorial;
- Tourists activities at Brownes Shaft and Block 10 Lookout;
- Communications tower;
- Olive plantation, and
- A number of buildings and residences owned by the Line of Lode Association.

Existing site infrastructure includes:

- Developed exploration decline (Rasp Decline);
- Kintore Pit and other disused open cut pits (Little Kintore Pit, BHP Pit and Block 14 / Blackwood Pit);
- disused mine shafts;
- rehabilitated TSF positioned in a central location near to the south-eastern (Eyre Street/ Holten Drive) site boundary;
- buildings associated with former mining activities, (mostly located in the south-western corner of CML7 in the vicinity of the main access road to the site and around Thompson and Browne Shafts);
- site access and internal sealed and unsealed roads and car parking;
- 22kVA overhead electrical transmission lines, transformers and poles which service surface infrastructure and underground workings;
- a fully fenced substation (owned by BHOP) and associated cabling for decline development;
- site services (including sewerage, potable water, raw water, telephone and data lines) are distributed to existing buildings and the workshop, proposed processing plant location and underground workings;
- disused rail spur line which runs across the western end of the site and connects to the main intercontinental railway line at a point just north of South Road;
- Hydrocarbon storage, portable magazines, vehicle wash down bay and settling dam on the eastern side of the workshop, and settling dams and oil / water separating system below the workshop and a weather station; and
- Communications hut for surface and underground radio communications.

The surface exclusion zones within the CML7 lease area are illustrated in **Figure 2**. These areas are not under BHOP's operational control and were therefore excluded from the assessment of feasible dust controls. Existing exposed area falling within the Project Area which are not rock armoured are indicated as “free surfaces” in this figure (red hatching). Several areas coinciding with infrastructure, indicated in yellow, are likely to be disturbed during the Project, and are defined as exposed areas for the operational phase of the Project.

2.5 Surrounding Land Use and Topography

The Project Area is located at Broken Hill in the Far West region of NSW, approximately 1150 km west of Sydney and 300 km north of Mildura.

The Project is located centrally within the City of Broken Hill and is surrounded by transport infrastructure, areas of commercial and industrial development and some residential housing. The Project is bounded by Eyre Street (from which it is accessed) and Holten Drive to the south and east, Menindee Road (MR 66) to the northeast, Crystal and Argent Streets to the north, and South Road (Silver City Highway SH 22) to the west. These roads form part of the existing trucking route through Broken Hill. The Broken Hill railway station is located directly to the north of the mine and lies on the main Sydney – Perth railway line. Residential and commercial areas are located to the west, north and south of the Project Area, Perilya Broken Hill Operations Pty Ltd mine developments to the east (North Mine) and west (Southern Operations) and the E B Mawsons & Sons Pty Ltd quarry to the east.

Nearby land uses include urban development within the City of Broken Hill, undeveloped arid landscapes beyond the city limits and extractive industries including mines and quarrying activities.

A series of regeneration reserves exist to the north and west of the town, comprising trees and local native vegetation. These were established during the 1930s as a buffer zone to combat the growing problem of sand drift and dust storms in Broken Hill.

The natural topography within the region and surrounding the Project Area is consistent with a relatively flat, arid setting. Notably elevated terrain exists through the centre of Broken Hill which has been the focus for historical mining activity. Historical mining has left the site with several pits, waste rock dumps, slag piles and tailings emplacements that rise up to 30 m above the RL of Eyre Street (**Figure 3**).

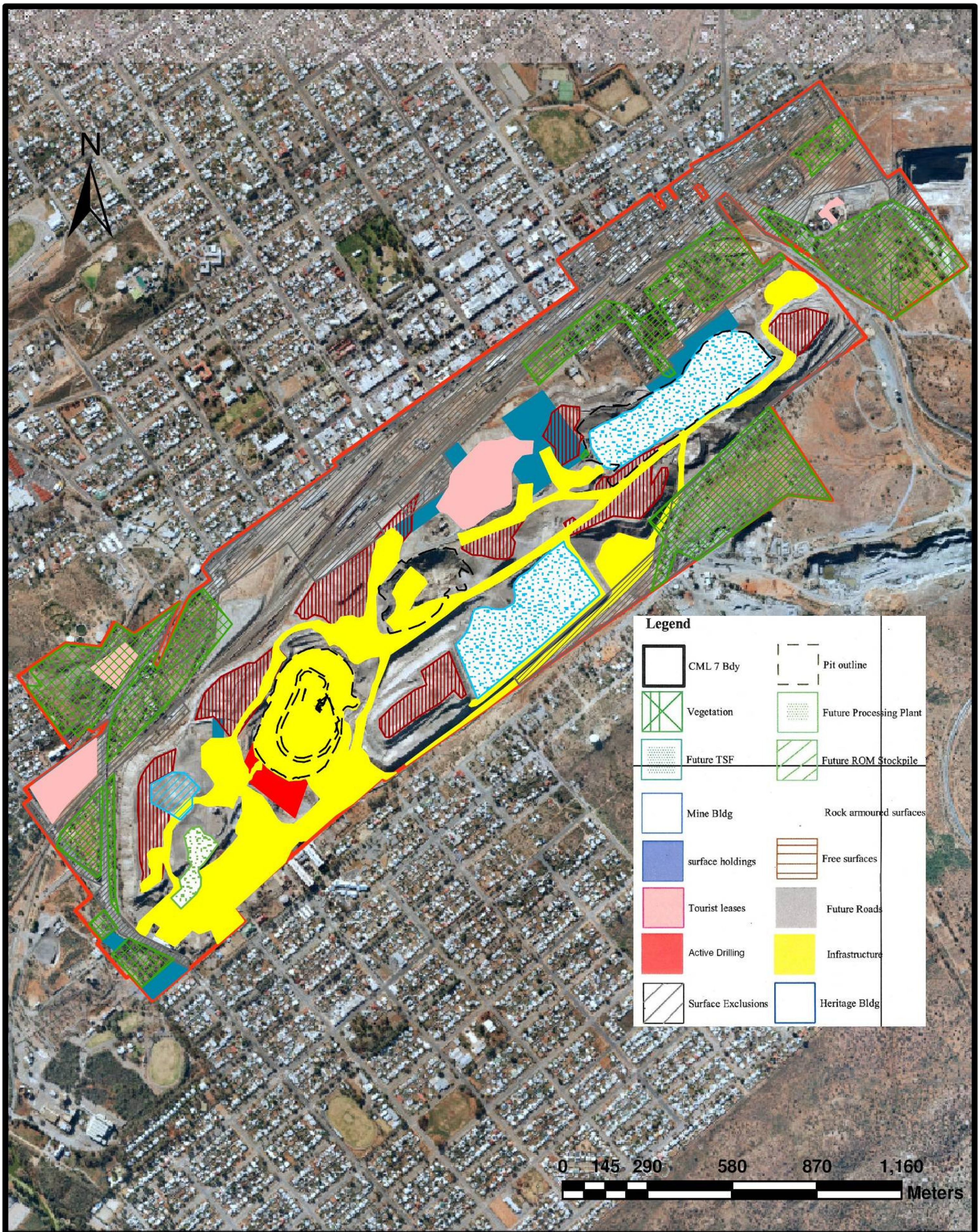

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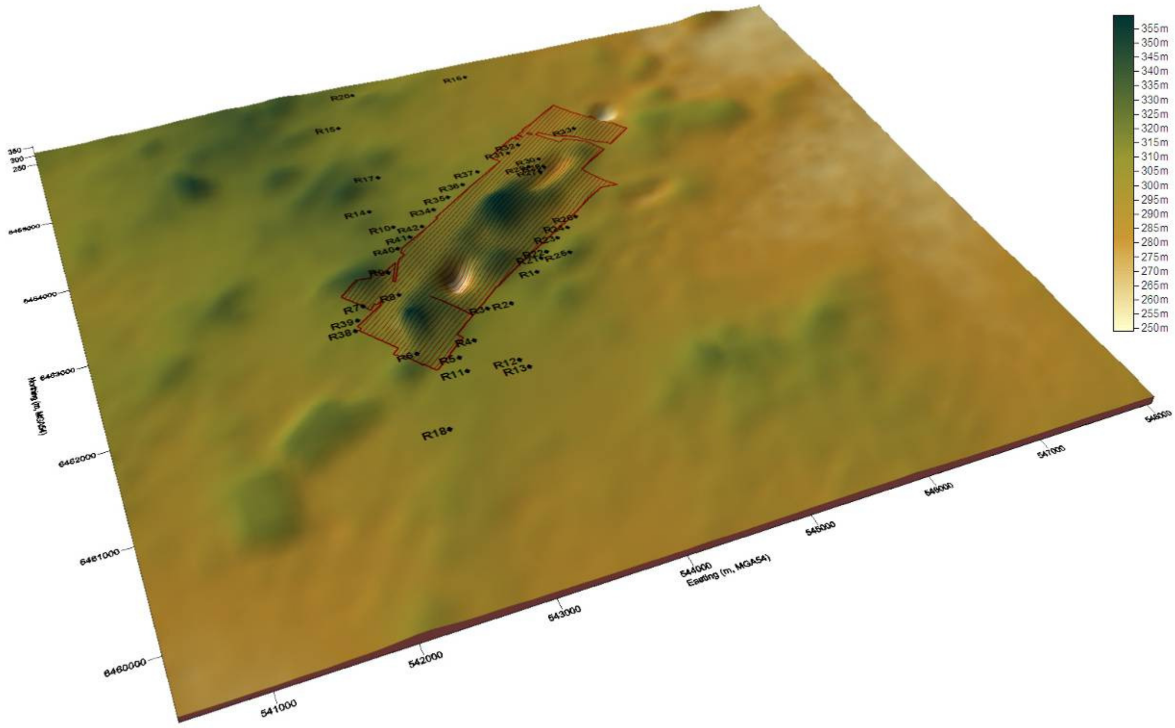
FIGURE 2:
CML7 Surface Holdings Showing Site Boundary

Figure

Drafter: SF Date: 16.03.10 Contract Number: AS121150 Approved: DAR Revised:



Note: Vertical Exaggeration = 2

Figure 3: Topography surrounding the Project Area

2.6 Sensitive Receptors

A number of occupied buildings used for a variety of purposes located near to the Project Area have been selected to represent sensitive receptors. These receptors are non-project related and are presented in **Table 4** and illustrated in **Figure 4**.

These comprise a selection of nearby residences and other sensitive receptors, consistent with the DECCW definition of sensitive receptors (DECCW, 2005) as:

> *A location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area.*

Receptor numbers R1 to R10 and R21 to R42 comprise individual residences or commercial offices located in the vicinity of the Project Area. Receptor numbers R11 to R20 represent schools, pre-schools and hospitals in the broader area. These localities represent places of greater community exposure potentials and are therefore of specific relevance to the Health Risk Assessment.

Table 4 – Potentially Affected Non-Project Related Representative Sensitive Receptors			
Sensitive Receptor	Description	MGA54 Dwelling Coordinates	
		East (m)	North (m)
R1	Piper Street North	544110	6462598
R2	Piper Street Central	543763	6462312
R3	Eyre Street North	543555	6462322
R4	Eyre Street Central	543324	6462003
R5	Eyre Street South	543140	6461859
R6	South Road	542833	6462000
R7	Carbon Lane	542604	6462718
R8	Old South Road	542923	6462744
R9	South Rd	542926	6463052
R10	Cnr Garnet and Blende Streets	543158	6463633
R11	Alma Bugldi Pre-school	543150	6461692
R12	Playtime Pre-school	543587	6461665
R13	Alma Primary School	543631	6461566
R14	Broken Hill High School	543019	6463916
R15	Broken Hill Hospital	543133	6465290
R16	North Broken Hill Primary School	544570	6465713
R17	Broken Hill Public School	543245	6464378
R18	Rainbow Pre-school	542815	6461151
R19	Willyama High School	544599	6466299
R20	Morgan Street Primary School	543420	6465782
R21	Eyre Street North	544212	6462762
R22	Eyre Street North	544288	6462828
R23	Eyre Street North	544456	6462974
R24	Eyre Street North	544591	6463090
R25	Water tank, Lawton Street #	544460	6462723
R26	Quarry offices	544723	6463208
R27	Proprietary Square	544666	6463926
R28	Proprietary Square	544731	6463988
R29	Iodide Street	544592	6464026
R30	Iodide Street	544728	6464112

Table 4 – Potentially Affected Non-Project Related Representative Sensitive Receptors			
Sensitive Receptor	**Description**	**MGA54 Dwelling Coordinates**	
		East (m)	**North (m)**
R31	Crystal Street	544503	6464328
R32	Crystal Street	544637	6464415
R33	Dwelling near Brownes Shaft	545231	6464450
R34	Crystal Street	543572	6463746
R35	Crystal Street	543748	6463873
R36	Crystal Street	543934	6464002
R37	Crystal Street	544127	6464141
R38	Gypsum Street	542459	6462467
R39	Gypsum Street	542512	6462581
R40	Silver City Hwy	543099	6463321
R41	Silver City Hwy	543249	6463439
R42	Silver City Hwy	543394	6463551

Assessed for suitability as a potential future air quality monitoring site.

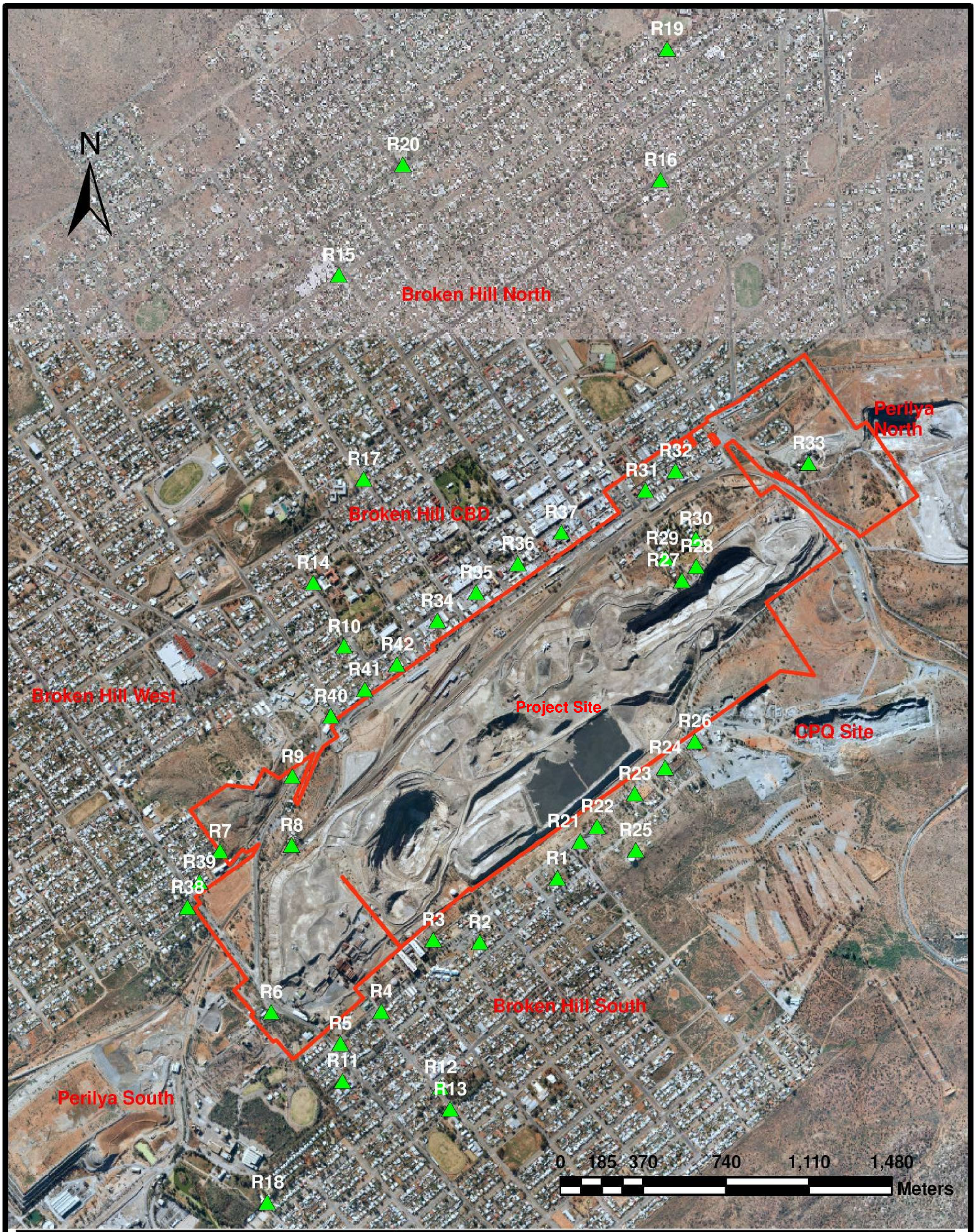


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FIGURE 4: Representative Sensitive Receptors in the vicinity of the Project

Figure

Drafter: SF | Date: 23.02.10 | Contract Number: AS121150 | Approved: DAR | Revised:

3 Proposed Dust Management

In view of the proposed Project's proximity to sensitive receptors, combined with the potential impacts associated with the production of the lead and zinc concentrates, BHOP have committed to best practice dust controls for the duration of the Project.

The following is a summary of the proposed dust management techniques / technologies committed to at the Project inception stage.

3.1 Best Practice Dust Management

3.1.1 Sealing of Roads

The haul road from the Kintore Pit to the ROM pad will be an estimated 2.05 km in length. Approximately 1.25 km of the haul road from the upper level of the Pit (approximately 10 m below the surface and 50 m from the exit/entry to the Pit) to the ROM pad will be sealed, using compacted road base sealed with bitumen. All main service roads on the site will additionally be sealed.

A street sweeper will be used periodically to clean sealed roads to reduce dust below a maximum silt loading, which will be determined by the air dispersion modelling. The frequency of sweeping will be determined through road silt load testing during the operation phase and will be incorporated within site procedures.

3.1.2 Chemical dust suppressant to all unsealed roads

Unsealed roads comprising of compacted road base will include the 800 m of the haul road situated within the Kintore Pit, and secondary service roads that receive minimal traffic.

Chemical dust suppressant will be applied as per the manufacturer's specifications to all unsealed roads on the site including the unsealed portion of the haul road.

The chemical dust suppressant for the site will be selected so as to be environmentally benign.

A grate is to be installed between unsealed and sealed sections of road to remove dust track-on from trucks.

While chemical dust suppressant is to be used as a standard dust control measure, static water sprays are already installed on the unsealed haul road and a portion of the service roads. These will be maintained and used as a backup interim measure.

3.1.3 Crushing Operations

The crushing circuit (primary, secondary and tertiary crushers and screens) is to be fully enclosed within a permanent structure. This enclosure is to be kept under negative pressure and vented via an appropriately sized baghouse with a high (>99%) control efficiency.

3.1.4 Conveyors and Transfer Points

All conveyors and transfer points that have the potential to be dust generating will be fully enclosed.

3.1.5 ROM Stockpile and Exposed Areas

Chemical dust suppressant is to be applied as per manufacturer's specifications to all vehicle areas (FEL and dump trucks) within the ROM stockpile area.

A commitment to the use of chemical dust suppressants to areas identified as being potentially impacted by wind erosion has been made, and will be documented within site procedures.

3.1.6 Real-time Air Quality Monitoring as Dust Management Tool

There is a commitment to use real-time meteorological and PM_{10} monitoring at suitable off-site locations. Monitoring will provide alarms (e.g. site specific investigation and action levels) to inform dust management in real-time. This may comprise notifications to relevant site personnel or the automatic implementation of dust controls (e.g. sprays at the TSF).

Suitable monitoring locations will be identified during the analysis of the air dispersion modelling and are discussed further in **Section 10**.

3.2 Additional Dust Management Practices

3.2.1 TSF1 Construction

The following summarises the dust control measures that are proposed for the construction of TSF1:

- embankments will be constructed of waste rock to eliminate dust generation of the side walls during operation;
- waste rock will be moisture conditioned prior to embankment placement to gain required compaction and reduce the potential for dust generation;
- use of a water cart or spray system to be in use when excavating waste rock material;
- water sprays to be installed along the access road from the waste rock stockpiles to TSF1;
- additional water spray during placement of rockfill layers at embankment via a water cart or sprays, to be used after spreading and during compaction;
- cessation of construction activities on days of high wind speed where the wind is directed towards neighbouring residences; and
- a Tailings Construction and Operations Manual to assist the construction contractor and operations personnel with the management of the facility and to implement the

above measures. This Manual will also identify monitoring and inspection requirements.

3.2.2 Tailings Storage Facility Operation

A preliminary dust management plan for the TSF will be developed with the objective of suppressing dust generation during construction, operation and closure of the facilities. The dust prevention strategy comprises the use of waste rock as embankment material, the use of temporary water sprays during construction, the installation of a spray system around the perimeter of each TSF1 cell and the application of chemical dust suppressant after a cycle of tailings deposition ceases. The dust suppressant currently proposed is a polymer and water mixture which forms a crust over the tailings surface.

During the period in which a cell or part of a cell is inactive, there is a potential for dust to be generated from the tailings surface if the tailings dries out sufficiently to release dust. A spray system comprising the following components is proposed to manage this risk:

- sprinklers and reticulation pipe;
- water supply, pump and control system; and
- dust suppressant (crusting) agent.

The spray system will apply a coating of chemical dust suppressant over the surface of the wet to moist tailings, using water as a medium to place the dust suppressant. The chemical dust suppressant coating forms a crust with the tailings, resulting in a surface that is resistant to both wind and water erosion with the durability of the crusting agent depending on the severity of surface disturbance. As there is no surface disturbance proposed on the tailings maximum efficiency of the dust suppressant product is expected.

The chemical dust suppressant being considered for application for the Project are reported to have a dust abatement efficiency of above 95% (Tunra Bulk Solids Handling Research Associates, July 2009; Introspec Consulting, November 2009). This dust control efficiency is based on wind tunnel testing of various tailings materials, including lead tailings, under wind speeds of 10 m/s.

Field trials will be undertaken prior to commencement of operation to establish the optimum concentration of chemical dust suppressant required to ensure there is no significant dust generation from this potential source. These trials will be carried out over a period of weeks to assess degradation of the dust suppressant crust with time. Trial criteria will include resistance to wind speeds of up to 50 km/hour (discussion on local meteorological conditions provided within **Section 5**).

The spray system is to be installed as part of the initial works for TSF1. The piping and sprays, with the associated control and mixing system could be activated at any time during operations. Six sprinklers are proposed around the perimeter of each cell. Each sprinkler has a maximum throw distance of 95 m and a maximum spacing of 75 m is proposed between sprinkler units. The 48 mm diameter spray nozzle has a capacity to spray 4500 litres/minute.

The control system would include a suppressant agent flow rate meter to ensure sufficient agent is delivered. If the agent source is depleted, an alarm will be activated and the system paused. A mainline flow meter would also be used to monitor the overall flow through the system.

The decant dam is the nominated source of water for the proposed spray system. Water would be pumped from the dam and the pump will be sized to supply at least 4500 litres/minute at a pressure of 8.5 bar. The site water balance indicates that the decant dam has sufficient capacity to meet the demands of the sprinklers.

The crusting agent would be added to water at an indicative rate of approximately 9 litres to 4500 litres of spray (i.e. 500:1 ratio). Supplier information has indicated that approximately 0.005 litres of crusting agent is required per square metre and that an application of the crusting agent would provide dust control for a number of months. The actual concentration of crusting agent to be adopted for the site will be determined based on field trials prior to the commencement of operation.

The estimated volume of agent required to cover the entire surface of TSF1 is between 500 and 750 litres. It is proposed to operate each cell for a period of one to two weeks before switching to the other cell resulting in one spray cycle per cell every two to four weeks. Generally only one application of the crusting agent is expected to be required after tailings deposition is switched to the adjacent cell. Additional applications of either crusting agent or water may be activated if the surface of the tailings appears to be at risk of generating dust.

The crusting agent takes up to ten minutes to apply, at the recommended rate, per sprinkler. The recommended dosing rate for the mixing of the crusting agent, and hence the application rate on the tailings surface, may be varied seasonally. A higher concentration or more frequent application of crusting agent can occur prior to a period of high wind, following intense rainfall events, or if disturbance of the tailings surface has occurred.

The sprinkler system also applies a significant amount of water onto the surface of the tailings, as part of the crusting agent application process. In addition the application of the crusting agent water could be sprayed on a specific section of the tailings surface if a localised issue developed with potential for the tailings to generate dust.

Significant contingency and redundancy has been built into the design of the TSF to ensure that adequate dust mitigation is available both during normal operations and under ‘upset’ conditions.

The proposed operation of the TSF will include:

- Tailings will be delivered to the active TSF cell as a slurry of 75% water and 25% solids by volume at a rate of ~137 000 litres per day;
- After tailings has stopped being applied to the active cell, it will take ~1 to 2 weeks for the surface to go from ‘wet’ to ‘spade-able’;
- The binding crusting agent will be applied to the TSF sometime between when the surface is wet until it dries out enough to become spadeable;

- The crusting agent will be applied via sprinkler systems that have overlapping arcs.
- The crusting agent will not be applied during high wind due to the potential for uneven distribution;
- Sufficient moisture will be retained in the tailings prior to the crusting agent being applied, such that during high wind conditions, emissions can be adequately controlled prior to the crusting agent being applied;
- It is conservatively estimated that there will be a period of 1 week between when the material becomes spadeable and when further drying presents a high risk of wind blown dust emissions. On this basis there will be time allowance to ensure that the crusting agent is applied under favourable meteorological conditions;
- Extra water can be supplied from the decant dam by the sprinklers surrounding the TSF cells at a maximum expected rate of 4,500 litres/minute (subject to the detailed design process);
- The tailings slurry can be directed to the inactive cell as a backup emission control, and it is estimated it would take approximately a 6 hour to flood the inactive cell. The time taken to cover the tailings surface with fresh tailings is an estimate based on the design tailings deposition rate. The areas most likely to dry first are the same areas that would be covered the quickest as these areas are near the spigot outlets;
- Tailings will only be directed to one cell at a time;
- The spigots that deliver the tailing slurry to the TSF cells have not currently been designed to enable the delivery of water from the decant dam to the inactive cell when tailings are being directed to the active cell. The technical feasibility of this additional control option is being investigated.
- Sprinklers can apply water to the surface of the inactive cell by switching on the pump without adding the crusting agent. This will not interfere with the tailings deposition on the active cell.

A summary of potential upset conditions, a qualitative assessment of their likelihood, and details of the contingency measures in place with regard to dust control are provided in **Table 5**.

Table 5 – Dust Mitigation Contingencies Under Potential 'Upset' Conditions at the TSF

Scenario	Effect	Likelihood	Level 1 Control	Level 2 Control	Alternative Control
Sprinkler pump blows at active cell	Anticipated to take between 7 days and two weeks for the material within active cell to dry out to a condition where it is spadeable. .	Possible	Replacement pumps kept on site as essential spares – estimated 2 hour period to replace.	Wet tailings may be applied through spigot closest to the inactive sprinkler. Spigots may be selected individually to target the area with potential to dry out.	Spigots designed to enable the delivery of water from the decant dam to inactive cell (subject to technical feasibility investigation).
Weather conditions (high winds) cause delay in application of chemical dust suppressant to inactive cell	Minimum one week window within which chemical dust suppressant may be applied once cell becomes inactive.	Possible	Application of water with sprinklers.	Whole cell may be covered with tailings layer using spigots within 6 hours	Spigots designed to enable the delivery of water from the decant dam to inactive cell (subject to technical feasibility investigation).
All sprinklers are rendered inactive as sprinkler water supply is cut by a site upset.	Minimum one week window before material dries out to a condition where it is spadeable.	Unlikely	Whole cell may be covered with a layer of tailings using spigots within 6 hours.	Spigots designed to enable the delivery of water from the decant dam to the inactive cell when tailings are being directed to the active cell. (subject to technical feasibility investigation).	
Inactive cell seen to be raising visible dust	Dust raising detected by visual inspection or via feedback from real-time PM_{10} monitoring equipment fitted with telemetry.	Possible	Sprinkler spray arcs overlap. Whole cell may be covered with additional chemical dust suppressant within 10 minutes	Water may be applied through sprinklers. Sprinklers to be used for water application may be selected individually to target the area raising dust.	Whole cell may be covered with tailings layer using spigots within 6 hours
Production upset leads to cessation of tailings deposition. Active cell seen to be raising visible dust	Dust raising detected by visual inspection or via feedback from real-time PM_{10} monitoring fitted with telemetry.	Unlikely	Sprinkler spray arcs overlap. Whole cell may be covered with additional water within 10 minutes	Whole cell may be covered with chemical dust suppressant using sprinklers	Spigots designed to enable the delivery of water from the decant dam to inactive cell (subject to technical feasibility investigation).

Note: As an alternative control measure, manual water spraying using vehicle or mobile equipment may be applied in any of the above scenarios.

3.2.3 Exhaust from Underground

If the ventilation shaft is not a ‘wet‘ shaft, as is expected, water sprays will be installed and used during blasts to maximise suppression of dust in the underground mine. The ventilation shaft outlet will be located within an existing open cut pit (Little Kintore Pit), with a proportion of coarse particulates retained within this pit.

3.2.4 ROM Stockpile Activities

Wind breaks will be used to deflect wind to reduce dust entrainment. It is proposed that the wind breaks be arranged in a series of rows orientated to the prevailing wind direction with ore being dumped and recovered from piles located between the breaks. Additionally, water sprays will be mounted on the wind breaks and directed at stockpiles.

Ring nozzle water sprays (atomised sprays) will be installed on the apron feeder hopper to the crushing circuit. Negative pressure will take this airflow to the crushing circuit bag-house.

3.2.5 Product Loading

Concentrate loading will take place in an enclosed building (solid roof and side walls) with rubber curtains at the points of entry and exit points for the wagons. Once the wagon has reached capacity a lid will automatically be placed on the wagon to maintain moisture content of the product (anticipated to be 9%) and eliminate any dust emissions during transport to port.

A wagon wash facility will be installed to remove and collect any potential spillage from the wagons. Material collected will be returned to the process.

3.2.6 Exposed Areas

A dust control strategy for exposed areas of the lease will be developed, including: limitation of vehicle or work access to open areas, maintaining a surface crust to minimise potential wind erosion, identification and remediation of areas where fines or silt has built up (typically after heavy rain storms) and remediation of any area disturbed due to works carried out on site (including surface exploration drilling sites). Remediation will include, but not be limited to, removal and burial of fine material, capping with inert waste rock, or use of chemical dust suppressants.

3.2.7 Construction and Ancillary Surface Mining Activities

BHOP has committed to use the following dust management measures during the construction phase:

- Excavation area to be hosed down prior to removal of material via a dedicated water cart and/or water sprays;
- Water sprays installed along the temporary waste rock transport route;
- Water sprays utilised during the placement of rockfill layers during construction of the TSF embankment after spreading and again during compaction;

- Sprinkler systems will be used to aid dust suppression on material stockpiles;
- Sprinkler system currently in use on haul roads and some service roads will be extended to all unsealed haul roads, or chemical dust suppressants will be used (control efficiency of water sprays is assumed to be conservative).
- Watering or chemical dust suppressants will be used (control efficiency of water sprays assumed to be conservative) on all unsealed service roads.
- Sprinkler system will be used at the crusher and truck loading;
- Mobile crusher has automatic dust suppression sprays installed;
- Mobile crusher and associated stockpiles to be located within an 18m deep gully to the north-west of Mt Hebbard;
- Cessation of potentially dust generating activities during high wind events;
- Product ore truck / trailer doubles will be fitted with covers and leave site via a truck wash facility to remove material or dust build-up;
- Trucks will exit the wash station and the site via a sealed road.

The construction contractor will be required to monitor and report on dust conditions taking additional action as required and as outlined in the Tailings Construction and Operations Manual. Wind speed and direction will be noted in the morning meetings and provided to the construction contractor. The Manual will form part of the construction contractor's contract, it will outline dust management measures, monitoring, inspection and reporting requirements.

3.2.8 Vehicle Wash Facilities

All vehicles that have passed the boom gate access point will be required to be washed down prior to leaving site. This is to remove any potential lead contamination that may be on the vehicle. For this purpose a vehicle wash facility has been installed as part of the exploration decline development. It is located on the main exit road prior to the boom gate access point. The main features of this facility are:

- fully automated wash system;
- deluge designed to wash wheels and undercarriage of cars and trucks;
- waste water treatment and recycling systems; and
- sediment collection and removal system.

Raw water will be used for the initial system fill and top up water. All water used in the washing process will be collected and recycled through a treatment system; including oil/water separator and sediment collector. The sediment will be collected on a regular basis for disposal in the BHP and / or Blackwood Pits.

The capacity of the facility will be in excess of 1000 vehicle movements per day.

4 Air Quality Criteria and Health Risk Thresholds

In order to satisfy the requirements of the NSW DECCW, proposed operations must demonstrate that cumulative air pollutant concentrations, taking into account incremental concentrations due to the operation's emissions and existing background concentrations, are within ambient air quality limits.

Suspended particulate concentrations, dust deposition rates and suspended metal/metalloid concentrations are evaluated based on identified air quality criteria including impact assessment criteria specified by DECCW (2005)[(1)] and supplemented by inhalation reference concentrations obtained from widely-referenced health risk information sources (e.g. WHO, US IRIS).

Relevant ambient air quality criteria applicable to the Project are presented in **Section 4.1**, **Section 4.2** and **Section 4.3**. Inhalation toxicity thresholds published in health risk advisory databases for metals/metalloids under review are presented in **Section 4.4**.

The air quality criteria and health risk thresholds presented in this section are only applicable to the inhalation of the relevant pollutants and do not support the evaluation of risk potentials due to other exposure pathways. Ingestion of deposited metals potentially represents a significant exposure pathway for some metals/metalloids. Suspended particulate concentrations, and metal/metalloid concentrations and deposition rates from this study will serve as input to the HRA being undertaken for the Project by Toxikos. The Toxikos HRA should be referred to for a completed understanding of the potential health risks associated with the Project.

4.1 Air Quality Limits for Airborne Particulate Matter and Lead

The impact of particles on human health is largely dependent on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential for particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit large dust particles to enter the nasal region, along with much finer airborne particulates (less than 10 µm). The larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (less than 10 µm) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (Environment Canada, 1998; Dockery and Pope, 1993).

1 The DECCW impact assessment criteria for metals/metalloids are applicable exclusively for acute exposures to incremental concentrations due to the Project. These criteria are typically regarded as screening levels which, when exceeded, should invoke the undertaking of a Health Risk Assessment.

Air quality limits for particulates are typically given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM_{10} (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates or $PM_{2.5}$ (i.e. particulate with an aerodynamic diameter of less than 2.5 µm). Although TSP is defined as all particulate with an aerodynamic diameter of less than 100 µm, an effective upper limit of 30 µm (USEPA, 2010) aerodynamic diameter is frequently assigned. PM_{10} and $PM_{2.5}$ are of concern due to their health impact potential.

Air quality standards issued by Federal and NSW government for particulates are given in **Table 6**.

Table 6 – Impact assessment criteria for particulates and lead

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Reference
TSP	annual	90	NSW DECCW(a)(b)
PM_{10}	24 hours	50	NSW DECCW(a)
	24 hours	50(d)	NEPM(c)
	annual	30	NSW DECCW(a)
$PM_{2.5}$	24 hours	25	NEPM(e)
	Annual	8	NEPM(e)
Lead	Annual	0.5	NSW DECCW(a)

(a) DECCW, 2005 *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*
(b) DECCW impact assessment criterion based on the subsequently rescinded National Health and Medical Research Council (NHMRC) recommended goal.
(c) NEPC, 2003, *National Environment Protection (Ambient Air Quality) Measure, as amended.*
(d) Provision made for up to five exceedances of the limit per year.
(e) Advisory reporting goal issued by the NEPC (NEPC, 2003).

The DECCW has not published an ambient air quality criterion for $PM_{2.5}$. Reference may however be made to the $PM_{2.5}$ advisory reporting standards and goals for issued by the NEPC (NEPC, 2003), as referenced in **Table 6**. The DECCW impact assessment criterion for lead is given in **Table 6.**

4.2 Dust Deposition Limits

Nuisance dust deposition is regulated through the stipulation of maximum permissible dust deposition rates. The DECCW impact assessment criteria for dust deposition are given in **Table 7** illustrating the allowable increment in dust deposition rates above ambient (background) dust deposition rates which would be acceptable so that dust nuisance could be avoided. Furthermore, a limit is set for total cumulative dust deposition rates which include existing deposition and any increment due to a proposed development. Cumulative annual average dust deposition rates within residential areas which are in excess of

4 g/m^2/month are generally considered to indicate that nuisance dust impacts are potentially occurring.

Table 7 - Dust deposition criteria published by the NSW DECCW

Pollutant	Maximum Increase in Dust Deposition	Maximum Total Dust Deposited Level
Deposited dust (assessed as insoluble solids)	2 g/m^2/month	4 g/m^2/month

Source: DECCW, 2005 *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.*

4.3 DECCW Impact Assessment Criteria for Toxic Air Pollutants

The DECCW specifies impact assessment criteria for a range of principal and individual toxic air pollutants (DECCW, 2005). A synopsis of the criteria relevant to metals of interest in the current study is given in **Table 8**.

The impact assessment criteria specified by the DECCW (2005) for toxic air pollutants must be applied at and beyond the boundary of the facility, with the *incremental* impact (predicted impacts due to the pollutant source alone) for each pollutant reported for an averaging period of 1 hour.

Table 8 – Impact assessment criteria for toxic air pollutants published by NSW DECCW

Substance	Averaging Period	Impact Assessment Criteria ($\mu g/m^3$)
Antimony and compounds	1 hour	9.0
Arsenic and compounds	1 hour	0.09
Barium (soluble compound)	1 hour	9.0
Beryllium	1 hour	0.004
Cadmium and compounds	1 hour	0.018
Chromium III and compounds	1 hour	9.0
Chromium VI and compounds	1 hour	0.09
Copper dusts and mists	1 hour	18
Manganese and compounds	1 hour	18
Mercury organic	1 hour	0.18
Mercury inorganic	1 hour	1.8
Nickel and compounds	1 hour	0.18
Zinc oxide fumes	1 hour	90

Source: DECCW, 2005 *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.*

4.4 Air Quality Goals for Combustion / Blasting Emissions

Emissions may occur as a result of underground blasting and vehicle use which is subsequently exhausted via the surface ventilation fan within the Little Kintore Pit:

Air quality limits issued by federal and NSW government applicable to these potential gaseous emissions are given in **Table 9**.

Table 9: Air quality goals for Combustion / Blasting Emissions

Pollutant	Averaging Period	Concentration		Reference
		$\mu g/m^3$ (unless otherwise stated)	ppm	
NO_2	1-hour	246	0.12	NSW DECCW[1]
		-	0.12	NEPM[2]
	Annual	62	0.03	NSW DECCW[1]
		-	0.03	NEPM
SO_2	10-minute	712	0.25	NSW DECCW1
	1-hour	570	0.20	NSW DECCW[1]
		-	0.20	NEPM[2]
	24-hour	228	0.08	NSW DECCW[1]
		-	0.08	NEPM[2]
	Annual	60	0.02	NSW DECCW[1]
		-	0.02	NEPM
CO	15-minute	$100mg/m^3$	87	NSW DECCW[1]
	1-hour	$30mg/m^3$	25	NSW DECCW[1]
	8-hour	$10mg/m^3$	9	NSW DECCW[1]
PAHs	1-hour	$0.4mg/m^3$	-	NSW DECCW[1,3]

Note 1: NSW DECCW, 2005, Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales

Note 2: Provision made for one exceedance of the limit per year.

Note 3: As Benzo[a]pyrene based on potency equivalency factors – see Section 1.4.2

4.5 Inhalation Health Risk Criteria for Toxic Substances

The NSW DECCW impact assessment criteria for toxins are applicable exclusively for screening short-term peaks in incremental concentrations due to the Project as indicated. Therefore, to consider longer term exposures reference is made to inhalation toxicity thresholds published in widely referenced health risk advisory databases including the following:

- World Health Organization (WHO) guideline values,
- Chronic and sub-chronic inhalation reference concentrations published by the US-EPA in its Integrated Risk Information System (IRIS),

- Reference exposure levels (RELs) published by the Californian Office of Environmental Health Hazard Assessment (OEHHA),
- Acute, sub-acute and chronic effect screening levels published by the Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division (TARA), and
- Minimal risk levels issued by the US Federal Agency for Toxic Substances and Disease Registry (ATSDR).

A synopsis of the toxicity values identified for the various metals/metalloids of interest in the current study is given in **Table 10**.

Table 10 - Non-carcinogenic inhalation health risk criteria

Constituent	WHO Guidelines (2000)		US-EPA IRIS Inhalation Reference Concentrations (referenced Feb 2010)	Californian OEHHA (February 2010)		US ATSDR Minimum Risk Levels (MRLs) (December 2008)			TARA ESLs (October 2009)	
	Acute & Sub-acute Guideline	Chronic Guidelines (year+)	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Antimony	-	-	-	-	-	-	-	-	5	0.5
Arsenic	-	-	-	0.2	0.015	-	-	-	0.1	0.01
Barium	-	-	-	-	-	-	-	-	5	0.5
Beryllium	-	-	0.02	0.2	0.007	-	-	-	0.02	0.002
Cadmium	-	0.005	-	-	0.02	0.03	-	0.01	0.1	0.01
Chromium	-	-	0.1			-	0.1	-	1	0.1
Copper	-	-	-	100	-	-	-	-	10	1
Iron	-	-	-	-	-	-	-	-	50	5
Lead	-	0.5		-	-	-	-	-	-	-
Manganese	-	0.15	0.05	0.17 (8hr)	0.09	-	-	3	2	0.2
Mercury	-	1	0.3	0.6	0.03	-	-	0.2	0.25	0.025
Nickel	-	-	-	6	0.05	-	0.2	0.09	0.15	0.015
Silver	-	-	-	-	-	-	-	-	0.1	0.01
Respirable Crystalline Silica	-	-	-	-	3	-	-	-	-	-
Zinc	-	-	-	-	-	-	-	-	50	5

Abbreviations: WHO – World Health Organisation; IRIS – Integrated Risk Information System; OEHHA – Office of Environmental Health Hazard Assessment; ATSDR – US Federal Agency for Toxic Substances and Disease Registry; TARA - Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division; TC – tolerable concentration; GV – guideline value; RfC – inhalation reference concentration; MRL – minimum risk level; ESL – effect screening level; REL – reference exposure level

5 Existing Air Quality Environment

The quantification of cumulative air pollution concentrations and the assessment of compliance with ambient air quality limits necessitate the characterisation of baseline air quality. Given that particulate matter and several heavy metals represent the primary emissions from the Project, it is pertinent that existing sources and ambient air pollutant concentrations of these pollutants be considered.

5.1 Existing Local Sources of Atmospheric Emissions

Industrial and mining activities operating within 5 km of the Project Area which are listed as either National Pollutant Inventory (NPI) reporting activities or DECCW licence holders are listed in **Table 11**.

Table 11 – Industrial operations and mines situated within 5 km of the Project Area

Facility Name	Distance from Site	Description
Perilya Broken Hill Operations Pty Ltd – South and North Mines	Operations located adjacent to northeast and southwest site boundaries	Zinc, lead and silver mines
Bemax Mineral Separation Plant	4.1 km WSW of southwest boundary	Mineral sand processing plant
E B Mawsons & Sons	Adjacent to southeastern site boundary	Gravel quarry and concrete batching plant

Extraction operations are currently at the nearby Mawsons Quarry. Perilya Broken Hill Operations Pty Ltd undertakes separate mining operations to the northeast and southwest of the Project Area. The northern operations are in a care and maintenance phase, with emissions from the site expected to be primarily from wind erosion of exposed surfaces. Perilya operations to the southwest comprise underground mining operations with surface processing. Tailings from this operation are currently sent to a storage facility located approximately 5 km to the southwest of the Project Area.

It is noted at this point that due to the scale and nature of the existing surrounding operations, these sources are not considered to be substantial contributors of particulate matter emission to the local air shed.

Rather, due to the arid location of Broken Hill, naturally generated dust storms are a likely significant contributor to elevated ambient particulate matter concentrations events in the region. Review of Bureau of Meteorology (BoM) records for recent years highlighted various occurrences of dust storms along with other days where sustained periods of high winds contributed to the persistence of significant levels of visible dust. Dust storms worthy of being recorded by the BoM due to their severity occurred on 2% of days over the 2007 to 2009 period. This is likely to exclude days on which more minor events resulted in dust episodes.

Wind blown dust thus represents a key component of suspended particulate concentrations and dust deposition in the area. Other potential sources of atmospheric emissions in the vicinity of the Project include:

- Dust entrainment due to vehicle movements along unsealed and sealed town and rural roads with high silt loading levels;
- Vehicle exhaust and rail related emissions; and
- Episodic emissions from vegetation fires.

Fugitive dust from long-range transport of fine particles is also expected to contribute to suspended particulate concentration in the study area.

5.2 Monitoring Data Available for Baseline Air Quality Characterisation

Monitoring data sets which were made available and used in the characterisation of the existing air quality in the study area are listed in **Table 12**. Permission was granted by the various data owners for the use of these data sets for the specific purpose of this air dispersion modelling assessment. The locations of the BHOP sampling stations are given in **Figure 5**.

Table 12 - Monitoring data sets used in the baseline air quality characterisation

Data Owner / Data Set	Sampling Sites	Parameters Measured	Monitoring Duration
BHOP HVAS	1 station: on-site adjacent to Dust Deposition Gauge D5	TSP and Lead (one-in-six day cycle)	May 2007 – Jan 2010
BHOP Dust Deposition	6 dust gauge sampling stations: D1 to D5 and Casuarina Ave	Dust deposition and Pb (30 day +/- 2 day cycle)	March 2007 – December 2009
Bemax HVAS	1 station: onsite adjacent to Bemax operations	PM_{10} (one-in-six day cycle)	May 2006 – Jan 2010

HVAS – high volume air samplers

Figure 5: Locations of BHOP monitoring stations

5.3 Ambient TSP Concentrations

The 24-hour average TSP concentrations recorded by the BHOP HVAS between January 2008 and December 2009 are presented in **Figure 6**. .

The maximum recorded 24-hour average TSP concentration for the period January 2008 and December 2009 was 415.3 µg/m³. This peak concentration occurred during a recorded dust storm event in March 2009.

Annual average TSP concentrations of 47.8 µg/m³ and 64.9 µg/m³ were recorded for 2008 and 2009 respectively, while the dataset average was 56.4 µg/m³. Ambient concentrations of TSP were therefore within the annual guideline value of 90 µg/m³ for 2008 and 2009, with measured levels comprising about 50% to 70% of the guideline value.

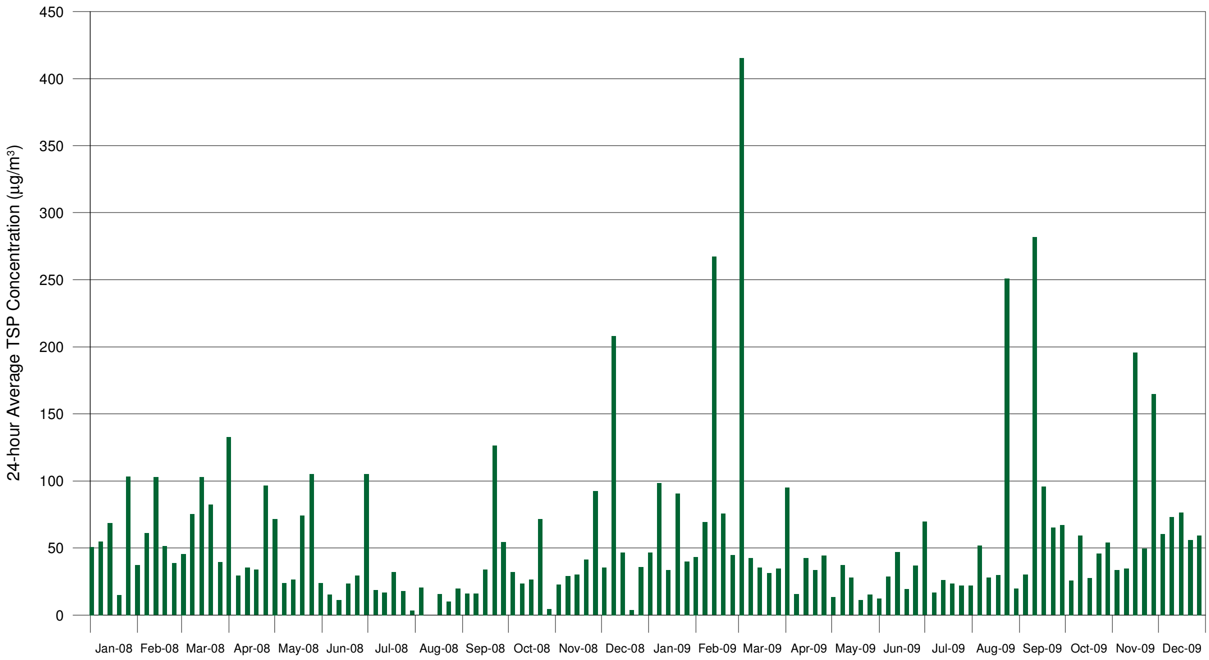


Figure 6: 24-hour average TSP concentrations recorded at BHOP HVAS during January 2008 to December 2009

5.4 Measured Ambient PM_{10} Concentrations

PM_{10} concentrations are not measured at the Project Site. Given the importance of providing an estimate of prevailing PM_{10} concentrations for the purposes of assessing cumulative concentrations, reference was made to the PM_{10} monitoring undertaken by Bemax Resources Limited (Bemax). Bemax conducts one-in-six day sampling of PM_{10} concentrations by HVAS at the Broken Hill Mineral Separation Plant situated approximately 4.1 km to the west-southwest of the Project Site.

The 24-hour average PM_{10} concentrations recorded by the Bemax HVAS between January 2008 and December 2009 are presented within **Figure 7**. It is noted that the PM_{10} concentrations are not measured by Bemax on the same days on which TSP concentrations are measured by BHOP.

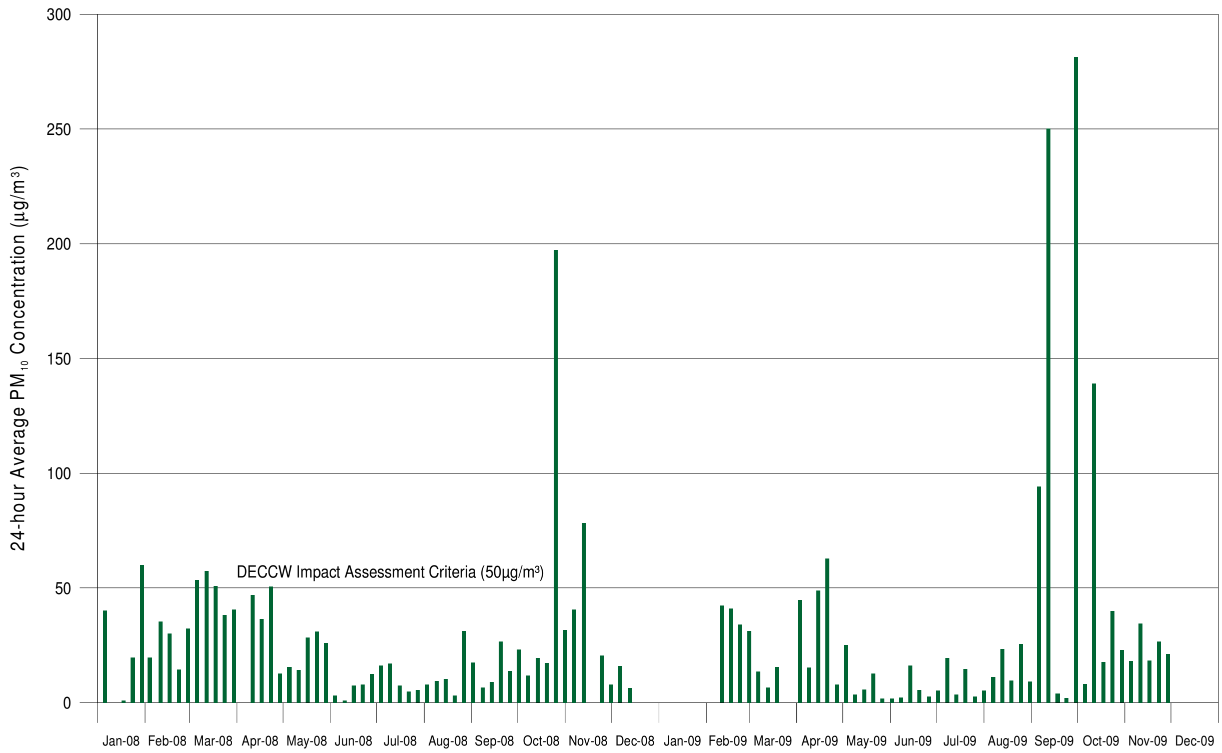


Figure 7: 24-hour Average PM10 concentrations recorded by Bemax during January 2008 to December 2009

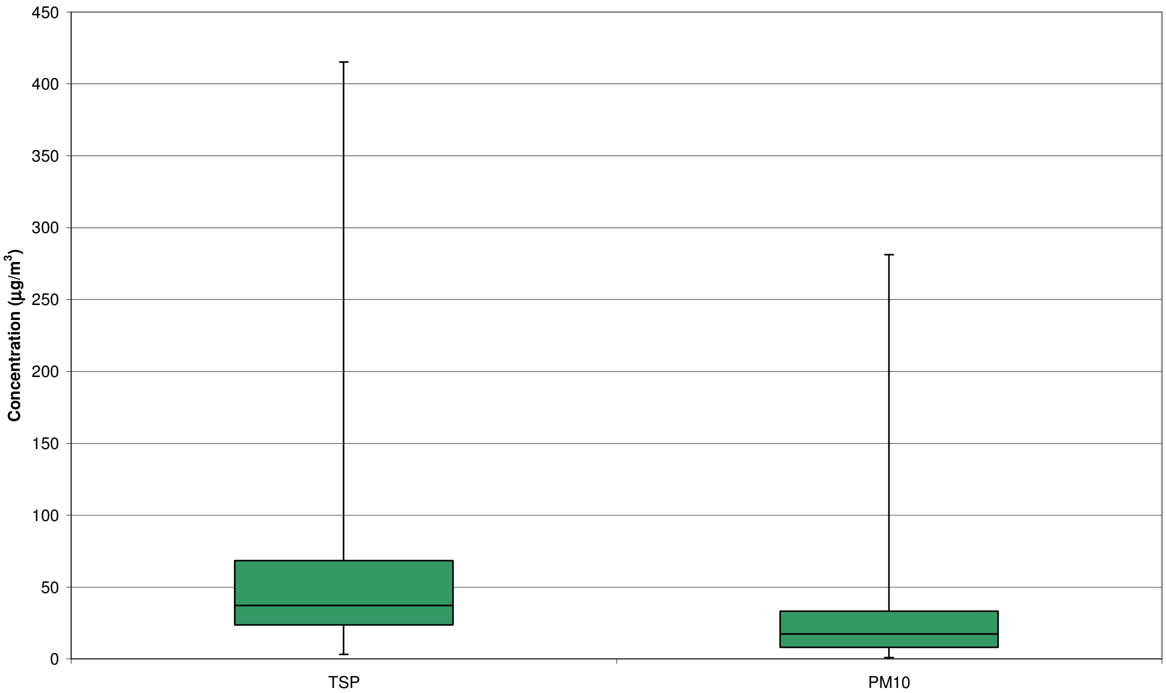
The maximum recorded 24-hour average PM_{10} concentration for the period January 2008 and December 2009 was 281.2 µg/m³, during a period of sustained dust storm activity during late September 2009. The 24-hour impact assessment guideline of 50 µg/m³ was exceeded on 12 separate occasions between January 2008 and December 2009 (11.7% of all data days).

Average PM_{10} concentrations of 26.3 µg/m³ and 32.3 µg/m³ were recorded for 2008 and 2009 respectively, with the period average of 29.1 µg/m³ across the 103 data days comprising about 97% of the impact assessment criterion of 30 µg/m³.

5.5 PM_{10} Concentrations as a Fraction of TSP Levels

Despite the BHOP TSP and Bemax PM_{10} monitoring days not being concurrent, a statistical analysis of these data sets provides for an assessment of likely PM_{10}/TSP ratios in the study area. Results from this analysis are presented in **Table 13** and illustrated in **Figure 8**.

Table 13 – TSP and PM10 Dataset Statistics – January 2008 to December 2009			
Statistic	**BHOP HVAS TSP Concentration (µg/m³)**	**Bemax HVAS PM_{10} Concentration (µg/m³)**	**PM_{10} to TSP Ratio**
Mean	56.4	29.1	0.52
Standard Deviation	59.4	43.2	0.73
Median	37.1	17.3	0.47
Lower Quartile (25th Percentile)	23.6	7.9	0.34
Upper Quartile (75th Percentile)	68.3	33.2	0.49
Minimum	3.2	0.9	0.28
Maximum	415.3	281.2	0.68



Note: Horizontal lines of boxes indicate 25th percentile, 50th percentile (Median) and 75th percentile concentrations for the dataset. Whiskers indicate the maxima and minima of the dataset.

Figure 8: Distribution of TSP and PM10 concentrations in Broken Hill region – January 2008 to December 2009

The PM_{10}/TSP ratio is thus in the range of about 0.3 to 0.7, and most typically of the order of 0.5. Based on experience gained in the analysis of PM_{10}/TSP ratios for rural and mining areas where mechanically generated dust sources dominate, it is anticipated that peak TSP concentrations will coincide with significantly lower PM_{10}/TSP ratios. Exceptions to this will occur during vegetation fire events, with such events likely to coincide with peak suspended particulate concentrations and significantly higher PM_{10}/TSP ratios.

5.6 Projected PM_{10} Concentrations for Project Assessment Purposes

For the purpose of projecting the magnitude of PM_{10} concentrations at the site, the median PM_{10}/TSP ratio of 0.47 was applied to the measured BHOP TSP data set to derive indicative PM_{10} levels.

This projected PM_{10} data set (comprising 121 data days) was combined with the measured Bemax PM_{10} data set (103 data days) to generate a constructed PM_{10} data set covering 224 days during the January 2008 to December 2009 period with all seasons represented.

The constructed PM_{10} data set, illustrated in **Figure 9**, provides an indication of temporal variations in PM_{10} levels and facilitates a more robust means of assessing cumulative air quality impacts due to the Project.

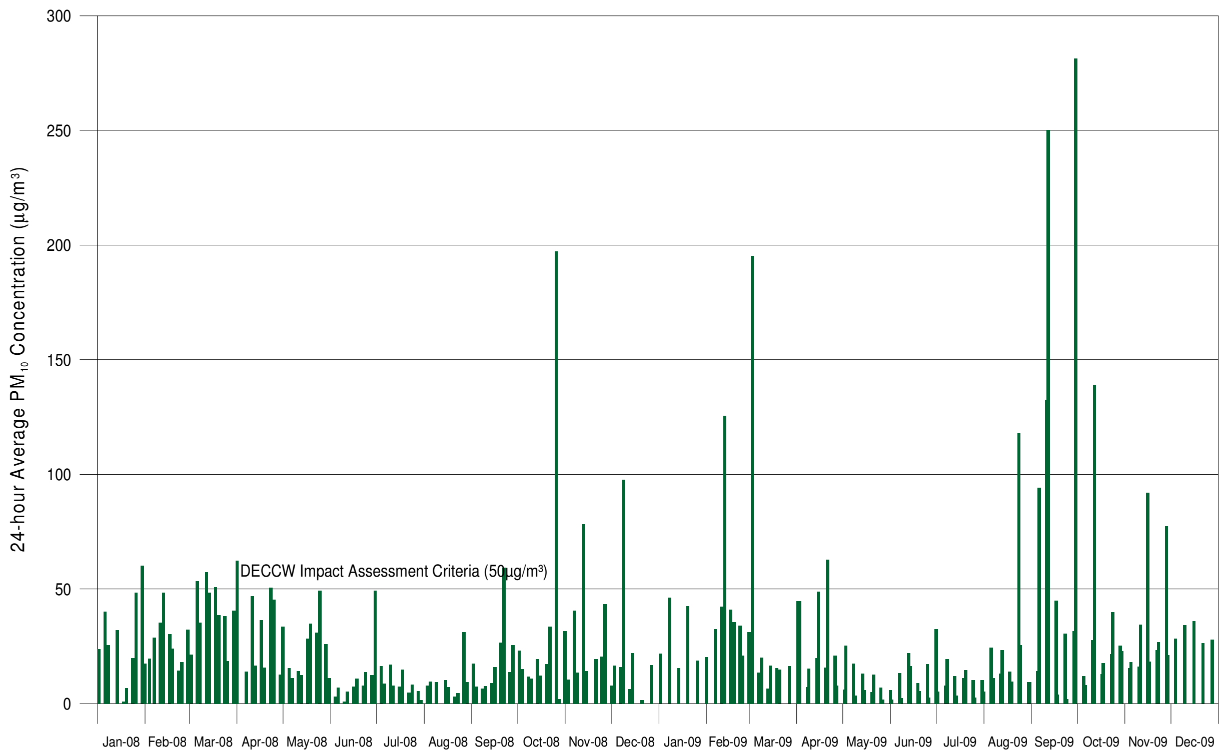


Figure 9: Constructed PM10 Concentration Dataset (January 2008 to December 2009) – Bemax PM10 and PM10 from BHOP HVAS TSP

Based on the constructed PM_{10} data set, daily average PM_{10} concentrations are given as ranging from about 1 µg/m³ to 280 µg/m³, with a period average concentration of 28 µg/m³ and a median value of 17 µg/m³. The DECCW daily assessment criterion of 50 µg/m³ is estimated to be exceeded on about 10% of days (**Figure 10**).

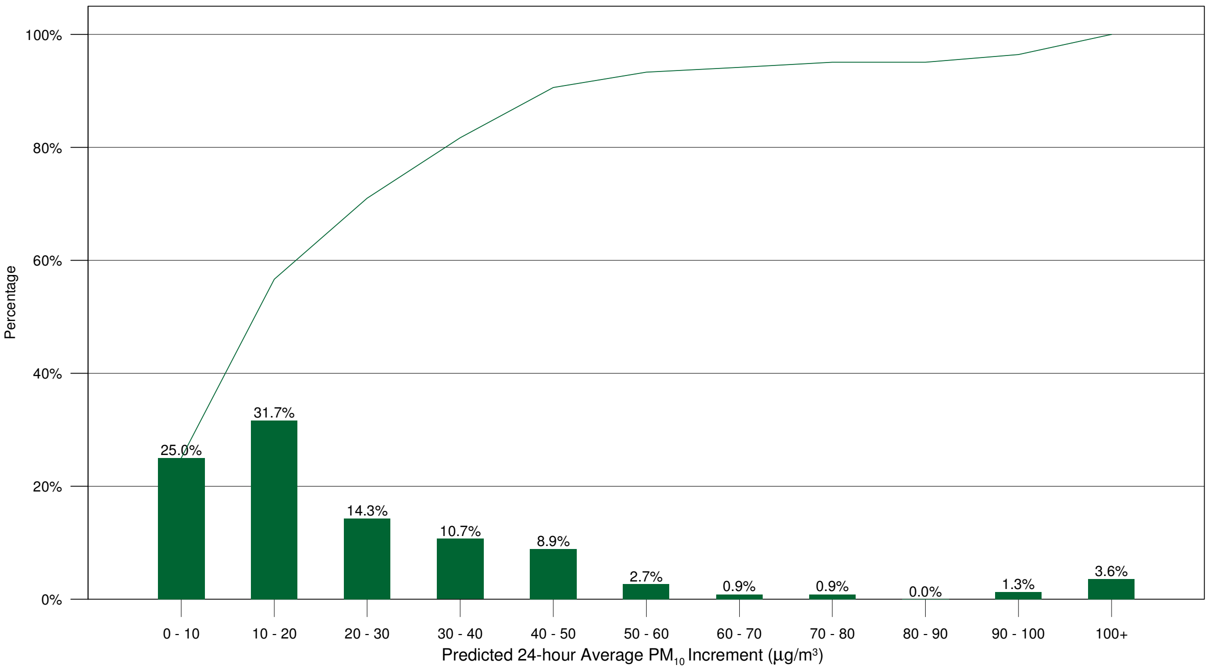


Figure 10: Distribution of Constructed PM10 Concentration (data set constructed from Bemax PM_{10} measurements and derived PM_{10} levels from BHOP HVAS TSP measurement) for January 2008 to December 2009

5.7 Ambient $PM_{2.5}$ Concentrations

No site-specific $PM_{2.5}$ monitoring data were available for the Broken Hill region for reference in this assessment. The impact assessment for this fraction will therefore be restricted to the consideration of the incremental concentration due to the Project.

5.8 Dust Deposition

Dust deposition is recorded at six separate locations by BHOP nominally on a 30 day +/- 2 day sampling period, as presented in **Figure 5.** All locations, with the exception of D5 which was established in December 2009, have recorded dust deposition rates since March 2007. D1 to D4 are situated at the Project Site, while the Casuarina Avenue sampling site is located to the south of the Project Site and represents a measure of ambient dust deposition away from significant influence of on-site emissions. Statistics for the five long term dust deposition monitoring locations are presented in **Table 14** with the associated box-and-whisker plot presented in **Figure 11**. Annual and period average dust deposition rates are presented in **Table 15.**

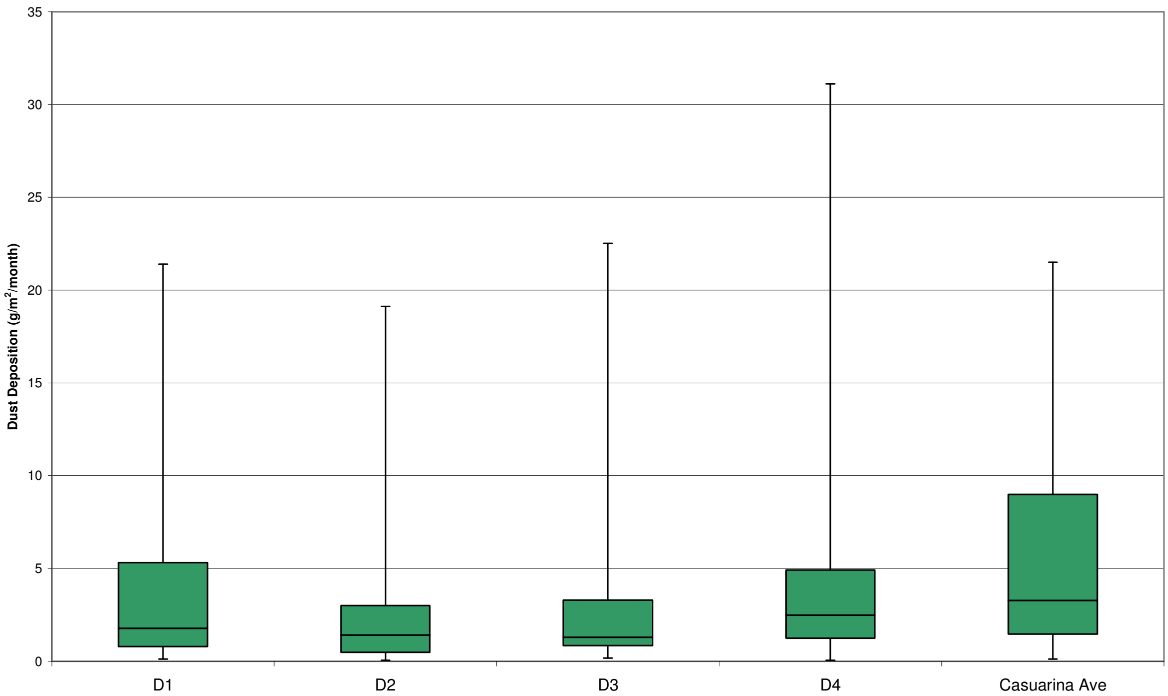
Dust deposition rates in the Broken Hill region are determined to be typically high based on the BHOP monitoring data, with annual averages recorded to range from 1.3 to

9.9 g/m^2/month across sites and years (2008, 2009). Of note is that dust deposition rates recorded at the Casuarina Avenue sampling site are typically higher than are measured at the BHOP site. This demonstrates the general dustiness of the Broken Hill region, likely to be due to regional scale wind entrainment.

Table 14 – Dust Deposition Statistics – March 2007 to December 2009

Statistics	Dust Deposition (g/m^2/month)				
	D1	D2	D3	D4	Casuarina Ave
Mean	4.0	3.1	4.3	5.7	5.8
Standard Deviation	5.4	4.3	6.5	8.2	6.2
Median	1.8	1.4	1.3	2.5	3.3
Lower Quartile (25th Percentile)	0.8	0.5	0.8	1.2	1.5
Upper Quartile (75th Percentile)	5.3	3.0	3.3	4.9	9.0
Minimum	0.1	0.1	0.2	0.1	0.1
Maximum	21.4	19.1	22.5	31.1	21.5

Note: Result of 60.1 g/m^2/month recorded at D2 in October 2008 excluded as erroneous based on corresponding samples at other locations.



Note: Horizontal lines of boxes indicate 25th percentile, 50th percentile (Median) and 75th percentile concentrations for the dataset. Whiskers indicate the maxima and minima of the dataset.

Figure 11: Distribution of BHOP Dust Deposition Levels – March 2007 to December 2009

Table 15 – Dust Deposition – Annual and Period Averages

Year	Dust Deposition (g/m²/month)				
	D1	D2	D3	D4	Casuarina Ave
2007	2.1	2.3	2.2	2.3	2.6
2008	3.5	1.3	3.3	4.9	4.5
2009	6.0	5.2	7.0	9.4	9.9
Average	**3.9**	**2.9**	**4.2**	**5.6**	**5.6**

5.9 Ambient Lead Concentrations

Ambient concentrations of lead (Pb) are recorded within the Project Area both through the TSP HVAS monitoring and dust deposition sampling and subsequent laboratory analysis. Measurements available for the May 2007 to December 2009 period are summarised in **Table 16** and illustrated as a time series in **Figure 12**.

Annual average suspended lead concentrations (in the TSP fraction) are of the order of 0.2 µg/m³, comprising about 40% of the DECCW criterion of 0.5µg/m³. On average, Pb concentrations represent about 0.3% of total TSP concentrations. Typically lower Pb fractions are recorded to coincide with peak TSP concentrations, indicating the likelihood that such peaks are associated with more regional dust events (**Figure 12**).

Table 16 - Pb concentrations from TSP Monitoring – BHOP HVAS

Period	Average 24-hour Concentration		% Pb of TSP	Pb % of DECCW Guideline Value
	TSP (µg/m³)	Pb (µg/m³)		
2007 (May-Dec)	67.4	0.21	0.32	43
2008	47.8	0.14	0.30	28
2009	65.0	0.22	0.34	45
Average	**59**	**0.19**	**0.32**	**38**

Note: DECCW Guideline – 0.5 (µg/m³)

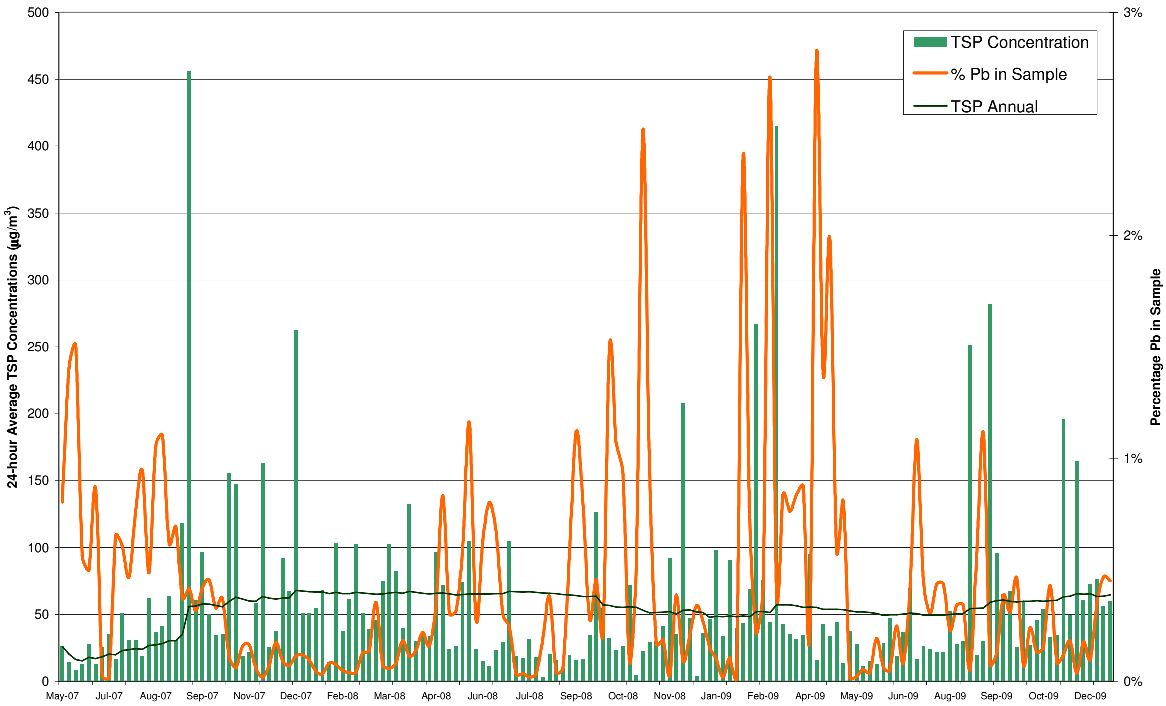


Figure 12: Percentage Lead Concentrations in 24-hour Average TSP Concentrations at BHOP HVAS – May 2007 to December 2009.

Insoluble Pb levels within the total dust deposition monitoring conducted, as reported by BHOP, are provided in **Table 17**. Pb constitutes on average 0.06% to 0.15% of the annual total dust deposition measured, with the lowest Pb content recorded for the Casuarina Avenue sampling location.

It is of note that the Pb content (~0.1%) of on-site deposited dust is lower than the 0.3% Pb content within suspended TSP concentrations.

Table 17 – Dust Deposition and Pb comparison – March 2007 to December 2009

Location	Average Dust Deposition ($g/m^2/month$)	Average Pb Deposition ($g/m^2/month$)	Percentage Pb to Dust Deposition (%)
D1	4.0	0.0034	0.09
D2	3.1	0.0045	0.15
D3	4.3	0.0046	0.11
D4	5.7	0.0060	0.11
Casuarina Ave	5.8	0.0036	0.06
Average	**4.6**	**0.0044**	**0.10**

Note: Results for D5 not included as only one month of data was available at time of reporting

5.10 Ambient Levels of Other Metals/Metalloids

Other than lead, metals/metalloids of interest in the current study include: antimony, arsenic, barium, beryllium, cadmium, chromium, copper, manganese, mercury, nickel, silver and zinc.

No measurements are however available for ambient air concentrations or deposition rates of metals other than lead. In order to provide more comprehensive information regarding background levels of metals of interest in the study, BHOP site emissions from exposed free surface areas will be estimated and modelled, as per discussion within Section 6.

6 Climate and Dispersion Meteorology

Meteorological mechanisms have a significant influence on the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, mixing depth, and shifts in the wind field (Oke, 2003; Sturman and Tapper, 2006).

Spatial variations and diurnal and seasonal changes in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales. Atmospheric processes at macro- and meso-scales need therefore be taken into account to accurately parameterise the atmospheric dispersion potential of a particular area.

Climate statistics obtained from the Bureau of Meteorology's (BoM) long-term climate station at Broken Hill (Porter Street) (station number 047007) and 30-minute averaged meteorological data recorded at the BoM Broken Hill Airport Automatic Weather Station (AWS) (station number 047048) between 2005 and 2009 were used to characterise the climate and dispersion meteorology of the study area.

The Broken Hill Airport AWS is situated approximately 3 km from the southern boundary of the Project Site. A three-dimensional representation of the topography between the Project Site and the Broken Hill Airport AWS is presented in **Figure 3**. The uncomplicated terrain between the Project Site and Broken Hill Airport AWS is unlikely to significantly influence wind speed and direction between the two sites. It is therefore considered that meteorological data recorded by the Broken Hill Airport AWS represents a suitable resource for analysing dispersion conditions likely to be experienced at the Project Site. It is noted that due to a dominance of flat paved surfaces at the Airport resulting in a lower localised surface roughness length than the area about the Project Site, it is expected that the wind speed measured by the Broken Hill Airport AWS would typically be marginally higher than that experienced at the Project Site.

Annual data completeness for the 30-minute meteorological data recorded at the Broken Hill Airport AWS between 2005 and 2009 was reviewed and is presented in **Table 18**. DECCW (2005) specifies that for Level 2 air quality impact assessments (such as is undertaken in this study), input meteorological data must be as a minimum 90% complete. At least one year of site representative meteorological data are required to be used for dispersion simulations. From **Table 18** it is evident that 2009, 2008 and 2005 are the three most suitable years of recent data based on data completeness. Further discussion on data suitability will be made in the following sections.

Table 18 – Broken Hill Airport Meteorological Data Completeness

Year	Missing 30-minute Observations	Percentage Complete
2005	179	99.0%
2006	7920	54.8%
2007	6540	62.7%
2008	211	98.8%
2009	64	99.6%

6.1 Climate Statistics

Long-term climate statistics from the BoM Broken Hill (Porter Street) Station (station number 047007) for the period 1889 to 2009 are presented in **Table 19**.

Table 19 – Climate statistics for Study Area - Broken Hill (Porter Street) BoM Climate Station – 1889 to 2009

Statistic Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (Degrees C)	32.8	32.2	29	23.9	19.2	15.6	15.2	17.3	21.1	25	28.7	31.4	24.3
Highest temperature (Degrees C)	46.8	46.6	41.5	36.7	31	26.3	26.7	31.5	37.2	39.7	44	43.9	46.8
Lowest maximum temperature (Degrees C)	16	14.4	11.5	13.3	9	7.9	6.3	8.4	9.6	6.1	14.8	13.9	6.1
Mean number of days >= 30 Degrees C	20.8	18	13	3.4	0	0	0	0	1.4	5.3	11.3	17.4	90.6
Mean number of days >= 35 Degrees C	10.9	8.8	3.6	0.2	0	0	0	0	0	0.9	4.1	7.9	36.4
Mean number of days >= 40 Degrees C	2.8	1.5	0.2	0	0	0	0	0	0	0	0.6	1.4	6.5
Mean minimum temperature (Degrees C)	18.5	18.2	15.6	11.8	8.6	6.2	5.4	6.4	8.9	11.7	14.7	17.1	11.9
Lowest temperature (Degrees C)	7.7	7.8	4.4	3.1	-1.1	-2.8	-2.2	-2.2	0.3	1.1	1.1	5	-2.8
Highest minimum temperature (Degrees C)	33	32.4	27.7	24.9	19.5	18.5	16.1	18.4	22.4	28.1	30.2	33.2	33.2
Mean rainfall (mm)	23.6	23.7	19.5	17.4	22.5	22.1	18.9	18.5	20.3	24.2	20.4	21.5	252.6
Highest rainfall (mm)	215.8	112.4	258.8	219	93.3	143.6	88.7	91	154.8	129.1	122.4	180.4	838
Lowest rainfall (mm)	0	0	0	0	0	0	0	0	0	0	0	0	57.4
Highest daily rainfall (mm)	73.6	94.8	139.4	93.5	62.2	58	32.8	46.5	91.4	55.1	103.1	87.2	139.4
Mean number of days of rain	3.2	3.1	2.8	2.9	4.4	5.3	5.6	5.1	4.4	4.6	3.8	3.4	48.6
Mean daily solar exposure (MJ/(m*m))	28.7	25.7	22.7	16.8	12.4	10.3	11.2	14.8	19.3	23.7	26.6	28.7	20.1
Mean number of clear days	16.3	14	17.2	13.9	10.7	8.9	10.1	12.7	13.3	13.3	12.5	14.7	157.6
Mean number of cloudy days	6	4.7	4.2	5.7	8.9	9.1	8.7	6.7	5.9	6.3	6.9	6.6	79.7
Mean 9am temperature (Degrees C)	23.5	22.8	20.2	16.4	12.5	9.3	8.8	10.6	14.1	17.4	20.2	22.6	16.5
Mean 9am wet bulb temperature (Degrees C)	16	16.1	14.5	12	9.7	7.5	6.7	7.6	9.6	11.5	13.4	15.2	11.6
Mean 9am dew point temperature (Degrees C)	10.1	10.5	9.2	7.8	6.9	5.4	4.1	3.7	4.8	5.4	6.8	8.4	6.9
Mean 9am relative humidity (%)	44	48	51	58	69	77	74	64	54	47	44	43	56
Mean 9am cloud cover (oktas)	2.1	2.2	2	2.4	3.2	3.6	3.2	2.7	2.5	2.7	2.8	2.5	2.7
Mean 9am wind speed (km/h)	15	13.6	12.7	10.9	9.2	9.6	10.1	11.5	13.6	15.2	15.3	15.1	12.6
Mean 3pm temperature (Degrees C)	31.1	30.6	27.8	22.9	18.2	14.9	14.5	16.5	20.2	23.6	26.9	29.7	23.1
Mean 3pm wet bulb temperature (Degrees C)	18.9	19	17.5	14.8	12.4	10.3	9.6	10.3	12.1	14	15.9	17.7	14.4
Mean 3pm dew point temperature (Degrees C)	9.6	10	8.7	7.2	6.4	5.3	3.7	2.6	3.4	3.9	5.8	7.5	6.2
Mean 3pm relative humidity (%)	28	30	32	39	48	54	49	41	34	30	27	27	37
Mean 3pm cloud cover (oktas)	2.7	2.8	2.5	2.9	3.7	3.9	3.7	3.4	3	3.1	3.3	3.1	3.2
Mean 3pm wind speed (km/h)	14.5	14.5	14.3	13.4	12.9	14.1	15.1	15.6	16	15.9	15.7	15.1	14.8

Source: Bureau of Meteorology (2010)

6.2 Prevailing Wind Regime

Emphasis is placed on site-specific meteorological data in terms of characterising the local wind regime. At least one year of wind data is required to adequately characterise seasonal fluctuations in the wind field for analysis and dispersion modelling purposes.

As discussed previously, 30-minute meteorological data has been sourced from the BoM Broken Hill Airport AWS for the period between 2005 and 2009. The recorded annual and seasonal variation in wind speed and wind direction was analysed for each of these years. Wind roses generated through this analysis are presented in **Appendix A**.

Annual wind patterns are comparable between each year, with a dominance of moderate to strong winds (3 m/s to greater than 10.5 m/s) from the southerly quadrant. However, variation between seasons is evident throughout the five calendar years of monitoring data, particularly for the winter wind roses. Review of the 2008 and 2009 seasonal wind roses identified that all potential inter-annual variations in wind speed and direction experienced between 2005 and 2009 were covered within the 2008 and 2009 datasets. Therefore, in order to ensure that all likely wind direction and speed conditions were accounted for within the dispersion modelling assessment, both the 2008 and 2009 meteorological data recorded by the BoM Broken Hill Airport AWS were utilised in the study.

Annual wind roses generated for 2008 and 2009 based on the Broken Hill Airport AWS dataset are compared in **Figure 13**. Wind speed distribution is compared in **Figure 14**. The distribution of wind direction and wind speed varies slightly between the 2008 and 2009, with a higher occurrence of stronger winds from the north, west and south. Percentage of calm wind conditions, identified as wind speed lower than 0.5 m/s, is comparable between the two years. All seasons of 2008 and 2009 are dominated by a southerly to northerly flow, with the exception of winter in 2009 which experienced a defined west to north flow.

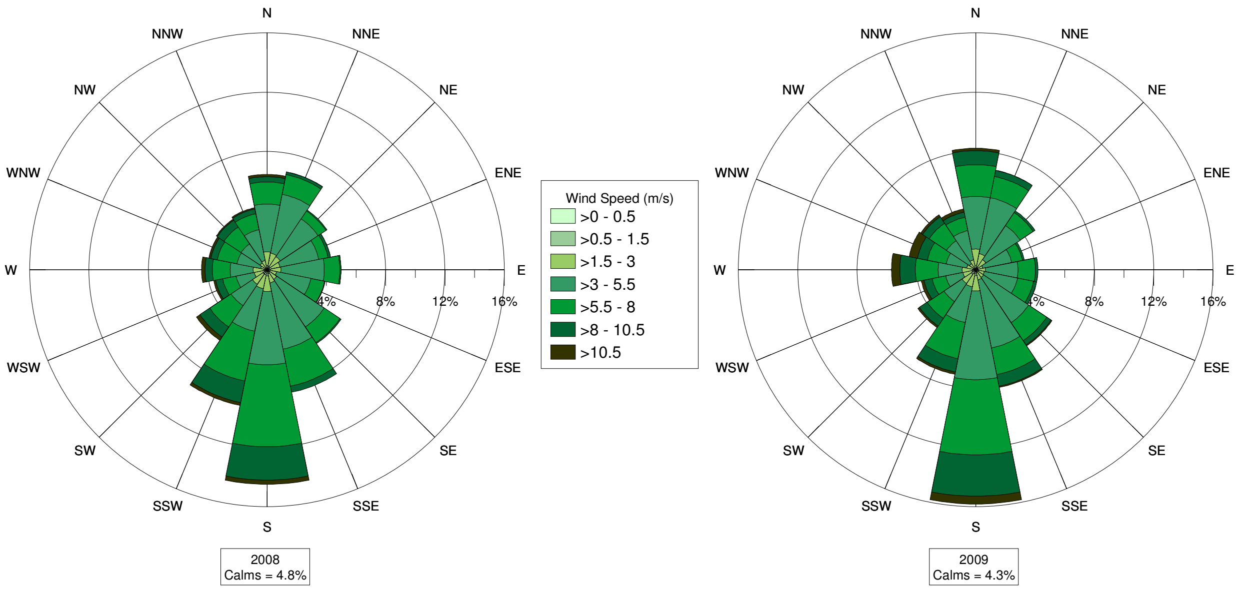


Figure 13: Comparison of Annual Wind Roses for Broken Hill Airport AWS – 2008 and 2009

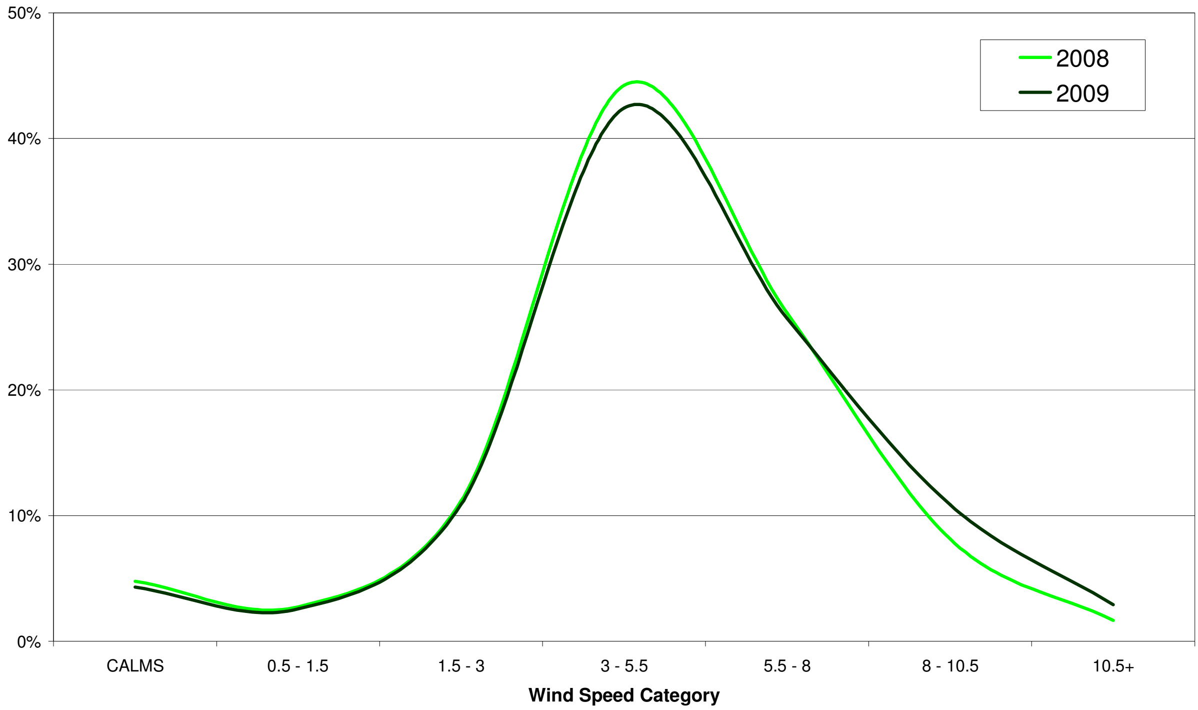
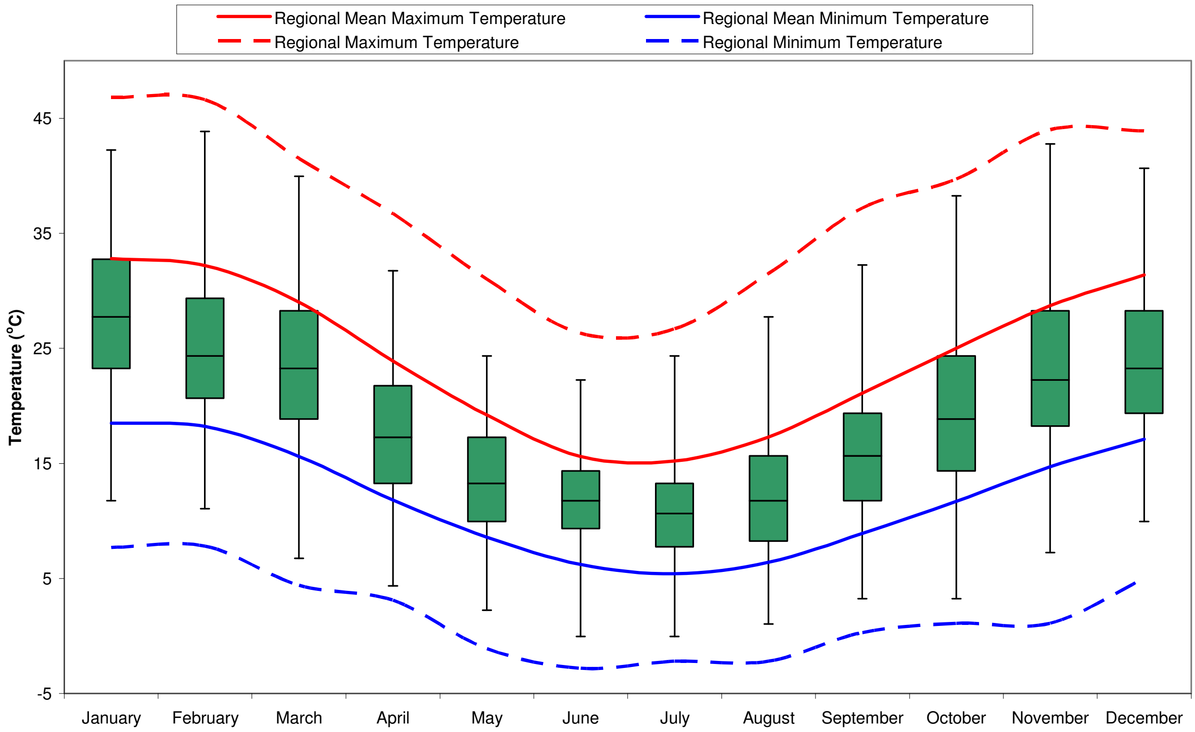


Figure 14: Comparison of Wind Speed Distribution for Broken Hill Airport AWS – 2008 and 2009

6.3 Ambient Temperature

Air temperature is important, both for determining the effect of plume buoyancy and determining the development of the mixing and inversion layers. The study area is characterised by a warm to hot climate, with mean 3pm temperatures in the range of 14℃ to 32℃ based on the long-term record. Peaks occur during summer months with the highest temperatures typically being recorded between December and February. The lowest temperatures are usually experienced during July.

Ambient temperature measured at the Broken Hill Airport AWS during 2008 and 2009 has been compared against the highest/lowest and mean minimum and maximum long term temperature records recorded by the BoM at the Broken Hill (Porter Street) station and presented in **Figure 15**. The monthly temperature range contained within the 2008 and 2009 datasets agrees well with the historical trends, suggesting that on the basis of ambient temperature, the 2008 and 2009 datasets are representative of the Broken Hill area.



Note: Horizontal lines of boxes indicate 25th percentile, 50th percentile (Median) and 75th percentile concentrations for the dataset. Whiskers indicate the maxima and minima of the dataset.

Figure 15: Ambient Temperature Comparison - Broken Hill Airport AWS (2008 and 2009) with Historic Data (1891 to 2009)

6.4 Rainfall and Evaporation

Precipitation is important to air pollution studies since it represents an effective removal mechanism of atmospheric pollutants. Annual rainfall in the Broken Hill region ranges from approximately 58 mm to 840 mm, and is on average about 250 mm. Mean rainfall is spread evenly throughout the year, with an average 49 rain days occurring per year.

Evaporation is a function of ambient temperature, wind and the saturation deficit of the air. On average the region experiences a high water deficit due to low rainfall and very high levels of evaporation, between 2400 mm/year to 2800 mm/year according to long term climate records from the BoM. This has important implications for the dust controls to be implemented for the proposed Project, and represents a key reason for the planned use of chemical dust suppression on fugitive dust sources.

6.5 Atmospheric Stability and Boundary Layer Depth

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface (mechanical mechanisms), or as result of the heat and moisture exchanges that take place at the surface (convective mixing) (Stull, 1997; Oke, 2003).

During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated subsidence inversion. Elevated inversions may occur for a variety of reasons including anticyclonic subsidence and the passage of frontal systems. Due to radiative flux divergence, nighttimes are typically characterised by weak vertical mixing and the predominance of stable conditions. These conditions are normally associated with low wind speeds, and hence lower dilution potentials.

For low level, non-buoyant, wind independent, continuous sources, the highest ground level concentrations tend to occur during stable, light wind, night-time conditions with pollutants accumulating close to the source. Sources characteristic of the proposed Project are mostly low level and wind dependent, with some of the dust generating activities restricted to day time hours. Atmospheric conditions conducive to peak ground level concentrations from such sources are more complicated and best characterised through the application of dispersion modelling in which temporal variations in atmospheric conditions and source profiles are adequately represented.

The Monin-Obukhov length (L) provides a measure of the stability of the atmospheric surface layer (i.e. the layer above the ground in which vertical variation of heat and momentum flux is negligible; typically about 10% of the mixing height). The Monin-Obukhov Length is zero for neutral conditions, and positive (negative) for stable (unstable) conditions. Stable conditions prevail during the night-time with unstable conditions occurring in the day as may be expected.

7 Emissions Inventory

Fugitive dust sources associated with both the construction and operation phases of the Project were principally quantified through the application of Australian National Pollutant Inventory (NPI) emission estimation techniques and United States Environmental Protection Agency (US-EPA) AP-42 predictive emission factor equations. Particulate releases were quantified for various particle size fractions, with the Total Suspended Particulate (TSP) fraction being estimated and simulated to provide an indication of nuisance dust deposition rates, and to support the projection of suspended lead concentrations (in the TSP fraction) and metal deposition rates. Fine particulates (PM_{10} and $PM_{2.5}$) were estimated using ratios for the different particle size fractions available within the literature (principally the US-EPA AP-42). Resultant concentrations simulated to assess compliance with air quality criteria, with the PM_{10} emission estimates also providing the basis for projecting suspended metal concentrations for comparison with health-based inhalation thresholds.

The study focuses on the quantification and simulation of dust emissions and associated heavy metal releases. Gaseous emissions, such as vehicle tailpipe releases, are considered a minor source due to the limited traffic movements. An estimate was however made of potential gaseous emissions from the ventilation shaft during the operational phase when underground blasting emissions and diesel vehicle activity is at a maximum.

7.1 Quantification of Construction Phase and Ancillary Surface Mining Emissions

Sources of atmospheric emissions associated with the construction phase, including ancillary surface mining activities, were identified as including the following activities/processes anticipated to occur concurrently:

- Use of excavator for the processing plant site development (approximately 180,000m^3 of material to be moved for major footings, foundations and permanent service lines over a 3 month period).
- Use of excavator to extract and load waste rock material at the proposed decant dam for use as the construction material for the TSF embankments (approximately 150,000m^3 of waste rock required to construct the starter embankment, over a 3 month duration.
- Approximately 9,500 truck movements over a 3 month period to move material from the decant dam to the starter embankment site.
- Truck dumping of waste rock to form the TSF starter embankment.
- Vehicle entrainment of particulate from unpaved on-site roads due to the transfer of ore from the base of the Kintore Pit to the temporary ROM stockpile. Estimated 16 truck movements per day, occurring 7 days per week.
- Trucks dumping ore to the temporary ROM stockpile.
- Wind erosion associated with a temporary ROM stockpile 25m by 25m and 7.5m in height, located at the entry to the mobile crusher.
- Loading of a mobile crusher using an excavator.

- Operation of a mobile crusher crushing to 115mm, with an average daily throughput of 500t/day, at a rate of 55t/hour (8am to 5pm weekdays).
- Wind erosion associated with a finished product ore stockpile 15m by 20m and 7.5m in height, located at the exit to the mobile crusher.
- Loading of finished product ore into 50t trucks using a Front End Loader, (maximum of 120,000t ore produced each year).
- Vehicle entrainment of particulate from on-site roads due to the transfer of product ore from the product stockpile to the truck wash facility (unpaved) and truck movements from the truck wash facility off site (paved). Estimated 21 truck movement cycles per day,.
- Vehicle entrainment from on-site roads due to delivery and maintenance vehicles servicing the site. Estimated 8 vehicle movement cycles per day. Assumed to be using site surface roads (sealed to processing area).
- Simulation of light vehicle use on the site through the addition of one additional vehicle movement on lease roads.
- Wind erosion from exposed areas.
- Emissions associated with the ventilation outlet exhausted through the existing Delprat Shaft (assumed to be 24-hours/day).
- Vehicle tailpipe releases.

Unless specified otherwise, construction activities are assumed to occur 12 hours / day (7am to 7pm) while activities associated with ore processing and dispatch are assumed to occur 11 hours per day, 7am to 6pm (weekdays).

The dust management measures summarised in **Section 3** are assumed to be used during the construction phase, and emission reduction factors have been applied consistent with these activities, as documented in **Table 20**.

Emissions estimates for the 3-month worst-case potentially dust generating stage of construction, taking account of the above documented dust mitigation measures, are presented in **Table 20.** Information on the emission factors applied in the quantification of sources is also provided, with the inputs used in the predictive emission factor equations also documented.

“Free” areas are defined as areas of exposed ground that have the potential for wind erosion. The free areas are categorised as either existing (representative of current wind erosion impacts associated with the CML7), and Project-related (representative of additional areas potentially exposed as a result of the Project). Project-related exposed area emissions are presented in Section 7.1 and 7.2 for the construction and operation phases respectively. Emissions from existing free areas are discussed in Section 7.3.

Emission estimates presented in **Table 20** are graphically presented in **Figure 16** to illustrate source contributions to total emissions. Aside from the contribution of existing free areas (under the status quo), fugitive dust emissions associated with Project-related free areas were estimated to comprise the main source of emissions after dust controls are applied.

Table 20 - Estimated emissions for Construction and Ancillary Surface Mining Activities

Source	TSP	PM_{10}	$PM_{2.5}$	Emission and Control Factor Applied	Calculation Inputs
	tonnes/ quarter	tonnes/ quarter	tonnes/ quarter		
Paved roads	1.8	0.4	0.0	US-EPA AP-42 Paved Roads (Section 13.2.1) (November 2006) Use of road sweeper assumed to limit silt loadings to ≤4.3 g/m²	Silt loading of 4.3 g/m² assumed based on site observations and generic loadings for similar operations with controls in place. Vehicle kilometres travelled (VKT) estimated to be approximately 11km per day, assuming maximum volumes of material paved road section of ~500 m The mean vehicle weight was taken to be 51t (accounting for full and empty trips).
Unpaved roads	8.6	2.4	0.2	US-EPA AP-42 Unpaved Roads (Section 13.2.2) (November 2006) 50% control factor associated with watering at 2L/m²/hour (NPI, 2000)	The silt content of the road surface material was assumed to be 4.4%, given by the US-EPA as being characteristic of haul roads within quarry operations. The mean vehicle weight was taken to be 67 tonnes (accounting for full and empty trips). The average vehicle weight is greater than for paved roads, as paved roads additionally account for service vehicle movements. Vehicle kilometres travelled (VKT) estimated to be approximately 107km per day for all heavy vehicle activities, assuming maximum volumes of material and unpaved road section of ~2.6km across the site.
Unloading ore and waste rock	0.7	0.3	0.1	US-EPA AP-42 Aggregate Handling (Section 13.2.4) (November 2006)	A mean wind speed of 4.9m/s (based on site measurements from BHOP Weather Station) was used in the calculations. A material moisture content of 3% was derived for the ore and was applied to waste rock handling. Unloading of ore occurs at the mobile crusher. Unloading a maximum of 150,000m³ of waste rock required for construction of TSF1 embankments during a 3-month period.
Excavator / Front End Loader operations	1.1	0.5	0.1	NPI EETM for Mining Version 2.3, Dec 2001 50% control factor to production area and decant dam excavator associated with use of mobile water sprays (NPI, 2000)	Excavators and Front End Loader conservatively assumed to operate 12 hours/day during construction hours. One excavator is assumed to be dedicated to construction activities at the Processing Area. One excavator and one front end loader are assumed to be dedicated to mobile crushing operations. One excavator is assumed to be dedicated to waste rock excavation at the decant dam.

Table 20 - Estimated emissions for Construction and Ancillary Surface Mining Activities

Source	TSP	PM_{10}	$PM_{2.5}$	Emission and Control Factor Applied	Calculation Inputs
	tonnes/ quarter	tonnes/ quarter	tonnes/ quarter		
Mobile Crushing	1.3	0.5	0.1	NPI EETM for Mining Version 2.3, Dec 2001	Emission factor corresponding to High Moisture Ores selected for ore crushing, with the assumption that particulate controls are comparable to water spraying during crushing. Modelling conducted based on 9-hour/day operation of a crusher at a rate of 55t/hour.
Stockpile Wind Erosion	1.8	0.8	0.2	Wind dependant emission rates applied consistent with US-EPA AP-42 Industrial Wind Erosion (Section 13.2.5 (2006)	Two interim stockpiles of ROM ore and product ore of dimensions 25m X 25m and 15m X 20m respectively are anticipated to be used either side of the mobile crushing operation.
Exhaust Ventilation to Delprat Shaft	0.2	0.1	0.0	NPI EETMs for: Mining and Processing of Non-metallic Minerals V2.0 (2000), Explosives Detonation and Firing Ranges V2.0 (2008), and Combustion Engines (2008b) 97%, 95% and 94% control factors applied to TSP, PM_{10} and $PM_{2.5}$ respectively.	Underground emissions quantified based on site specific data for blasting, drilling and underground vehicle exhaust emissions. Control factors estimated based on comparison between vent shaft stack testing data (EML, 2005) for an underground (coal) mine of known annual throughput. Construction phase volumetric flows and emissions apportioned based on proposed extraction rate compared to maximum operation (125kt ore:750kt ore).
Project Related Free Areas	7.7	3.5	1.0	Wind dependant emission rates applied consistent with US-EPA AP-42 Industrial Wind Erosion (Section 13.2.5 (2006). 80% control factor applied associated with application of chemical dust suppressant (US-EPA, 2006)	Project-related disturbed areas taken to coincide with major infrastructure (roads, pits, ROM pad, etc.) (see **Section 2.4**, yellow areas). These areas exclude the existing exposed 'free areas' (see **Section 2.4**, red hatched areas) which are separately quantified (see **Section 7.3**). Threshold wind velocity taken to be 5.4 m/s.
TOTAL	**23.2**	**8.7**	**1.7**		

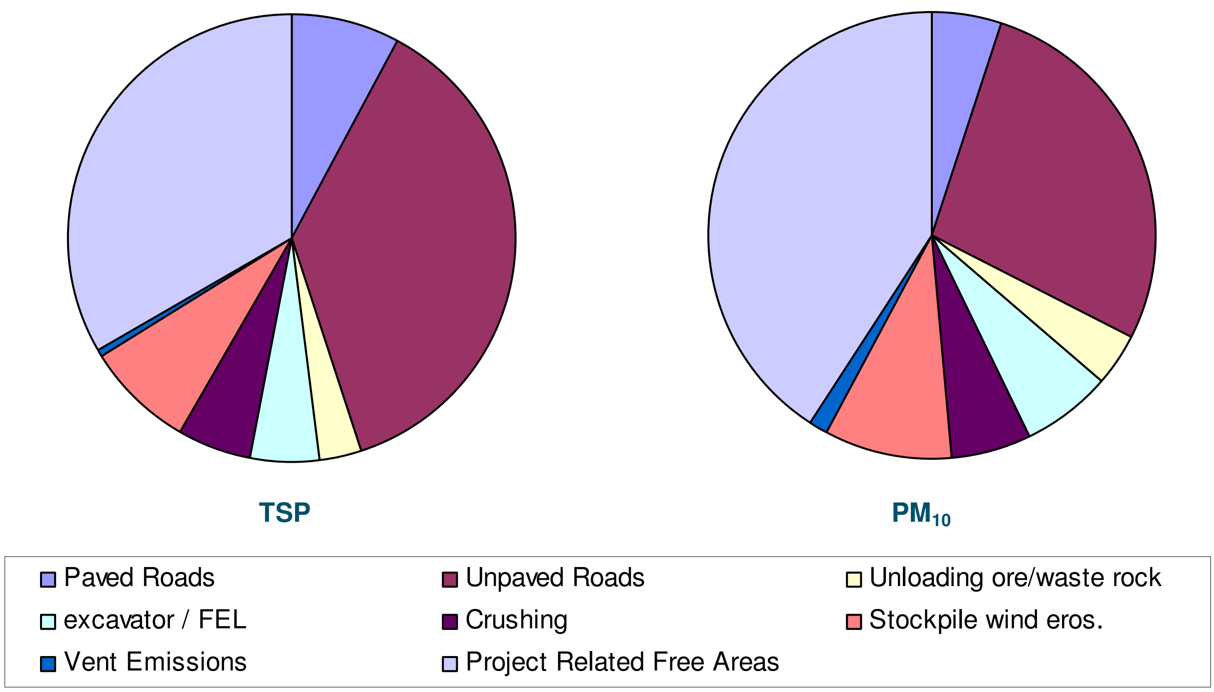


Figure 16: Summary of Construction Phase Emission Estimates by Source and Particle Size

7.2 Quantification of (Maximum Production) Operation Phase Emissions

Sources of atmospheric emissions associated with maximum production activities during the operation phase were identified as including the following activities anticipated to occur concurrently:

- Vehicle entrainment of particulate due to the haulage of ore along the haul road between the base of the Kintore Pit and the ROM pad. Estimated 84 truck movements per day along 0.8km unpaved (chemical dust suppressant controlled) road length and 1.25km paved road length to ROM pad. There is anticipated to be an additional 28 vehicle movements per day along a 0.3km paved road linking the haul road to the workshop. Emissions assumed to occur 7 days per week, 24 hours per day.
- Trucks dumping of ore to the ROM stockpile.
- Wind erosion associated with a ROM stockpile of area 2,500m^2, located at the ROM pad. Water sprays and wind breaks (perpendicular to the dominant wind direction) applied.
- FEL activities at the ROM pad, including loading apron feeder at a rate of 750,000 tpa (12 hours per day) and stockpile management (12 hours per day).
- Baghouse emissions associated with the baghouse servicing the crushing circuit (primary secondary and tertiary crushers and screens) contained within a permanent structure under negative pressure. The baghouse is assumed to have a control efficiency of 99.5%.

- Handling of concentrate as it is transferred via conveyor direct from filters to rail wagons via an overhead loading facility which the wagons pass under. Enclosed building with a rubber curtains at entry and exit of wagons. Lid automatically placed on filled wagons to maintain moisture content and eliminate any dust emissions during transport to port.
- Wind erosion associated with operation of the Tailings Storage Facilities (TSF). Dust generation controlled via crusting agent application (inactive cell) and tailings deposition management and water sprays (active cell). Tailings pumped to a storage facility at 50% solids. Water sprays are anticipated to be able to cover whole TSF within 30 minutes. (Comprehensive description of TSF dust controls provided in **Section 3**.)
- Wind erosion of both existing free areas and Project-related disturbed areas. All exposed areas are assumed to be controlled using chemical dust suppression.
- Vehicle entrainment of particulate due to the movement of vehicles on site access roads, including deliveries to the workshops (fuel, general, spares), (disused) BHP Pit (explosives), Kintore Pit (underground stores) and processing plant. Primary roads will be paved with secondary access roads unpaved and controlled with chemical dust suppressant. Approximately 15 trips per day over a total of 3km road length attributed to site deliveries.
- Simulation of light vehicle use on the site through the addition of one additional light vehicle movement travelling at 30km/hour on unpaved (chemically stabilised) lease roads 24-hours per day.
- Emissions associated with the ventilation shaft outlet exhausted via a fan located in the existing Little Kintore Pit, including emissions due to underground drilling, blasting and vehicle tailpipe releases.

The dust management measures summarised in **Section 3** are assumed to be used during the operation phase, and emission reduction factors have been applied consistent with these activities, as documented in **Table 21**.

7.2.1 Particulate Emissions

Particulate emissions estimates for the maximum production operational phase, taking account of documented dust mitigation measures, are presented in **Table 21**. Information on the emission factors applied in the quantification of sources is also provided, with the inputs used in the predictive emission factor equations also documented in the table.

Table 21 - Estimated Particulate Emissions for Maximum Production Operations					
Source	**TSP**	**PM10**	**PM2.5**	**Emission and Control Factor Applied**	**Calculation Inputs**
	tonnes/ annum	**tonnes/ annum**	**tonnes/ annum**		
Paved roads	18.5	3.5	0.5	US-EPA AP-42 Paved Roads (Section 13.2.1) (November 2006) Use of road sweeper assumed to limit silt loadings to <0.5 g/m² (i.e. 90% control efficiency)	Uncontrolled silt loading of 4.3 g/m² estimated based on generic loadings for extractive operations (US-EPA, 2006), and taking into account measured site-specific unpaved road material silt contents. VKT estimated to be approximately 105km per day for the haul road, assuming maximum volumes of material and a paved road section of 1.25km. VKT estimated at 8.4 km/day for the haul road to workshop route (28 trips over the 0.3km road section). Delivery vehicle VKT estimated to be 8.4 km/day. The mean vehicle weight was taken to be 51t (accounting for full and empty trips).
Unpaved roads	21.4	6.4	0.6	US-EPA AP-42 Unpaved Roads (Section 13.2.2) (November 2006) 80% control factor applied associated with application of chemical dust suppressant (US-EPA, 2006)	Based on site-specific measurements of unpaved road material, the silt content was taken to be 4.4% and the uncontrolled moisture content 2.05%. Haul truck related VKT were estimated to be 67 km/day (84 trips over the 0.8km unpaved haul road section). Other vehicle activity on unpaved roads across the site was conservatively estimated to be represented by 480 VKT/day (1 vehicle travelling 20 km/day, for 24-hours per day). The mean vehicle weight was taken to be 67t (accounting for full and empty trips). The average vehicle weight is greater than for paved roads, as paved roads additionally account for service vehicle movements.
Unloading ore to ROM stockpile	3.0	1.4	0.2	US-EPA AP-42 Aggregate Handling (Section 13.2.4) (November 2006) 0% control efficiency.	A mean wind speed of 4.9m/s (based on site measurements from BHOP Weather Station) was used in the calculations. A material moisture content of 3% was derived for the ore from the reference literature (J de la Vergne, 2000, Hard Rock Miner's Handbook, McIntosh Engineering, Ontario). Unloading occurs at a maximum rate of 750,000tpa ore.
Front End Loader operations	0.7	0.3	0.1	NPI EETM for Mining Version 2.3, Dec 2001 50% control factor conservatively assumed – due to water (atomising) sprays on apron feeder hopper, increased moisture content of material	Front End Loader conservatively assumed to operate 12 hours/day loading 750,000tpa ore to apron feeder and 12 hours/day managing the ROM stockpile (using a 750ktpa throughput).

Table 21 - Estimated Particulate Emissions for Maximum Production Operations

Source	TSP tonnes/ annum	PM_{10} tonnes/ annum	$PM_{2.5}$ tonnes/ annum	Emission and Control Factor Applied	Calculation Inputs
				due to stockpile water sprays, and operation of FEL between wind breaks	
Crusher Circuit Baghouse	1.5	1.5	0.2	NPI EETM for Mining Version 2.3, Dec 2001 99.5% control factor – conservative estimation of control quoted within US-EPA RACT/BACT Clearinghouse for enclosure and baghouse.	Emissions from primary, secondary, tertiary crushing and associated screening calculated based on 750ktpa throughput. Control factor applied associated with use of a permanent full enclosure under negative pressure and vented to a baghouse with a control efficiency of 99.5%. Baghouse stack parameters assumed based on good engineering practice: 10m/s gas exit velocity, 1.5m stack diameter, 15m stack height.
ROM Stockpile Wind Erosion	6.7	3.1	0.9	Wind dependant emission rates calculated based on US-EPA AP-42 Industrial Wind Erosion (Section 13.2.5 (2006) 65% control efficiency due to combined use of water sprays and wind breaks (NPI, 2000).	A ROM stockpile of area 2,500m^2 (maximum height of 5 m) assumed, located at the ROM pad. Water sprays and wind breaks (perpendicular to the dominant wind direction) used for dust control. Threshold wind velocity taken to be 5.4 m/s.
Concentrate Handling	0.017	0.008	0.001	US-EPA AP-42 Aggregate Handling (Section 13.2.4) (November 2006) 70% control factor for loading to trains due to building enclosure (NPI, 2000).	Uncontrolled emissions were initially estimated based on a mean wind speed of 4.9m/s (based on site measurements from BHOP Weather Station). The minimum material moisture content of 9% was assumed for the concentrate. Following which a 70% control efficiency was applied.
TSF Wind Erosion	6.4	2.9	0.9	Wind dependant emission rates calculated using US-EPA AP-42 Industrial Wind Erosion equations (Section 13.2.5 (2006). 95% control factor applied to 25% of inactive storage cell (i.e. 1.24 ha) – remainder assumed to have negligible emission potential.	Active storage cell (north cell for modelling scenario) assumed to be continually kept wet, thus zero emissions. Inactive storage cell has chemical dust suppressant applied with surface initially still wet due to recent tailings deposition, with gradual drying until the next deposition cycle. A highly conservative estimate of the maximum surface area of the inactive cell likely to dry out sufficiently to be prone to wind exposure (assuming no controls) is given as 25% of the surface area of the inactive storage cell (personnel communication F. Gassner, Golder & Associates). Chemical dust suppression will be applied over the entire inactive storage cell surface including the wet beach and potentially drier areas.

Table 21 - Estimated Particulate Emissions for Maximum Production Operations					
Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**Emission and Control Factor Applied**	**Calculation Inputs**
	tonnes/ annum	**tonnes/ annum**	**tonnes/ annum**		
					The control efficiency of the types of crusting agent products being proposed for use is documented to be >95% (Tundra Bulk Solids Handling Research Associates, July 2009; Introspec Consulting, November 2009). This dust control efficiency is based on wind tunnel testing of various tailings materials, including lead tailings, under wind speeds of 10 m/s. BHOP propose to have the site-specific control efficiency confirmed through field testing (as discussed in Section 3). TSF emissions were estimated based on site specific wind data and particle size distribution (PSD) data for existing *in situ* tailings (as obtained from Golder and Associates, February 2010).
Exhaust Ventilation to Little Kintore Pit	3.8	2.9	0.9	NPI EETMs for: Mining and Processing of Non-metallic Minerals V2.0 (2000), Explosives Detonation and Firing Ranges V2.0 (2008), and Combustion Engines (2008b) 97%, 95% and 94% control factors applied to TSP, PM_{10} and $PM_{2.5}$ respectively.	Underground emissions quantified based on site specific data for blasting, drilling and underground diesel vehicle activity. 72.5 t/month of ANFO used. 5300 holes drilled per month. 133.7 kL of diesel consumed per month. Control factors estimated based on comparison between estimated uncontrolled ventilation shaft emissions (including blasting, drilling, diesel combustion releases) and vent shaft stack testing data (EML, 2005) for an underground (coal) mine of known annual throughput (5.2 Mtpa). Volumetric flows (300 m^3/s) and vent fan dimensions provided based on preliminary ventilation design work. Modelled as a horizontally discharging point source within the Little Kintore Pit.
Project Related Free Areas	30.9	14.2	4.0	Wind dependant emission rates applied consistent with US-EPA AP-42 Industrial Wind Erosion (Section 13.2.5 (2006). 80% control factor applied associated with application of chemical dust suppressant (US-EPA, 2006)	Project-related disturbed areas taken to coincide with major infrastructure (roads, pits, ROM pad, etc.) (see **Section 2.4**, yellow areas). These areas exclude the existing exposed 'free areas' (see Section 2.4, red hatched areas) which are separately quantified (see **Section 7.3**). Threshold wind velocity taken to be 5.4 m/s. A total area of 2.03 ha was taken to comprise Project-related free areas.
TOTAL	**93.0**	**36.3**	**8.3**		

According to the US-EPA (2006), the control effectiveness of chemical dust suppressants depends on: (a) the dilution rate used in the mixture; (b) the application rate (volume of solution per unit road surface area); (c) the time between applications; (d) the size, speed and amount of traffic during the period between applications; and (e) meteorological conditions (rainfall) during the period. Other factors that affect the performance of dust suppressants include other traffic characteristics (e.g. track-on from unpaved areas) and road characteristics.

Due to the above factors, and given the difference between individual dust control products, the actual control efficiencies of chemical dust suppressants is difficult to estimate. According to the US-EPA (2006) past field testing of emissions from controlled unpaved roads has shown that chemical dust suppressants provide a PM_{10} control efficiency of about 80% when applied at regular intervals of 2 weeks to 1 month (US-EPA, 2006, AP42 Section 13.2.2 Unpaved Roads, p. 13). Detailed discussion regarding the dust control efficiency of a range of products, which will potentially be used at the Project Site, is provided within Annexure I(B) (ENVIRON, 2010) of the Environmental Assessment for the Project.

Emission estimates presented in **Table 21** are graphically presented in **Figure 17** to illustrate source contributions to total emissions.

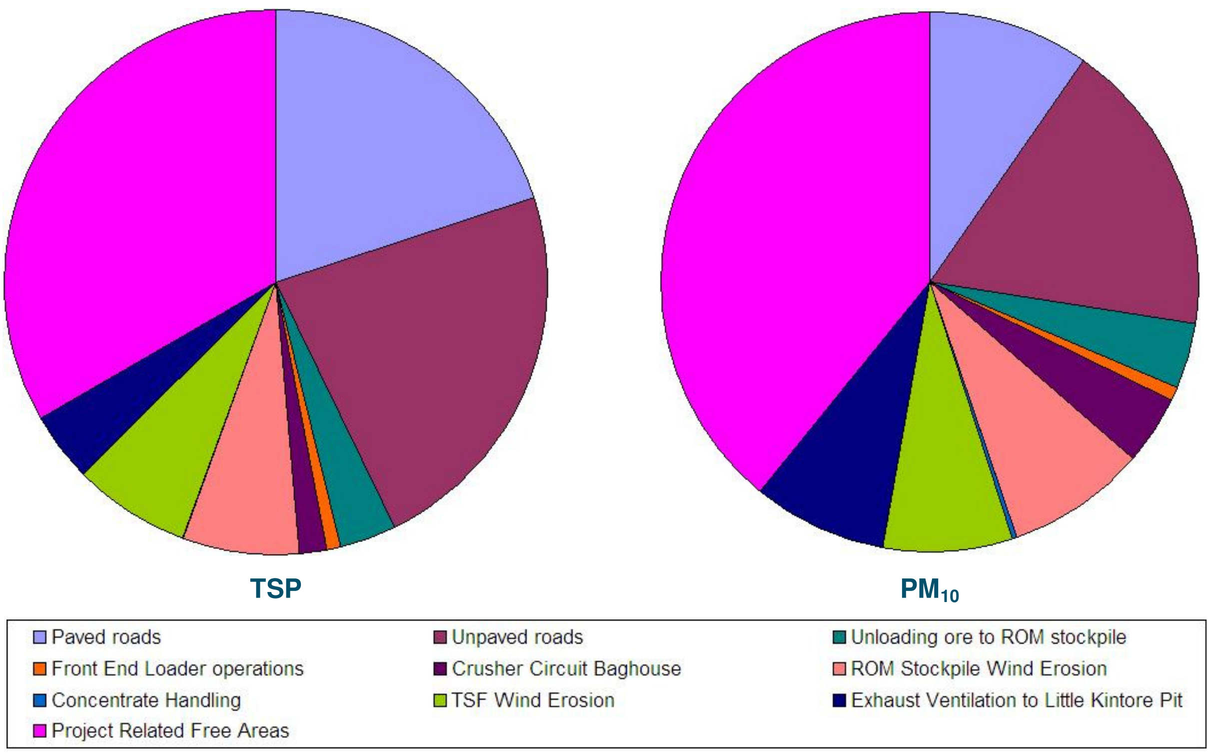


Figure 17: Summary of Operation Phase TSP and PM_{10} Emissions by Source

Wind erosion of Project-related disturbed/exposed (free) areas is estimated to contribute significantly to total TSP and PM_{10} emissions. Vehicle entrainment from paved and unpaved roads represents the next largest sources of dust emissions. The contribution of vehicle entrainment to PM_{10} emissions is lower, due to PM_{10} emissions only comprising about 20% of paved road TSP emissions and about 30% of unpaved road TSP emissions (US-EPA, 2006). The contribution of sources such as the ventilation shaft (which includes blasting emissions) and the baghouse stack is enhanced for PM_{10} due to these sources being characterised by particle size distributions with a higher proportion of finer particles.

7.2.2 Heavy Metal Emissions

A range of metals are present in the particulate emissions. To provide an estimate of metal emissions reference was made to metals analysis undertaken for various materials including:

- Metal analyses of ROM Ore (about 90 samples tested and metal content reported by Abesque Engineering and Construction Ltd; as obtained from BHOP).
- Metals analysis of existing free area material – including 5 grab samples with subsequent laboratory testing (Onsite Laboratory Services, 4 February 2010), and *in situ* metal scanning conducted at over 500 points across existing free surfaces during November 2009.
- Metals analysis of lead and zinc concentrates – data for three samples of each provided by BHOP.
- Metals analysis of unpaved road material – comprising three grab samples with subsequent laboratory testing (Onsite Laboratory Services, 16 October 2009).
- Metals analysis of tailings material – composite tailings sample data from *in situ* tailings material from the existing tailings emplacement; data obtained from Golder and Associates (February 2010).

Metal contents were generally taken as the averages across samples. Based on the comparison of the data from *in situ* elemental scanning with laboratory analysis of the material, it was determined that the medians of the *in situ* scan data provided the best estimate of the metal content of free area materials for all metals except for lead. In the case of lead, the 95th percentile highest lead concentration across over 500 scan sample points (1.9% Pb) was found to be of a similar order to the grab sample analysis (1.4% Pb).

A summary of the metal analysis of the various materials of interest in the current study is given in **Table 22**. It is recognised that the metal content is likely to vary with particle size class. Insufficient information was however available to characterise specifically the metal content of the PM_{10} fraction. The metal content was therefore assumed representative across particle size fractions. (Although metals data for the unpaved road and free area grab samples were available for a range of particle sizes, the differences in concentrations for size ranges within the <38µm group were found to be negligible.)

Table 22 – Composite Metal/Metalloid Content of Materials

	Lead Concentrates	Zinc Concentrates	Tailings	Free Areas	Unpaved Road material (<38µm)	ROM Ore	Units
Antimony	339	50	9	77		96	ppm
Arsenic	589	85	47	121		554	ppm
Barium			20				ppm
Beryllium			0.5				ppm
Cadmium	125	1885	9	34		227	ppm
Chromium			38	134			ppm
Copper			192	227	1167	857	ppm
Iron			2.1	4.3	12.0	3.7	%
Lead	73.3		0.2	1.9	2.2	4.7	%
Manganese			0.1	1.0			%
Mercury	1.0	9.0	0.2	16			ppm
Nickel	49	17	11	97			ppm
Silver	925		6	17	27	47	ppm
Zinc		49	0.26	0.47	3.17	6.04	%

The metals profile for the free areas material was used to estimate metal emissions due to wind entrainment from Project-related exposed areas.

The ROM Ore metals profile was used to quantify metal releases from ore handling, wind erosion of the ore stockpile, the baghouse stack and the ventilation shaft.

The unpaved roads profile was used to estimate metal emissions from vehicle entrainment from both unpaved and paved roads (it being assumed that the silt loading on the paved surface was likely to occur as a result of material tracked or blown onto the surface from adjacent road shoulders).

The metals profile for lead and zinc concentrates was used to estimate metal emissions from concentrate loading to rail wagons.

The metals analysis for existing *in situ* tailings was taken to be representative of the metal content of estimated emissions from the proposed facilities.

Metal emission estimates for maximum production operations are summarised in **Table 23**, with source contributions to lead emissions illustrated in **Figure 18**.

Table 23 - Estimated Metal/Metalloid Emissions for Maximum Production Operations

	TSP fraction (kg/annum)	PM10 fraction (kg/annum)	PM2.5 fraction (kg/annum)
Antimony	3.9	2.0	0.5
Arsenic	12.8	7.0	1.8
Barium	0.13	0.06	0.02

Beryllium	0.003	0.001	0.000
Cadmium	4.7	2.6	0.7
Chromium	4.4	2.0	0.6
Copper	68.3	23.3	4.4
Iron	6822	2200	410
Lead	2208	924	208
Manganese	309	141	40
Mercury	0.5	0.2	0.1
Nickel	3.1	1.4	0.4
Silver	2.4	1.0	0.2
Zinc	2382	949	194

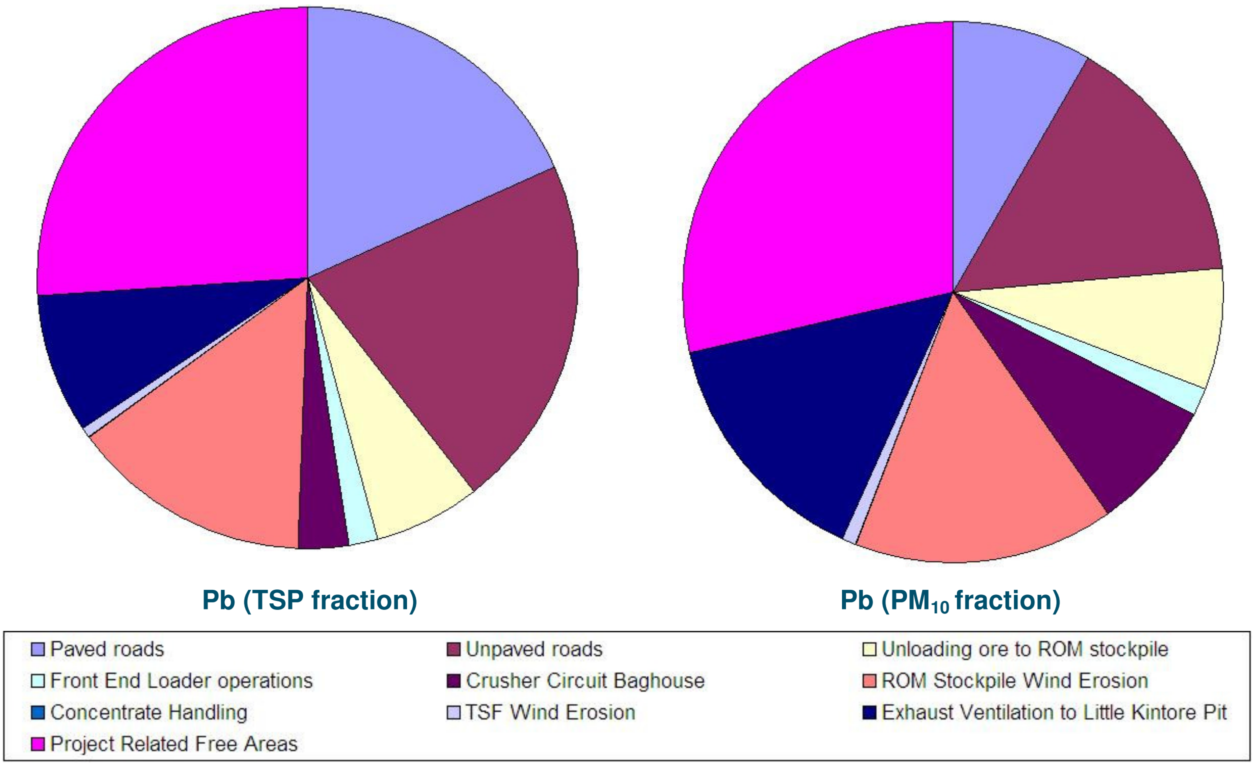


Figure 18: Summary of Operation Phase Lead Emission Estimates by Source and Particle Size

7.2.3 Gaseous Emissions

Gaseous emissions from the ventilation shaft proposed to be located within the Little Kintore Pit were quantified. These emissions include primarily blasting and diesel combustion releases.

Blasting emissions of carbon monoxide (CO), nitrogen oxide (NO_x) and sulphur dioxide (SO_2) were quantified based on Emission Factors for Detonation of Explosives (NPI, 2008). Approximately 72.5 tonnes of ANFO is to be used per month (comprising 42.8 tonnes/month for production and 29.7 tonnes/month for development).

Diesel-driven equipment exhaust emissions were estimated based on the emission factors for miscellaneous heavy diesel vehicles given in the NPI Combustion Engines Emission Estimation Technique Manual (NPI, 2008b). An estimated 133.7 kL of diesel is estimated to be used each month. Emission estimates were made of NOx, SO_2, volatile organic compounds (VOCs), CO and polycyclic aromatic hydrocarbons (PAH).

Total gaseous emissions from the ventilation shaft are summarised in **Table 24**. These emissions represent uncontrolled emissions. It is expected that such emissions would be partially controlled through the application of water sprays (or the shaft being a 'wet shaft'). Given however that a control efficiency could not be established for gaseous emissions, uncontrolled emissions were quantified and their dispersion simulated and assessed to as an initial screening assessment. Due to the screening assessment concluding that the potential for impacts was negligible (Refer to **Section 9**), no further work was undertaken to refine the gaseous emission estimates.

Table 24 - Estimated Gaseous Emissions for Maximum Production Operations

Pollutant	Blasting Emissions (tpa)	Diesel-consumption Emissions (tpa)	Total Emissions (tpa)
NOx	7.0	36.9	43.9
VOCs		2.9	2.9
SO_2	0.9	0.03	0.9
PAH			1.14 kg/annum
CO	29.6	10.9	40.5

7.2.4 Silica Emissions

Insufficient site-specific information is available to provide an estimate of silica emissions from Project-related sources. Silica dust is released during operations in which rocks, sand and some ores are crushed or broken.

Health thresholds established for the protection of public exposures tend to be set for respirable crystalline silica. The California Office of Environmental Health Hazard Assessment (OEHHA) specifies a chronic inhalation reference exposure limit for respirable crystalline silica as 3µg/m³ (OEHHA, 2008). According to the US-EPA (1996), "*for healthy individuals not compromised by other respiratory ailments and for ambient environments expected to contain 10% of less crystalline silica fraction in PM_{10}, maintenance of the 50 µg/m³ annual National Ambient Air Quality Standard for PM_{10} should be adequate to protect against silicotic effects from ambient crystalline silica exposures".* It is noted that the NSW annual PM_{10} criterion is more stringent (30 µg/m³).

It is noted that potential Project-related sources of silica dust (ventilation shaft emissions of underground drilling and blasting emissions; crusher circuit baghouse emissions) are estimated to contribute about 12% of total Project-related PM_{10} emissions and about 7% of total Project-related $PM_{2.5}$ emissions. It is therefore expected that the silica fraction in the PM_{10} emissions for the Project will be well below 10%.

The absence of silica emission estimates for the Project is noted as a limitation of the current study. Taking into account the contributions of potential sources of silica dust emissions, it is however expected that compliance with the annual $PM_{2.5}$ and PM_{10} air quality criteria would be sufficiently protective of potential exposures to silica dust.

7.3 Characterisation of Existing 'Free Area' Emissions

Existing potentially wind exposed (free) areas within the CML7 lease area which are under BHOP's operational control are illustrated in **Figure 2**. Despite these areas already existing and not being Project-related, wind blown emissions from such areas were quantified for the following reasons:

- To permit the quantification of total BHOP site emissions, including Project-related releases and emissions from free areas over which BHOP has control.
- To assess potential reductions in ambient particulate concentrations and deposition rates due to the application of dust controls on existing free areas under BHOP's control.
- Whereas lead concentrations and lead deposition are measured on-site, no measurements are available to characterise background concentrations and deposition rates of other metals. The quantification and simulation of metals emitted from existing 'free areas' (using the metals concentration data within **Table 22** to deterimine likely off-site concentrations and deposition rates) provides a partial quantification of background levels.
- Provides a means for assessing whether emission estimates for Project-related wind blown dust emissions were within a reasonable order of magnitude. (Site-specific particle size distribution and wind data were used to quantify and simulate emissions from existing free areas, with predicted TSP concentrations and dust deposition rates compared to measured levels for the same period. Although the measured levels obviously include contributions from other sources, this comparison ensured that wind blown dust from the site was not significantly over estimated.)

Wind erosion from existing free areas was quantified as wind dependent, hourly varying emissions based on the US-EPA AP-42 Industrial Wind Erosion equations (Section 13.2.5; 2006). These predictive equations represent a revision of the current NPI emission factors for wind erosion which are based on older US-EPA AP42 methodologies. The threshold wind velocity was taken to be 5.4 m/s.

Existing free areas were quantified for two emission control scenarios: (i) assuming a 0% control efficiency, and (ii) assuming an 80% control efficiency due to the application of chemical dust suppression. It is of note that the 0% control efficiency scenario was predicted to overestimate dust deposition rates, when compared to on-site dust deposition measurements. This is likely to be due to sections of the existing free areas having crusted areas with lower erosion potentials.

Emission estimates and resultant predicted metal concentrations and deposition rates based on the 80% control efficiency scenario are termed the "future baseline" for the purpose of this study. Although the levels represent a limited estimate of potential future background levels, they provide a basis for a partial quantification of whole of site (cumulative) levels given Project-related contributions.

In the estimation of emission reference was made to wind field measurements from the Broken Hill Airport AWS and Particle size distribution (PSD) data from on-site sampling of free area material. Based on such sampling TSP (PM_{30}) was observed to comprise 58% of the material, PM_{10} 45.8% and $PM_{2.5}$ 12.8%.

Period average (2008-9) uncontrolled free area emissions were of the following order: 8.7 kg/ha/hr TSP, 4.0 kg/ha/hr PM_{10} and 1.1 kg/ha/hr $PM_{2.5}$. When controlled, these emission rates reduced to 1.7 kg/ha/hr TSP, 0.8 kg/ha/hr PM_{10} and 0.2 kg/ha/hr $PM_{2.5}$. The emission rates are comparable to emission estimates and measurements from the literature (SKM, 2005; US-EPA, 2006).

Given the extent of the existing free areas (22.3 ha), total controlled annual emissions were calculated to be 340 tpa TSP, 155.7 tpa PM_{10} and 43.5 tpa $PM_{2.5}$.

Metal emissions from existing free areas were estimated based on the metals profile established from site-specific sampling as documented in **Section 7.2.2** (**Table 22**). Estimated metal emissions due to wind entrainment from existing free areas (assuming an 80% control efficiency) are summarised in **Table 25**.

Table 25 - Estimated Metal/Metalloid Emissions for Maximum Production Operations

	TSP fraction (kg/annum)	PM10 fraction (kg/annum)	PM2.5 fraction (kg/annum)
Antimony	26.0	11.9	3.3
Arsenic	41.3	18.9	5.3
Cadmium	11.6	5.3	1.5
Chromium	45.4	20.8	5.8
Copper	77.3	35.4	9.9
Iron	14543	6661	1861
Lead	6343	2905	812
Manganese	3358	1538	430
Mercury	5.3	2.4	0.7
Nickel	33.0	15.1	4.2
Silver	5.9	2.7	0.8
Zinc	1614	739	207

8 Dispersion Modelling Methodology and Results

8.1 Dispersion Model Selection and Application

Ausplume version 6.0 or later is the approved dispersion model for use in most simple, near-field applications in NSW, where coastal effects and complex terrain are of no concern (DECCW, 2005). This model is based on the US EPA Industrial Source Complex Short Term model (ISCST3) which was the previous US regulatory model for similar applications until it was replaced by AERMOD. AERMOD was identified as the most suitable model for application for the Project due to the source types and nature of terrain (e.g. location of sources at elevated heights compared to surrounding receptor sites). Its use was discussed with, and approved by the DECCW, pending adequate implementation.

A detailed account of the model selection and modelling methodology is presented in **Appendix C**.

The dispersion of pollutants was modelled for an area covering 5 km (east – west) and 4 km (north – south). Gridded receptor points were specified at intervals of 200 m, with discrete receptor points (42 receptors) also being specified for selected sensitive receptor points as listed in **Section 2.6**. The model simulates ground-level concentrations for each of the gridded and discrete receptor grid points for each hour of meteorological data.

A two year modelling period was evaluated (2008 and 2009). Two years were selected to account for inter-annual variations in the wind field including the anomalous (and potentially dust generating) meteorological conditions experienced during the 2009 calendar year.

8.2 Unit Emission Rate Modelling

Given the time-intensity associated with multiple complex model runs, and that several iterations of the model runs are required during the validation process, ENVIRON have adopted a 'unit emission rate' approach to the modelling.

This approach, also termed "Chi-over-Q" modelling, assigns a nominal unit emission rate to each source (e.g. 1 g/s). Model outputs are then created for each individual source, providing concentration data for every hour of the model run, from gridded receptors spaced at 200 m intervals across the modelling domain (5 km × 4 km, centred around CML7).

Using in-house software, each source-specific concentration prediction is able to be scaled to be representative of the actual emission rate. The premise is that the predicted source concentrations are directly proportional to the emission rate which is the case where the other emission characteristics have not changed.

For example, if the actual emission rate for a given source is 0.5 g/s, model outputs for this source may be scaled post-process such that the original predicted ground level concentration is multiplied by this value (0.5). This methodology is based on the assumption that there is no chemical transformation between source and receptor. Since modelling is being conducted in relative proximity of CML7, and parameters of concern are particulate and metals, this assumption is deemed valid.

The time-intensity to conduct such a scaling exercise is many orders of magnitude lower than having to re-run the model and allows greater flexibility for combining sources and identifying the major contributors to the predicted Project impacts. In this manner, several iterations were conducted for validation purposes, and emission scenarios explored in a more straightforward manner.

ENVIRON have produced distinct unit emission rate output data sets reflecting the particle size distribution of the TSP emissions, as well as the PM_{10} and $PM_{2.5}$ size fractions. In this manner, all pollutants of interest may be characterised.

8.3 Source and Emissions Data

The methodology and results of the emissions inventory developed for the study are presented in **Section 7**. Detailed source parameters used in the dispersion modelling are presented in **Appendix B**.

8.4 Modelling of NO_X Emissions

NO_x emissions from the ventilation shaft were specifically modelled using the Ozone Limiting Method within AERMOD. No site specific ozone concentrations are available for the study area. Reference was however made to measurements of background continental ozone levels in the rural US southwest desert, where such levels were observed to be in the range of 19 ppb to 44 ppb with the diurnal pattern exhibiting marked repeatability (Hoffer *et al*., 1982). Ozone concentrations of a similar magnitude are anticipated to be experience in the region of Broken Hill given the local setting and land uses.

8.5 Model Results

Dispersion simulations were undertaken and results analysed for TSP, PM_{10}, $PM_{2.5}$ and a range of heavy metal concentrations and dust deposition. Simulations were also undertaken for gaseous emissions from the planned ventilation shaft to be situated in the Little Kintore Pit during the operation phase.

Incremental Project-related concentrations and deposition rates occurring due to both construction and maximum production emissions were modelled (termed '**Project-related incremental**').

The potential for cumulative TSP and PM_{10} concentrations and dust deposition rates was assessed based on the background air quality levels established for the study area (Refer **Section 5**). These levels are termed '**Measured Background Levels**'.

To provide a partial estimate of baseline metal concentration/deposition, simulations were undertaken for the existing free areas assuming the implementation of future controls with a control efficiency of 80%. These model outputs are termed '**Future Baseline**' metal concentrations and deposition rates. The combined assessment of Project-related Incremental and Future Baseline metal concentrations and deposition rates provides for a cumulative assessment of BHOP site related impacts.

Model results are expressed as the maximum predicted concentration for each averaging period at the sensitive receptors over the two years period that was modelled.

Results are presented in the following formats:

- Contour plots, illustrating spatial variations in Project-related incremental TSP, PM_{10}, $PM_{2.5}$, lead concentrations and dust (based on TSP emissions) and lead deposition rates for construction and (maximum production) operation phase activities, are provided in **Appendix D**.
- Tabulated results of particulate concentrations and dust deposition rates at discrete receptor points are presented and discussed in **Section 9** for both Project-related incremental and cumulative levels taking into account Measured Background Levels.
- Tabulated results of Project-related incremental gaseous pollutant concentrations due to maximum production operations are presented as the maximum predicted across discrete receptors in **Section 9** for screening assessment purposes.
- Tabulated results of Project-related Incremental and Cumulative (Project-related Incremental + Future Baseline) heavy metal concentrations due to maximum production activities are presented as the maximum predicted across discrete receptors in **Section 9** for screening assessment purposes.
- Project-related Incremental and Cumulative (Project-related Incremental + Future Baseline) metal concentrations and deposition rates on an individual discrete receptor basis, required as input for the health risk assessment, are presented in **Appendix E**.

Contour plots of the maximum daily average concentrations presented in **Appendix D** do not represent the dispersion pattern on any individual day, but rather illustrate the maximum daily concentration that was simulated to be possible at each receptor point given the range of meteorological conditions occurring over the two year period modelled.

9 Air Quality Impact Assessment

An air quality assessment typically comprises an analysis of compliance with ambient air quality criteria as a result of atmospheric emissions due to a proposed project.

In the current assessment predicted pollutant levels are evaluated against identified air quality criteria including impact assessment criteria specified by DECCW (2005) and reference concentrations from widely-referenced health risk information sources (Refer to **Section 4**).

The air quality assessment presented in this study does not evaluate the potential for health risk impacts. Results for the air quality study documented in this section and the related appendices have been used for the multi-pathway health risk assessment being undertaken for the Project by Toxikos. The health risk assessment should be referred to for a completed understanding of the potential health risks associated with the atmospheric emissions from the Rasp Mine.

For compliance purposes, proposed projects must demonstrate that cumulative particulate concentrations, taking into account incremental concentrations due to the operation's emissions and existing background concentrations, are within DECCW air quality criteria. Dust deposition criteria are specified for both project-related incremental deposition and cumulative deposition. Both Project-Incremental and Cumulative particulate concentrations and deposition rates are therefore presented in subsequent subsections.

DECCW impact assessment criteria for toxic air pollutants is specified for the evaluation of project specific Incremental concentrations. Project-related Incremental concentrations are therefore presented and screened against the criteria for compliance assessment purposes.

Metals emitted from existing 'free areas' were however quantified and simulated to provide a partial characterisation of background levels (termed Future Baseline). The addition of Project-Incremental metal concentrations/deposition with Future Baseline levels provides more comprehensive data for use in the HRA.

Whereas tabulated results are presented for discrete receptors in this section, contour plots illustrating spatial variations in pollutant levels across the study area are presented in **Appendix D**. In the case of metals, a summary of the maximum metal concentrations across discrete receptor sites is presented in this section, with more detailed metal concentration and deposition data provided as input to the HRA study documented in **Appendix E**.

9.1 Construction Phase Assessment

9.1.1 Suspended Particulate

Incremental maximum daily and annual average particulate concentration simulated to occur at nearby receptor locations due to construction activities during the 3-month period of peak potential dust generating activities are summarised in **Table 26** and are presented spatially as contours in **Appendix D**.

Table 26 – Predicted Incremental Suspended Particulate Concentrations due to Construction Activities at Nearby Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	TSP	PM_{10}		$PM_{2.5}$	
		Annual Average (µg/m³)	Highest Daily Average (µg/m³)	Annual Average (µg/m³)	Highest Daily Average (µg/m³)	Annual Average (µg/m³)
R1	Piper Street North	1.2	5.4	0.4	1.4	0.1
R2	Piper Street Central	1.1	3.6	0.4	1.4	0.1
R3	Eyre Street North	1.9	4.6	0.7	1.3	0.2
R4	Eyre Street Central	1.7	10.8	0.7	1.6	0.2
R5	Eyre Street South	1.4	4.3	0.6	1.5	0.2
R6	South Road	1.4	5.6	0.7	1.6	0.1
R7	Carbon Lane	0.2	0.8	0.1	0.3	<0.1
R8	Old South Road	0.6	2.0	0.3	0.5	0.1
R9	South Rd	0.4	1.9	0.2	0.8	<0.1
R10	Cnr Garnet and Blende Streets	0.4	1.6	0.2	0.6	<0.1
R11	Alma Bugldi Pre-school	0.4	2.1	0.2	0.6	<0.1
R12	Playtime Pre-school	0.3	1.5	0.1	0.4	<0.1
R13	Alma Primary School	0.3	1.3	0.1	0.5	<0.1
R14	Broken Hill High School	0.3	1.4	0.1	0.4	<0.1
R17	Broken Hill Public School	0.2	1.0	0.1	0.5	<0.1
R18	Rainbow Pre-school	0.2	1.0	0.1	0.3	<0.1
R21	Eyre Street North	2.0	8.6	0.7	1.5	0.1
R22	Eyre Street North	2.7	9.9	0.9	1.7	0.2
R23	Eyre Street North	4.9	11.8	1.5	2.2	0.3
R24	Eyre Street North	4.0	11.4	1.3	2.4	0.3
R25	Water tank, Lawton Street #	1.3	5.1	0.4	1.0	0.1
R26	Quarry offices	2.2	8.4	0.8	2.0	0.2
R27	Proprietary Square	1.5	7.3	0.7	1.9	0.2
R28	Proprietary Square	1.1	5.4	0.5	1.3	0.1
R29	Iodide Street	0.8	3.5	0.3	0.8	0.1
R30	Iodide Street	0.6	2.9	0.3	0.7	0.1
R31	Crystal Street	0.5	2.2	0.2	0.5	<0.1
R32	Crystal Street	0.4	2.0	0.2	0.4	<0.1
R33	Brownes Shaft Dwelling	0.5	3.0	0.3	0.9	0.1
R34	Crystal Street	0.7	2.9	0.3	1.3	0.1
R35	Crystal Street	0.7	2.8	0.3	0.9	0.1
R36	Crystal Street	0.7	2.5	0.3	0.6	0.1
R37	Crystal Street	0.6	2.8	0.3	0.7	0.1
R38	Gypsum Street	0.2	0.8	0.1	0.2	<0.1
R39	Gypsum Street	0.2	0.9	0.1	0.3	<0.1
R40	Silver City Hwy	0.5	1.9	0.2	0.8	<0.1
R41	Silver City Hwy	0.6	1.9	0.2	0.7	0.1
R42	Silver City Hwy	0.7	2.1	0.3	0.8	0.1

The incremental maximum daily and annual average concentrations of all particle size fractions at the nearest sensitive receptor sites due to emissions from the worst-case 3-month period of dust generation during construction are predicted to satisfy DECCW air quality criteria.

Both incremental 24-hour and annual average concentrations for all size fractions are predicted to be low (less than 25% of the corresponding air quality goal). Taking background particulate concentrations into account it is not expected that construction activities will cumulatively give rise to levels above annual air quality criteria.

Given such predicted incremental concentrations, it is not anticipated that construction activities are likely to contribute to additional exceedances of DECCW air quality criteria.

However, it is acknowledged that the DECCW suspended particulate criteria are cumulative criteria (i.e. should consider background air quality). Further discussion as to the evaluation of cumulative impacts from the maximum operations phase of the project is provided in **Section 9.2**.

As seen in **Section 9.2**, incremental suspended particulate concentrations during the (worst-case) construction phase are anticipated to be comparable to operation impacts. The conclusions reached with respect to operation phase cumulative impacts are anticipated to be valid for the construction phase assessment.

Finally, it is noted that the construction phase has been modelled based on a maximum dust generating scenario which is expected to occur over a 3-month period. As such, predictions of annual average impacts should be viewed as conservatively high.

9.1.2 Dust Deposition

A maximum incremental annual average dust deposition rate of 0.7 g/m²/month (expressed as an annual average, and assuming 12-months of worst-case dust generating construction activities) was predicted to occur across the sensitive receptor locations. This rate is within the NSW DECCW incremental dust deposition limit of 2 g/m²/month. It should be noted that the modelled activities are anticipated to occur over a 3-month period, and as such predicted dust deposition rates associated with the construction period should be regarded as conservatively high.

Contour plots, illustrating spatial variations in predicted incremental dust deposition rates due to construction phase activities (and assuming a full year of worst-case dust emissions) are provided in **Appendix D**.

9.2 Maximum Production Phase Assessment

9.2.1 24-Hour PM_{10}

Incremental highest 24-hour average PM_{10} concentrations predicted to occur at nearby receptor locations due to operations at maximum production levels for the modelled years 2008 and 2009 are summarised in **Table 27**.

Predicted concentrations are presented spatially as contours in **Appendix D**. These contours represent the predicted maximum 24-hour concentrations across both modelled years.

Table 27 – Predicted Incremental 24-Hour Average PM_{10} Concentrations (µg/m³) at Representative Sensitive Receptors due to Maximum Production Activities

	Receptors	– Maximum for Model Years 2008 and 2009	
		Project-Related Increment	**Conc. as % of DECCW Criterion**
R1	Piper Street North	2.3	5%
R2	Piper Street Central	3.6	7%
R3	Eyre Street North	5.9	12%
R4	Eyre Street Central	4.2	8%
R5	Eyre Street South	4.3	9%
R6	South Road	6.5	13%
R7	Carbon Lane	3.1	6%
R8	Old South Road	10.5	21%
R9	South Rd	3.4	7%
R10	Cnr Garnet & Blende Streets	1.8	4%
R11	Alma Bugldi Pre-school	2.8	6%
R12	Playtime Pre-school	1.7	3%
R13	Alma Primary School	1.5	3%
R14	Broken Hill High School	1.5	3%
R15	Broken Hill Hospital	0.9	2%
R16	N. Broken Hill Primary School	0.7	1%
R17	Broken Hill Public School	1.2	2%
R18	Rainbow Pre-school	1.3	3%
R19	Willyama High School	0.5	1%
R20	Morgan Street Primary School	0.7	1%
R21	Eyre Street North	3.0	6%
R22	Eyre Street North	3.6	7%
R23	Eyre Street North	2.6	5%
R24	Eyre Street North	2.4	5%
R25	Water tank, Lawton Street #	1.9	4%
R26	Quarry offices	2.6	5%
R27	Proprietary Square	2.0	4%
R28	Proprietary Square	2.2	4%
R29	Iodide Street	1.8	4%
R30	Iodide Street	1.5	3%
R31	Crystal Street	1.4	3%
R32	Crystal Street	1.4	3%
R33	Brownes Shaft Dwelling	1.6	3%
R34	Crystal Street	2.2	4%
R35	Crystal Street	2.0	4%
R36	Crystal Street	1.5	3%
R37	Crystal Street	1.4	3%
R38	Gypsum Street	2.3	5%

Table 27 – Predicted Incremental 24-Hour Average PM_{10} Concentrations (µg/m³) at Representative Sensitive Receptors due to Maximum Production Activities

	Receptors	– Maximum for Model Years 2008 and 2009	
		Project-Related Increment	**Conc. as % of DECCW Criterion**
R39	Gypsum Street	2.5	5%
R40	Silver City Hwy	2.6	5%
R41	Silver City Hwy	2.7	5%
R42	Silver City Hwy	2.7	5%
Maximum Across All Receptors		**10.5**	**21%**

The Project-incremental concentration is predicted to contribute as a maximum about 21% of the DECCW criterion of 50µg/m³ for the worst case 24-hour period across all receptors and the two years of modelling (**Table 27**). This is made possible, despite the nature of the operation and the proximity of sensitive receptors, due to the application of the best practice dust management practices detailed in **Section 3**.

However, the DECCW criterion of 50 µg/m³ (24-hour average) is a cumulative criterion, and thus further evaluation is required.

Baseline air quality data documented in **Section 5** indicates that, in the absence of any additional inputs to the local airshed, exceedances of the maximum daily PM_{10} criterion are likely to occur in the region on about 10% of days (i.e. in excess of 35 occasions annually). Such exceedances are primarily due to episodic regional dust storms due to high winds and extensive exposed areas regionally.

The DECCW Approved Methods (2005) provides the following guidance for dealing with elevated background concentrations:

> *In some locations, existing ambient air pollutant concentrations may exceed the impact assessment criteria from time to time. In such circumstances, a licensee must demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of the proposed activity and that best management practices will be implemented to minimise emissions of air pollutants as far as is practical.*

In accordance with the DECCW Approved Methods, the likelihood that any further exceedances of the impact assessment criterion would occur as a result of the Project is evaluated.

Concurrent predicted and observed PM_{10} concentrations may be examined to establish the acceptability of cumulative impacts. Predicted Project-related Incremental concentrations at two representative sensitive receptors, R3 and R8 are plotted in combination with concurrent estimations of background 24-hour PM_{10} for the modelled years 2008 and 2009 respectively in **Figure 19**, **Figure 20**, **Figure 21** and **Figure 22**.

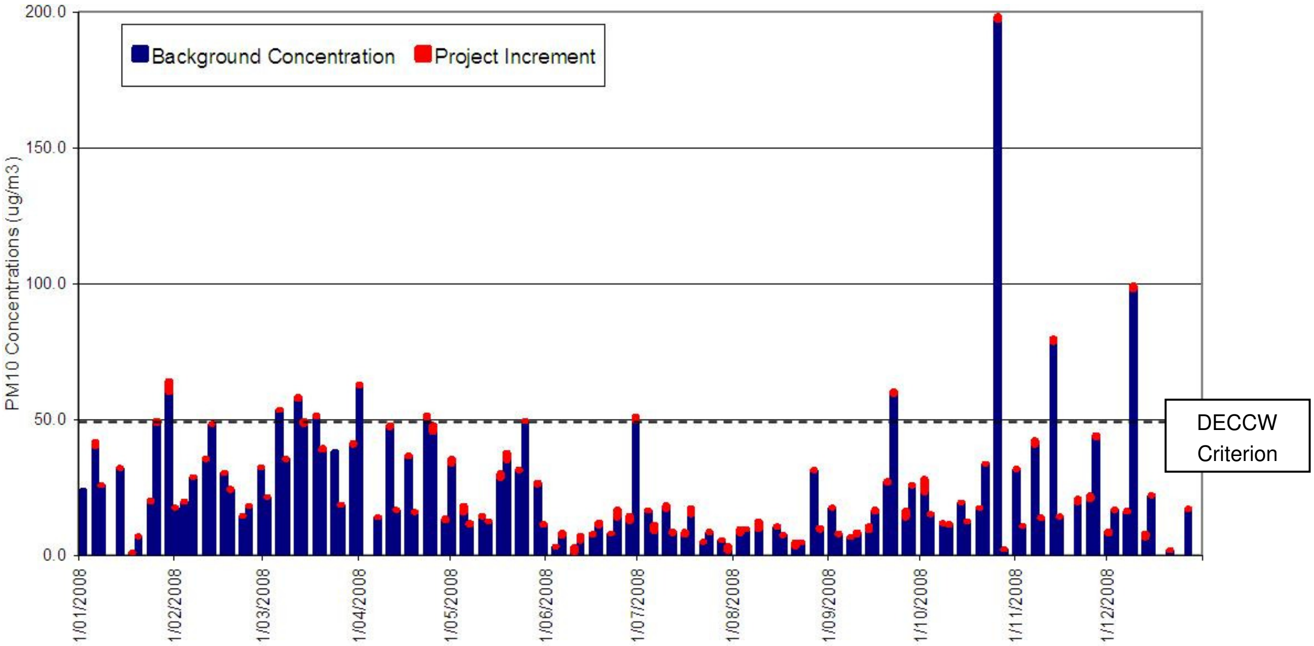


Figure 19 – Predictions of 24-hour PM_{10} at Receptor R3 Combined with Concurrent Estimations of Background, 2008

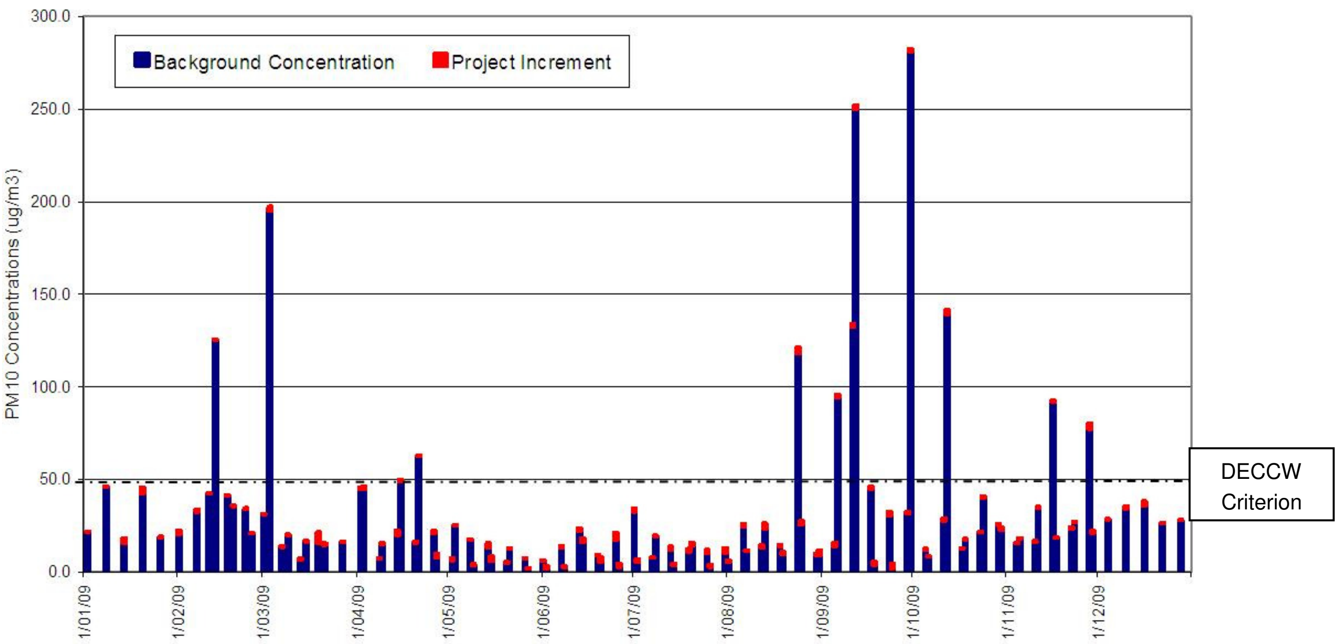


Figure 20 – Predictions of 24-hour PM_{10} at Receptor R3 Combined with Concurrent Estimations of Background, 2009

DECCW

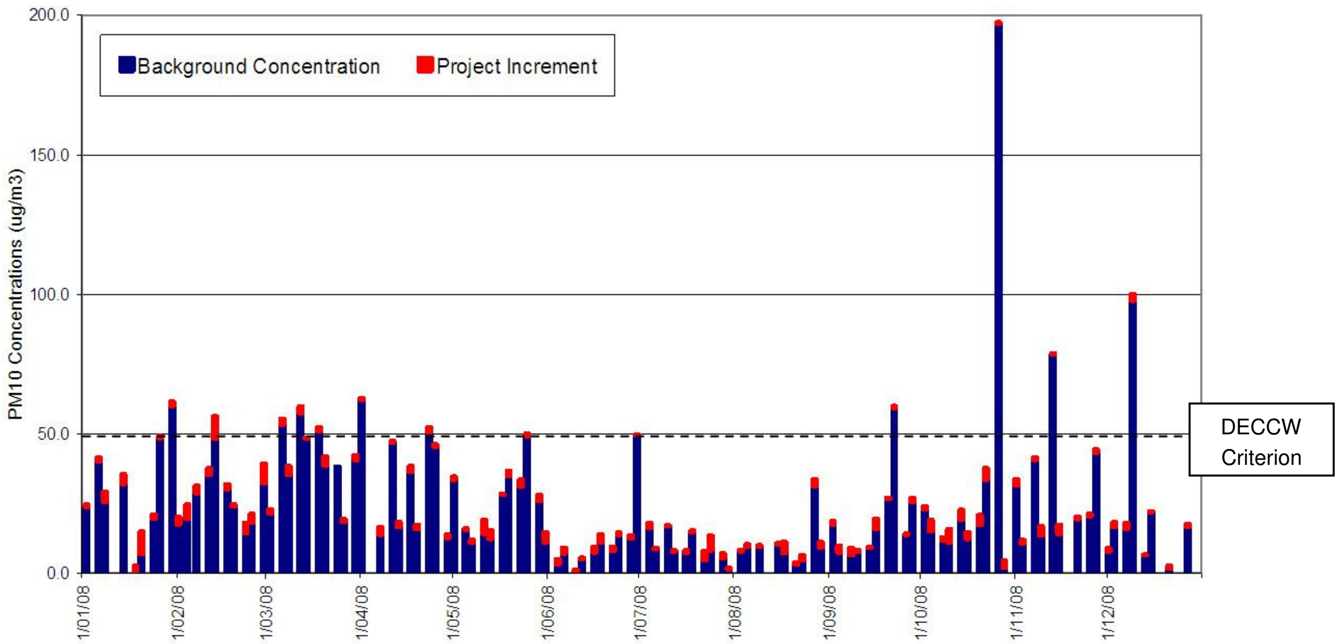


Figure 21 – Predictions of 24-hour PM_{10} at Receptor R8 Combined with Concurrent Estimations of Background, 2008

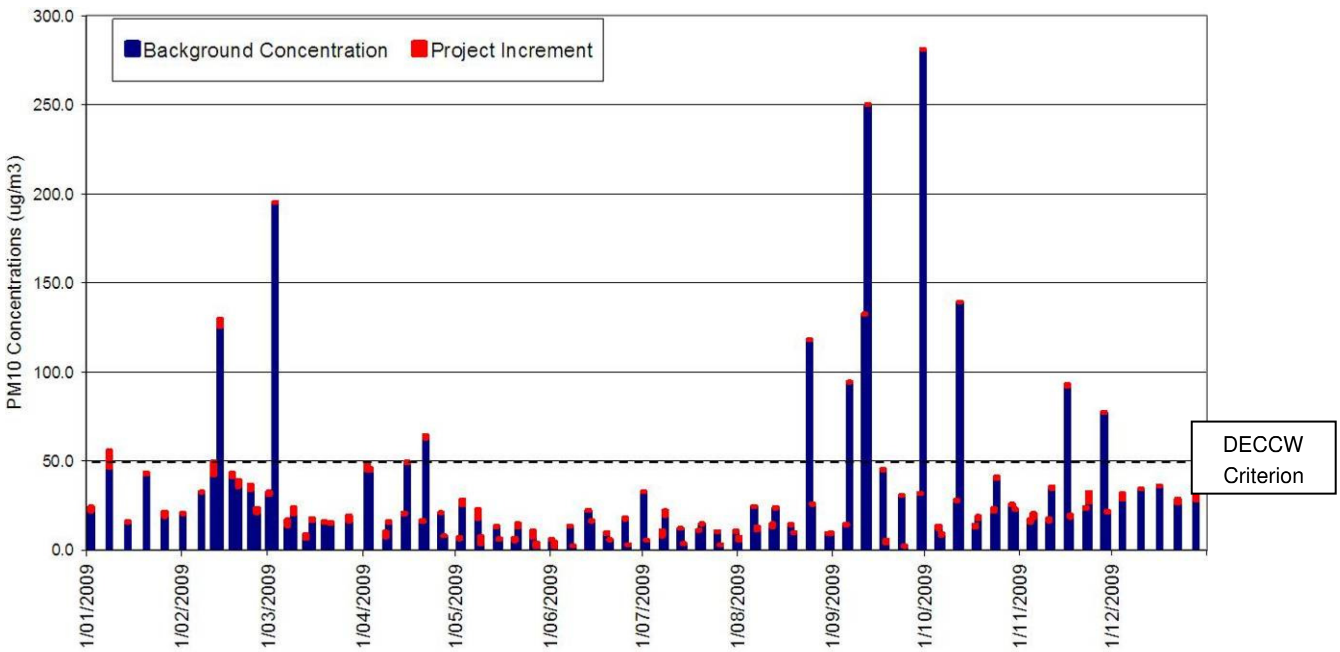


Figure 22 – Predictions of 24-hour PM_{10} at Receptor R8 Combined with Concurrent Estimations of Background, 2009

Figure 19 and **Figure 20** indicate that the predicted Project-related 24-hour PM_{10} concentration at receptor R3 combined with concurrent estimations of background for the area are anticipated to trigger one additional exceedance of the DECCW 24-hour PM_{10} criterion over the two modelled years.

The estimated background on this day of potential exceedance is recorded as 49.5µg/m³ (thus allowing for an increment of 0.5µg/m³ to ensure the criterion is not exceeded).

Figure 21 and **Figure 22** indicate that the predicted Project-related 24-hour PM_{10} concentration at Residence R8 combined with concurrent estimations of background for the area are anticipated to trigger two additional exceedances of the DECCW 24-hour PM_{10} criterion over the two modelled years.

The estimated background on these days of potential exceedance are recorded as 48.3µg/m³ and 46.2µg/m³ respectively (thus allowing for an increment of 1.7µg/m³ and 3.8µg/m³ respectively to ensure the criterion is not exceeded).

Finally, to provide additional clarity as to the likelihood of exceedances of the 24-hour PM_{10} criterion following the addition of Project-related air quality impacts, the frequency of occurrence of predicted concentrations may be examined.

Figure 23 shows the frequency of occurrence of predicted 24-hour concentrations at receptors R3 and R8 over the two model years 2008 and 2009.

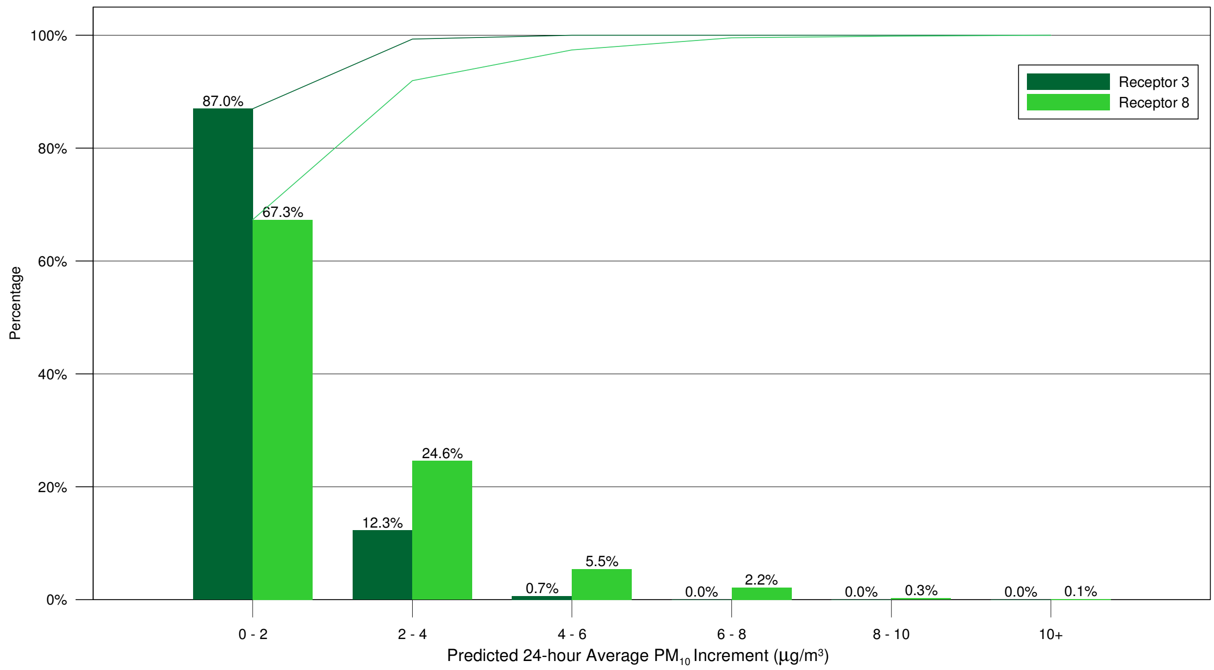


Figure 23 – Frequency Distribution of Predicted Project-related 24-hour PM_{10} Concentrations over Two Years Modelled

Figure 23 indicates that greater than 99% of predictions at Receptor R3 are anticipated to be less than 4µg/m^3 (expressed as a 24-hour average). Greater than 99% of predictions at Receptor R8 are anticipated to be less than 8µg/m^3 (expressed as a 24-hour average).

Given the low frequency of occurrence of predicted 24-hour average concentrations in excess of 8µg/m^3 at either Receptor R3 or R8 (3 occasions), the likelihood that increments attributable to the Project will cause any additional exceedance of the Project air quality criterion of 50µg/m^3 is low. This is even when considering that approximately 10% of occasions of background concentrations are anticipated to exceed 40 µg/m^3 (refer **Figure** 10)

A management and monitoring plan for the PM_{10} size fraction is suggested to ensure adequate dust control is undertaken and to further reduce the potential for ambient air quality criterion exceedances. Details of such monitoring are provided in **Section 10**.

The recommended dust mitigation activities to derive the predictions presented are noted explicitly within **Section 3**. It is considered appropriate that these dust controls are implemented as standard operating procedure.

9.2.2 Annual Average PM_{10}

Annual average PM_{10} concentrations simulated to occur at nearby receptor locations due to operations at maximum production levels are summarised in **Table 28**, expressed as maximum predictions over the model years 2008 and 2009. They are presented spatially as contours in **Appendix D**. These contours represent a composite of predicted worst case concentrations across both model years (i.e. are the maximum annual average concentration predicted for either model year).

Table 28 – Predicted Annual Average PM_{10} Concentrations due to Maximum Production Activities at Representative Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	PM_{10} Concentrations (µg/m³)			
		Measured Background Conc. [1]	Project-Related Increment	Cumulative. (Background + Increment)	Cumulative as % of DECCW Criterion
R1	Piper Street North	27.7	0.4	28.1	94%
R2	Piper Street Central	27.7	0.5	28.2	94%
R3	Eyre Street North	27.7	0.9	28.6	95%
R4	Eyre Street Central	27.7	0.8	28.5	95%
R5	Eyre Street South	27.7	0.6	28.3	94%
R6	South Road	27.7	0.8	28.5	95%
R7	Carbon Lane	27.7	0.4	28.1	94%
R8	Old South Road	27.7	1.7	29.4	98%
R9	South Rd	27.7	0.7	28.4	95%
R10	Cnr Garnet & Blende Streets	27.7	0.4	28.1	94%
R11	Alma Bugldi Pre-school	27.7	0.4	28.1	94%
R12	Playtime Pre-school	27.7	0.2	27.9	93%
R13	Alma Primary School	27.7	0.2	27.9	93%
R14	Broken Hill High School	27.7	0.2	27.9	93%
R15	Broken Hill Hospital	27.7	0.1	27.8	93%
R16	N. Broken Hill Primary School	27.7	0.1	27.8	93%
R17	Broken Hill Public School	27.7	0.2	27.9	93%
R18	Rainbow Pre-school	27.7	0.2	27.9	93%
R19	Willyama High School	27.7	0.0	27.7	92%
R20	Morgan Street Primary School	27.7	0.1	27.8	93%
R21	Eyre Street North	27.7	0.4	28.1	94%

Table 28 – Predicted Annual Average PM_{10} Concentrations due to Maximum Production Activities at Representative Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	PM_{10} Concentrations (µg/m³)			
		Measured Background Conc. [1]	Project-Related Increment	Cumulative. (Background + Increment)	Cumulative as % of DECCW Criterion
R22	Eyre Street North	27.7	0.5	28.2	94%
R23	Eyre Street North	27.7	0.4	28.1	94%
R24	Eyre Street North	27.7	0.4	28.1	94%
R25	Water tank, Lawton Street #	27.7	0.3	28.0	93%
R26	Quarry offices	27.7	0.4	28.1	94%
R27	Proprietary Square	27.7	0.2	27.9	93%
R28	Proprietary Square	27.7	0.2	27.9	93%
R29	Iodide Street	27.7	0.3	28.0	93%
R30	Iodide Street	27.7	0.2	27.9	93%
R31	Crystal Street	27.7	0.2	27.9	93%
R32	Crystal Street	27.7	0.2	27.9	93%
R33	Brownes Shaft Dwelling	27.7	0.2	27.9	93%
R34	Crystal Street	27.7	0.4	28.1	94%
R35	Crystal Street	27.7	0.4	28.1	94%
R36	Crystal Street	27.7	0.3	28.0	93%
R37	Crystal Street	27.7	0.3	28.0	93%
R38	Gypsum Street	27.7	0.3	28.0	93%
R39	Gypsum Street	27.7	0.3	28.0	93%
R40	Silver City Hwy	27.7	0.6	28.3	94%
R41	Silver City Hwy	27.7	0.5	28.2	94%
R42	Silver City Hwy	27.7	0.5	28.2	94%

Note 1: Background concentration of PM_{10} derived as per **Section 5**.

Annual average PM_{10} concentrations are predicted to be below the DECCW air quality criterion of 30µg/m³. Taking background particulate concentrations into account, the maximum (cumulative) concentration predicted over the two years of modelling is anticipated to be between 93% and 98% of the DECCW criterion across all sensitive receptors.

It is noted that the maximum predicted Project-related increment in annual PM_{10} concentrations across all receptors and modelled years is 1.7 µg/m³, or 6% the DECCW criterion. The background annual average PM_{10} concentration within the region represents 92% of the DECCW criterion in isolation.

9.2.3 Total Suspended Particulate

Annual average TSP concentrations predicted to occur at representative receptor locations due to operations at maximum production levels are summarised in **Table 29**, expressed as maximum concentrations over the model years 2008 and 2009. They are presented spatially as contours in **Appendix D**. These contours represent a composite of predicted worst case concentrations across both model years.

Table 29 – Predicted Annual Average Total Suspended Particulate (TSP) Concentrations due to Maximum Production Activities – Maximum for Model Years 2008 and 2009

	Receptors	TSP Concentrations (µg/m³)			
		Measured Background Conc. [1]	Project-Related Increment	Cumulative. (Background + Increment)	Cumulative as % of DECCW Criterion
R1	Piper Street North	64.9	0.7	65.6	73%
R2	Piper Street Central	64.9	1.0	65.9	73%
R3	Eyre Street North	64.9	1.8	66.8	74%
R4	Eyre Street Central	64.9	1.4	66.3	74%
R5	Eyre Street South	64.9	1.1	66.0	73%
R6	South Road	64.9	1.5	66.4	74%
R7	Carbon Lane	64.9	0.7	65.7	73%
R8	Old South Road	64.9	3.0	68.0	76%
R9	South Rd	64.9	1.3	66.3	74%
R10	Cnr Garnet & Blende Streets	64.9	0.7	65.7	73%
R11	Alma Bugldi Pre-school	64.9	0.6	65.6	73%
R12	Playtime Pre-school	64.9	0.4	65.4	73%
R13	Alma Primary School	64.9	0.3	65.3	73%
R14	Broken Hill High School	64.9	0.4	65.4	73%
R15	Broken Hill Hospital	64.9	0.1	65.1	72%
R16	N. Broken Hill Primary School	64.9	0.1	65.1	72%
R17	Broken Hill Public School	64.9	0.3	65.2	72%
R18	Rainbow Pre-school	64.9	0.3	65.2	72%
R19	Willyama High School	64.9	0.1	65.0	72%
R20	Morgan Street Primary School	64.9	0.1	65.1	72%
R21	Eyre Street North	64.9	0.8	65.8	73%
R22	Eyre Street North	64.9	0.9	65.8	73%
R23	Eyre Street North	64.9	0.8	65.7	73%
R24	Eyre Street North	64.9	0.8	65.8	73%
R25	Water tank, Lawton Street #	64.9	0.5	65.4	73%
R26	Quarry offices	64.9	0.8	65.8	73%
R27	Proprietary Square	64.9	0.3	65.3	73%
R28	Proprietary Square	64.9	0.3	65.3	73%
R29	Iodide Street	64.9	0.5	65.4	73%
R30	Iodide Street	64.9	0.4	65.3	73%
R31	Crystal Street	64.9	0.4	65.3	73%

Table 29 – Predicted Annual Average Total Suspended Particulate (TSP) Concentrations due to Maximum Production Activities – Maximum for Model Years 2008 and 2009

	Receptors	TSP Concentrations (µg/m³)			
		Measured Background Conc. [1]	Project-Related Increment	Cumulative. (Background + Increment)	Cumulative as % of DECCW Criterion
R32	Crystal Street	64.9	0.3	65.3	73%
R33	Brownes Shaft Dwelling	64.9	0.6	65.5	73%
R34	Crystal Street	64.9	0.8	65.8	73%
R35	Crystal Street	64.9	0.7	65.7	73%
R36	Crystal Street	64.9	0.7	65.6	73%
R37	Crystal Street	64.9	0.5	65.5	73%
R38	Gypsum Street	64.9	0.5	65.5	73%
R39	Gypsum Street	64.9	0.6	65.6	73%
R40	Silver City Hwy	64.9	1.1	66.1	73%
R41	Silver City Hwy	64.9	1.2	66.1	73%
R42	Silver City Hwy	64.9	1.0	66.0	73%

Note 1: Background concentration of TSP derived as per **Section 5**.

Annual average concentrations of TSP are predicted to be below the DECCW air quality criterion of 90 µg/m³. Taking background particulate concentrations into account, the maximum (cumulative) concentration predicted over the two years of modelling is anticipated to be 76% of the DECCW criterion across all sensitive receptors.

Table 29 indicates that the maximum predicted percentage of the DECCW criterion varies from 55% to 76% across receptors between the 2008 and 2009 modelled year. This reflects both the elevated background air quality within the region, and the variability in background concentration associated with the frequency of dust storms impacting the region.

9.2.4 Dust Deposition

Annual average dust deposition rates simulated to occur at representative receptor locations due to the Project are summarised in **Table 30**, expressed as the average monthly dust deposition rate (maximum across two model years) deposition rate over the model years 2008 and 2009. They are presented spatially as contours in **Appendix D**. These contours represent a composite of predicted worst case deposition across both model years.

Table 30 – Predicted Annual Average Monthly Dust Deposition due to Maximum Production Activities – Maximum for Model Years 2008 and 2009

	Receptors	Dust Deposition (g/m^2/month)	
		Project-Related Increment	% of DECCW Incremental Criterion
R1	Piper Street North	0.21	11%
R2	Piper Street Central	0.29	15%

Table 30 – Predicted Annual Average Monthly Dust Deposition due to Maximum Production Activities – Maximum for Model Years 2008 and 2009

	Receptors	Dust Deposition (g/m^2/month)	
		Project-Related Increment	% of DECCW Incremental Criterion
R3	Eyre Street North	0.55	28%
R4	Eyre Street Central	0.30	15%
R5	Eyre Street South	0.22	11%
R6	South Road	0.25	13%
R7	Carbon Lane	0.16	8%
R8	Old South Road	0.94	47%
R9	South Rd	0.37	19%
R10	Cnr Garnet & Blende Streets	0.18	9%
R11	Alma Bugldi Pre-school	0.14	7%
R12	Playtime Pre-school	0.09	5%
R13	Alma Primary School	0.07	4%
R14	Broken Hill High School	0.10	5%
R15	Broken Hill Hospital	0.02	1%
R16	N. Broken Hill Primary School	0.02	1%
R17	Broken Hill Public School	0.06	3%
R18	Rainbow Pre-school	0.05	2%
R19	Willyama High School	0.01	1%
R20	Morgan Street Primary School	0.02	1%
R21	Eyre Street North	0.28	14%
R22	Eyre Street North	0.30	15%
R23	Eyre Street North	0.22	11%
R24	Eyre Street North	0.14	7%
R25	Water tank, Lawton Street #	0.14	7%
R26	Quarry offices	0.11	5%
R27	Proprietary Square	0.09	5%
R28	Proprietary Square	0.08	4%
R29	Iodide Street	0.08	4%
R30	Iodide Street	0.07	3%
R31	Crystal Street	0.06	3%
R32	Crystal Street	0.05	3%
R33	Brownes Shaft Dwelling	0.04	2%
R34	Crystal Street	0.17	8%
R35	Crystal Street	0.13	7%
R36	Crystal Street	0.11	6%
R37	Crystal Street	0.09	4%
R38	Gypsum Street	0.10	5%
R39	Gypsum Street	0.12	6%
R40	Silver City Hwy	0.30	15%
R41	Silver City Hwy	0.28	14%
R42	Silver City Hwy	0.24	12%

A maximum incremental annual average dust deposition rate of 0.9 g/m²/month was predicted to occur across the receptor locations due to maximum production activities. This rate is within the NSW DECCW incremental dust deposition limit of 2 g/m²/month.

As noted in **Section 5**, background period-average (2008-2009) dust deposition is estimated to be in the order of 3.3 to 7.2 g/m²/month. Thus cumulative annual average dust deposition rates are expected to exceed the NSW DECCW cumulative dust deposition limit of 4 g/m²/month.

It is queried however whether the cumulative dust deposition criterion should be applied in the region of Broken Hill. Broken Hill is in an arid desert climate, impacted by frequent dust storm events. As such, dust deposition levels due to natural processes are elevated compared to other regions, and are likely to approach or exceed the DECCW cumulative dust deposition limit without the impact of anthropogenic sources.

Contour plots, illustrating spatial variations in the predicted incremental dust deposition rates due to maximum production activities are provided in **Appendix D**.

9.2.5 24-Hour and Annual Average $PM_{2.5}$

Incremental highest daily and annual average $PM_{2.5}$ concentrations simulated to occur at nearby receptor locations due to maximum production activities are summarised in **Table 31** and are presented spatially as contour plots in **Appendix D**.

Table 31 – Predicted Incremental $PM_{2.5}$ Concentrations due to Maximum Production Activities at Representative Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	$PM_{2.5}$ Concentrations (µg/m³)			
		Highest Daily Average (µg/m³)	Annual Average (µg/m³)	Highest daily Increment as % of NEPM	Annual Ave. Increment as % of NEPM
R1	Piper Street North	0.88	0.10	4%	1%
R2	Piper Street Central	1.32	0.14	5%	2%
R3	Eyre Street North	1.64	0.25	7%	3%
R4	Eyre Street Central	1.35	0.22	5%	3%
R5	Eyre Street South	1.09	0.17	4%	2%
R6	South Road	1.75	0.21	7%	3%
R7	Carbon Lane	0.81	0.12	3%	1%
R8	Old South Road	3.48	0.46	14%	6%
R9	South Rd	1.09	0.19	4%	2%
R10	Cnr Garnet & Blende Streets	0.43	0.10	2%	1%
R11	Alma Bugldi Pre-school	0.61	0.10	2%	1%
R12	Playtime Pre-school	0.53	0.07	2%	1%
R13	Alma Primary School	0.47	0.06	2%	1%
R14	Broken Hill High School	0.32	0.06	1%	1%
R15	Broken Hill Hospital	1.22	0.03	5%	0%
R16	N. Broken Hill Primary School	0.17	0.02	1%	0%
R17	Broken Hill Public School	0.28	0.04	1%	1%

Table 31 – Predicted Incremental $PM_{2.5}$ Concentrations due to Maximum Production Activities at Representative Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	$PM_{2.5}$ Concentrations (µg/m³)			
		Highest Daily Average (µg/m³)	Annual Average (µg/m³)	Highest daily Increment as % of NEPM	Annual Ave. Increment as % of NEPM
R18	Rainbow Pre-school	0.34	0.04	1%	1%
R19	Willyama High School	0.14	0.02	1%	0%
R20	Morgan Street Primary School	0.15	0.02	1%	0%
R21	Eyre Street North	1.18	0.13	5%	2%
R22	Eyre Street North	1.15	0.13	5%	2%
R23	Eyre Street North	0.94	0.12	4%	2%
R24	Eyre Street North	0.93	0.12	4%	2%
R25	Water tank, Lawton Street #	0.56	0.08	2%	1%
R26	Quarry offices	0.90	0.12	4%	1%
R27	Proprietary Square	0.64	0.11	3%	1%
R28	Proprietary Square	0.60	0.10	2%	1%
R29	Iodide Street	0.60	0.09	2%	1%
R30	Iodide Street	0.52	0.08	2%	1%
R31	Crystal Street	0.42	0.06	2%	1%
R32	Crystal Street	0.40	0.06	2%	1%
R33	Brownes Shaft Dwelling	0.77	0.07	3%	1%
R34	Crystal Street	0.62	0.10	2%	1%
R35	Crystal Street	0.59	0.09	2%	1%
R36	Crystal Street	0.56	0.08	2%	1%
R37	Crystal Street	0.50	0.07	2%	1%
R38	Gypsum Street	0.61	0.08	2%	1%
R39	Gypsum Street	0.71	0.09	3%	1%
R40	Silver City Hwy	0.63	0.15	3%	2%
R41	Silver City Hwy	0.60	0.14	2%	2%
R42	Silver City Hwy	0.70	0.12	3%	2%

The incremental maximum daily average $PM_{2.5}$ concentrations at the representative sensitive receptor sites due to maximum production emissions are predicted to peak at 14% of the 24-hour air quality criterion of 25 µg/m³. Taking into account the $PM_{2.5}/PM_{10}$ ratios characteristic of rural environments, and the proportion of fines in Project-related emissions it is anticipated that the PM_{10} air quality criterion will be sufficiently protective of incremental $PM_{2.5}$ exposure potentials.

Similarly, annual average concentrations of $PM_{2.5}$ are predicted to peak at 6% of the air quality criterion of 8 µg/m³ and as such are not anticipated to cause an exceedance of the DECCW criterion in the event that the PM_{10} criterion is complied with.

9.2.6 Heavy Metal Concentrations

A synopsis of maximum Project-related incremental 99.9th percentile hourly and annual average heavy metal concentrations predicted to maximum production activities across all discrete receptor locations is given in **Table 32**, with reference made to relevant DECCW impact assessment criteria. Such criteria are reported at the predicted 99.9th percentile (or 9th highest 1-hourly average) concentration, consistent with Section 7.2.2 of the DECCW Approved Methods.

Table 32 – Predicted Incremental 99.9th Percentile Hourly Heavy Metal Concentrations Predicted due to Maximum Production Activities

Substance	Predicted 99.9th Percentile Concentrations (µg/m³) across Sensitive Receptors	Receptor	DECCW Hourly Impact Assessment[a] Criteria (µg/m³)	Incremental concentration as % DECCW Criterion
Antimony	3.6×10^{-3}	R8	9	0.04%
Arsenic	2.1×10^{-2}	R8	0.09	23.33%
Barium	1.1×10^{-4}	R22	9	0.00%
Beryllium	2.8×10^{-6}	R22	0.004	0.07%
Cadmium	8.6×10^{-3}	R8	0.018	47.79%
Chromium	8.6×10^{-4}	R28	9 (as Cr III)	0.01%
			0.09 (as Cr VI)	0.96%
Copper	3.8×10^{-2}	R8	18	0.21%
Manganese	6.2×10^{-2}	R28	18	0.35%
Mercury	9.9×10^{-5}	R28	0.18	0.05%
Nickel	6.1×10^{-4}	R28	0.18	0.34%
Silver	2.0×10^{-3}	R8	0.18	1.09%

(a) Specified for evaluation of incremental concentrations due to proposed projects

No exceedances of the relevant DECCW impact assessment criteria for the above toxic air pollutants were predicted to occur.

No data is available concerning the partitioning of chromium (Cr) between Cr III and Cr VI oxidation states. However, inspection of **Table 32** indicates that even using the highly conservative assumption that all Cr is found as Cr VI (Cr III is the most stable oxidation state), Cr is anticipated to comprise 1% of the DECCW 1-hour criterion.

DECCW specify an annual air quality criterion for lead that is specific for cumulative concentrations. Performance against this criterion is evaluated in **Table 33**.

Table 33 – Predicted Annual Average Lead (Pb) Concentrations due to Maximum Production Activities at Representative Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	Pb Concentrations (µg/m³)			
		"Future Baseline" (Existing Free Areas, 80% Control Efficiency)	Project-Related Increment	Cumulative Pb (Baseline + Project Increment)	Cumulative Pb. as % of DECCW Criterion
R1	Piper Street North	0.041	0.015	0.056	11%
R2	Piper Street Central	0.026	0.026	0.052	10%
R3	Eyre Street North	0.028	0.049	0.076	15%
R4	Eyre Street Central	0.018	0.037	0.056	11%
R5	Eyre Street South	0.014	0.030	0.044	9%
R6	South Road	0.023	0.041	0.063	13%
R7	Carbon Lane	0.017	0.023	0.040	8%
R8	Old South Road	0.119	0.109	0.228	46%
R9	South Rd	0.046	0.040	0.086	17%
R10	Cnr Garnet & Blende Streets	0.028	0.018	0.046	9%
R11	Alma Bugldi Pre-school	0.010	0.018	0.028	6%
R12	Playtime Pre-school	0.008	0.011	0.020	4%
R13	Alma Primary School	0.007	0.009	0.016	3%
R14	Broken Hill High School	0.015	0.011	0.026	5%
R15	Broken Hill Hospital	0.006	0.004	0.009	2%
R16	N. Broken Hill Primary School	0.006	0.003	0.009	2%
R17	Broken Hill Public School	0.012	0.007	0.020	4%
R18	Rainbow Pre-school	0.004	0.007	0.011	2%
R19	Willyama High School	0.004	0.002	0.006	1%
R20	Morgan Street Primary School	0.005	0.003	0.008	2%
R21	Eyre Street North	0.050	0.015	0.064	13%
R22	Eyre Street North	0.042	0.014	0.056	11%
R23	Eyre Street North	0.031	0.014	0.045	9%
R24	Eyre Street North	0.030	0.017	0.047	9%
R25	Water tank, Lawton Street #	0.025	0.010	0.035	7%
R26	Quarry offices	0.031	0.018	0.048	10%
R27	Proprietary Square	0.056	0.015	0.071	14%
R28	Proprietary Square	0.042	0.014	0.055	11%
R29	Iodide Street	0.047	0.013	0.059	12%
R30	Iodide Street	0.033	0.011	0.044	9%
R31	Crystal Street	0.026	0.008	0.035	7%
R32	Crystal Street	0.021	0.008	0.029	6%
R33	Brownes Shaft Dwelling	0.027	0.011	0.036	7%
R34	Crystal Street	0.044	0.018	0.063	13%
R35	Crystal Street	0.037	0.016	0.053	11%
R36	Crystal Street	0.030	0.013	0.043	9%
R37	Crystal Street	0.027	0.011	0.038	8%
R38	Gypsum Street	0.010	0.016	0.023	5%
R39	Gypsum Street	0.017	0.020	0.036	7%

Table 33 – Predicted Annual Average Lead (Pb) Concentrations due to Maximum Production Activities at Representative Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	Pb Concentrations (µg/m³)			
		"Future Baseline" (Existing Free Areas, 80% Control Efficiency)	Project-Related Increment	Cumulative Pb (Baseline + Project Increment)	Cumulative Pb. as % of DECCW Criterion
R40	Silver City Hwy	0.044	0.029	0.074	15%
R41	Silver City Hwy	0.045	0.028	0.073	15%
R42	Silver City Hwy	0.048	0.024	0.071	14%

Baseline lead concentrations have been estimated based on modelled contributions from lead-bearing existing "free" areas (areas susceptible to wind erosion) across CML7. Given the Proponent's commitment to stabilise existing free areas using chemical dust suppressants the "future baseline" lead concentration (assuming 80% control efficiency for existing free areas) is shown as a reflection of background lead concentrations during the operation phase.

In all cases, the DECCW cumulative (baseline plus project increment) lead criterion of 0.5 µg/m³ is predicted to be satisfied at all receptors.

Project maximum cumulative heavy metal concentrations based on highest concentrations due to the proposed Project across sensitive receptor sites and maximum background concentrations projected from monitoring data (**Section 5**) are given in **Table 34** with reference made to widely used inhalation Health Risk Assessment criteria (refer **Section 3**).

Table 34 – Maximum cumulative short-term peak (maximum 1-hour) and annual average heavy metal concentrations predicted due to Maximum Production Activities

Substance	Site-related Maximum Cumulative Concentrations(a)		Inhalation Health Risk Criteria (Ref. Section 3)	
	Short-term Peak (Maximum 1-hour) (µg/m³)	Annual Average (µg/m³)	Acute Exposure Criteria (µg/m³) (Applied to short-term peak)	Chronic Exposure Criteria (µg/m³) (Applied to Annual Average)
Antimony	0.15	0.00	5	0.5
Arsenic	0.24	0.000	0.2	0.015
Barium	0.00	0.00	5	0.5
Beryllium	0.00	0.000	0.2	0.007
Cadmium	0.07	0.000	NC	0.005
Chromium	0.26	0.00	1	0.1

Table 34 – Maximum cumulative short-term peak (maximum 1-hour) and annual average heavy metal concentrations predicted due to Maximum Production Activities

Substance	Site-related Maximum Cumulative Concentrations(a)		Inhalation Health Risk Criteria (Ref. Section 3)	
	Short-term Peak (Maximum 1-hour) (µg/m³)	Annual Average (µg/m³)	Acute Exposure Criteria (µg/m³) (Applied to short-term peak)	Chronic Exposure Criteria (µg/m³) (Applied to Annual Average)
Copper	2.18	0.02	100	1
Iron	64.86	0.60	50	5
Lead	36.98	0.36	NC	0.5
Manganese	19.54	0.16	NC	0.15
Mercury	0.03	0.00	0.6	0.03
Nickel	0.19	0.00	6	0.05
Silica	0.00	0.00	NC	0.01
Silver	0.03	0.20	0.1	5
Zinc	15.25	0.00	50	0.5

NC – no criteria specified

(a) Site-related cumulative concentrations, including highest Project-related incremental concentrations (across sensitive receptor sites, Ref. **Table 32**) and 'concentrations due to 'future baseline' emissions.

The above screening analysis indicates that short term peak arsenic and iron concentrations, as well as annual average manganese concentrations are likely to require further evaluation within the health risk assessment that accompanies the Environmental Assessment.

9.2.7 Gaseous Concentrations

A synopsis of Project-related incremental gaseous pollutant concentrations, as a maximum across all discrete receptor sites, is given in **Table 32**, with reference made to relevant DECCW impact assessment criteria.

Although the air quality criteria are applicable to cumulative concentrations, background levels of these gases are expected to be low due to the nature of the area. The comparison of the predicted Project-related incremental concentrations with the air quality criterion is therefore considered justified as a preliminary measure.

Table 35 – Maximum *Incremental* Gaseous Concentrations Predicted due to Maximum Production Activities

Project-related Incremental Concentrations			
Substance	**Highest Hourly Average (µg/m³)**	**Highest Daily Average (µg/m³)**	**Annual Average (µg/m³)**
NO_2	167	19	2.2
VOCs	85	5	0.2
SO_2	26	1	0.1
PAH(a)	0.034	0.002	0.000
CO	1191	18	0.7
DECCW Impact Assessment Criteria			
Substance	**Highest Hourly Average (µg/m³)**	**Highest Daily Average (µg/m³)**	**Annual Average (µg/m³)**
NO_2	246		62
VOCs			
SO_2	570	228	60
PAH (as Benzo[a]pyrene)	0.4		
CO	30000		

(a) Conservatively screened against the PAH impact assessment criterion which is specified as benzo[a]pyrene

Project-related incremental gaseous concentrations are within DECCW criteria, with all maximum concentrations representing less than 10% of the relevant criteria with the exception of peak hourly NO_2 (about 70% of hourly criterion). Evaluation of NO_2 has been conducted using the Ozone Limiting Method described in **Section 8.4**.

Project-related incremental concentrations are based on the assumption of 0% control efficiency for gaseous releases from the ventilation shaft. Given the use of water sprays or operation of the ventilation shaft as a “wet shaft”, it is likely that the gaseous emissions would be at least partially controlled.

9.3 Source Contributions to Annual Incremental Particulate Concentrations

To assist future potential dust management, it is instructive to view Project-related incremental increases by source contribution.

Source contributions to annual average PM_{10} and lead deposition, both as Project-related increment only and site-related cumulative (i.e. project increment + controlled existing ‘free areas’), are illustrated in **Figure 27**, **Figure 28**, **Figure 29** and **Figure 30**.

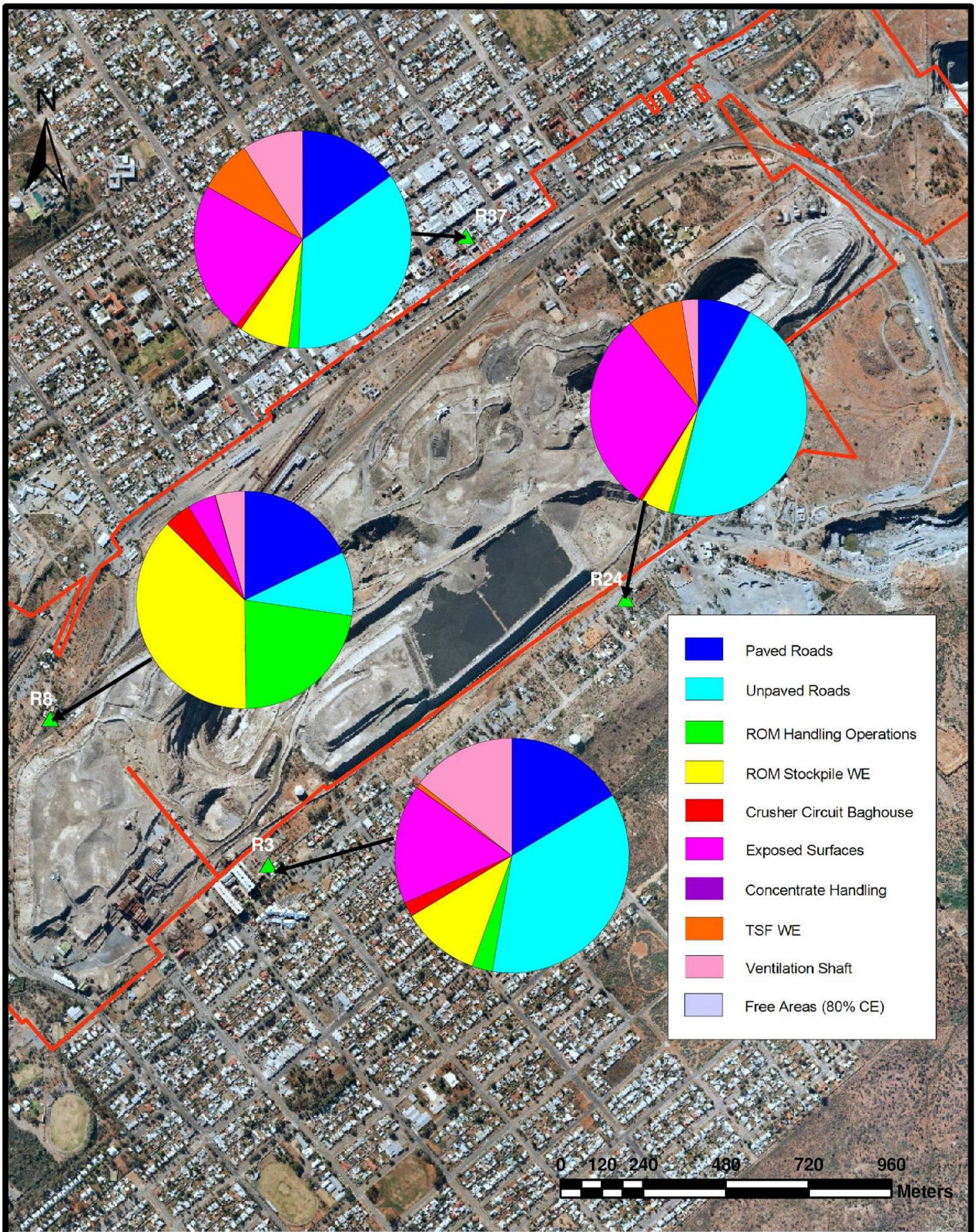


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FIGURE 27: Predicted Source Apportionment of Annual Average PM_{10} at Surrounding Receptors - Project Increment Only -

Figure

Drafter: SF Date: 24.02.10 Contract Number: AS121150 Approved: DAR Revised:

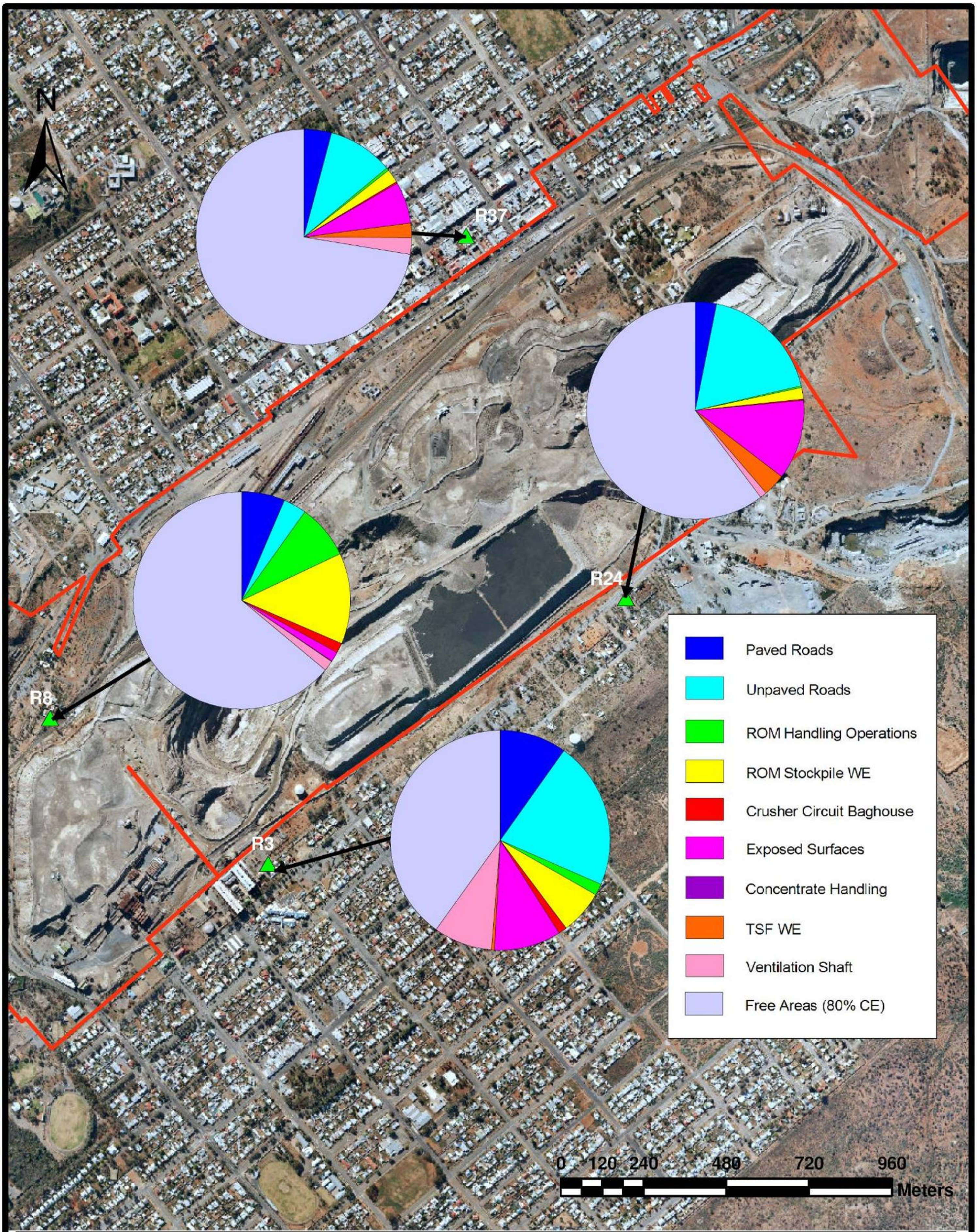

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FIGURE 28: Predicted Source Apportionment of Annual Average PM_{10} at Surrounding Receptors - Cumulative Impact (80% CE) -

Figure

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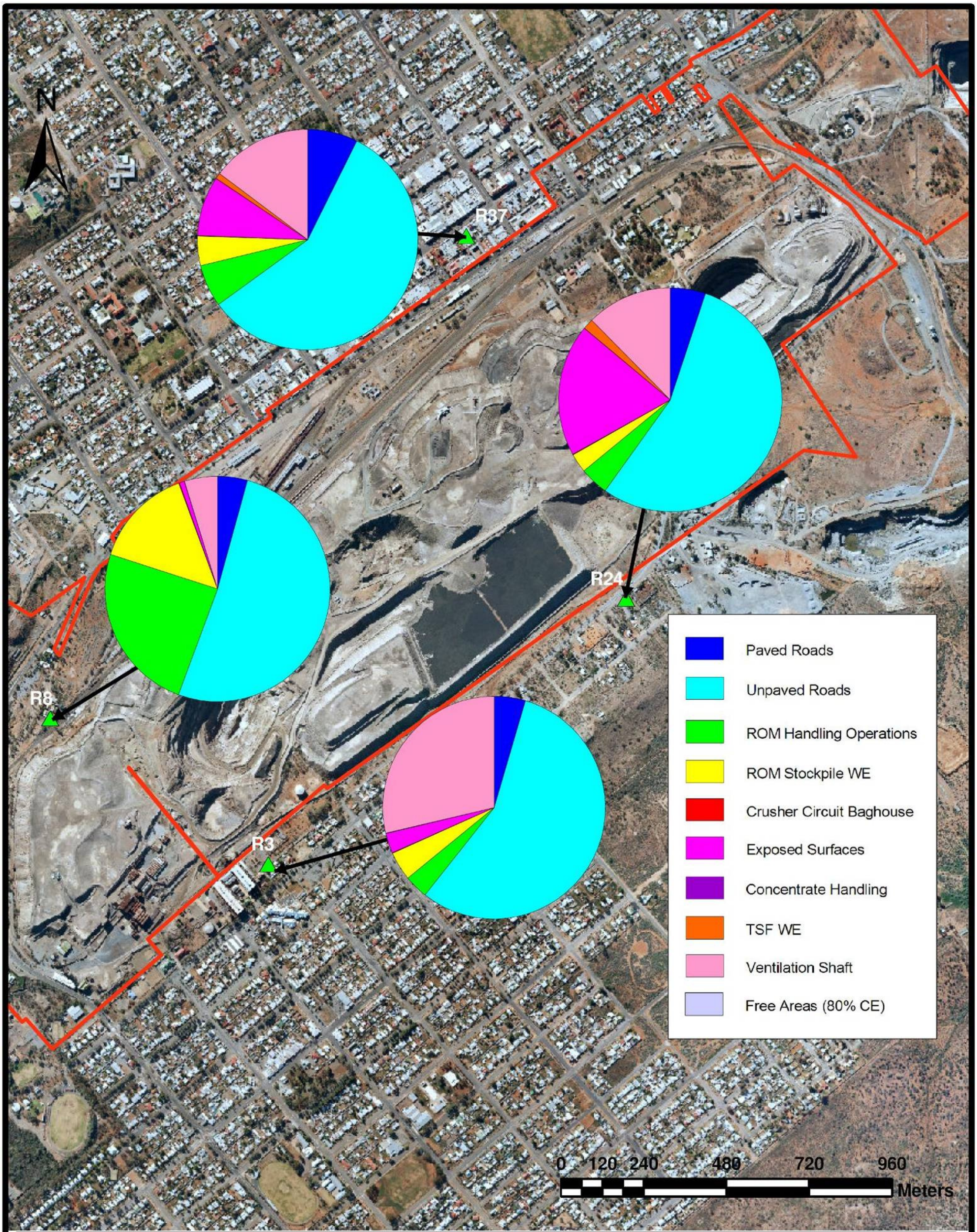

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FIGURE 29: Predicted Source Apportionment of Annual Average Lead Deposition at Surrounding Receptors - Project Increment Only -

Figure

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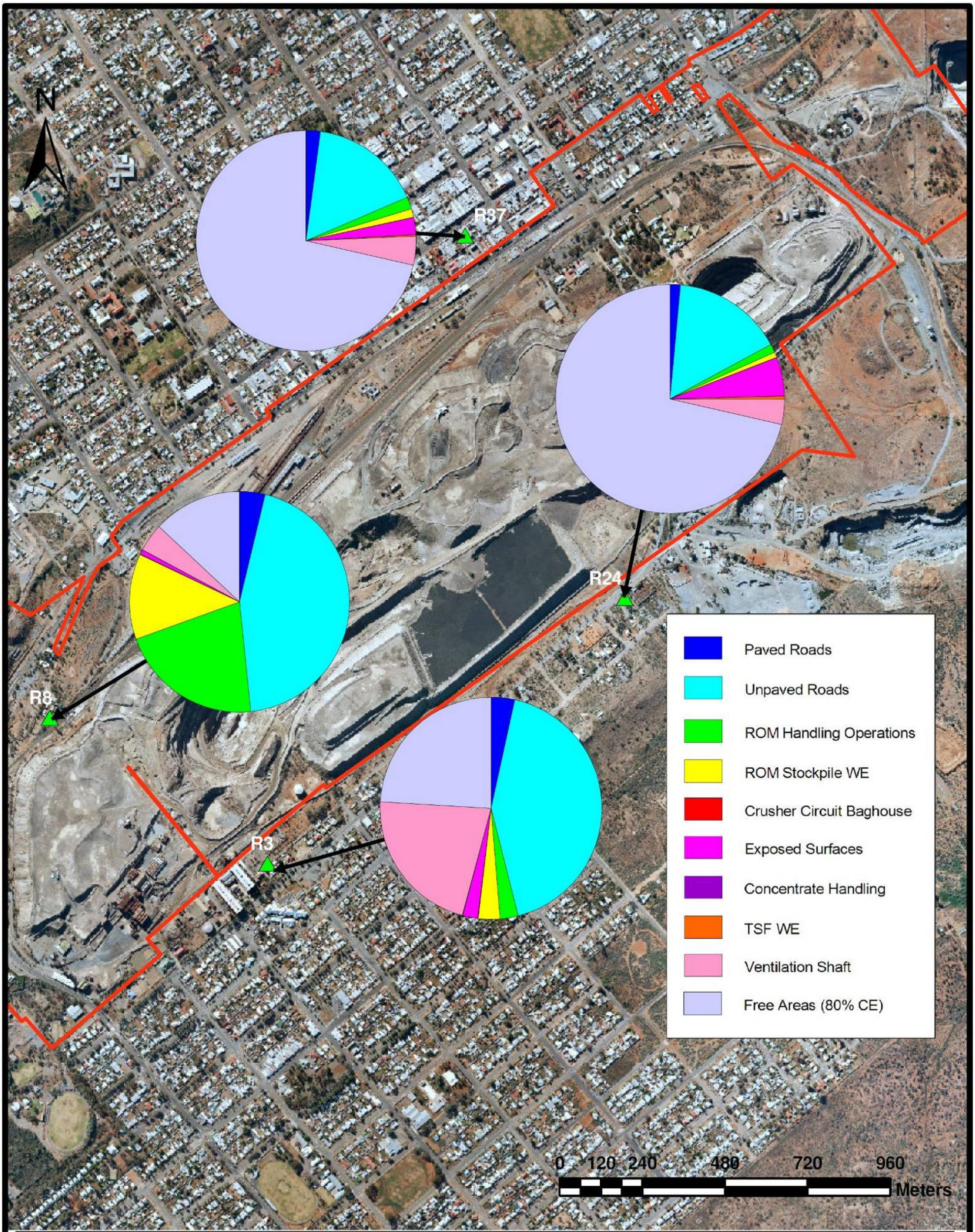

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FIGURE 30: Predicted Source Apportionment of Annual Average Lead Deposition at Surrounding Receptors - Cumulative Impact (80% CE) -

Figure

Drafter: SF | Date: 24.02.10 | Contract Number: AS121150 | Approved: DAR | Revised:

Figure 27 indicates that the principal contributing source of incremental annual PM_{10} at sensitive receptors is predicted to be PM_{10} generated due to vehicle movement on unpaved roads. The unpaved road source category includes the unpaved (in pit) section of the haul road and delivery vehicle and general light vehicle movement along other unpaved roads. A further prominent source is wind erosion from Project-related exposed surfaces.

An exception to the source apportionment profiles is evident at Receptor R8, where wind blown dust from the ROM ore stockpiles and ore handling are the dominant sources. This is due to the proximity of this receptor to the ROM pad.

Figure 28 illustrates that when existing free areas are included to assess BHOP site-related cumulative concentrations, these free areas are expected to be the dominant contributing source at all receptors even given the proposed 80% control due to remediation with chemical dust suppressant.

Figure 29 and **Figure 30** indicate that vehicle entrainment along unpaved roads is anticipated to be a dominant contributing source to annual lead deposition at receptors R8 and R3, both when Project-related incremental deposition and site-related cumulative deposition (including free areas) are considered. From **Figure 30** it is evident that wind erosion from existing free areas potentially represents the most significant contribution to annual lead deposition at more northerly located receptors (R24 and R37).

Although the source apportionment is presented for annual average concentrations, it should be noted that the contribution of wind-dependent sources will increase significantly on high wind days. Furthermore, peak background concentrations tend to occur on high wind days due to regional dust events thus increasing the potential for higher cumulative concentrations. The effective day-to-day control of wind-dependent and roadway sources is therefore seen to be a priority for the Project.

10 Mitigation and Monitoring Recommendations

As documented within **Section 3**, the Project Proponent has committed to best practice dust controls at the Project inception stage for the duration of the Project.

Given the above, there is little scope for additional mitigation to be implemented for the proposed Project configuration. One area that should be discussed further is the commitment to control and manage dust emissions from existing free areas through the addition of chemical dust suppressants. Existing open areas have the potential to contribute to off-site dust and metals. The sealing (through use of chemical dust suppressants) and ongoing control of free areas will therefore significantly reduce existing particulate and metal concentrations / deposition occurring in the vicinity of the site.

By way of illustration, **Figure 24** and **Figure 25** show contours of predicted 24-hour PM_{10} concentrations from the existing free areas including and excluding control (i.e., chemical dust suppressants). A comparison of these figures indicates that there are tangible air quality benefits associated with the application of dust suppressants on, and ongoing management of existing free areas at the site.

It is anticipated that such an activity will go some way towards offsetting additional air quality impacts associated with the Project.

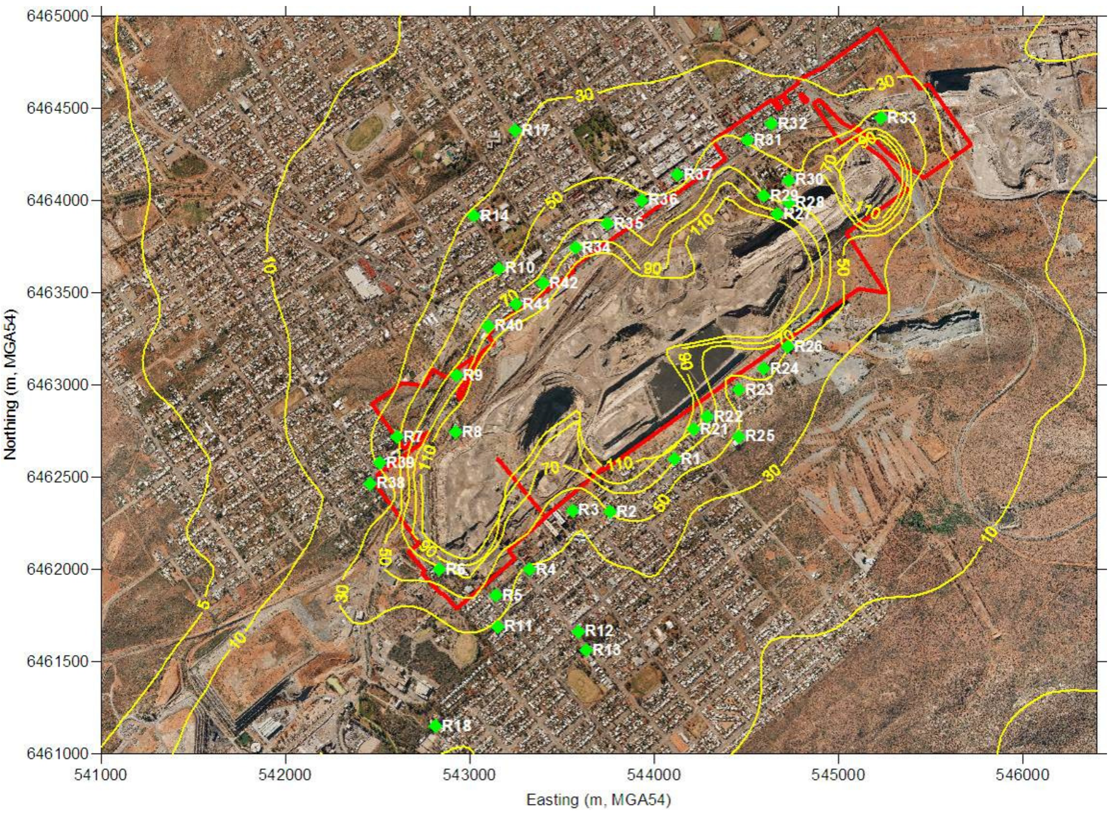

Figure 24: Existing Uncontrolled Free Areas – Predicted Maximum 24 Hour Average PM_{10} Concentrations ($\mu g/m^3$)

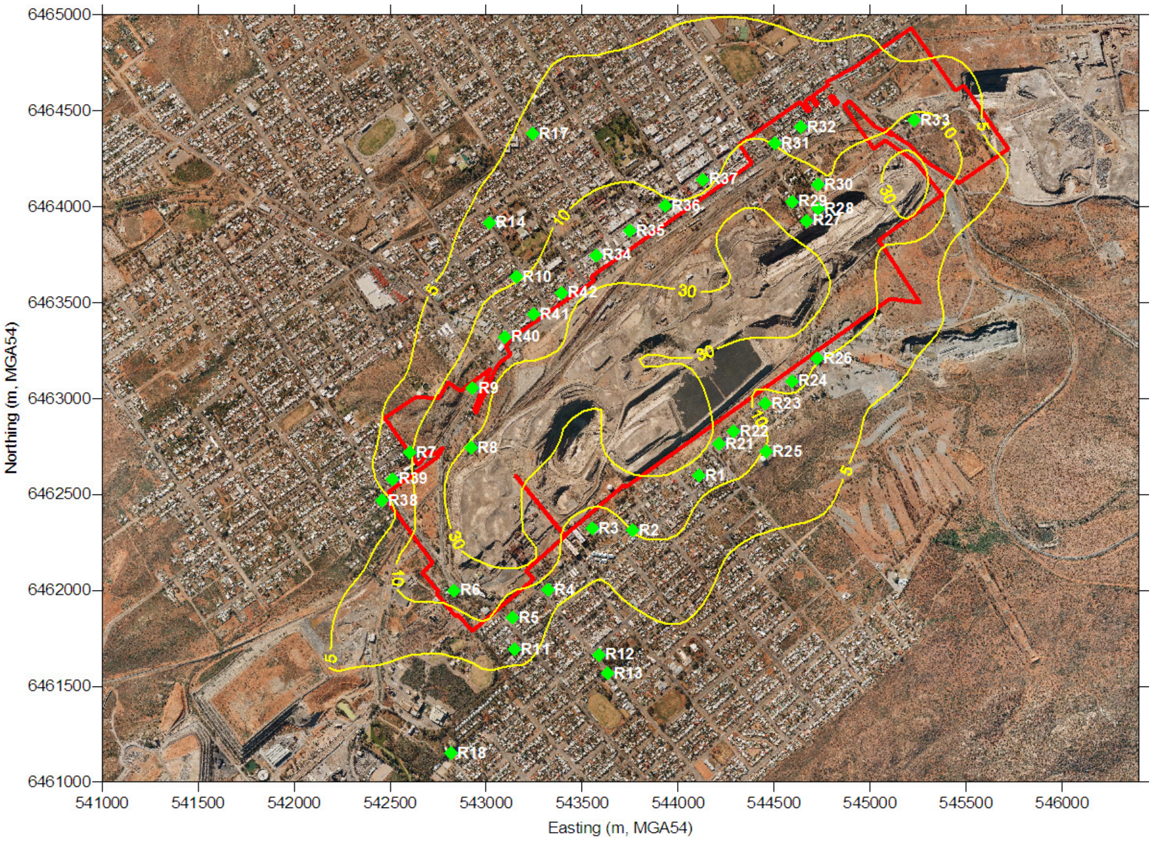

Figure 25: Existing Free Areas 80% Controlled – Maximum Predicted 24 Hour Average PM_{10} Concentrations (µg/m^3)

10.1 Air Quality Monitoring

While all reasonable dust control measures have been provided for, it is considered that the Project is situated close to sensitive receptors in a region characterised by high particulate levels. The implementation of an effective Air Quality Monitoring Program to confirm on an on-going basis, the consistent and effective implementation of dust management measures is therefore considered a priority.

Key recommendations in respect of the Air Quality Monitoring Program, including source-based and receptor-based measurement techniques are discussed below.

10.1.1 Source-based Measurements

The effectiveness of using a sweeper to limit silt loading on the paved haul road surface should be periodically (quarterly) checked. This could be done through sampling and quantification of road surface silt loadings.

Periodic maintenance and inspection of the crusher circuit baghouse and all other dust control technologies, as per supplier recommendations.

Design and implementation of a suitable field trial to determine the *in situ* dust control effectiveness of applying the preferred chemical dust suppression products on the TSFs.

Staff awareness training on dust emissions, and the timely reporting of any visible dust emissions by site personnel followed by prompt action represents a routine but effective dust management measure for extractive operations.

10.1.2 Particulate Monitoring

In addition to the existing TSP High Volume Air Sampler on site, it is recommended that BHOP establish concurrent monitoring of PM_{10} using a high volume sampler.

Further, near real-time access to measured meteorological (specifically wind) data and PM_{10} concentrations, and the use of such information to inform dust management planning and impact potential minimisation is recommended.

BHOP are also committed to the introduction of real-time, continuous PM_{10} monitors placed within the vicinity of the sensitive receptors predicted to experience the highest impacts of this parameter (e.g. Receptors R3, R4 or R8).

Additionally, monitoring to assess, on an on-going basis, the effectiveness of the TSF dust mitigation strategy is recommended to be included within the facility's ambient monitoring program. Inspection of the predicted 24-hour PM_{10} contours indicates that Receptor R22 or equivalent would be a suitable location for this instrument[(2)]. Such instrumentation would enable a proactive monitoring strategy utilising short-term trigger values at boundary monitor(s) to provide early warning of potentially unacceptable dust events, in this instance an exceedance of the 24-hour PM_{10} criterion.

The following further recommendations are made in respect of air quality monitoring for the Project:

- Additional dust deposition monitoring should be conducted at off-site locations to characterise dust deposition rates not influenced by activities at CML7, as well as at increasing distances from the mine lease.
- Continuous PM_{10} monitors described above should be installed well in advance of the Project implementation to establish a robust data set of background air quality surrounding the Project area.

All compliance monitoring should be conducted in accordance with Australian Standards as referenced in the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (DECC, 2005b). Of specific relevance are:

2 Initially the water tank fenced area on Lawson Street (Receptor No. R25) was considered as a potentially suitable location for PM_{10} monitoring. However, the dispersion modelling indicated that lower concentrations are expected to occur at this site when compared to nearby receptor sites (e.g. R22).

- AS 3580.10.1-2003 *Methods for Sampling and Analysis of Ambient Air - Determination of Particulates - Deposited Matter - Gravimetric Method* (DECCW Method AM-19);
- AS 3580.9.6-2003 *Particulate Matter - PM10 - high volume sampler with size-selective inlet* (DECCW Method AM-18); and
- AS 3580.9.8-2008 *Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM10 continuous direct mass method using a tapered element oscillating microbalance analyser* (DECCW Method AM-22)

10.1.3 Monitoring of Metals

It is standard procedure to conduct an analysis for lead within both High Volume Air Sampler (HVAS) and Dust Deposition Gauge samples.

It is recommended that this is continued, with periodic (quarterly) analysis for the full suite of metals identified within this report.

Regarding the analysis of lead on HVAS filters, given the 1-day-in-6 sampling regime, it is highlighted that there is the potential for lead deposition onto the filters outside the actual sampling period.

10.2 Air Quality Management Plan

Air pollution mitigation measures and the air quality monitoring program will be comprehensively documented within an Air Quality Management Plan.

11 Conclusion

ENVIRON has been commissioned by BHOP to undertake an Air Quality Assessment for the expansion of the Rasp Mine located on CML7 in Broken Hill, NSW.

Given the nature of the Rasp Mine and recommendations by environmental authorities, Best Practice dust controls have been identified and, to the extent practicable, integrated into the Project.

Air pollutants evaluated in the study include suspended particulate matter and dust deposition, in addition to a range of metals/metalloids including lead, zinc, cadmium, mercury, nickel, arsenic and manganese contained in the particulate matter.

Predicted pollutant levels were evaluated against identified air quality criteria including impact assessment criteria specified by DECCW and inhalation reference concentrations from widely-referenced health risk information sources.

Atmospheric dispersion modelling predictions of fugitive emissions from the Project were undertaken using the AERMOD Gaussian Plume Dispersion Model software developed by the US-EPA. Existing air quality was characterised for the purpose of assessing the potential for cumulative air pollution levels due to the Project.

Predictions indicate that, provided the comprehensive dust controls documented within this report are implemented, Project-related incremental particulate concentrations and dust deposition will be within DECC air quality criteria at all surrounding non-project related residences. It is however noted that the criteria are specified for the evaluation of cumulative concentrations.

In the assessment of cumulative Project impacts, the potential exists for criteria relating to 24-hour PM_{10} and annual dust deposition to be exceeded. In the assessment of cumulative (Project plus existing background) impact potentials cognisance should be given to the nature of the local environment. The existing air quality of Broken Hill is influenced by its arid climatic and desert setting, resulting in frequent dust storm events. As such, existing PM_{10} and dust deposition levels are elevated compared to other regions, and are likely to approach or exceed the DECCW cumulative limits due to natural processes alone.

Predicted peak concentrations of arsenic and manganese marginally exceed the air quality criteria used in this report. The significance of these and other metals will be assessed in the multi-pathway health risk assessment being conducted by Toxikos.

Predicted suspended particulate concentrations, and metal/metalloid concentrations and deposition rates were provided to Toxikos to facilitate the health risk assessment process.

The Toxikos health risk assessment should be referred to for a complete understanding of the potential health risks associated with the Project.

12 References

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13 Glossary of Acronyms And Symbols

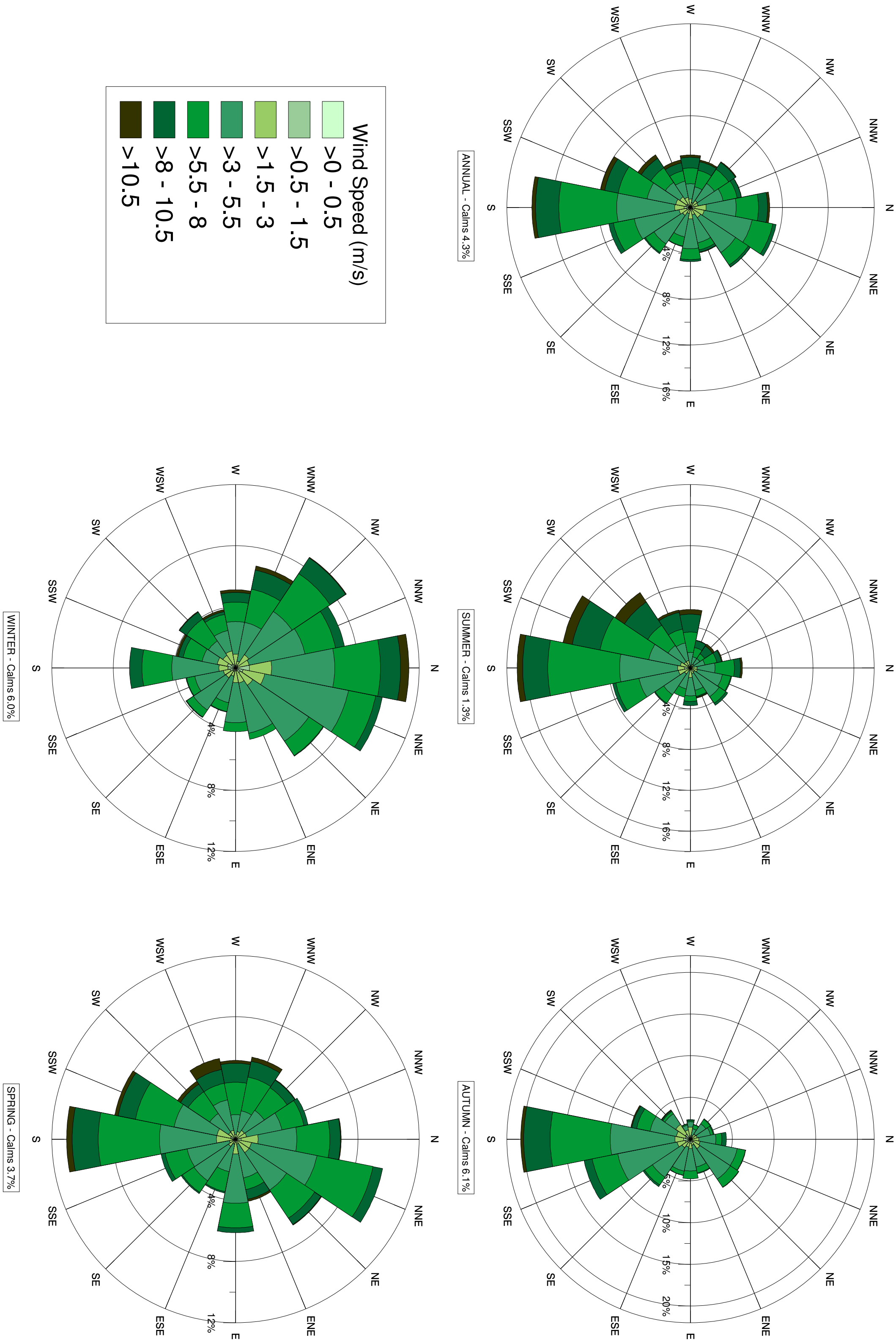
AERMOD	US-EPA Regulatory Atmospheric Dispersion Model AERMOD Version 09292
AMMAAP	Approved Methods for the Modelling and Assessment of Air Pollutants in NSW,
ATSDR	US Federal Agency for Toxic Substances and Disease Registry
BoM	Australian Bureau of Meteorology
BHOP	Broken Hill Operations Pty Ltd
CBH	CBH Resources Ltd
ML	Consolidated Mine Lease
DECCW	NSW Department of the Environment, Climate Change and Water
EETM	Emission Estimation Technique Manual
ENVIRON	ENVIRON Australia Pty Ltd
ESL	Effect Screening Level, issued by TARA
HVAS	High volume air sampler
IRIS	USEPA Integrated Risk Information System
ISCST3	Industrial Source Complex Short Term model, Version 3
LOAEL	Lowest observed adverse effect level
mg	Milligram (g x 10-3)
µg	Microgram (g x 10-6)
µm	Micrometre or micron (metre x 10-6)
m^3	Cubic metre
RL	Reference Level
RML	Minimum Risk Levels issued by ATSDR
Mtpa	Megatonnes per annum
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NOAEL	No observed adverse effect level
NPI	National Pollutant Inventory
OEHHA	California Office of Environmental Health Hazard Assessment
PM_{10}	Particulate matter less than 10microns in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5microns in aerodynamic diameter
REL	Reference Exposure Limits issued by the California OEHHA
RFC	Inhalation Reference Concentrations published by the USEPA IRIS
ROM	Run-of-Mine
TARA	Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division
TEOM	Tapered Element Oscillating Microbalance
The Project	The Rasp Mine expansion, Broken Hill
TSP	Total Suspended Particulate
USEPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled
WHO	World Health Organization

Appendices

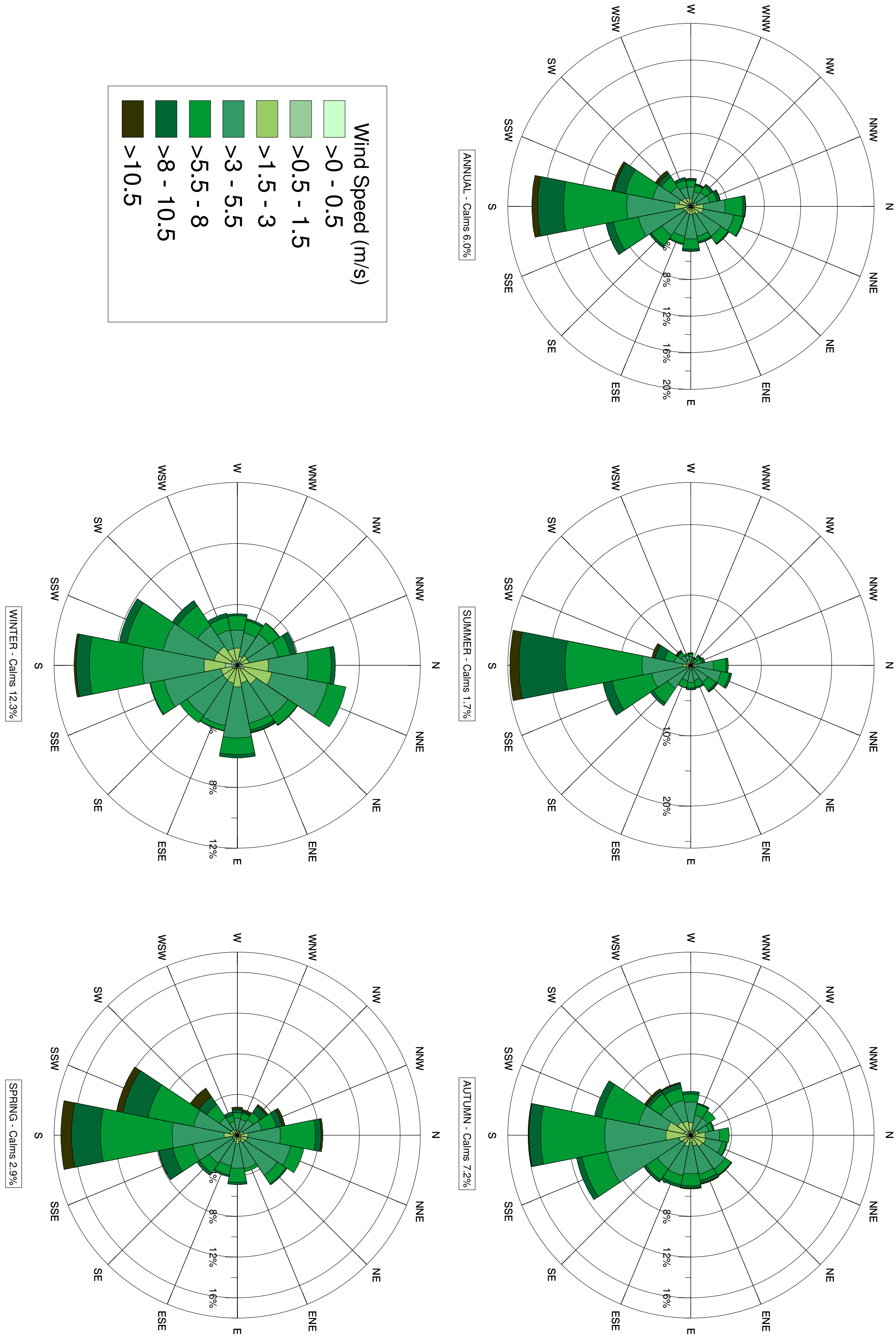
Appendix A	Wind Roses for BoM Broken Hill Airport AWS – 2005 to 2009
Appendix B	Project Emissions Inventory
Appendix C	Dispersion Modelling Methodology and Data Inputs
Appendix D	Incremental Suspended Particulate and Dust Deposition Contours (Construction and Operation)
Appendix E	Predicted Air Quality Indicator Concentrations and Deposition at Discrete Receptor Sites (Construction and Maximum Operations Scenarios)

Appendix A
Wind Roses for BoM Broken Hill Airport AWS – 2005 to 2009

2005


Wind Speed (m/s)
>0 - 0.5
>0.5 - 1.5
>1.5 - 3
>3 - 5.5
>5.5 - 8
>8 - 10.5
>10.5
ANNUAL - Calms 4.3%
WINTER - Calms 6.0%
SUMMER - Calms 1.3%
SPRING - Calms 3.7%
AUTUMN - Calms 6.1%

2006


Wind Speed (m/s)
>0 - 0.5
>0.5 - 1.5
>1.5 - 3
>3 - 5.5
>5.5 - 8
>8 - 10.5
>10.5
ANNUAL - Calms 6.0%
SUMMER - Calms 1.7%
WINTER - Calms 12.3%
AUTUMN - Calms 7.2%
SPRING - Calms 2.9%
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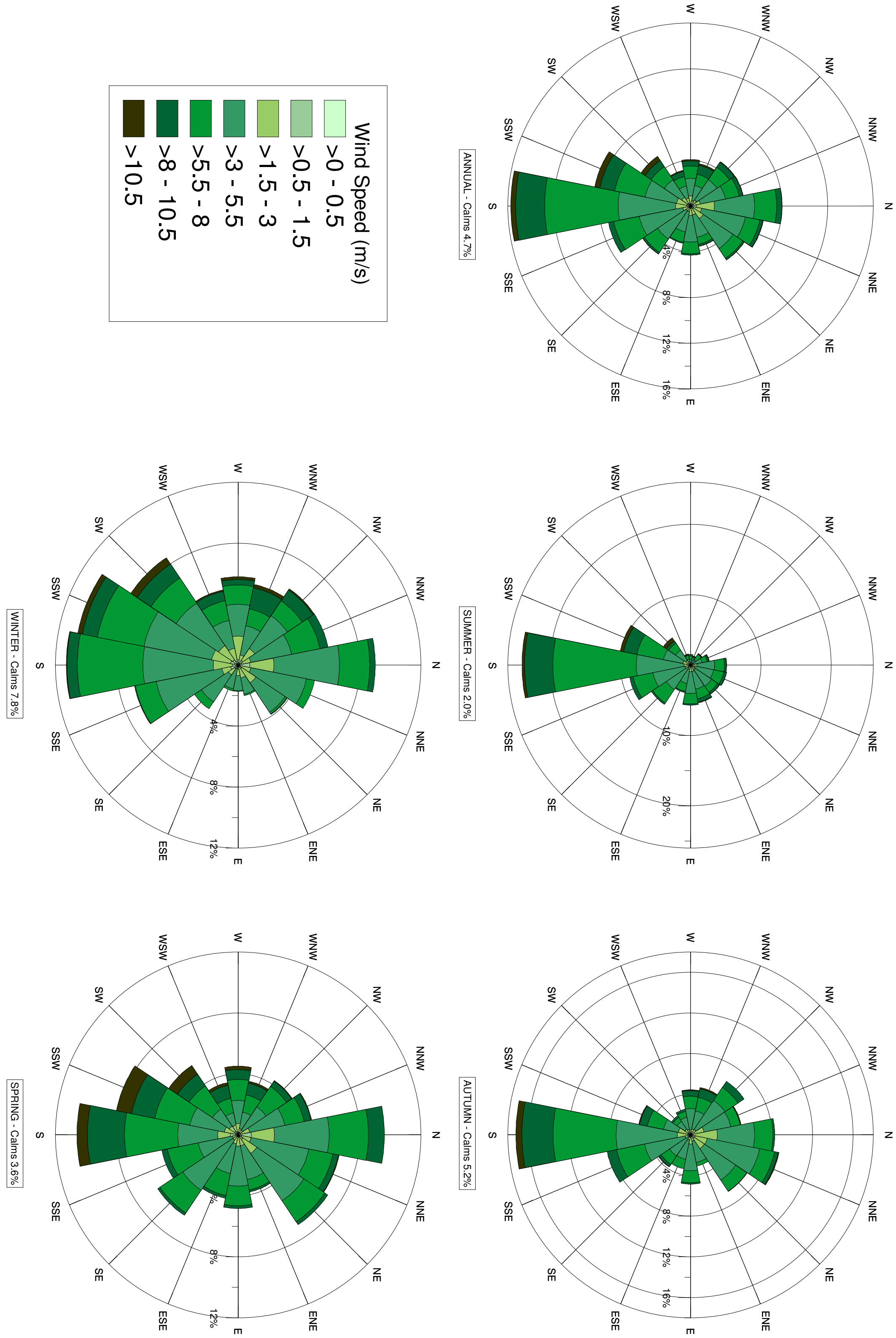
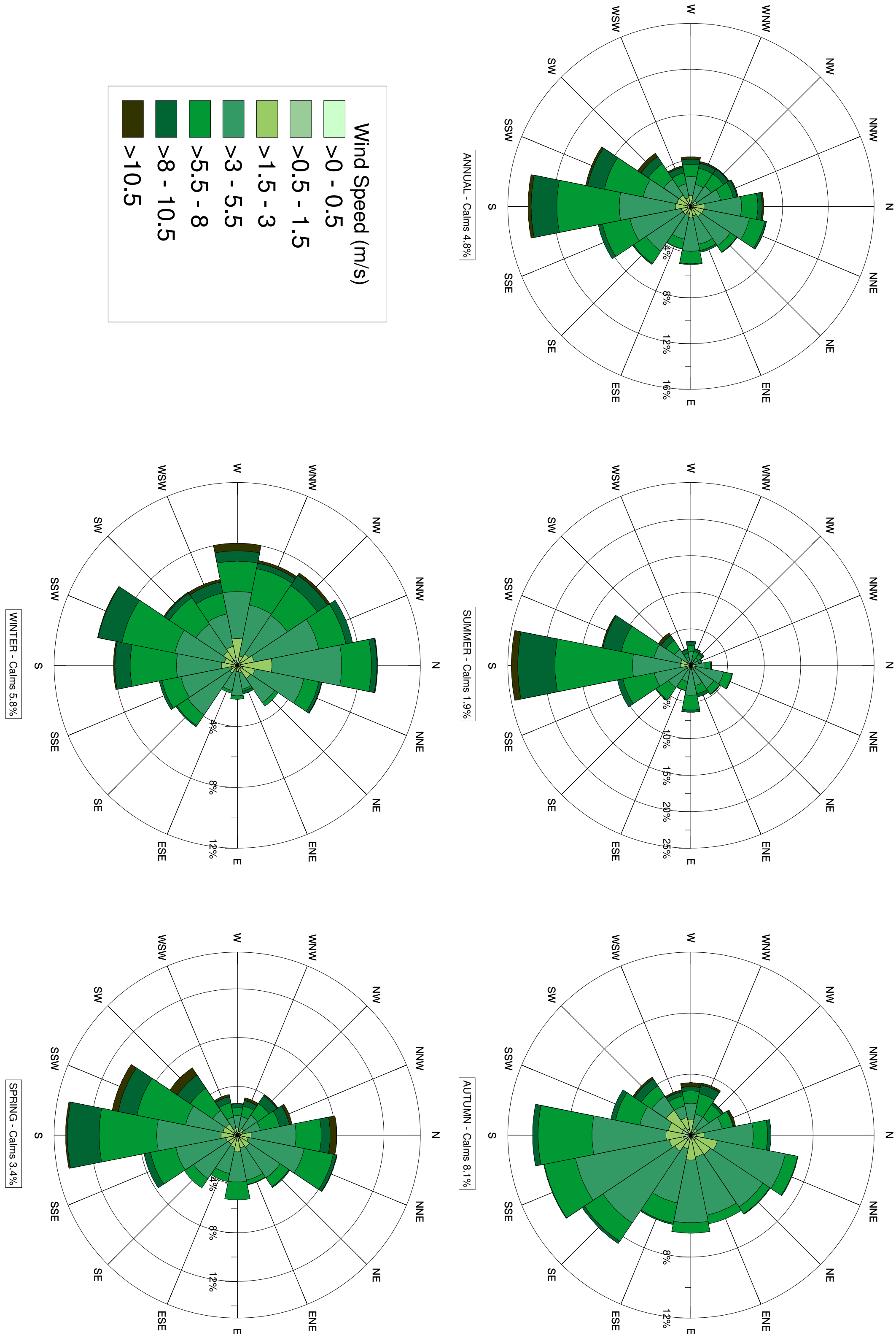
WSW
W
WNW
NW
NNW

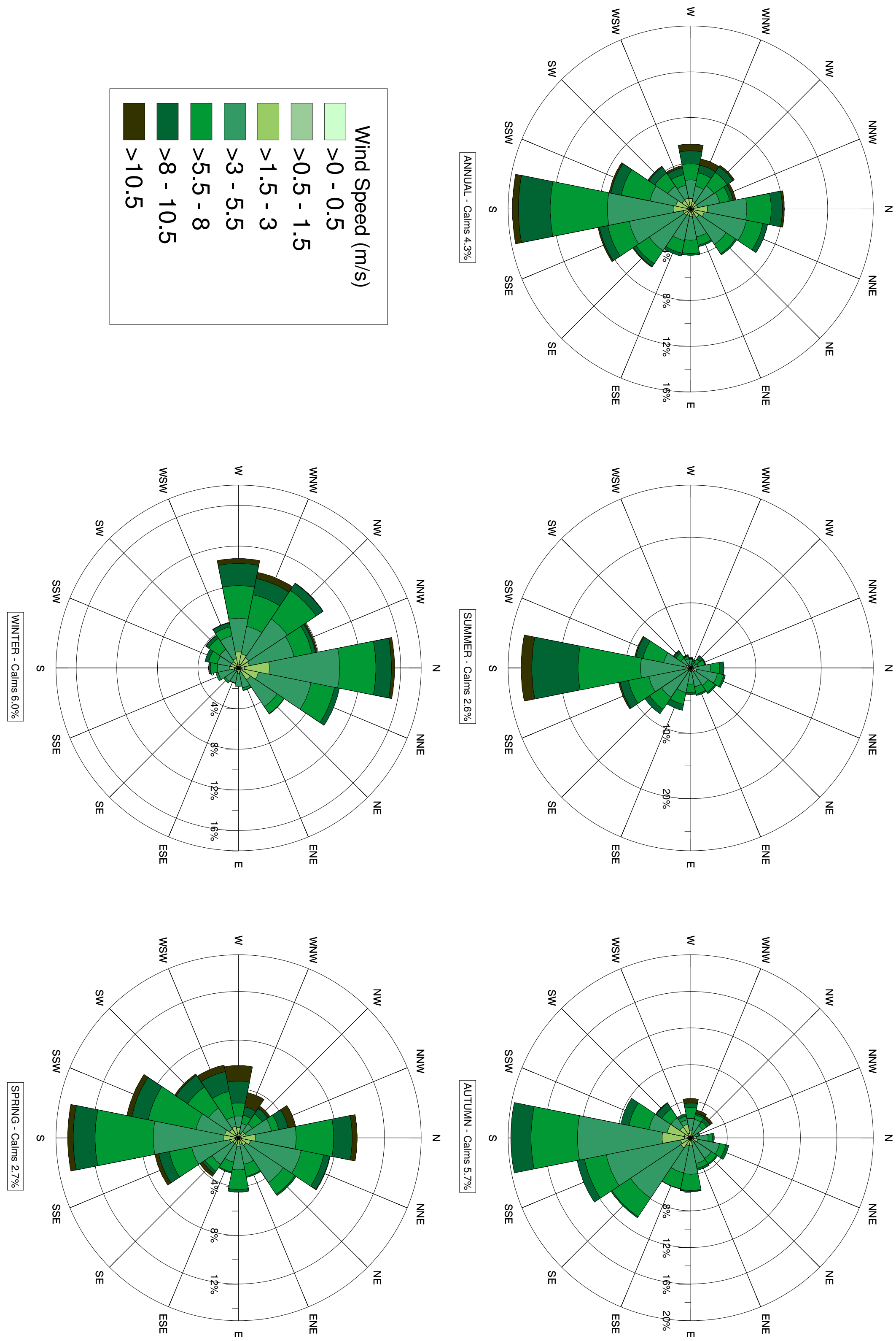
2007


Wind Speed (m/s)
>0 - 0.5
>0.5 - 1.5
>1.5 - 3
>3 - 5.5
>5.5 - 8
>8 - 10.5
>10.5
ANNUAL - Calms 4.7%
SUMMER - Calms 2.0%
WINTER - Calms 7.8%
AUTUMN - Calms 5.2%
SPRING - Calms 3.6%

2008


Wind Speed (m/s)
>0 - 0.5
>0.5 - 1.5
>1.5 - 3
>3 - 5.5
>5.5 - 8
>8 - 10.5
>10.5
ANNUAL - Calms 4.8%
SUMMER - Calms 1.9%
WINTER - Calms 5.8%
AUTUMN - Calms 8.1%
SPRING - Calms 3.4%

2009


Wind Speed (m/s)
>0 - 0.5
>0.5 - 1.5
>1.5 - 3
>3 - 5.5
>5.5 - 8
>8 - 10.5
>10.5
ANNUAL - Calms 4.3%
WINTER - Calms 6.0%
SUMMER - Calms 2.6%
SPRING - Calms 2.7%
AUTUMN - Calms 5.7%
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WSW
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WNW
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NNW

Appendix B
Construction and Operation Emissions Inventory and Source Locations

Construction Phase Source Group	Description	Source IDs	TSP Emission Factor	PM10 Emission Factor	PM2.5 Emission Factor	Emission Factor Units	Throughput (tonnes per hour)	VKT/day	Working days / Quarter	Working hours / day	TSP / Dust Deposition Emission Rate (t/quarter)	PM2.5 Emission Rate (t/quarter)	PM10 Emission Rate (t/quarter)
STKPILES	Temporary ROM stockpile next to crusher and Finished Product Ore Stockpile	ROM_PILE, PRODPILE	Temporally Varying - Wind Dependent			N/A	N/A	N/A	N/A	N/A	1.76	0.81	0.23
ORE+PROD	Ore and Product Haulage	UHAUL 14-17	2.354	0.566	0.057	kg/VKT	N/A	6	65	11	0.69	0.31	0.03
OREDELIV	ore delivery and empty truck return	UHAUL 18-25	2.354	0.566	0.057	kg/VKT			65	11	0.72	0.17	0.02
HAUL+DMP	ore delivery and empty truck return - Includes truck dumping at ROM stockpile	UHAuL 26	2.354	0.566	0.057	kg/VKT			65	11	0.16	0.05	0.01
PROD	Empty product truck and return full	UHAUL 27-28	2.354	0.566	0.057	kg/VKT			65	11	0.22	0.05	0.01
SER_VEHS	service vehicles	PROAD 3-11	0.679	0.130	0.019	kg/VKT			65	11	0.07	0.01	0.00
PROD+SRV	Empty product truck and return full plus service vehs	UHAUL29-33, UHAUL35-39	2.354	0.566	0.057	kg/VKT			65	11	1.65	0.41	0.04
PAVED	Empty product truck and return full plus service vehs - Paved	PROAD 1-2	2.792	0.535	0.077	kg/VKT			65	11	0.10	0.02	0.00
OREHAUL	Ore from pit and empty truck return	UHAUL 1-13	2.354	0.566	0.057	kg/VKT			65	11	0.69	0.31	0.03
FEL	FEL loading finished product ore into 50t trucks	FEL	0.001	0.001	0.000	kg/t			65	11	0.24	0.11	0.02
CRUSHER	Mobile Crusher fitted with Water Sprays	CRSHR	0.010	0.004	0.001	kg/VKT			65	8	1.25	0.50	0.08
EXCAV_P	Use of excavator for processing plant site development	EXCAV1	0.0019	0.0009	0.0001	kg/t			90	12	0.31	0.16	0.02
EXCAV_WR	Excavator to extract and load waste rock at decant dam for TSF construction	EXCAV2	0.0019	0.0009	0.0001	kg/t			90	12	0.34	0.16	0.02
HAUL_WR	Hauling waste rock from decant dam for TSF construction	TSFHAUL1-7	2.354	0.566	0.057	kg/VKT			90	12	4.03	0.97	0.10
HL_WR+DP	Hauling waste rock from decant dam for TSF construction plus rock dumping	TSFHAUL8-11	2.354	0.566	0.057	kg/VKT			90	12	3.14	0.91	0.11
EXCAV_L	Excavator loading mobile crusher	EXCAV3	0.0019	0.0009	0.0001	kg/t			65	8	0.24	0.11	0.02
VENT	Exhaust Ventilation to Delprat Shaft	DELPRATV	Sum of emission factors for all U/G mining activities withcontrol factor			N/A			90	24	0.15	0.12	0.02

Figure B1 Overview of Modelling Domain, Sources and Receptors – Construction Scenario

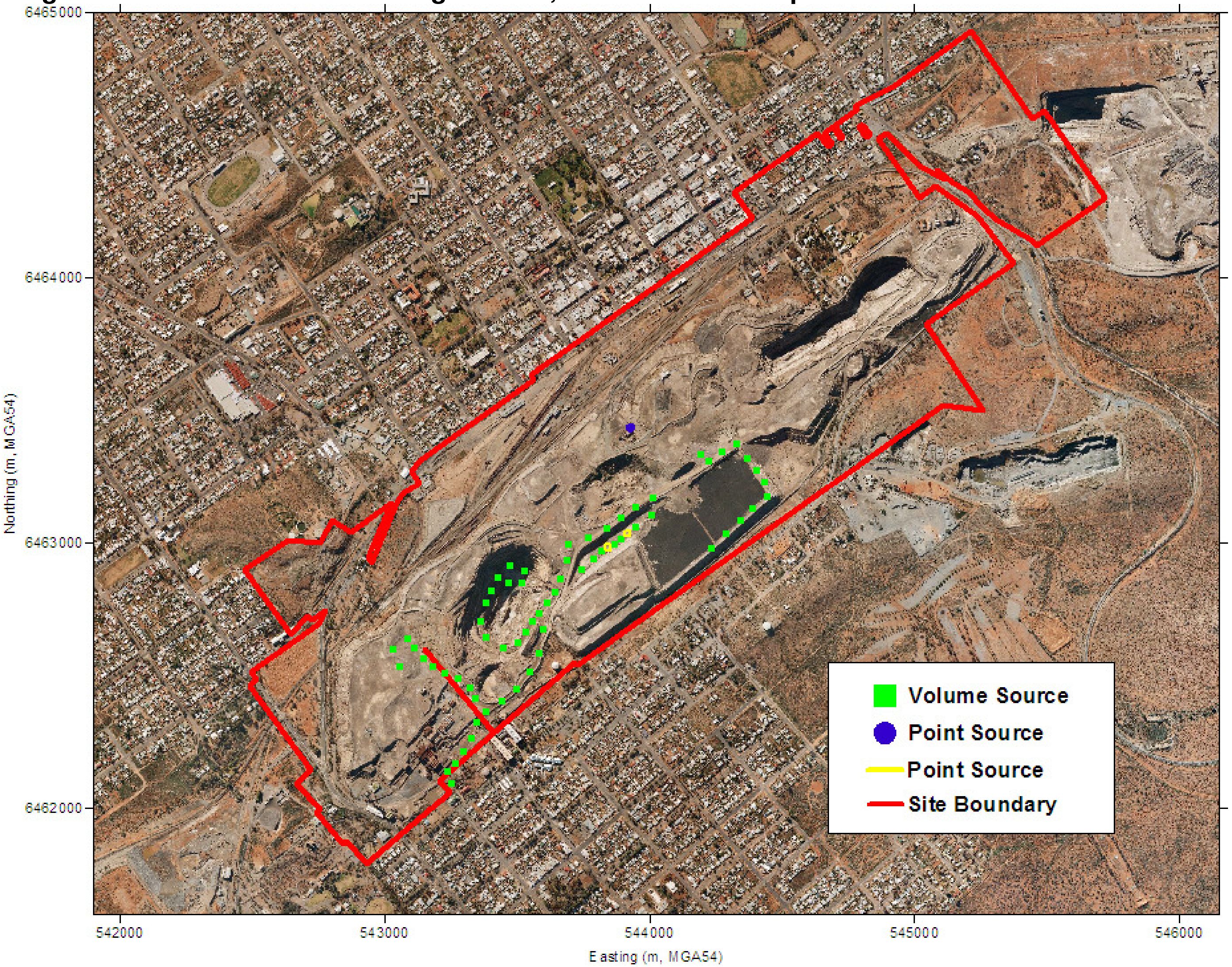

Figure B2 Overview of Modelling Domain, Sources and Receptors – Maximum Production Operations Scenario

Operational Phase Emissions

Unpaved Haul Road

Emissions from the unpaved haul road were modelled as 13 volume sources with the following dimensions: height (0.5m); lateral dimension (23.3 m); vertical dimension (0.5 m). The locations of the sources are shown in Figure B.2. Constant emission rates are given in Table B.1. Total emissions across all individual sources are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Paved Haul Road

Emissions from the paved haul road were modelled as 20 volume sources with the following dimensions: height (0.5m); lateral dimension (23.3 m); vertical dimension (0.5 m). The locations of the sources are shown in Figure B.2. Constant emission rates are given in Table B.1. Total emissions across all individual sources are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Other Paved Roads

Emissions from other paved roads (other than the main haul road) were modelled as 23 volume sources with the following dimensions: height (0.5m); lateral dimension (23.3 m); vertical dimension (0.5 m). The locations of the sources are shown in Figure B.2. Constant emissions rates are given in Table B.1. Total emissions across all individual sources are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Project-Related Free Areas

Wind entrained emissions from Project-related free areas were simulated as 134 volume sources with the following dimensions: height (0.25m); lateral dimension (2.3 m); vertical dimension (0.2 m). The locations of the sources are shown in Figure B.2. Hourly-varying PM_{10} emissions rates used are illustrated in Figure B.3. Total emissions across all individual sources are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Ore Handling (FEL Activity; Truck Dumping)

Summed emissions from FEL activity and truck dumping at the ROM Pad were simulated as 3 volume sources with the following dimensions: height (1.5m); lateral dimension (1.2 m); vertical dimension (1.4 m). The location of this source is shown in Figure B.2. Constant emissions rates are given in Table B.1. Total emissions are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Concentrate Handling

Emissions from concentrate handling were modelled as a volume source with the following dimensions: height (1.5 m); lateral dimension (1.2 m); vertical dimension (1.4 m). The location of the source is shown in Figure B.2. Constant emissions rates are given in Table

B.1. Total emissions are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Ventilation Shaft

The ventilation shaft was modelled as a horizontal point source with dimensions as follows: stack height 1.5 m; stack velocity 10 m/s; equivalent stack diameter 6.2 m; ambient temperature assumed. The location of the source is shown in Figure B.2. Constant emissions rates are given in Table B.1. Total emissions are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

ROM Ore Pile

Wind entrained emissions from the ore pile was simulated as a single area source with the following dimensions: height (5 m); length (80 m); width (32 m). The location of the source is shown in Figure B.2. Hourly-varying emissions rates used are illustrated in Figure B.4. Total emissions across all individual sources are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Tailings Storage Facility Cell 1 (TSF1)

TSF1 was simulated as a complex (multi-sided) area source at a height above ground of 6 m. The location of the source is shown in Figure B.2. Hourly-varying PM_{10} emissions rates used are illustrated in Figure B.5. Total emissions are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Baghouse Stack

The baghouse stack was modelled as a point source with dimensions as follows: stack height 15 m; stack velocity 10 m/s; stack diameter 1 m; stack exit temperature 290K. The location of the source is shown in Figure B.2. Constant emissions rates are given in Table B.1. Total emissions are given in the Emissions Inventory Section of the current report. Particles were assumed to primarily be within the PM2.5 size range.

Existing Free Areas

Wind entrained emissions from Project-related free areas were simulated as 117 volume sources with the following dimensions: height (0.25m); lateral dimension (2.3 m); vertical dimension (0.2 m). The locations of the sources are shown in Figure B.2. Hourly-varying PM_{10} emissions rates used are illustrated in Figure B.6. Total emissions across all individual sources are given in the Emissions Inventory Section of the current report. Particle size distribution data are given in Table B.2.

Table B.1: Constant emission rates for operation phase sources

Source	TSP	PM10	PM2.5	Units	Hours/Day
Unpaved Haul Road	0.02756	0.00663	0.00862	g/s	24 hrs/day
Paved Haul Road	0.02474	0.00474	0.01360	g/s	24 hrs/day
Other Paved Roads	0.00400	0.00077	0.00253	g/s	24 hrs/day
Ore Handling	0.16546	0.07826	0.01183	g/s	24 hrs/day
Concentrate Handling	0.00107	0.00051	0.00008	g/s	07h00 - 18h00
Ventilation Shaft	0.12203	0.09223	0.02897	g/s	24 hrs/day
Baghouse Stack	0.09513	0.09513	0.09513	g/s	07h00 - 18h00
General Vehicle Travel over Site	0.00238	0.00087	0.01170	g/s	24 hrs/day

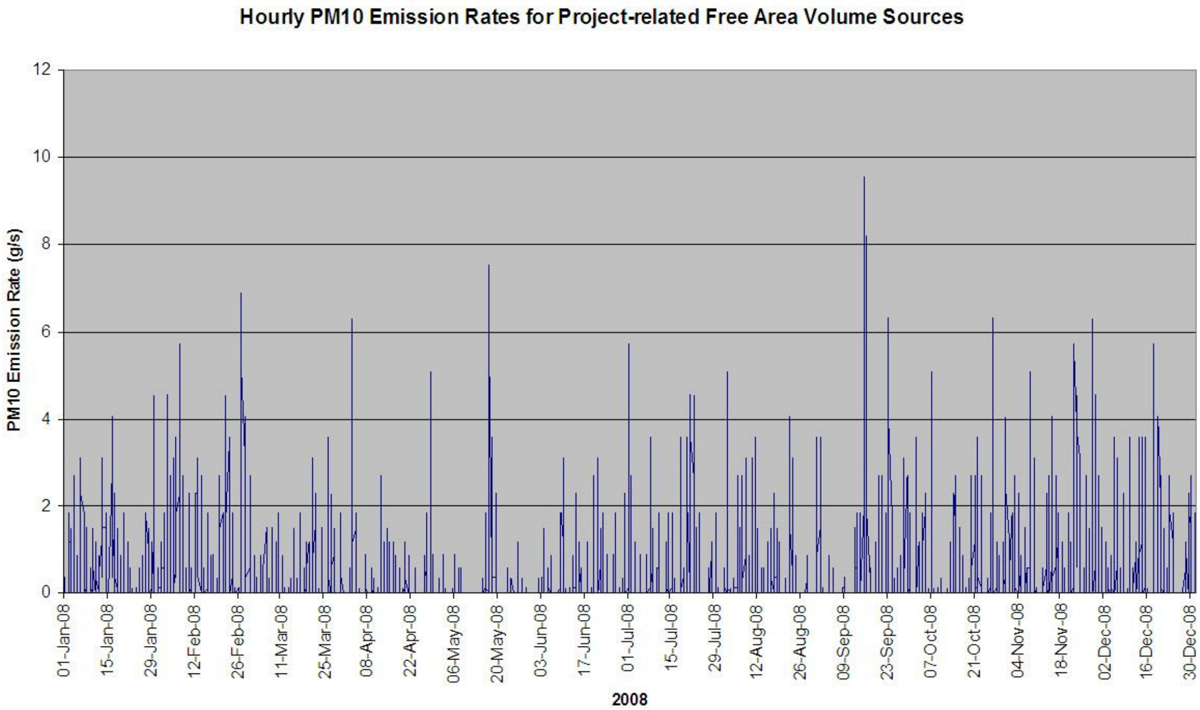

Figure B.3 Hourly variable PM10 emission rates for Project-related Free Areas, as illustrated for 2008.

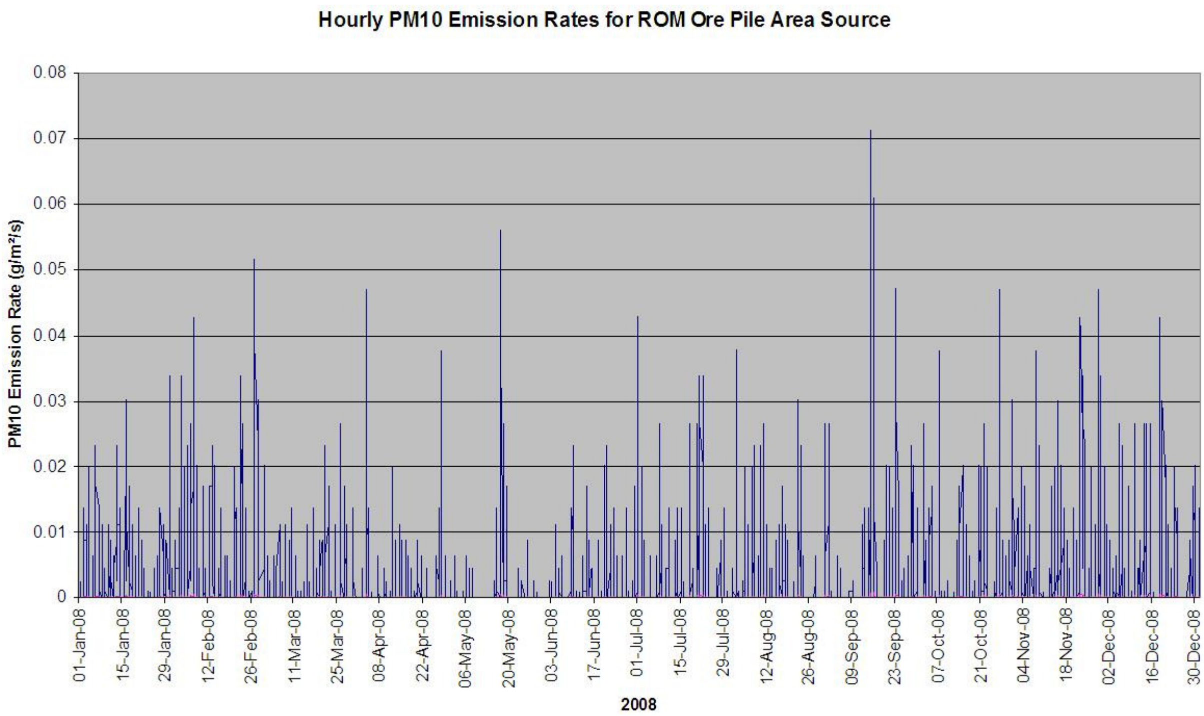

Figure B.4 Hourly variable PM10 emission rates for ROM Ore Pile, as illustrated for 2008.

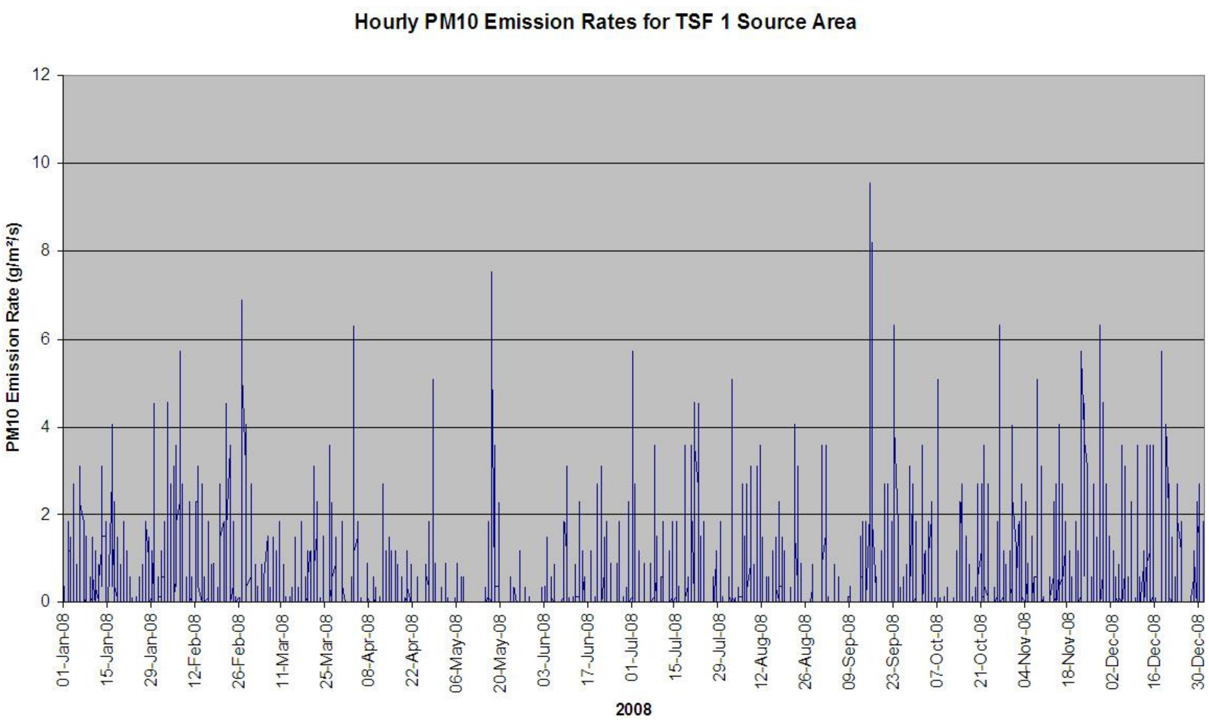

Figure B.5 Hourly variable PM10 emission rates for TSF1 (active, dry area), as illustrated for 2008.

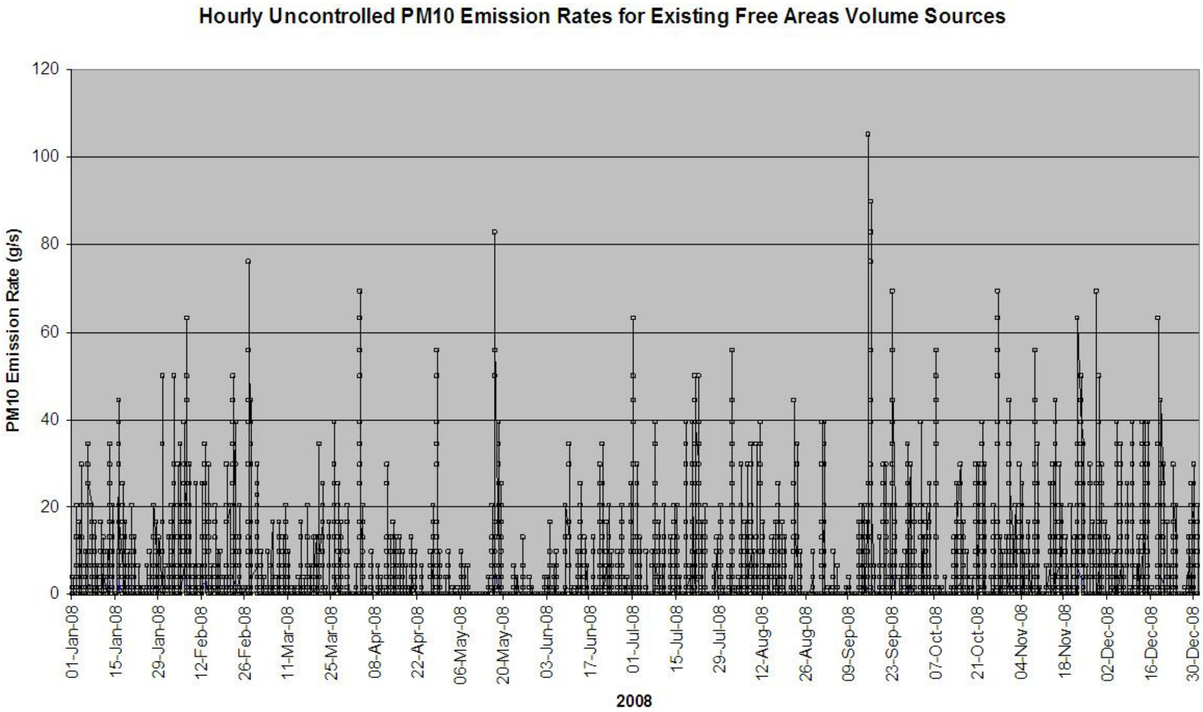

Figure B.6 Hourly variable PM10 emission rates for Existing Free Areas (uncontrolled), as illustrated for 2008.

Table B.3: Particle Size Distributions for Operation Phase Sources					
	Particle Size as Fraction of Total PM Emissions				
	PM30	PM15	PM10	PM5	PM2.5
TSF1	0.39	0.26	0.18	0.11	0.06
Paved Roads	0.69	0.16	0.131		0.019
Unpaved Roads	0.75		0.23		0.02
FEL Activity	0.644		0.31		0.046
Wind erosion sources(a)	0.46	0.28	0.23		0.03
Materials Handling	0.65		0.31		0.04

(a) Includes ROM Ore Pile, Existing Free Area, Project Related Free Areas

Appendix C
Dispersion Modelling Methodology and Data Inputs

Dispersion Model Selection and Application

Dispersion models compute ambient concentrations and deposition rates as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations. Knowledge of spatial and temporal variations in pollutant concentrations is essential for the assessment of the potential which exists for non-compliance with ambient air quality limits and for impact on human health and the biophysical environment.

Given the nature of the source and the local environment, AERMOD was selected for application in the prediction of ambient particulate concentrations and dust deposition rates occurring due to the Rasp Mine construction and operation-related emissions. AERMOD is the US-EPA's recommended steady-state plume dispersion model for US regulatory purposes. AERMOD is designed to handle a variety of pollutant source types, including surface and buoyant elevated sources, in a wide variety of settings such as rural and urban as well as flat and complex terrain(3). Source types for which AERMOD is able to predict pollutant concentrations include point, area and volume sources in addition to 'open pit' sources.

AERMOD replaced the Industrial Source Complex (ISC) model for regulatory purposes in the US in December 2006 as it provides more realistic results with concentrations that are generally lower and more representatives of actual concentrations compared to the conservative ISC model. Ausplume, a steady state Gaussian plume dispersion model developed by the Victorian EPA and frequently used in Australia for simple near-field applications.

Compared to ISC and Ausplume, AERMOD represents an advanced new-generation model which requires additional meteorological and land use inputs to provide more refined predictions. The most important feature of AERMOD, compared to ISC and Ausplume, is its modification of the basic dispersion model to account more effectively for a variety of meteorological factors and surface characteristics. In particular it uses the Monin-Obukhov length scale rather than Pasquill-Gifford stability categories to account for the effects of atmospheric stratification. Whereas Ausplume and ISC parameterise dispersion based on semi-empirical fits to field observations and meteorological extrapolations, AERMOD uses surface-layer and boundary-layer theory for improved characterisation of the planetary boundary layer turbulence structure.

Verification studies have been undertaken for AERMOD both locally and abroad (Hanna *et al.,* 2001*;* Perry *et al*., 2005; Hurley 2006). Hanna *et al.* (2001) concluded that AERMOD performed better than ISC with predictions generally within a factor of two of actual values. It was noted that AERMOD did tend to under-predict actual concentrations by 20% to 40%, with predictions more accurate for short-term averaging periods. Perry *et al.* (2005) summarises the performance of AERMOD across 17 field study databases placing emphasis on statistics that demonstrate the model's abilities to reproduce the upper end of the concentration distribution which are of importance in terms of regulatory modelling. The

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3 Under complex wind conditions and for regional applications, CALPUFF is the US-EPA's recommended model for regulatory purposes.

field studies include flat and complex terrain cases, urban and rural conditions and elevated and surface releases with and without building wake effects. Perry et al. (2005) concludes that, with few exceptions AERMOD's performance was superior to that of the other applied models tested.

Hurley (2006) compared the performance of Ausplume, AERMOD and TAPM across several case studies including flat terrain, flat terrain with building downwash, in complex terrain and coastal terrain. AERMOD was determined to perform acceptably for all of the datasets but was found unable to simulate shoreline fumigation in the case of the Kwinana case study. This potential limitation of AERMOD is not relevant to this Project due to nature of the location.

AERMET Meteorological Modelling

The AERMOD system is composed of two pre-processors that generate the input files required by the AERMOD dispersion model: AERMET (for the preparation of meteorological data) and AERMAP (for the preparation of terrain data. Terrain data for the modeling domain was sourced from NASA's Shuttle Radar Topography Mission (SRTM) Data. This data set provides high-resolution topography at 3 arc-second (~90m) grid spacings.

AERMET produces data characterising the planet boundary layer (PBL) such as friction velocity, mixing height. Inputs in the AERMET modeling are described below.

Surface Characteristics

In applying the AERMET meteorological processor to prepare the meteorological data for the AERMOD model appropriate values for three surface characteristics need to be determine, viz.: surface roughness length, albedo, and Bowen ratio. The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

Aerial photographs and site observations were used to define the land use and associated effective surface roughness on a sector-by-sector basis within a 1km radius around the Broken Hill Airport meteorological station. Values of Bowen ratio and albedo were determined over a greater domain (10 km by 10 km) centered on the Broken Hill Airport meteorological station as recommended. Desert scrubland prevailed within proximity to the Station. Reference was made to the AERMET user's guide (EPA, 2004) and to Sturman and Tapper (2006) in assigning surface roughness, Bowen ratio and albedo values to designated land cover categories.

The land use values of surface roughness, Albedo and Bowen rations are tabulated below. The Bowen ratio was calculated assuming dry conditions. Surface roughness has been allocated consistent with a desert scrubland setting.

Month	Surface Roughness	Albedo	Bowen
Jan	0.3	0.45	6.0
Feb	0.3	0.45	6.0
Mar	0.3	0.3	3.0
Apr	0.3	0.3	3.0
May	0.3	0.3	3.0
Jun	0.3	0.28	4.0
Jul	0.3	0.28	4.0
Aug	0.3	0.28	4.0
Sep	0.3	0.28	6.0
Oct	0.3	0.28	6.0
Nov	0.3	0.28	6.0
Dec	0.3	0.45	6.0

Meteorological Inputs

AERMET typically requires surface and upper air meteorological data as input. The Breeze version of AERMET facilitates the input of UK-ADMS meteorological data without the need for upper air data due to this package incorporating the PBLAER module. PBLAER computes mixing heights in the absence of upper air sounding data, using a semi-empirical method to estimate the surface similarity parameters of friction velocity, sensible heat flux, temperature scale and Monin-Obukhov length using the routinely collected meteorological variables of cloud cover, ceiling height, wind speed, temperature and estimates of surface roughness (Trinity Consultants, 2007). Surface meteorological data for the modeling period (January 1 2008 to December 31 2009) from the Broken Hill Airport meteorological station were formatted in ADMS format for input to AERMET.

AERMET Outputs

AERMET calculates planetary boundary layer parameters, including: friction velocity, Monin-Obukhov length, convective velocity scale, temperature scale, mixing height and surface heat flux based on the input meteorological data. These parameters are used, in conjunction with measurements, to calculate vertical profiles of wind speed, lateral and vertical turbulent fluctuations, potential temperature gradient and potential temperature based on similarity theory.

AERMET outputs two files: a surface data file and a profile data file for input to AERMOD (US-EPA, 2004).

AERMOD Dispersion Modelling

Input data types required for the AERMOD model include: meteorological data (from AERMET), source data (from the emissions inventory compiled), and information on the nature of the receptor grid.

Meteorological Inputs

The AERMET generated meteorological files were used as input in the dispersion simulations.

Source and Emissions

Emissions estimated for the Project, as documented in **Section 7** and **Appendix B**, were simulated using a mixture of volume and area sources. Hourly varying TSP, PM_{10} and $PM_{2.5}$ emission files generated during the emissions inventory were input in the dispersion modelling to facilitate dust deposition rates (in the case of TSP emissions) and suspended PM_{10} and $PM_{2.5}$ concentrations.

Receptor Grid and Discrete Receptors

The dispersion of pollutants was modelled for an area covering 5km (east – west) and 4km (north – south). Gridded receptor points were specified at intervals of 200m, with discrete receptor points also being specified for selected sensitive receptor as summarised in **Section 2.6**.

Ground-level concentrations and deposition rates were simulated for the gridded receptors for use in the generation of contour plots to demonstrate spatial variations in pollutant concentrations/deposition rates. Model outputs for discrete receptor points were used in the compliance assessment of cumulative levels.

Model Results

Dispersion simulations were undertaken and results analysed for annual average Total Suspended Particulate (TSP) and dust deposition and highest 24-hour and annual average PM_{10} and $PM_{2.5}$ concentrations. Results were presented as contour plots (Ref **Appendix D**), illustrating spatial variations in particulate concentrations and dust deposition, and tabulated results for discrete receptor points (Refer **Appendix E**).

Model Accuracy

Base on the findings of the verification studies it is expected that AERMOD will perform well in the current case, particularly given the near-field and moderately flat terrain of the application. AERMOD predictions are likely to be within 20% of actual peak concentrations and within 40% of longer-term averages.

The accuracy of model predictions is dependent on model suitability, the accuracy of the emissions and meteorological data use and the complexity of the terrain and is typically in the range of -50% to 200%. Considering the ratings of the emission factors applied, the high level of meteorological data availability, the uncomplicated nature of the local terrain and the capabilities of the dispersion model selected, the level of uncertainty in the model predictions is estimated to be well within the typical range. Model performance and accuracy was taken into account in the air quality assessment.

Appendix D
Incremental Suspended Particulate and Dust Deposition Contour Plots (Construction and Operation)

Figure D1 Construction – Maximum Predicted Incremental 24 Hour Average PM_{10} Concentrations ($\mu g/m^3$) Criterion = $50\mu g/m^3$ (cumulative)

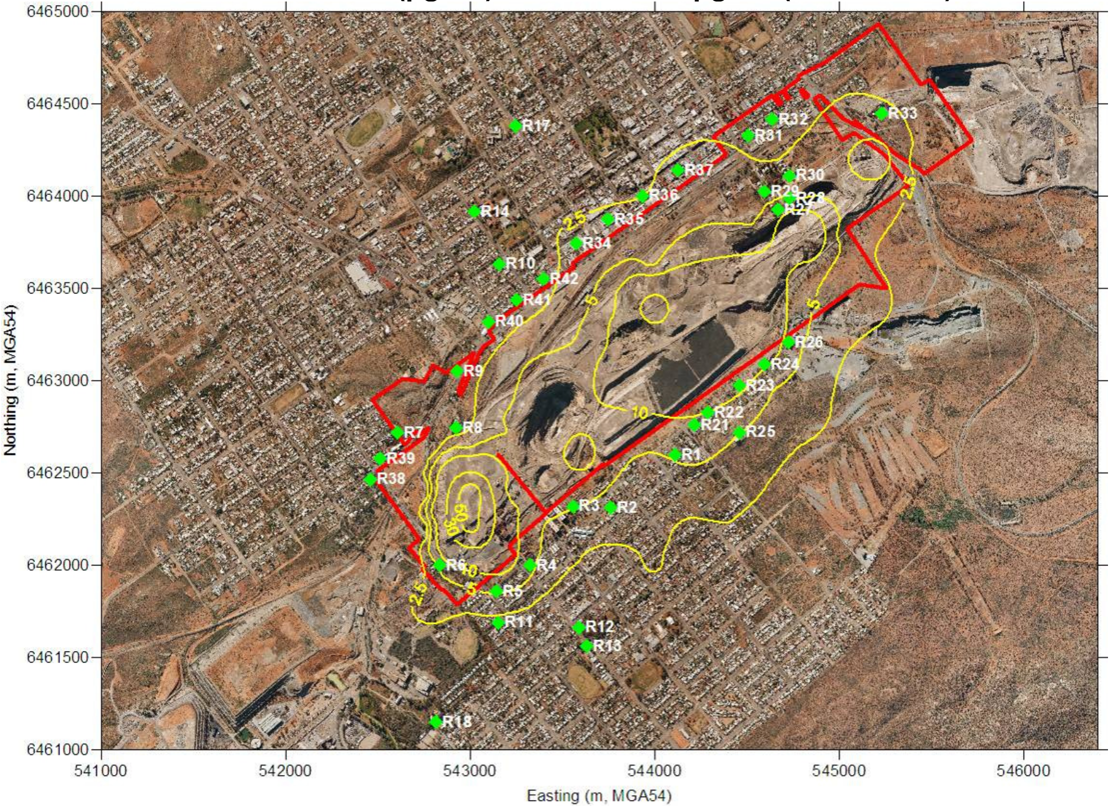


Figure D2 Construction – Predicted Incremental Annual Average PM_{10} Concentrations ($\mu g/m^3$) Criterion = $30\mu g/m^3$ (cumulative)

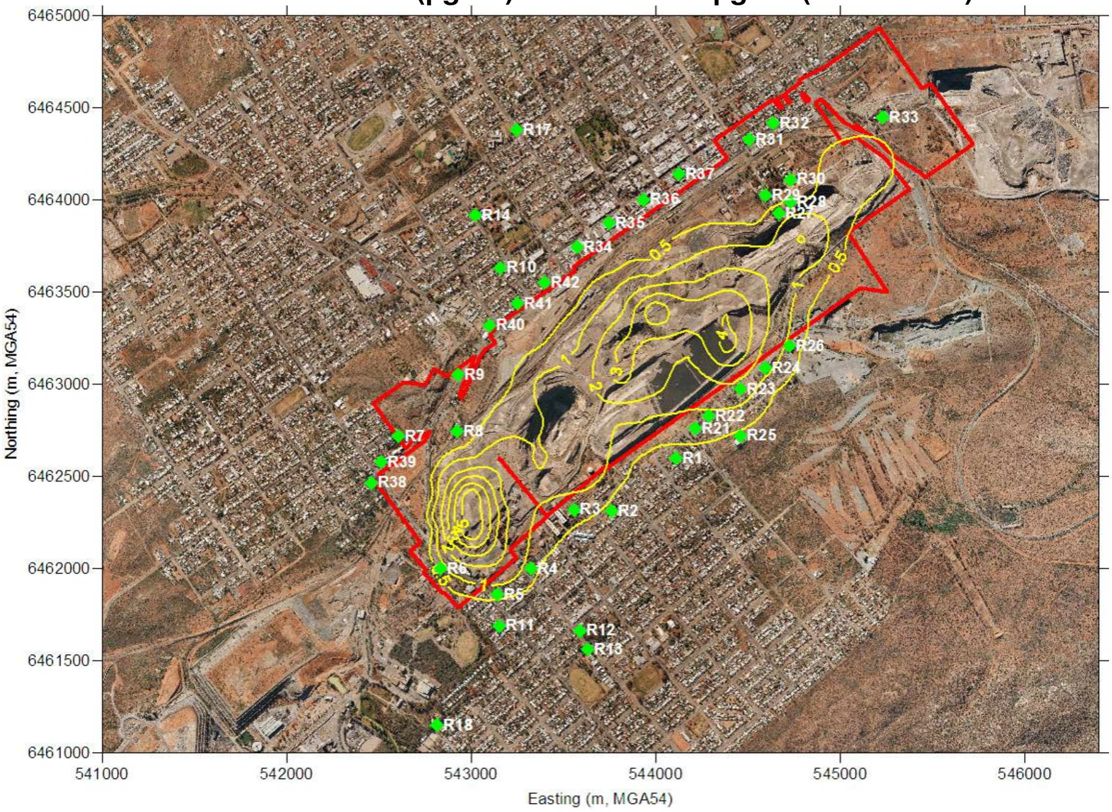


Figure D3 Construction – Maximum Predicted Incremental 24 Hour Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) Criterion = $25\mu g/m^3$ (cumulative)

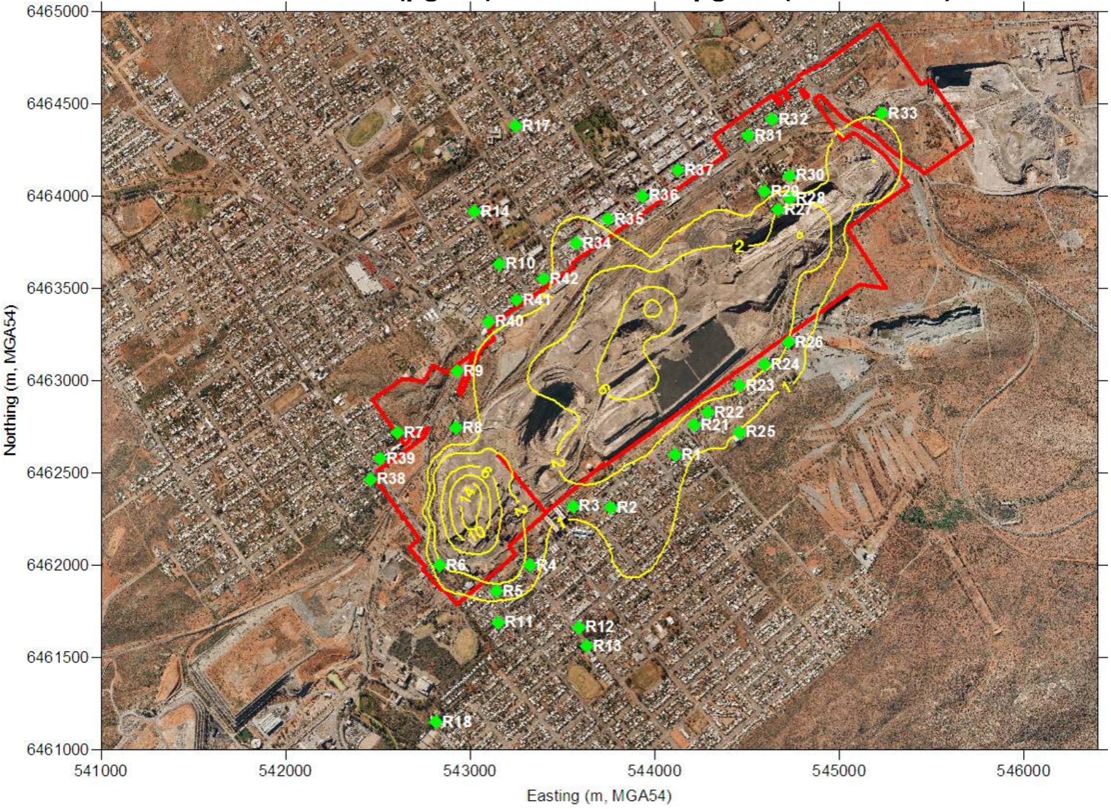


Figure D4 Construction – Predicted Incremental Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) Criterion = $8\mu g/m^3$ (cumulative)

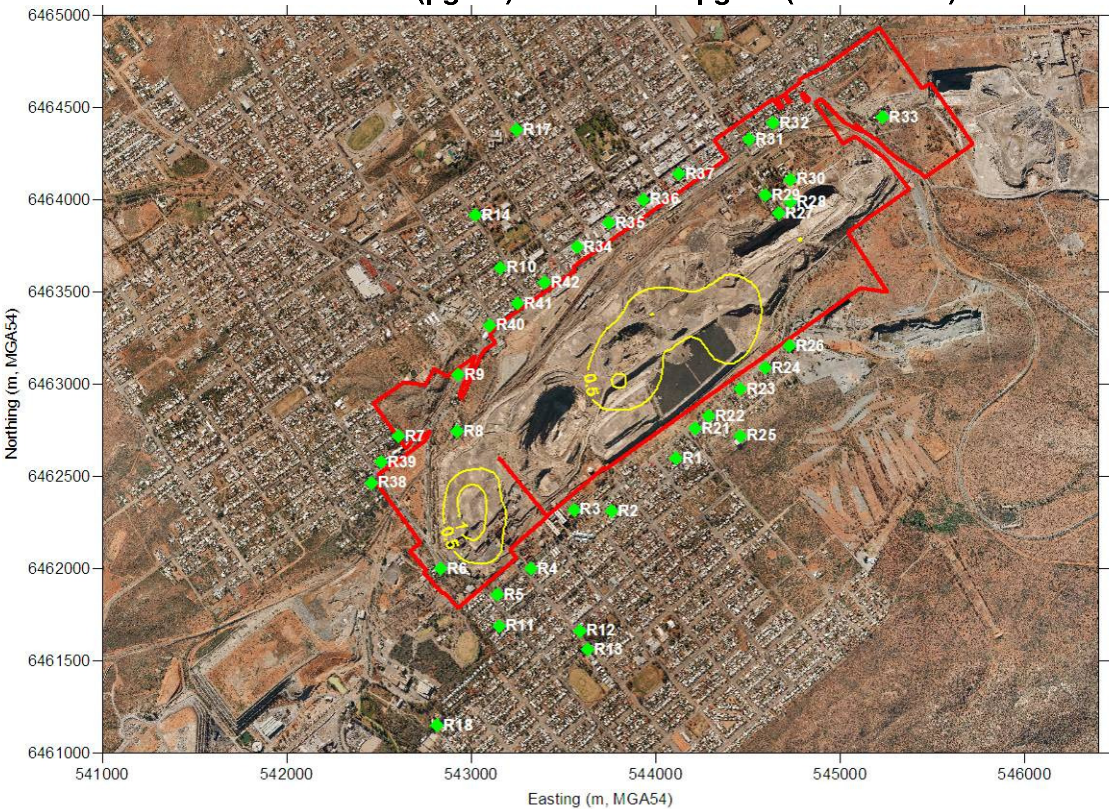


Figure D5 Construction –Predicted Incremental Annual Average TSP Concentrations (µg/m^3) Criterion = 90µg/m^3 (cumulative)

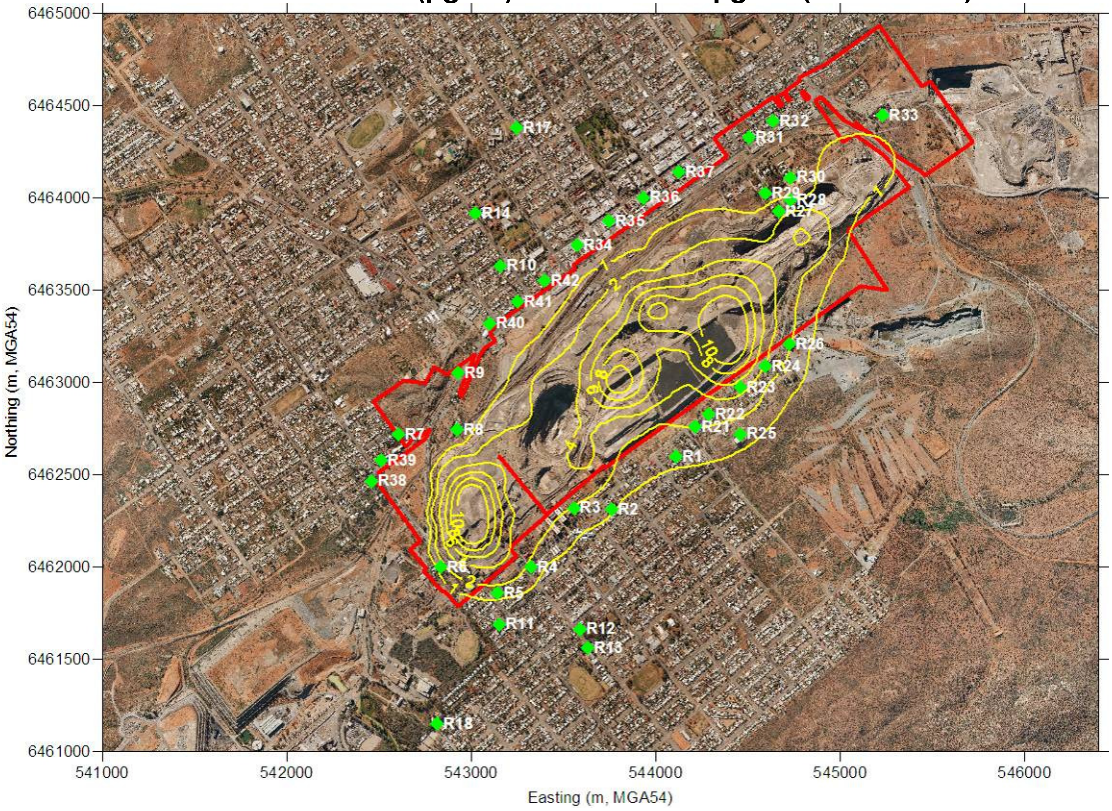


Figure D6 Construction –Predicted Incremental Dust Deposition (g/m^2/month) Criterion = 2g/m^2/month (incremental)

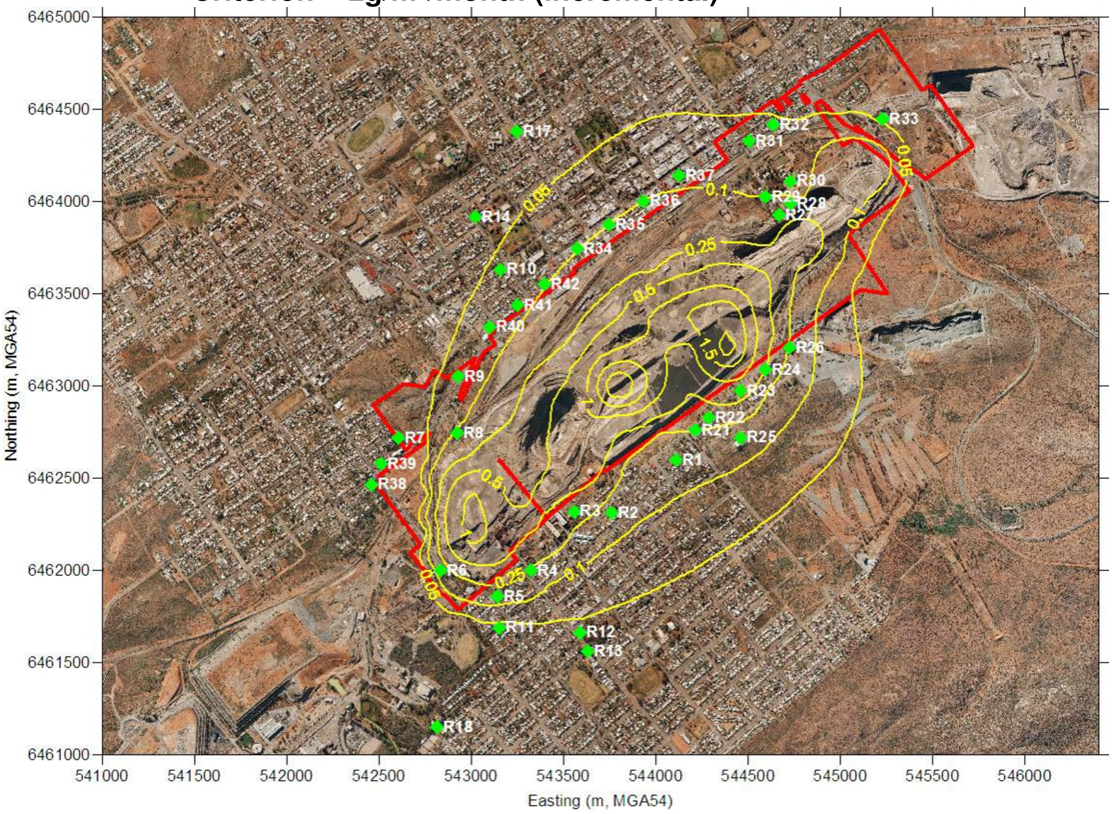


Figure D7 Operation (Project Increment) – Maximum Predicted 24 Hour Average PM_{10} Concentrations ($\mu g/m^3$) Criterion = $50\mu g/m^3$

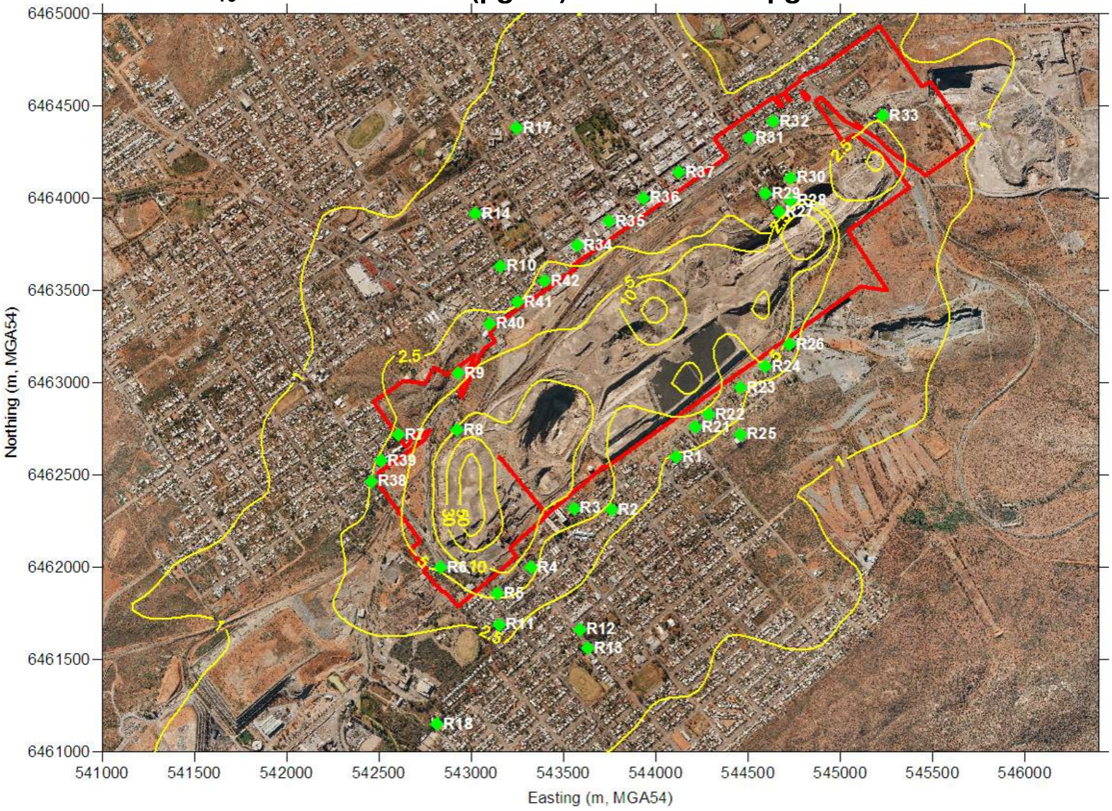


Figure D8 Operation (Project Increment) –Predicted Annual Average PM_{10} Concentrations ($\mu g/m^3$) Criterion = $30\mu g/m^3$ (cumulative)

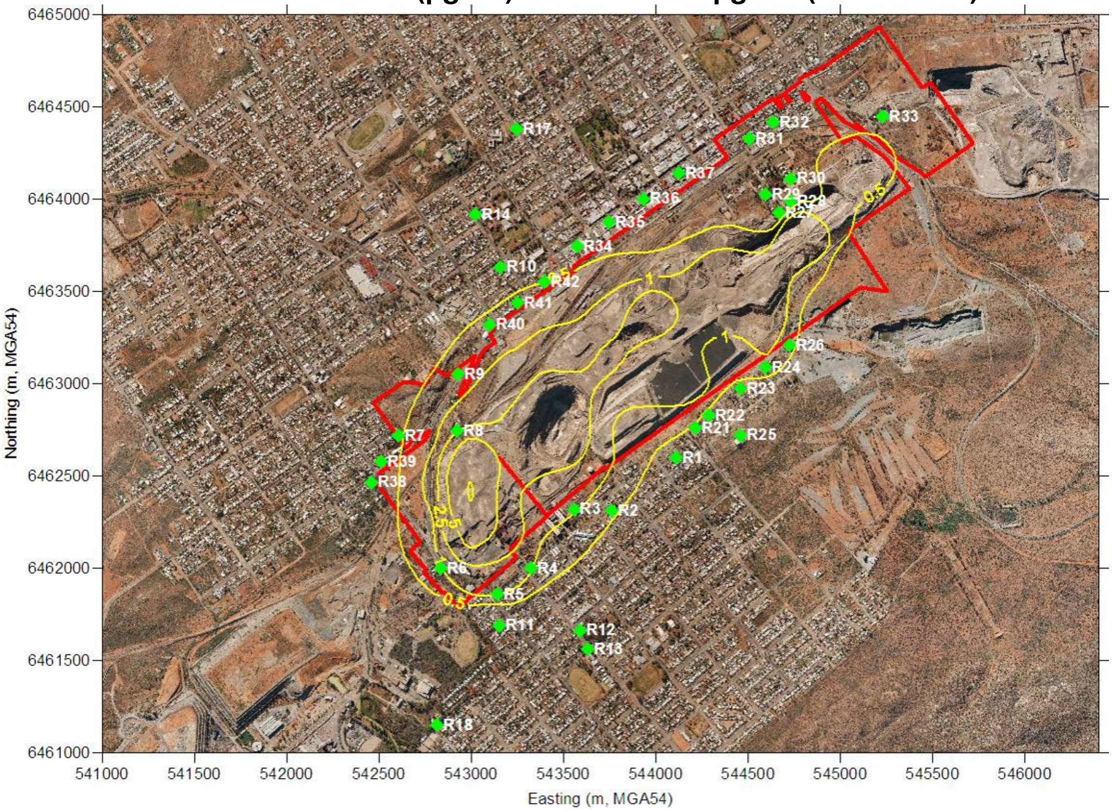


Figure D9 Operation (Project Increment) – Maximum Predicted 24 Hour Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) Criterion = 25µg/m³ (cumulative)

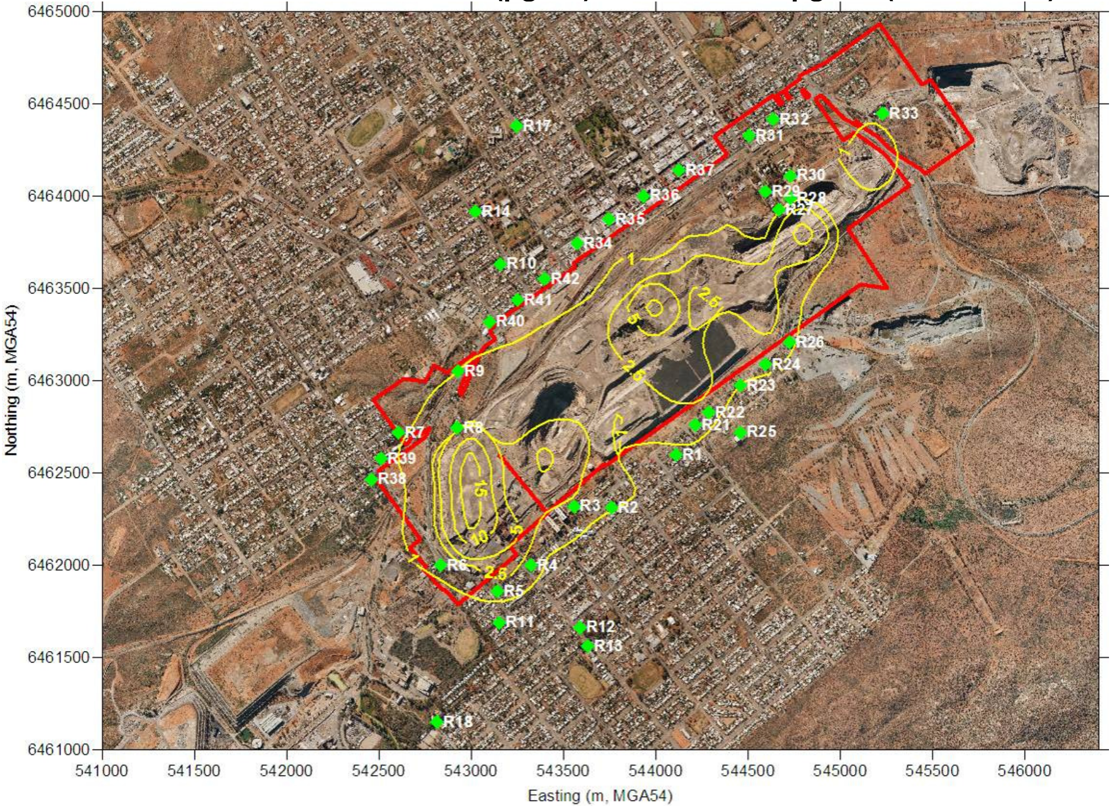


Figure D10 Operation (Project Increment) – Predicted Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) Criterion = 8µg/m³ (cumulative)

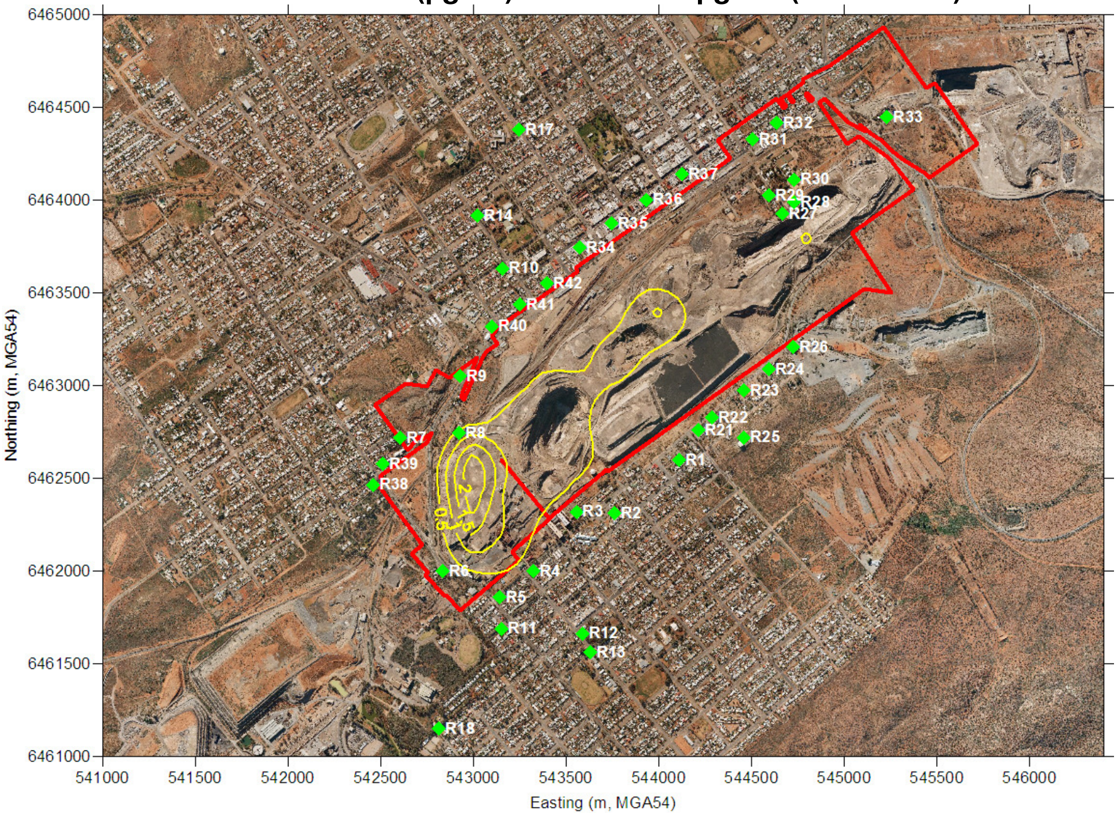


Figure D11 Operation (Project Increment) – Predicted Annual Average TSP Concentrations (µg/m³) Criterion = 90µg/m³ (cumulative)

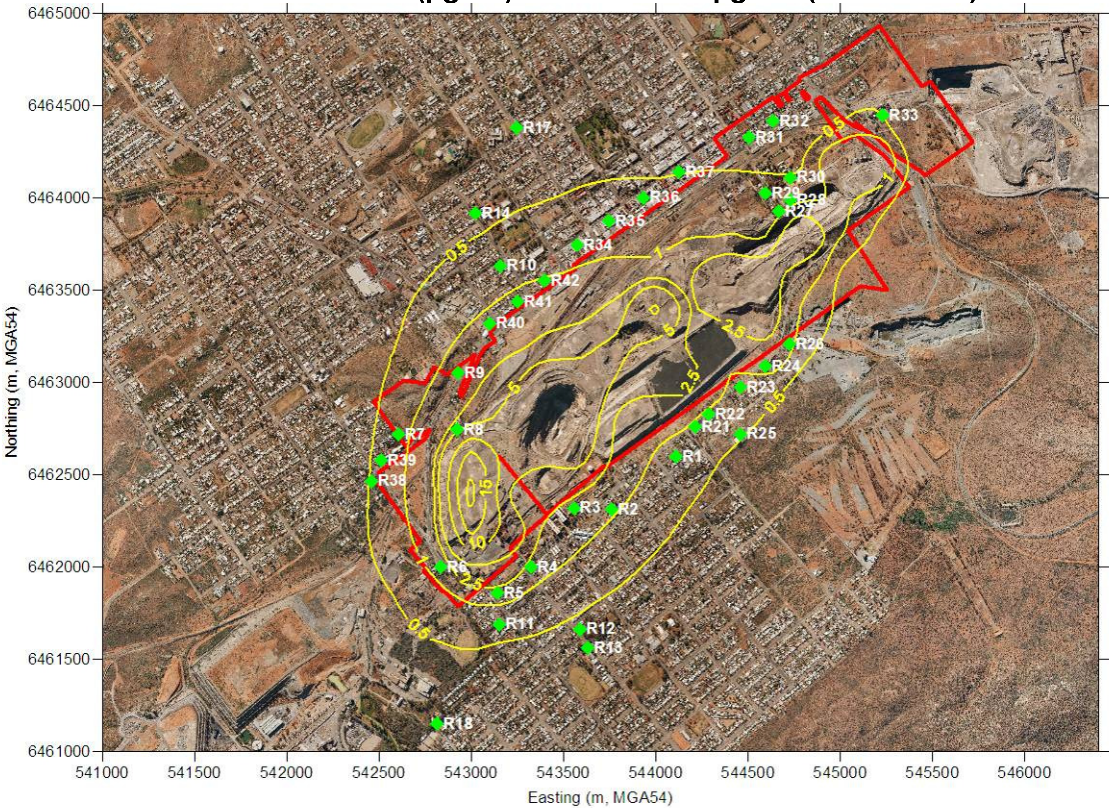
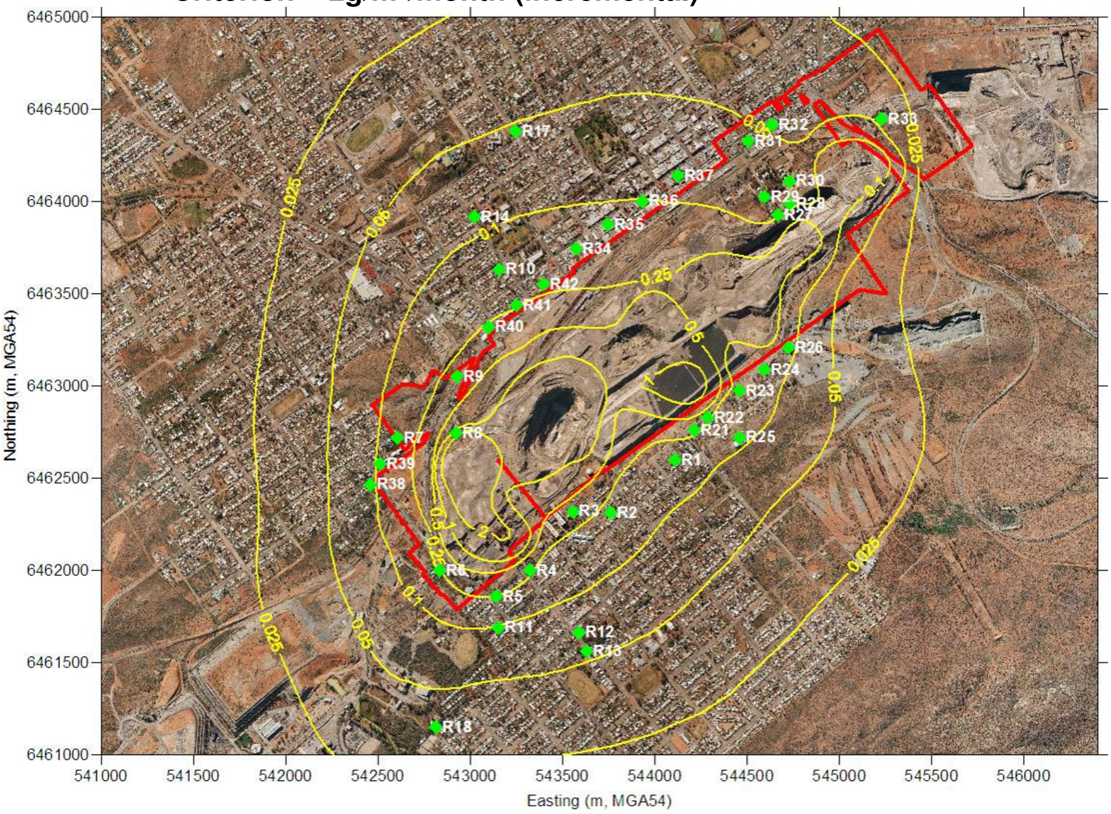


Figure D12 Operation (Project Increment) –Predicted Dust Deposition (g/m²/month) Criterion = 2g/m²/month (incremental)



Appendix E
Predicted Air Quality Indicator Concentrations and Deposition at Discrete Receptor Sites (Construction and Maximum Operations Scenarios)

Table E1 – Predicted Incremental TSP Concentrations due to Construction Activities at Nearby Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	TSP	PM_{10}		$PM_{2.5}$	
		Annual Average (µg/m³)	Highest Daily Average (µg/m³)	Annual Average (µg/m³)	Highest Daily Average (µg/m³)	Annual Average (µg/m³)
R1	Piper Street North	1.2	5.4	0.4	1.4	0.1
R2	Piper Street Central	1.1	3.6	0.4	1.4	0.1
R3	Eyre Street North	1.9	4.6	0.7	1.3	0.2
R4	Eyre Street Central	1.7	10.8	0.7	1.6	0.2
R5	Eyre Street South	1.4	4.3	0.6	1.5	0.2
R6	South Road	1.4	5.6	0.7	1.6	0.1
R7	Carbon Lane	0.2	0.8	0.1	0.3	<0.1
R8	Old South Road	0.6	2.0	0.3	0.5	0.1
R9	South Rd	0.4	1.9	0.2	0.8	<0.1
R10	Cnr Garnet and Blende Streets	0.4	1.6	0.2	0.6	<0.1
R11	Alma Bugldi Pre-school	0.4	2.1	0.2	0.6	<0.1
R12	Playtime Pre-school	0.3	1.5	0.1	0.4	<0.1
R13	Alma Primary School	0.3	1.3	0.1	0.5	<0.1
R14	Broken Hill High School	0.3	1.4	0.1	0.4	<0.1
R17	Broken Hill Public School	0.2	1.0	0.1	0.5	<0.1
R18	Rainbow Pre-school	0.2	1.0	0.1	0.3	<0.1
R21	Eyre Street North	2.0	8.6	0.7	1.5	0.1
R22	Eyre Street North	2.7	9.9	0.9	1.7	0.2
R23	Eyre Street North	4.9	11.8	1.5	2.2	0.3
R24	Eyre Street North	4.0	11.4	1.3	2.4	0.3
R25	Water tank, Lawton Street #	1.3	5.1	0.4	1.0	0.1
R26	Quarry offices	2.2	8.4	0.8	2.0	0.2
R27	Proprietary Square	1.5	7.3	0.7	1.9	0.2
R28	Proprietary Square	1.1	5.4	0.5	1.3	0.1
R29	Iodide Street	0.8	3.5	0.3	0.8	0.1
R30	Iodide Street	0.6	2.9	0.3	0.7	0.1
R31	Crystal Street	0.5	2.2	0.2	0.5	<0.1
R32	Crystal Street	0.4	2.0	0.2	0.4	<0.1
R33	Brownes Shaft Dwelling	0.5	3.0	0.3	0.9	0.1
R34	Crystal Street	0.7	2.9	0.3	1.3	0.1
R35	Crystal Street	0.7	2.8	0.3	0.9	0.1
R36	Crystal Street	0.7	2.5	0.3	0.6	0.1
R37	Crystal Street	0.6	2.8	0.3	0.7	0.1
R38	Gypsum Street	0.2	0.8	0.1	0.2	<0.1
R39	Gypsum Street	0.2	0.9	0.1	0.3	<0.1
R40	Silver City Hwy	0.5	1.9	0.2	0.8	<0.1
R41	Silver City Hwy	0.6	1.9	0.2	0.7	0.1
R42	Silver City Hwy	0.7	2.1	0.3	0.8	0.1

Table E2 – Predicted Incremental 24-Hour Average PM_{10} Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Years 2008 and 2009

	Receptors	PM_{10} Concentrations (µg/m³) 2008 Modelling		PM_{10} Concentrations (µg/m³) 2009 Modelling	
		Project-Related Increment	Conc. as % of DECCW Criterion	Project-Related Increment	Conc. as % of DECCW Criterion
R1	Piper Street North	2.0	4%	2.3	5%
R2	Piper Street Central	3.0	6%	3.6	7%
R3	Eyre Street North	5.1	10%	5.9	12%
R4	Eyre Street Central	4.2	8%	3.9	8%
R5	Eyre Street South	2.8	6%	4.3	9%
R6	South Road	4.5	9%	6.5	13%
R7	Carbon Lane	2.7	5%	3.1	6%
R8	Old South Road	8.7	17%	10.5	21%
R9	South Rd	3.4	7%	3.2	6%
R10	Cnr Garnet & Blende Streets	1.8	4%	1.6	3%
R11	Alma Bugldi Pre-school	1.7	3%	2.8	6%
R12	Playtime Pre-school	1.5	3%	1.7	3%
R13	Alma Primary School	1.4	3%	1.5	3%
R14	Broken Hill High School	1.5	3%	1.3	3%
R15	Broken Hill Hospital	0.9	2%	0.6	1%
R16	N Broken Hill Primary School	0.7	1%	0.5	1%
R17	Broken Hill Public School	1.2	2%	0.9	2%
R18	Rainbow Pre-school	1.3	3%	1.3	3%
R19	Willyama High School	0.5	1%	0.5	1%
R20	Morgan Street Primary School	0.7	1%	0.5	1%
R21	Eyre Street North	2.6	5%	3.0	6%
R22	Eyre Street North	3.0	6%	3.6	7%
R23	Eyre Street North	2.6	5%	2.6	5%
R24	Eyre Street North	2.1	4%	2.4	5%
R25	Water tank, Lawton Street #	1.7	3%	1.9	4%
R26	Quarry offices	2.3	5%	2.6	5%
R27	Proprietary Square	1.7	3%	2.0	4%
R28	Proprietary Square	2.2	4%	1.9	4%
R29	Iodide Street	1.8	4%	1.5	3%
R30	Iodide Street	1.5	3%	1.4	3%
R31	Crystal Street	1.4	3%	1.1	2%
R32	Crystal Street	1.4	3%	1.0	2%
R33	Brownes Shaft Dwelling	1.5	3%	1.6	3%
R34	Crystal Street	2.2	4%	1.7	3%
R35	Crystal Street	2.0	4%	1.7	3%
R36	Crystal Street	1.5	3%	1.5	3%
R37	Crystal Street	1.4	3%	1.3	3%
R38	Gypsum Street	2.2	4%	2.3	5%
R39	Gypsum Street	2.5	5%	2.3	5%
R40	Silver City Hwy	2.6	5%	2.4	5%
R41	Silver City Hwy	2.7	5%	2.4	5%
R42	Silver City Hwy	2.7	5%	2.3	5%

Table E3 – Predicted Annual Average PM_{10} Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Year 2008					
	Receptors	**Sensitive Receptors - PM_{10} ncentrations (µg/m³)**			
		Measured Background Conc.	**Project-Related Increment**	**Cumulative TSP Concs. (Background + Increment)**	**Cumulative Conc. as % of DECCW Criterion**
R1	Piper Street North	27.7	0.3	28.0	93%
R2	Piper Street Central	27.7	0.5	28.1	94%
R3	Eyre Street North	27.7	0.9	28.6	95%
R4	Eyre Street Central	27.7	0.6	28.3	94%
R5	Eyre Street South	27.7	0.5	28.2	94%
R6	South Road	27.7	0.8	28.5	95%
R7	Carbon Lane	27.7	0.4	28.1	94%
R8	Old South Road	27.7	1.6	29.3	98%
R9	South Rd	27.7	0.7	28.4	95%
R10	Cnr Garnet & Blende Streets	27.7	0.3	28.0	93%
R11	Alma Bugldi Pre-school	27.7	0.3	28.0	93%
R12	Playtime Pre-school	27.7	0.2	27.9	93%
R13	Alma Primary School	27.7	0.2	27.9	93%
R14	Broken Hill High School	27.7	0.2	27.9	93%
R15	Broken Hill Hospital	27.7	0.1	27.8	93%
R16	N Broken Hill Primary School	27.7	0.1	27.8	93%
R17	Broken Hill Public School	27.7	0.1	27.8	93%
R18	Rainbow Pre-school	27.7	0.1	27.8	93%
R19	Willyama High School	27.7	0.0	27.7	92%
R20	Morgan Street Primary School	27.7	0.1	27.8	93%
R21	Eyre Street North	27.7	0.4	28.1	94%
R22	Eyre Street North	27.7	0.4	28.1	94%
R23	Eyre Street North	27.7	0.3	28.0	93%
R24	Eyre Street North	27.7	0.4	28.1	94%
R25	Water tank, Lawton Street #	27.7	0.2	27.9	93%
R26	Quarry offices	27.7	0.4	28.0	93%
R27	Proprietary Square	27.7	0.2	27.9	93%
R28	Proprietary Square	27.7	0.2	27.9	93%
R29	Iodide Street	27.7	0.3	28.0	93%
R30	Iodide Street	27.7	0.2	27.9	93%
R31	Crystal Street	27.7	0.2	27.9	93%
R32	Crystal Street	27.7	0.2	27.9	93%
R33	Brownes Shaft Dwelling	27.7	0.2	27.9	93%
R34	Crystal Street	27.7	0.4	28.1	94%
R35	Crystal Street	27.7	0.3	28.0	93%
R36	Crystal Street	27.7	0.3	28.0	93%
R37	Crystal Street	27.7	0.3	28.0	93%
R38	Gypsum Street	27.7	0.3	28.0	93%
R39	Gypsum Street	27.7	0.3	28.0	93%
R40	Silver City Hwy	27.7	0.5	28.2	94%
R41	Silver City Hwy	27.7	0.5	28.2	94%
R42	Silver City Hwy	27.7	0.5	28.2	94%

Table E4 – Predicted Annual Average PM_{10} Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Year 2009

	Receptors	Sensitive Receptors - PM_{10} Concentrations (µg/m³)			
		Measured Background Conc.	Project-Related Increment	Cumulative TSP Concs. (Background + Project Increment)	Cumulative Conc. as % of DECCW Criterion
R1	Piper Street North	27.7	0.4	28.1	94%
R2	Piper Street Central	27.7	0.5	28.2	94%
R3	Eyre Street North	27.7	0.9	28.6	95%
R4	Eyre Street Central	27.7	0.8	28.5	95%
R5	Eyre Street South	27.7	0.6	28.3	94%
R6	South Road	27.7	0.8	28.5	95%
R7	Carbon Lane	27.7	0.4	28.1	94%
R8	Old South Road	27.7	1.7	29.4	98%
R9	South Rd	27.7	0.7	28.4	95%
R10	Cnr Garnet and Blende Streets	27.7	0.4	28.1	94%
R11	Alma Bugldi Pre-school	27.7	0.4	28.1	94%
R12	Playtime Pre-school	27.7	0.2	27.9	93%
R13	Alma Primary School	27.7	0.2	27.9	93%
R14	Broken Hill High School	27.7	0.2	27.9	93%
R15	Broken Hill Hospital	27.7	0.1	27.8	93%
R16	North Broken Hill Primary School	27.7	0.1	27.8	93%
R17	Broken Hill Public School	27.7	0.2	27.9	93%
R18	Rainbow Pre-school	27.7	0.2	27.9	93%
R19	Willyama High School	27.7	0.0	27.7	92%
R20	Morgan Street Primary School	27.7	0.1	27.8	93%
R21	Eyre Street North	27.7	0.4	28.1	94%
R22	Eyre Street North	27.7	0.5	28.2	94%
R23	Eyre Street North	27.7	0.4	28.1	94%
R24	Eyre Street North	27.7	0.4	28.1	94%
R25	Water tank, Lawton Street #	27.7	0.3	28.0	93%
R26	Quarry offices	27.7	0.4	28.1	94%
R27	Proprietary Square	27.7	0.1	27.8	93%
R28	Proprietary Square	27.7	0.1	27.8	93%
R29	Iodide Street	27.7	0.2	27.9	93%
R30	Iodide Street	27.7	0.1	27.8	93%
R31	Crystal Street	27.7	0.2	27.9	93%
R32	Crystal Street	27.7	0.1	27.8	93%
R33	Brownes Shaft Dwelling	27.7	0.2	27.9	93%
R34	Crystal Street	27.7	0.4	28.1	94%
R35	Crystal Street	27.7	0.4	28.1	94%
R36	Crystal Street	27.7	0.3	28.0	93%
R37	Crystal Street	27.7	0.3	28.0	93%
R38	Gypsum Street	27.7	0.3	28.0	93%
R39	Gypsum Street	27.7	0.3	28.0	93%
R40	Silver City Hwy	27.7	0.6	28.3	94%
R41	Silver City Hwy	27.7	0.5	28.2	94%
R42	Silver City Hwy	27.7	0.5	28.2	94%

Table E5 – Predicted Annual Average TSP Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Year 2008					
	Receptors	**Sensitive Receptors - TSP Concentrations (µg/m³)**			
		Measured Background Conc.	**Project-Related Increment**	**Cumulative TSP Concs. (Background + Project Increment)**	**Cumulative Conc. as % of DECCW Criterion**
R1	Piper Street North	47.8	0.6	48.4	54%
R2	Piper Street Central	47.8	0.9	48.7	54%
R3	Eyre Street North	47.8	1.7	49.5	55%
R4	Eyre Street Central	47.8	1.2	49.0	54%
R5	Eyre Street South	47.8	1.0	48.7	54%
R6	South Road	47.8	1.5	49.2	55%
R7	Carbon Lane	47.8	0.7	48.4	54%
R8	Old South Road	47.8	3.0	50.8	56%
R9	South Rd	47.8	1.3	49.1	55%
R10	Cnr Garnet and Blende Streets	47.8	0.7	48.4	54%
R11	Alma Bugldi Pre-school	47.8	0.5	48.3	54%
R12	Playtime Pre-school	47.8	0.4	48.1	53%
R13	Alma Primary School	47.8	0.3	48.1	53%
R14	Broken Hill High School	47.8	0.4	48.2	54%
R15	Broken Hill Hospital	47.8	0.1	47.9	53%
R16	North Broken Hill Primary School	47.8	0.1	47.9	53%
R17	Broken Hill Public School	47.8	0.3	48.0	53%
R18	Rainbow Pre-school	47.8	0.2	48.0	53%
R19	Willyama High School	47.8	0.1	47.8	53%
R20	Morgan Street Primary School	47.8	0.1	47.9	53%
R21	Eyre Street North	47.8	0.7	48.5	54%
R22	Eyre Street North	47.8	0.7	48.5	54%
R23	Eyre Street North	47.8	0.6	48.4	54%
R24	Eyre Street North	47.8	0.7	48.5	54%
R25	Water tank, Lawton Street #	47.8	0.4	48.2	54%
R26	Quarry offices	47.8	0.6	48.4	54%
R27	Proprietary Square	47.8	0.3	48.1	53%
R28	Proprietary Square	47.8	0.3	48.1	53%
R29	Iodide Street	47.8	0.5	48.2	54%
R30	Iodide Street	47.8	0.4	48.1	53%
R31	Crystal Street	47.8	0.4	48.1	53%
R32	Crystal Street	47.8	0.3	48.1	53%
R33	Brownes Shaft Dwelling	47.8	0.4	48.2	54%
R34	Crystal Street	47.8	0.7	48.5	54%
R35	Crystal Street	47.8	0.7	48.4	54%
R36	Crystal Street	47.8	0.6	48.3	54%
R37	Crystal Street	47.8	0.5	48.3	54%
R38	Gypsum Street	47.8	0.5	48.3	54%
R39	Gypsum Street	47.8	0.6	48.4	54%
R40	Silver City Hwy	47.8	1.1	48.9	54%
R41	Silver City Hwy	47.8	1.1	48.8	54%
R42	Silver City Hwy	47.8	1.0	48.7	54%

Table E6 – Predicted Annual Average TSP Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Year 2009

	Receptors	Sensitive Receptors - TSP Concentrations (µg/m³)			
		Measured Background Conc.	Project-Related Increment	Cumulative TSP Concs. (Background + Project Increment)	Cumulative Conc. as % of DECCW Criterion
R1	Piper Street North	64.9	0.7	65.6	73%
R2	Piper Street Central	64.9	1.0	65.9	73%
R3	Eyre Street North	64.9	1.8	66.8	74%
R4	Eyre Street Central	64.9	1.4	66.3	74%
R5	Eyre Street South	64.9	1.1	66.0	73%
R6	South Road	64.9	1.4	66.4	74%
R7	Carbon Lane	64.9	0.7	65.7	73%
R8	Old South Road	64.9	3.0	68.0	76%
R9	South Rd	64.9	1.3	66.3	74%
R10	Cnr Garnet and Blende Streets	64.9	0.7	65.7	73%
R11	Alma Bugldi Pre-school	64.9	0.6	65.6	73%
R12	Playtime Pre-school	64.9	0.4	65.4	73%
R13	Alma Primary School	64.9	0.3	65.3	73%
R14	Broken Hill High School	64.9	0.4	65.4	73%
R15	Broken Hill Hospital	64.9	0.1	65.1	72%
R16	North Broken Hill Primary School	64.9	0.1	65.1	72%
R17	Broken Hill Public School	64.9	0.3	65.2	72%
R18	Rainbow Pre-school	64.9	0.3	65.2	72%
R19	Willyama High School	64.9	0.1	65.0	72%
R20	Morgan Street Primary School	64.9	0.1	65.1	72%
R21	Eyre Street North	64.9	0.8	65.8	73%
R22	Eyre Street North	64.9	0.9	65.8	73%
R23	Eyre Street North	64.9	0.8	65.7	73%
R24	Eyre Street North	64.9	0.8	65.8	73%
R25	Water tank, Lawton Street #	64.9	0.5	65.4	73%
R26	Quarry offices	64.9	0.8	65.8	73%
R27	Proprietary Square	64.9	0.1	65.1	72%
R28	Proprietary Square	64.9	0.1	65.1	72%
R29	Iodide Street	64.9	0.4	65.4	73%
R30	Iodide Street	64.9	0.2	65.2	72%
R31	Crystal Street	64.9	0.3	65.2	72%
R32	Crystal Street	64.9	0.2	65.2	72%
R33	Brownes Shaft Dwelling	64.9	0.6	65.5	73%
R34	Crystal Street	64.9	0.8	65.8	73%
R35	Crystal Street	64.9	0.7	65.7	73%
R36	Crystal Street	64.9	0.7	65.6	73%
R37	Crystal Street	64.9	0.5	65.5	73%
R38	Gypsum Street	64.9	0.5	65.4	73%
R39	Gypsum Street	64.9	0.5	65.5	73%
R40	Silver City Hwy	64.9	1.1	66.1	73%
R41	Silver City Hwy	64.9	1.2	66.1	73%
R42	Silver City Hwy	64.9	1.0	66.0	73%

Table E7 – Predicted Incremental $PM_{2.5}$ Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Maximum for Model Years 2008 and 2009

	Receptors	2008 – 2009			
		Highest Daily Average (µg/m³)	Annual Average (µg/m³)	Highest daily Incremental concentration as % of NEPM Criterion	Annual Average Incremental concentration as % of NEPM Criterion
R1	Piper Street North	0.88	0.10	4%	1%
R2	Piper Street Central	1.32	0.14	5%	2%
R3	Eyre Street North	1.64	0.25	7%	3%
R4	Eyre Street Central	1.35	0.22	5%	3%
R5	Eyre Street South	1.09	0.17	4%	2%
R6	South Road	1.75	0.21	7%	3%
R7	Carbon Lane	0.81	0.12	3%	1%
R8	Old South Road	3.48	0.46	14%	6%
R9	South Rd	1.09	0.19	4%	2%
R10	Cnr Garnet and Blende Streets	0.43	0.10	2%	1%
R11	Alma Bugldi Pre-school	0.61	0.10	2%	1%
R12	Playtime Pre-school	0.53	0.07	2%	1%
R13	Alma Primary School	0.47	0.06	2%	1%
R14	Broken Hill High School	0.32	0.06	1%	1%
R15	Broken Hill Hospital	1.22	0.03	5%	0%
R16	North Broken Hill Primary School	0.17	0.02	1%	0%
R17	Broken Hill Public School	0.28	0.04	1%	1%
R18	Rainbow Pre-school	0.34	0.04	1%	1%
R19	Willyama High School	0.14	0.02	1%	0%
R20	Morgan Street Primary School	0.15	0.02	1%	0%
R21	Eyre Street North	1.18	0.13	5%	2%
R22	Eyre Street North	1.15	0.13	5%	2%
R23	Eyre Street North	0.94	0.12	4%	2%
R24	Eyre Street North	0.93	0.12	4%	2%
R25	Water tank, Lawton Street #	0.56	0.08	2%	1%
R26	Quarry offices	0.90	0.12	4%	1%
R27	Proprietary Square	0.64	0.11	3%	1%
R28	Proprietary Square	0.60	0.10	2%	1%
R29	Iodide Street	0.60	0.09	2%	1%
R30	Iodide Street	0.52	0.08	2%	1%
R31	Crystal Street	0.42	0.06	2%	1%
R32	Crystal Street	0.40	0.06	2%	1%
R33	Brownes Shaft Dwelling	0.77	0.07	3%	1%
R34	Crystal Street	0.62	0.10	2%	1%
R35	Crystal Street	0.59	0.09	2%	1%
R36	Crystal Street	0.56	0.08	2%	1%
R37	Crystal Street	0.50	0.07	2%	1%
R38	Gypsum Street	0.61	0.08	2%	1%
R39	Gypsum Street	0.71	0.09	3%	1%
R40	Silver City Hwy	0.63	0.15	3%	2%
R41	Silver City Hwy	0.60	0.14	2%	2%
R42	Silver City Hwy	0.70	0.12	3%	2%

Table E8 – Predicted Annual Average Lead (Pb) Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Year 2008

	Receptors	Sensitive Receptors - Pb Concentrations (µg/m³)			
		"Baseline" (Existing Free Areas, 0%CE)	Project-Related Increment	Cumulative Lead Concentration (Baseline + Project Increment)	Cumulative Conc. as % of DECCW Criterion
R1	Piper Street North	0.14	0.01	0.2	31%
R2	Piper Street Central	0.08	0.02	0.1	20%
R3	Eyre Street North	0.09	0.04	0.1	26%
R4	Eyre Street Central	0.06	0.03	0.1	19%
R5	Eyre Street South	0.05	0.02	0.1	14%
R6	South Road	0.07	0.04	0.1	22%
R7	Carbon Lane	0.06	0.02	0.1	16%
R8	Old South Road	0.51	0.10	0.6	122%
R9	South Rd	0.18	0.04	0.2	43%
R10	Cnr Garnet and Blende Streets	0.11	0.02	0.1	26%
R11	Alma Bugldi Pre-school	0.03	0.01	0.0	9%
R12	Playtime Pre-school	0.03	0.01	0.0	7%
R13	Alma Primary School	0.02	0.01	0.0	6%
R14	Broken Hill High School	0.06	0.01	0.1	14%
R15	Broken Hill Hospital	0.02	0.00	0.0	5%
R16	N Broken Hill Primary School	0.03	0.00	0.0	7%
R17	Broken Hill Public School	0.05	0.01	0.1	11%
R18	Rainbow Pre-school	0.01	0.01	0.0	3%
R19	Willyama High School	0.02	0.00	0.0	5%
R20	Morgan Street Primary School	0.02	0.00	0.0	5%
R21	Eyre Street North	0.15	0.01	0.2	32%
R22	Eyre Street North	0.12	0.01	0.1	27%
R23	Eyre Street North	0.10	0.01	0.1	22%
R24	Eyre Street North	0.10	0.01	0.1	22%
R25	Water tank, Lawton Street #	0.07	0.01	0.1	16%
R26	Quarry offices	0.11	0.01	0.1	24%
R27	Proprietary Square	0.28	0.01	0.3	59%
R28	Proprietary Square	0.21	0.01	0.2	44%
R29	Iodide Street	0.23	0.01	0.2	49%
R30	Iodide Street	0.16	0.01	0.2	35%
R31	Crystal Street	0.13	0.01	0.1	28%
R32	Crystal Street	0.11	0.01	0.1	23%
R33	Brownes Shaft Dwelling	0.14	0.01	0.1	29%
R34	Crystal Street	0.20	0.02	0.2	44%
R35	Crystal Street	0.18	0.01	0.2	39%
R36	Crystal Street	0.15	0.01	0.2	31%
R37	Crystal Street	0.13	0.01	0.1	29%
R38	Gypsum Street	0.03	0.02	0.0	10%
R39	Gypsum Street	0.08	0.02	0.1	20%
R40	Silver City Hwy	0.18	0.03	0.2	42%
R41	Silver City Hwy	0.19	0.03	0.2	43%
R42	Silver City Hwy	0.21	0.02	0.2	47%

Table E9 – Predicted Annual Average Lead (Pb) Concentrations due to Maximum Production Activities at Nearby Sensitive Receptors – Calendar Year 2009

	Receptors	Sensitive Receptors - Pb Concentrations (µg/m³)			
		"Baseline" (Existing Free Areas, 0%CE)	Project-Related Increment	Cumulative Lead Concentration (Baseline + Project Increment)	Cumulative Conc. as % of DECCW Criterion
R1	Piper Street North	0.20	0.01	0.2	44%
R2	Piper Street Central	0.13	0.02	0.2	31%
R3	Eyre Street North	0.14	0.05	0.2	37%
R4	Eyre Street Central	0.09	0.04	0.1	25%
R5	Eyre Street South	0.07	0.03	0.1	20%
R6	South Road	0.11	0.04	0.2	31%
R7	Carbon Lane	0.08	0.02	0.1	21%
R8	Old South Road	0.60	0.11	0.7	141%
R9	South Rd	0.23	0.04	0.3	54%
R10	Cnr Garnet & Blende Streets	0.14	0.02	0.2	31%
R11	Alma Bugldi Pre-school	0.05	0.02	0.1	13%
R12	Playtime Pre-school	0.04	0.01	0.1	10%
R13	Alma Primary School	0.03	0.01	0.0	9%
R14	Broken Hill High School	0.07	0.01	0.1	17%
R15	Broken Hill Hospital	0.03	0.00	0.0	6%
R16	N Broken Hill Primary School	0.03	0.00	0.0	7%
R17	Broken Hill Public School	0.06	0.01	0.1	14%
R18	Rainbow Pre-school	0.02	0.01	0.0	5%
R19	Willyama High School	0.02	0.00	0.0	5%
R20	Morgan Street Primary School	0.02	0.00	0.0	5%
R21	Eyre Street North	0.25	0.01	0.3	53%
R22	Eyre Street North	0.21	0.01	0.2	44%
R23	Eyre Street North	0.15	0.01	0.2	33%
R24	Eyre Street North	0.15	0.02	0.2	33%
R25	Water tank, Lawton Street #	0.13	0.01	0.1	27%
R26	Quarry offices	0.15	0.02	0.2	34%
R27	Proprietary Square	0.27	0.01	0.3	57%
R28	Proprietary Square	0.18	0.01	0.2	39%
R29	Iodide Street	0.22	0.01	0.2	46%
R30	Iodide Street	0.14	0.01	0.2	31%
R31	Crystal Street	0.13	0.01	0.1	27%
R32	Crystal Street	0.10	0.01	0.1	21%
R33	Brownes Shaft Dwelling	0.12	0.01	0.1	27%
R34	Crystal Street	0.22	0.02	0.2	48%
R35	Crystal Street	0.19	0.02	0.2	40%
R36	Crystal Street	0.15	0.01	0.2	33%
R37	Crystal Street	0.13	0.01	0.1	29%
R38	Gypsum Street	0.05	0.01	0.1	12%
R39	Gypsum Street	0.06	0.02	0.1	15%
R40	Silver City Hwy	0.22	0.03	0.3	50%
R41	Silver City Hwy	0.23	0.03	0.3	51%
R42	Silver City Hwy	0.24	0.02	0.3	52%