ATLAS-CAMPASPE
Mineral Sands Project
ENVIRONMENTAL IMPACT STATEMENT

APPENDIX K › AIR QUALITY AND GREENHOUSE GAS ASSESSMENT

CRISTAL

Resource Strategies

Atlas-Campaspe Mineral Sands Project - Air Quality and Greenhouse Gas Assessment

Prepared for

Cristal Mining Australia Limited

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Final

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Glossary

Term	Definition
BOM	Bureau of Meteorology
CO	Carbon monoxide
CO_2	Carbon dioxide
DEC	Department of Environment and Conservation
DGRs	Director-General's Requirements
DMU	Dry mining unit
DPI	Department of Primary Industries
ENSO	El Niño southern oscillation
HMC	Heavy mineral concentrate
km	Kilometre
km/h	Kilometre per hour
kVa	Kilovolt-ampere
m	Metre
m/s	Metres per second
m^2	Square metres
m^3	Cubic metres
m^3/s	Cubic metres per second
mg	Milligram
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
NPI	National Pollutant Inventory
OEH	Office of Environment and Heritage (formerly DEC)
Ou	Odour units
PM	Particulate matter (fine dust)
$PM_{2.5}$ and PM_{10}	Particulate matter less than 2.5 or 10 microns, respectively
SOI	Southern oscillation index
SO_2	Sulfur dioxide
T	Tonnes
Mt	Million tonnes
Tpa	Tonnes per annum
TSP	Total suspended particulates
US EPA	United States Environmental Protection Agency
WHIMS	Wet high intensity magnetic separation
$\mu g/m^3$	Micrograms per cubic metre
µm	Micrometres
°C	Degrees Celsius

Executive Summary

An Air Quality and Greenhouse Gas Assessment has been conducted for the proposed Atlas-Campaspe Mineral Sands Project in New South Wales. The assessment has been conducted in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DEC, 2005).

The Air Quality and Greenhouse Gas Assessment investigated the potential for air quality impacts associated with the mining operations, on-site power generation, transport of mineral concentrate, and the operation of the Ivanhoe Rail Facility. Worst-case ground-level concentrations of air pollutants have been predicted by considering operational data equivalent to the highest activity rate for the proposed Atlas-Campaspe Mine and Ivanhoe Rail Facility.

Key on-site sources of particulate matter emissions include:

- *Extraction, transport, handling and stockpiling of overburden, ore and mineral concentrate and wind erosion of stockpiles and exposed surfaces at the Atlas-Campaspe Mine*
- *Transport, handling and stockpiling of mineral concentrates and wind erosion of stockpiles and exposed surfaces at the Ivanhoe Rail Facility.*

The potential for impacts associated with the operation of four on-site 1,000 kVa diesel generators for power generation has also been assessed. Impacts associated with the combustion of fuel through vehicle activity are accounted for in the emission factors for PM_{10} and $PM_{2.5}$.

Consideration of particulate matter emissions associated with mineral concentrate transport on unsealed public roads was also undertaken for completeness.

Predicted ground-level concentrations of dust (as TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates) have been predicted in isolation and with conservative background levels.

Predictions were made at sensitive receptors and on a grid of evenly-spaced receptors. Predicted ground-level concentrations of particulate matter and dust deposition rates have been compared with the impact assessment criteria specified in the Approved Methods.

The key Project sources of air quality emissions are located at significant distances from potential receptors, with the closest sensitive receptor to the Atlas-Campaspe Mine located at approximately 7 km and the closest receptors to the Ivanhoe Rail Facility located at approximately 4.5 km. The nearest sensitive receptor to potential emissions associated with mineral concentrate transport is located some 800 m from the unsealed public road and is some 15 km from the Atlas-Campaspe Mine.

The results of the assessment of the Atlas-Campaspe Mine and Ivanhoe Rail Facility show:

- *Compliance with annual average impact assessment criteria for TSP, PM_{10} and dust deposition at all sensitive receptors for the Project in isolation*
- *Compliance with 24-hour impact assessment criteria at all sensitive receptors for the Project in isolation*
- *Compliance with annual average impact assessment criteria for TSP, PM_{10} and dust deposition for the Project plus conservative background levels*
- *No additional exceedances of the 24-hour PM_{10} impact assessment criteria as a result of the Project in conjunction with conservative background levels*

- *Compliance with annual average advisory reporting standards for $PM_{2.5}$ for the Project in isolation and with the inclusion of conservative background levels*
- *Compliance with the 24-hour advisory reporting standards for $PM_{2.5}$ for the Project in isolation and with the inclusion of conservative background levels.*

The results of the assessment of the on-site power generation using four 1,000 kVa diesel generators show:

- *The predicted maximum ground-level concentrations of NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$ are below the relevant impact assessment criteria at all sensitive receptors.*

The results of the greenhouse gas assessment of the Project show:

- *The predicted annual emission rate of Scope 1 greenhouse gases from the Project is 0.045Mt CO_2-e or 0.008% of Australia's estimated greenhouse gas emissions for the year to March 2012 (546.8 Mt CO_2-e) (DCCEE, 2012b).*

1. Introduction

Katestone Environmental Pty Ltd (Katestone) has prepared an Air Quality and Greenhouse Gas Assessment for the proposed Atlas-Campaspe Mineral Sands Project (the Project) on behalf of Cristal Mining Australia Limited (Cristal Mining). The Project includes the development of a:

- Mineral sands mining operation (Atlas-Campaspe Mine)
- Rail load out facility located near the township of Ivanhoe (Ivanhoe Rail Facility).

And the utilisation of paved and unpav ed public roads for the transport of mineral concentrates and waste product (mineral concentrate transport route) between the Atlas-Campaspe Mine and the Ivanhoe Rail Facility. Electrical power will be supplied to site by the commissioning of four 1,000 kilovolt-ampere (kVa) diesel generators.

In accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW) (Approved Methods) (Department of Environment and Conservation [DEC], 2005) the air quality assessment consists of the following:

- Project description
- Assessment methodology
- Characterisation of the local environment across the Project region, including background air quality, terrain and land use characteristics, climate and meteorology
- Description of the legislative framework for air quality and impact assessment criteria
- An emissions inventory of particulate matter for the following components of the Project:
    - Activity at the Atlas-Campaspe Mine
    - Transport of the mineral concentrates to the Ivanhoe Rail Facility via the unsealed sections of the mineral concentrate transport route
    - Activities associated with the operation of the Ivanhoe Rail Facility
- An emissions inventory of relevant pollutants associated with on-site power generation
- Dispersion modelling to predict ground-level concentrations of air pollutants due to the Project
- Evaluation of the results of dispersion modelling against air quality impact assessment criteria
- Identification of additional best practice mitigation measures that could be implemented to minimise emissions and impacts at sensitive locations
- An assessment of greenhouse gas emissions associated with the Project.

2. Project Description

The proposed life of the Project is approximately 20 years, commencing approximately 1 July 2013 or upon the grant of all required approvals. The Project would involve two main development components (Figure 1):

1. Construction and development of infrastructure for mining operations at the Atlas and Campaspe deposits (the proposed Atlas-Campaspe Mine) (Figure 2).
2. Construction and operation of the Ivanhoe Rail Facility (Figure 3).

A full description of operations at the Atlas-Campaspe Mine is provided in Section 2 in the Main Report of the Environmental Impact Statement. The main activities associated with the development of the Atlas-Campaspe Mine (Figure 4) would include:

- Ongoing exploration activities
- Sequential development and operation of two separate mineral sands ore extraction areas within the Mining Lease Application 1 area
- Use of conventional mobile equipment to mine and place mineral sands ore into dry mining unit(s)[1] (DMU) at a maximum ore production rate of up to 7.2 million tonnes per annum
- Mineral processing infrastructure including the primary gravity concentration unit, salt washing facility and a wet high intensity magnetic separation (WHIMS) circuit
- Mineral concentrate stockpiles and materials handling infrastructure (e.g. towers and stackers)
- Progressive backfilling of mine voids with overburden behind the advancing ore extraction areas or in overburden emplacements adjacent to the mine path
- Placement of sand residues and coarse rejects (and Broken Hill Mineral Separation Plant [MSP] process wastes[2]) following mineral processing to either the active mining area (behind the advancing ore extraction area) or in sand residue dams
- Development of a groundwater borefield at the Atlas deposit and localised dewatering systems (bores, spearfields and trenches) at both the Atlas and Campaspe deposits, including associated pump and pipeline systems
- Reverse osmosis (RO) plant to supply the salt washing facility and potable water
- Progressive development of water storage dams, sediment basins, pumps, pipelines and other water management equipment and structures
- Administration/office buildings, car parking facilities, workshop and stores
- On-site accommodation camp
- Sewage treatment plant
- Diesel powered generators, electricity distribution station and associated internal electricity transmission lines
- Site access road, internal access roads and haul roads
- Roadworks along the proposed mineral concentrate transport route to the Ivanhoe Rail Facility
- Transport of mineral concentrates along the mineral concentrate transport route to the Ivanhoe Rail Facility
- Road transport of MSP process waste[2] in sealed storage containers from the Ivanhoe Rail Facility to the Atlas-Campaspe Mine for subsequent unloading, stockpiling and placement behind the advancing ore extraction areas
- Development of soil stockpiles and laydown areas

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[1] Mining would use conventional open pit methods and would not involve dredge mining.

[2] Following cessation of operations at the Ginkgo and Snapper Mines (approximately Year 12 of the Project).

- Monitoring and rehabilitation and
- Other associated minor infrastructure, plant, equipment and activities.

The activities associated with the development of the Ivanhoe Rail Facility of the Project are summarised below:

- Development of a rail siding for:
    - Loading of train wagons with mineral concentrate for rail transport to the MSP via the Orange – Broken Hill railway and
    - Unloading of MSP process waste[3] in sealed storage containers (transported via the Orange – Broken Hill railway) from train wagons
- Site access road and internal haul roads/pavements
- Hardstand areas for mineral concentrate and MSP process waste[3] unloading, stockpiling/sealed container storage and loading
- A retention basin, drains, pumps, pipelines and other water management equipment and structures
- Site office and car parking facilities
- Extension to existing 11 kilovolt (kV) powerline
- Monitoring, landscaping and rehabilitation and
- Other associated minor infrastructure, plant, equipment and activities.

2.1 Project location

The proposed Atlas-Campaspe Mine is located approximately 80 kilometres (km) north of Balranald, NSW and 270 km south-east of Broken Hill, NSW (Figure 1). The proposed Ivanhoe Rail Facility is located approximately 135 km north-east of the Atlas-Campaspe Mine (Figure 1). The Project will integrate with currently existing and approved Cristal Mining operations, including (Figure 1):

- MSP located approximately 270 km north-west of the proposed Atlas-Campaspe Mine
- Snapper Mine located approximately 105 km to the west of the proposed Atlas-Campaspe Mine
- Ginkgo Mine located approximately 100 km to the west of the proposed Atlas-Campaspe Mine.

2.2 Atlas-Campaspe Mine

Mining at the Atlas-Campaspe Mine would commence with the development of an initial excavation at the south-eastern end of the Atlas deposit and then progress in a north-westerly direction during Years 2 to 5 of the Project. Mining of the Campaspe deposit at the Atlas-Campaspe Mine would commence once mining within the Atlas footprint is complete. Mining operations are expected to continue 24 hours a day seven days a week. The general sequence of mining operations relevant to the air quality assessment is outlined below:

1. Vegetation would be progressively cleared over the life of the Project ahead of overburden removal and ore extraction areas. A fleet of dozers, scrapers and water trucks would typically be used for vegetation clearing and soil stripping activities.

[3] Following cessation of operations at the Ginkgo and Snapper Mines (approximately Year 12 of the Project).

2. Overburden removed during the initial development of mining operations at both the Atlas and Campaspe deposits would be placed in off-path overburden emplacements. The overburden emplacements would be constructed to a maximum height of approximately 20 metres (m) above the natural ground surface.

3. With the exception of the initial development of mining operations, overburden mined during the development of the Atlas-Campaspe Mine would be used to progressively backfill the mine voids behind the advancing ore extraction areas.

4. Overburden extraction ahead of the advancing ore extraction areas would be undertaken using a fleet of excavators, dozers and front end loaders. Haul trucks would be used to transport the overburden to either behind the advancing ore extraction areas or in overburden emplacements adjacent to the mine path.

5. Mining would typically involve dozers and loaders placing mineral sands ore in a DMU located in the ore extraction area. At the DMU, the mineral sands ore would be slurried, screened and pumped to the primary gravity concentration unit for on-site processing. Approximately 109 million tonnes of mineral sands ore would be mined from the Atlas and Campaspe deposits during the life of the Project.

6. Ore slurry would undergo on-site processing through the primary gravity concentration unit and WHIMS circuit to produce leucoxene-rich, ilmenite-rich and non-magnetic mineral concentrates (mineral concentrates). The mineral concentrates would be stockpiled at the heavy mineral concentrate (HMC) treatment facility (Figure 4) before transport to the MSP via the Ivanhoe Rail Facility.

7. Progressive rehabilitation would be under taken behind the advancing mining operation.

2.3 Ivanhoe Rail Facility

The Ivanhoe Rail Facility would be located approximately 4.5 km south-west of the Ivanhoe township to facilitate the transport of mineral concentrates from the Atlas-Campaspe Mine to the MSP. Mineral concentrate haulage vehicles would enter the Ivanhoe Rail Facility via the access road off the Balranald-Ivanhoe Road. A turn-around loop at Ivanhoe Rail Facility would enable the haulage vehicles to turn-around, unload and exit using the same access road.

Mineral concentrate emptied from the haulage vehicles would be dumped directly onto a mineral concentrate stockpiles within the hardstand area. A front end loader would be used to reclaim mineral concentrate from the stockpiles at the Ivanhoe Rail Facility and load directly into containers on train wagons. A forklift would be used to remove and replace covers on the train wagons.

2.4 Mineral concentrate transport route

Mineral concentrate would be hauled via road approximately 175 km from the Atlas-Campaspe Mine to the Ivanhoe Rail Facility. The mineral concentrate would be transported in covered road trains[4]. Road transport of mineral concentrate would be undertaken 24 hours per day, seven days per week.

Up to a maximum total of 48 vehicle movements per day would be required to transport mineral concentrates to the Ivanhoe Rail Facility and return to the Atlas-Campaspe Mine. For the first 12 years of the Project vehicles returning to the Atlas-Campaspe Mine will be unladen. From approximately Year 12 of the Project onwards, MSP process waste in sealed containers would be loaded onto haulage vehicles for the return trip to the Atlas-Campaspe Mine. Therefore, no additional mineral concentrate haulage vehicle movements would be required for the Project in order to transport the MSP process waste.

The proposed mineral concentrate transport route to the Ivanhoe Rail Facility is shown on Figure 1. The road haulage route would comprise sections of the following public roads:

- Link Road
- Boree Plains-Gol Gol Road
- Magenta Road
- Hatfield-The Vale Road and
- Balranald-Ivanhoe Road.

A 37 km portion of the mineral concentrate transport route which links the Atlas-Campaspe Mine with Balranald-Ivanhoe Road and comprises sections of the following public roads would remain unsealed throughout the life of the Project (with the exception of a 2 km section of Magenta Road):

- Link Road
- Boree Plains-Gol Gol Road
- Magenta Road and
- Hatfield-The Vale Road.

In addition, a section of Balranald-Ivanhoe Road, located approximately 71 km north of the intersection with Hatfield-The Vale Road is generally unsealed with short sections of sealed surfaces.

2.5 Construction activities

Construction activities at the Atlas-Campaspe Mine would be undertaken up to 24 hours per day, seven days per week. Construction activities associated with roadworks along the mineral concentrate transport route and Ivanhoe Rail Facility would be undertaken on a campaign basis during daytime hours only. The initial construction period (Year 1 of the Project) would be focussed on the development of the following Project infrastructure components.

- Atlas-Campaspe Mine:
    - site access roads and internal access roads
    - on-site accommodation camp and sewage treatment plant
    - water supply infrastructure (including groundwater borefield, RO plant and associated pump and pipeline systems)

[4] Type 1 road train, as defined by the NSW Roads and Maritime Services, 2012.

- power supply infrastructure (including diesel generators, electricity distribution station and transmission lines)
    - fixed infrastructure areas (including administration/office buildings and car parking facilities, workshop and stores, services corridor and laydown areas)
    - DMU assembly
    - mineral processing infrastructure (including primary gravity concentration unit, salt washing facility and WHIMS)
    - materials handling infrastructure (including pumps and pipelines for mineral sands ore, HMC and process wastes, and towers and stackers for stockpiling mineral concentrates) and
    - off-path sand residue dams and process water storages.
- Roadworks along the mineral concentrate transport route including sections of:
    - Link Road
    - Boree Plains-Gol Gol Road
    - Magenta Road and
    - Hatfield-The Vale Road.
- Ivanhoe Rail Facility:
    - a rail siding
    - site access road and internal haul roads/pavements
    - hardstand areas, including stockpiles/sealed container storage areas
    - a retention basin, drains, pumps, pipelines and other water management equipment and structures
    - site office, ablutions and car parking facilities
    - perimeter fencing
    - night-lighting
    - extension to existing 11 kV powerline and
    - landscaping, including retention of existing vegetation along the site access road.

It should be noted that further construction activities would be undertaken during Year 5 of operations, however, these activities would not require any material additional mobile fleet or workforce.

2.6 Rail transport

Mineral concentrates would be railed from the Ivanhoe Rail Facility to the MSP via the Orange-Broken Hill railway. The Project would require a maximum of three trains per week over the life of the Project. All rail wagons containing mineral concentrates would be covered prior to departure from the Ivanhoe Rail Facility.

From approximately Year 12 of the Project, MSP process waste in sealed containers would be unloaded from trains at the Ivanhoe Rail Facility prior to returning to the Atlas-Campaspe Mine. No additional rail movements for MSP process waste would be required for the Project.

3. Legislative Framework and Air Quality Criteria

An air quality assessment has been undertaken with reference to the air quality and greenhouse gas components of the Director-General's Requirements (DGRs) for the Project, which require:

Air Quality *– including a quantitative assessment of potential:*

- *Construction and operational impacts, with a particular focus on dust emissions, including $PM_{2.5}$ and PM_{10} emissions*
- *Reasonable and feasible mitigation measures to minimise dust emissions, including evidence that there are no such measures available other than those proposed and*
- *Monitoring and management measures, in particular real-time air quality monitoring.*

Greenhouse Gases *– including:*

- *A quantitative assessment of potential Scope 1, 2 and 3 greenhouse gas emissions*
- *A qualitative assessment of the potential impacts of these emissions on the environment and*
- *An assessment of reasonable and feasible measures to minimise greenhouse gas emissions and ensure energy efficiency.*

The NSW Department of Primary Industries (DPI) and the NSW Environment Protection Authority (EPA) have provided the following guidance to the air quality assessment:

> *DPI: Air quality issues, including type and amount of greenhouse gases, dust, smoke, chemicals and odours generated during construction, operation and decommissioning/recommissioning of the mine*
>
> *EPA: The goal of the project in relation to air quality should be to ensure sensitive receptors are protected from any adverse impacts from dust. Details would need to be provided on the proposed measures to manage dust from all sources. Measures to prevent or control the emissions of dust from sand mining activities must be detailed based on the outcome of an assessment for dust undertaken in accordance with our guidelines the 'Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales' (EPA, 2005). The assessment must identify all sensitive receptors in proximity to the proposed development. Emissions from any plant must meet the design criteria detailed in the Protection of the Environment (Clean Air) Regulation 2002. Details need to be provided on the proposed air pollution control techniques, including proposed measures to manage and monitor efficiency and performance.*

The potential environmental impacts of mining are primarily regulated under the NSW *Protection of the Environment (Operations) Act, 1997* (POEO Act). The POEO Act provides a framework for the:

- Development of Protection of the Environment Policies
- Licensing by the EPA of activities that are defined under Schedule 1 of the POEO Act
- Development of regulations and guidelines that promulgate impact assessment criteria and emission standards for industry
- Definition of offences and penalties in relation to air pollution (sections 124-129 of the POEO Act)

- Provision of a mechanism for public participation in the environmental assessment of activities that may be licensed by the EPA, in conjunction with the NSW *Environmental Planning and Assessment Act, 1979.*

Air quality assessment criteria are promulgated by the NSW Office of Environment and Heritage (OEH) in the Approved Methods, which lists the statutory methods and air quality criteria that are to be used to model and assess emissions and impacts of air pollutants from stationary sources in NSW.

The NSW *Protection of the Environment Operations (Clean Air) Regulation, 2010* is the core legislative and r egulatory instrument for air quality issues in NSW and prescribes requirements for domestic solid fuel heaters, control of burning, motor vehicle emissions and industrial emissions, such as volatile organic compounds.

The impact assessment criteria are summarised in Table 1. In addition, the advisory reporting standards defined by the *National Environment Protection (Ambient Air Quality) Measure 1998* (Air NEPM) (National Environment Protection Council [NEPC], 1998) for $PM_{2.5}$ have also been adopted.

Table 1 Impact assessment criteria used in the assessment

Pollutant	Averaging period	Impact assessment criteria (µg/m³ except where otherwise stated)	Source
Sulfur dioxide	10 minutes	712	NHMRC (1996)
	1 hour	570	NEPC (1998)
	24-hour	228	NEPC (1998)
	Annual	60	NEPC (1998)
Nitrogen dioxide	1 hour	246	NEPC (1998)
	Annual	62	NEPC (1998)
Particles as PM_{10}	24-hour	50	NEPC (1998)
	Annual	30	EPA (1998)
Particles as $PM_{2.5}$	24-hour	25	Air NEPM [a]
	Annual	8	Air NEPM [a]
Total suspended particulates	Annual	90	NHMRC (1996)
Deposited dust	Annual	2 g/m²/month [b] 4 g/m²/month [c]	NERDDC (1998)
Carbon monoxide	15 minutes	100,000	WHO (2000)
	1 hour	30,000	WHO (2000)
	8 hour	10,000	NEPC (1998)

Table notes:
[a] Advisory reporting standard.
[b] Maximum incremental increase in deposited dust level.
[c] Maximum total deposited dust level.
WHO = World Health Organisation.
µg/m³ = micrograms per cubic metre.
g/m²/month = grams per square metre per month.
NHMRC = National Health and Medical Research Council.
NERDDC = National Energy Research Development and Demonstration Council.

4. Existing Environment

4.1 Local terrain and land use

The terrain of the Atlas-Campaspe Mine is highly complex with numerous closed minor depressions, while the terrain surrounding the Atlas-Campaspe Mine is relatively flat and ephemeral lakes are scattered around the Atlas-Campaspe Mine, the largest of which is Garnpung Lake to the northwest. Land use surrounding the proposed Atlas-Campaspe Mine is largely agricultural including both livestock and cropping and natural expanses of semi-arid vegetation.

The proposed Atlas-Campaspe Mine is located approximately 5 km east of the Mungo National Park. Other sensitive land uses in the vicinity of the proposed Atlas-Campaspe Mine include Mungo State Conservation Area and the Willandra Lakes Region World Heritage Area, located approximately 8 km and 10 km west of the Atlas-Campaspe Mine, respectively.

The proposed Ivanhoe Rail Facility is located approximately 4.5 km south-west of Ivanhoe township in an area largely characterised as agricultural, primarily livestock and semi-arid vegetation. The terrain surrounding the Ivanhoe Rail Facility is generally flat and void of any notable topographic features.

4.2 Sensitive receptors

4.2.1 Atlas-Campaspe Mine

There are limited residences located proximal to the Atlas-Campaspe Mine. The sensitive receptors identified in the region that have been used in this assessment of Atlas-Campaspe Mine operations are provided in Table 2 and Figure 5, along with the distance and direction from the approximate extent of the proposed surface development. During the life of the Atlas-Campaspe Mine, all the identified residences are at least 7 km from the active mining areas.

The Willandra Lakes Region World Heritage Area is located to the west of the Atlas-Campaspe Mine. The Willandra Lakes Region World Heritage Area covers an area of 240,000 hectares and includes the ancient Lake Mungo, Lake Leaghur, much of Mungo National Park and a large area of leasehold grazing country.

There are three camping grounds within the Mungo National Park, however, these are not classified as sensitive receptors as they are likely to be temporarily occupied only. The nearest camp ground to the Project operations (Belah Campground) has been assessed as a receptor location in this air quality assessment for completeness. The health-based impact assessment criteria are not applicable to Mungo National Park. Air quality impacts are expected to be lower at the Willandra Lakes Regional World Heritage Area than the results at the nearest boundary of the Mungo National Park as they are located a greater distance from the Atlas-Campaspe Mine.

Table 2 Nearest sensitive receptors to the Atlas-Campaspe Mine included in the assessment

Receptor name	Receptor description	Location		Approximate distance and direction from mine site [1]	
		Easting (m)	Northing (m)	Distance (km)	Direction
Wampo	Residence	697145	6246702	17	West-southwest
Boree Plains	Residence	720368	6265625	7	North-northeast
Magenta	Residence	737481	6250503	15	East-southeast
Langleydale	Residence	737887	6243340	18	Southeast
Glen Tilt	Residence	735466	6264558	17	Northeast
Marona	Residence	734301	6261197	14	Northeast
Mungo National Park[2]	Belah Campground	701866	6267470	9	West

Table notes:

1 Mine site location taken as approximate extent of proposed surface development.

2 Not a sensitive receptor, but included to evaluate potential Project contributions at the camp grounds within the Mungo National Park.

4.3 Mineral concentrate transport route

The mineral concentrate transport route spans a distance of approximately 175 km and includes sections of public unpaved and paved roads generally at a considerable distance from any sensitive receptor. One section of the unpaved public road route does pass within 1 km of a sensitive receptor and has been assessed here for air quality impacts. While there is no requirement to assess potential dust emissions associated with vehicle movements on the public road network, an evaluation of maximum dust emissions from mineral concentrate transport by road train on unsealed roads has been undertaken for completeness.

4.4 Ivanhoe Rail Facility

All potential sensitive receptors for air quality at the site of the Ivanhoe Rail Facility are located at the Ivanhoe Township, approximately 4.5 km northeast of the proposed Ivanhoe Rail Facility (Figure 6).

4.5 Ambient air quality

4.5.1 Existing sources

There are no industries that report to the National Pollutant Inventory (NPI) that are proximal to the proposed Atlas-Campaspe Mine or the Ivanhoe Rail Facility. The nearest reporting industries are the Ginkgo and Snapper Mines, approximately 100 km to the west of the Atlas-Campaspe Mine. Due to the remote location and the absence of any major industrial source, the ambient background levels of pollutants including sulphur dioxide(SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), total hydrocarbons and odour are likely to be negligible.

Natural sources of wind-blown dust are likely to contribute to ambient concentrations in the region. This is particularly due to the location and proximity of the Project to nearby ephemeral lakes, which can be a considerable source of dust in dry periods. Significant amounts of silt can be deposited into these lakes as rain water drains into them, and after the surface dries this material becomes available to be swept up by the wind.

4.5.2 Summary of monitoring data

4.5.2.1 PM_{10}

Ambient air quality monitoring of PM_{10} levels is carried out by the OEH Lower Murray Darling Catchment Management Authority and Commonwealth of Australia 2012 as part of the NSW DustWatch program. One-hour average PM_{10} concentration data has been provided for the sites at Pooncarie (PNC), Ivanhoe (IVH) and Penarie (PNR) in western NSW. These sites are located approximately 80 km northwest (Pooncarie), 135 km northeast (Ivanhoe) and 70 km south-southeast (Penarie) of the Atlas-Campaspe Mine. The DustWatch program is a community based program that is designed to monitor wind erosion levels across Australia; however, the program is not designed to report on air quality and health related issues. A summary of the monitoring data from the Pooncarie, Ivanhoe and Penarie sites during 2007 to 2011 has been provided in Table 3, for completeness. Unfortunately this data has been recorded using a DustTrak device and does not comply with the *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW* (Approved Methods for Sampling) (DEC, 2007) and is therefore not suitable for use in impact assessments.

The closest monitoring sites that do comply with the Approved Methods for Sampling are the OEH's air quality monitoring station at Wagga Wagga, approximately 400 km to the southeast, which records hourly PM_{10} data; and the Cristal Mining operated site at the MSP, with 24-hour concentrations of PM_{10} recorded using a high volume air sampler (HiVol). Statistics for the data collected from 2007 to 2011 by the OEH and Cristal Mining are summarised in Table 4.

While the Broken Hill and Wagga Wagga monitoring sites will experience differences in localised sources of dust due to geographic features of the central NSW regions and the synoptic weather patterns, both monitoring sites are likely to experience similar regional dust influences. The climate of the region is characterised by the year round passage of cold fronts, which generally move across southern Australia from west to east. Consequently, regional dust influences, such as dust storms are likely to move across the central NSW region and be experienced at Broken Hill followed by Wagga Wagga, with the Project site located in between likely to experience similar levels. The similar range and statistics shown in the ambient PM_{10} monitoring data recorded at the two sites indicates that regional dust influences are important contributors to the dust levels recorded at the two sites.

The OEH DustWatch monitoring data measured at Pooncarie, Ivanhoe and Penarie shows that dust levels recorded at these sites are significantly lower than those measured at Broken Hill and Wagga Wagga. This is to be expected due to the isolated location of the Pooncarie, Ivanhoe and Penarie sites and the absence of any significant nearby industrial or urban dust sources. These records indicate that the use of the Wagga Wagga data for the establishment of average background PM_{10} levels is likely to be conservative.

Figure 7 shows the estimated frequency of dust storms in Australia, showing that the general area that includes Broken Hill, Wagga Wagga and the proposed Project area is prone to dust storms. In particular, the upper range of the PM_{10} data collected at the monitoring sites may be attributed to this.

Table 3 Statistics for 24-hour averaged PM_{10} monitoring data from the monitoring sites at Pooncarie, Ivanhoe and Penarie during 2007 to 2011 as part of the DustWatch program

Parameter	2007			2008			2009			2010			2011		
	PNC	IVH	PNR	PNC	IVH	PNR	PNC	IVH	PNR	PNC	IVH	PNR	PNC	IVH	PNR
Count	365	365	365	366	366	366	365	365	365	365	365	365	365	365	365
Min	0	0	0	0.2	0	0.6	0	0.4	0.6	0.2	0.3	0.7	0	0	0
Mean	6.8	4.2	4.1	8.8	4.9	4.9	5.8	8.1	4.1	3.3	3.9	3.6	3.3	3.6	3.5
Max	294.3	19.6	45	384	95.9	84.2	250.3	242.9	43.6	48.9	61.5	11	9	10.3	11.5
99.90%	294.3	19.6	45	384	95.9	84.2	250.3	242.9	43.6	48.9	61.5	11	9	10.3	11.5
99.50%	218.8	17.3	28.9	323	52.8	78	128.9	205	37.5	35.3	53.5	9.9	7.2	7.3	9.1
99%	45	15	20.2	171	37.2	18.7	81.4	136.5	18.8	13.6	30.1	8.7	7	6.8	8.8
90%	10.3	8	7.3	9.7	7.6	8.1	8.2	11	6.7	5.3	5.6	5.7	5.3	5.6	5.9
80%	7	6.4	6.1	6	5.9	6.4	5.5	6.3	5	4.1	4.6	4.8	4.7	5	5.3
70%	5.5	5.3	5.2	4.8	4.7	5	4.1	5.2	4.2	3.7	4.1	4.3	4	4.3	4.8
50%	4.1	3.7	4	3.1	3.5	3.3	2.3	3.8	3.4	2.7	3.2	3.3	3.1	3.6	3.8

Table notes:
% = percent.
PNC = Pooncarie.
IVH = Ivanhoe.
PNR = Penarie.

Table 4 Statistics for 24-hour averaged PM_{10} monitoring data at the MSP and NSW OEH Wagga Wagga

Parameter	2007		2008		2009		2010		2011	
	MSP	OEH	MSP	OEH	MSP	OEH	MSP	OEH	MSP	OEH
Count	58	356	52	343	45	301	29	354	47	264
Min	1	3.8	0.9	4.5	1.8	4.2	0.1	1.8	0.1	0.9
Mean	22.3	26.1	26.1	24.9	32.3	27	14.1	17.2	12.1	15
Max	105.3	110.3	197.1	295	281	297.4	66	64.9	60.1	36
99.90%	103.8	102.5	190.6	278	280	275.4	65.9	60.8	59.2	35.6
99.50%	97.8	83.9	164.5	126	274	222.3	65.7	52.9	55.7	34.1
99%	90.3	80.3	131.9	68.2	267	202.6	65.4	51.6	51.3	32.8
90%	39.8	47.3	50.8	44.9	53.1	45.9	34.5	29	24.9	23.8
80%	30.5	35.7	38.2	32.2	37.8	34.7	19	23.6	16.3	20.2
70%	25.5	29.6	31.2	26.2	25.7	27.7	13	19.5	13.8	17.8
50%	18.3	21.7	17.4	21	15.9	19.8	8.1	15.5	8.5	14.3
Number of exceedances	3	34	7	23	5	21	1	6	1	0

4.5.2.2 Dust deposition

Cristal Mining has a network of dust deposition gauges in place, which consists of six dust deposition gauges surrounding the proposed Atlas-Campaspe Mine. A summary of the available dust deposition data from these monitoring locations is provided in Table 5.

Table 5 Summary of dust deposition data (insoluble solids g/m²/month) recorded by Cristal Mining near the Project site

Month[1]	Insoluble solids (g/m²/month)					
	Site DC01	Site DC02	Site DC03	Site DC04	Site DC05	Site DC06
November 2011	0.9	0.9	1.0	1.1	0.7	1.4
December 2011	0.9	NA[2]	1.0	1.1	1.5	2.8
January 2012	1.0	0.6	0.6	4.1	0.3	0.3
February 2012	NA	NA	NA	NA	NA	NA
March 2012	0.6	1.0	0.1	22.4	0.2	0.2
April 2012	0.4	10.5	0.4	2.1	0.3	0.4
May 2012	0.5	0.7	0.3	NA	0.2	0.0
June 2012	0.1	0.4	0.6	0.1	0.0	0.0
July 2012	0.3	0.7	0.5	0.5	1.4	0.9
August 2012	0.1	2.2	0.3	0.1	0.4	0.1
Average	0.5	2.1	0.5	3.9	0.6	0.7
Average excluding outliers	0.5	0.9[3]	0.5	1.3[4]	0.6	0.7
Maximum	1.0	10.5	1.0	22.4	1.5	2.8

Table notes:

1 Data collected for the period 15 November to 5 September 2012.

2 Data not available e.g. sample bottle broken.

3 Insoluble solid measurements of 10.5 g/m²/month for April at Site DC02 contaminated. This value has been removed from the calculated average.

4 Insoluble solid measurements of 22.4 g/m²/month for March at Site DC04 considered unusually high and not representative of the regional background levels based on concurrent measurements at all other sites. This value has been removed from the calculated average.

5. Methodology

The air quality impact assessment for the Atlas-Campaspe Minerals Sands Project has been conducted in accordance with the Approved Methods. The assessment is based on a dispersion modelling study that incorporates source characteristics and emission rates, site-specific meteorology, terrain, land-use and geographic location of nearest sensitive receptors. The results and recommendations have been developed with consideration of the *NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining* (Katestone, 2011).

Year 16 of the Project was selected as a representative year for quantitative dispersion modelling at the Atlas-Campaspe Mine due to the mining activities proximity to the nearest sensitive receptors and is conservatively assumed to have the largest tonnage of overburden and topsoil removed and the largest tonnage of ore extracted.

This period also coincides with the transport of MSP process waste from the Ivanhoe Rail Facility. As conservative assumptions regarding the rate of overburden and ore extraction have been included in the Year 16 modelling scenario, no further scenarios need to be modelled.

Operations at the Ivanhoe Rail Facility were modelled for a typical worst case operational scenario which assumes concurrent operation of all relevant fleet items.

5.1 Existing environment

The existing environment across the Project region has been described in terms of:

- Regional terrain and land-use
- Location of nearest sensitive receptors
- Climate and meteorology
- Existing air quality based on a summary of the following ambient air quality monitoring data:
    - Ambient monitoring of PM_{10} concentrations by the OEH at Wagga Wagga
    - Ambient monitoring of PM_{10} concentrations by Cristal Mining at the MSP
    - Ambient monitoring of PM_{10} concentrations by the NSW DustWatch program for the Pooncarie, Ivanhoe and Penarie sites in western NSW
    - Dust deposition monitoring conducted by Cristal Mining near the Project site.

5.2 Meteorology

In accordance with the requirements of the Approved Methods, the separate TAPM meteorological models for the Atlas-Campaspe Mine and the Ivanhoe Rail Facility were run for a five year consecutive period (2005 to 2009), with a detailed analysis of the output meteorology conducted against observations from the Pooncarie Mail Agency and Ivanhoe Post Office Bureau of Meteorology (BOM) stations to allow the selection of the most representative model year for use in the assessment. The results of this detailed analysis indicated that the 2007 model year was the most representative (Section 7).

The output from the model TAPM was downscaled and formatted for use in the Project area using the CALMET meteorological pre-processor. This was conducted following the OEH's recommended approach that is detailed in the document *Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia'* (TRC Environmental Corporation, 2011). Refer to Attachment A for a de tailed discussion of the model configuration and evaluation.

5.3 Emissions inventory

The air quality impact assessment has focused on the pollutants identified as most critical in terms of impacts to air quality, namely:

- Atlas-Campaspe Mine, mineral concentrate transport route and Ivanhoe Rail Facility:
  - Total suspended particulates (TSP)
  - Particulate matter with an aerodynamic diameter of less than or equal to 10 microns (PM_{10})
  - Particulate matter with an aerodynamic diameter of less than or equal to 2.5 microns ($PM_{2.5}$)
  - Dust deposition rates.
- On-site power generation:
  - Nitrogen dioxide (NO_x)
  - SO_2
  - CO
  - Particulates including TSP, PM_{10}, $PM_{2.5}$ and dust deposition
  - Total hydrocarbons.

Emission estimates for particulate matter (TSP, PM_{10} and $PM_{2.5}$) associated with the Project operations have been sourced from the following:

- Site layout, infrastructure and operating details provided by Cristal Mining, Emission factors published in the NPI Handbooks and the United States Environmental Protection Agency (US EPA) AP-42 Emission Estimation Manuals.

Emission estimates for NO_x, SO_2, CO, PM_{10}, $PM_{2.5}$ and total hydrocarbons associated with the four 1,000 kVa on-site diesel generators have been sourced from the following:

- Stack test data and s pecifications for Cummins QST30-G4 model generators, published by Cummins and
- Emission factors published in the NPI Handbooks.

5.4 Dispersion modelling

The meteorological models TAPM developed by the Commonwealth Scientific and Industrial Research Organisation (Version 4.0.5) and CALMET developed by EarthTec (Version 6.327) were used to develop a three-dimensional wind field representing wind flows in the region. The three-dimensional wind field produced by CALMET was then used to create a meteorological file suitable for use with the dispersion model CALPUFF developed by EarthTec (Version 6.267) CALPUFF was used to predict ground-level concentrations of all air pollutants assessed. Refer to Attachment A for details of the model configuration.

5.5 Impact assessment

The air quality impact assessment of the Atlas-Campaspe Mine and Ivanhoe Rail Facility includes predictions of ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ and dust deposition rates across a Cartesian grid and at the nearest sensitive receptors for the Project in isolation and a cumulative assessment that includes a conservative background concentration.

The predicted ground-level concentrations have been compared with relevant air quality criteria for TSP, PM_{10} and dust deposition rates published in the Approved Methods. Concentrations of $PM_{2.5}$ have been assessed against the Air NEPM advisory reporting standards.

The air quality assessment of the mineral concentrate transport route includes the predicted maximum 1-hour average ground-level PM_{10} concentration at various distances from 1.5 km to 25 m from the unsealed sections of the mineral concentrate transport route attributable to mineral concentrate transport vehicles. The rate of dust emissions from vehicle activity is highly dependent on vehicle speed. A sensitivity analysis has been conducted for the unsealed sections of the mineral concentrate transport route under vehicle speeds of 100 kilometres per hour (km/h), 80 km/h, 60 km/h and 40 km/h.

The air quality impact assessment of the on-site power generation predicted maximum concentrations of NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$ and total hydrocarbons at the nearest sensitive receptors. Ambient air quality monitoring data for NO_2, CO and SO_2 is not available for the Project region; however, due to the absence of any major industrial source in the surrounding region background levels of these pollutants are predicted to be low. Subsequently, no background levels have been included for the assessment of these pollutants from the on-site diesel generators. As impacts of PM_{10} and $PM_{2.5}$ from the on-site diesel generators at nearby receptors are expected to be negligible in comparison to impacts from fugitive emissions and mining activities (extraction, handling and transport of material), the particulate matter impacts from the on-site diesel generators have been assessed in isolation only.

5.6 Background levels used in cumulative assessment of Project

5.6.1 PM_{10}

Given the elevated particulate matter concentrations recorded at Wagga Wagga during 2007, the cumulative assessment for PM_{10} has been conducted using a Level 2 assessment (DEC, 2005). This involves the addition of hourly average contemporaneous background particulate concentrations obtained from monitoring data, to the predicted hourly average ground-level particulate concentrations due to the Project at each sensitive receptor location. The predicted maximum concentrations due to the Project with background at the sensitive receptor locations are then compared to the relevant OEH air quality criteria.

A detailed discussion of the suitability of the available ambient PM_{10} monitoring data for use in the cumulative assessment of the Project is provided in Attachment A. The detailed analysis of the available monitoring data showed that, while the monitoring site at Broken Hill is likely to be more representative of the Project site due to similarities in geographical features and fewer industrial and residential sources compared to the site at Wagga Wagga, the data from Broken Hill is recorded using a high volume air sampler once every six days and does not provide a complete data set suitable for use as a contemporaneous background in the assessment.

The cumulative assessment of the Project has been carried out using the 24-hour average PM_{10} concentrations recorded at the OEH site at Wagga Wagga during the 2007 assessment period to coincide with the results of the meteorological modelling.

The use of the 24-hour average PM_{10} concentrations recorded at the OEH site at Wagga Wagga during the 2007 assessment period can be considered conservative due to higher concentrations from anthropogenic sources (including light industry and vehicular traffic) likely to be experienced at Wagga Wagga.

In accordance with the Level 2 assessment requirements, the 24-hour average PM_{10} concentration measured at Wagga Wagga for each 24-hour period during the 2007 model year was added to the predicted 24-hour average ground-level PM_{10} concentration due to the Project at each of the sensitive receptor locations for the corresponding 24-hour period. As discussed in the appendix, several 24-hour averages were missing from the data recorded at Wagga Wagga, and these values were filled using the average of the 24-hour average immediately preceding and following the missing data point. As a result of the method chosen to fill the missing data, an additional exceedance of the 24-hour assessment criterion was generated and is included in the contemporaneous background data; taking the total to 35. The results have been presented as the maximum 24-hour average PM_{10} concentration and the total number of exceedances of the 24-hour PM_{10} concentration due to the Project with background.

Considering the above, the background annual average concentration of PM_{10} that was used in the assessment was 26.2 µg/m^3.

5.6.2 TSP

As with the cumulative assessment of PM_{10}, the cumulative assessment of TSP emissions from the Project has been conducted using a Level 2 assessment in accordance with the Approved Methods (i.e. the addition of each background 24-hour average TSP concentration to the corresponding concentration due to the Project).

As there is no available long-term TSP monitoring data from the Project region, the cumulative assessment of TSP emissions from the Project has been conducted using the available 24-hour average PM_{10} monitoring data from the OEH site at Wagga Wagga during the 2007 assessment period and a conservative TSP to PM_{10} ratio.

Previous assessments by Katestone and standard conversion ratios detailed in the US EPA's Compilation of Air Pollution Emission Factors Volume 1 (AP-42) and in the NPI Handbooks have found that PM_{10} is usually 50% of the TSP concentration. Due to the absence of any measurements of TSP, this ratio has been employed for this study. The 24-hour average contemporaneous TSP data were then added to the ground-level concentrations of TSP as predicted by the model.

Considering the above, the background annual average concentration of TSP that was used in the assessment was 52.3 µg/m^3.

5.6.3 $PM_{2.5}$

As with the cumulative assessment of PM_{10} emissions from the Project, the cumulative assessment of $PM_{2.5}$ emissions from the Project has been conducted using a Level 2 assessment in accordance with the Approved Methods (i.e. the addition of the background 24-hour average $PM_{2.5}$ concentration to the corresponding concentration due to the Project).

As there is no available long-term $PM_{2.5}$ monitoring data from the Project region, the cumulative assessment of $PM_{2.5}$ emissions from the Project has been conducted using the available 24-hour average PM_{10} monitoring data from the OEH site at Wagga Wagga during the 2007 assessment period and a conservative estimate of the $PM_{2.5}$ to PM_{10} ratio.

There is no data on the ratio of $PM_{2.5}$ to PM_{10} at the Project site. In urban or industrial centres the ratio has been found to be approximately 0.5. $PM_{2.5}$ emissions in urban and industrial centres typically include significant contributions from combustion sources such as wood-fired heaters, coal fired power stations, vehicle emissions and refineries. In the Project area, wind erosion of the surrounding ground will be the dominant contribution to the ambient background rather than combustion sources. The AP-42 (US EPA, 2006b; US EPA, 2006a) recommends $PM_{2.5}$ to PM_{10} ratios of 0.1 for emissions from unpaved roads and construction activities, and 0.15 for material transfers and open area wind erosion, which are all major sources of particulate matter at mine sites and significant contributors to the ambient background. Due to the absence of any measurements of $PM_{2.5}$, a conservative $PM_{2.5}$ to PM_{10} ratio of 0.2 has been employed to obtain a contemporaneous $PM_{2.5}$ dataset for this study that reflects the lack of significant industrial and urban combustion sources in the Project area. The 24-hour average $PM_{2.5}$ contemporaneous data were then added to the ground-level concentrations of $PM_{2.5}$ as predicted by the model.

Considering the above, the background annual average concentration of $PM_{2.5}$ used in the assessment was 5.23 $\mu g/m^3$.

5.6.4 Dust Deposition

The maximum average dust deposition rate for all dust gauges during the data period was 1.3 g/m^2/month and has been applied as the background value for the air quality impact assessment. Where measurements were considered unusually high and not representative of the regional background levels based on concurrent measurements at other sites, these values have been removed from the calculated average.

6. Climate and Regional Meteorology

The climate and regional meteorology in the Project region were analysed using historical meteorological data recorded by the BOM at monitoring sites including Ivanhoe, Pooncarie and Mildura. A detailed climatology is provided in Attachment B, and includes the cyclical climate patterns and extreme weather events that are experienced in the region, and a description of historical wind speed, wind direction, temperature, rainfall, relative humidity and evaporation measurements at selected BOM monitoring sites.

To summarise, based on the modified Köppen classification system of Australian climate classes (BOM, 2011a) the climate of the region is classified as "Grassland" with a warm, persistently dry climate that typically experiences very low average annual rainfall, hot dry summers and cold winters.

The longer-term El Niño Southern Oscillation (ENSO) cycle and the shorter-term movements of cold fronts and high pressure systems significantly influence the region's climate. The oscillation of the ENSO cycle between El Niño and La Nina periods influences the seasonal rainfall patterns in the region, with a drier climate and periodic droughts typical during El Niño periods, and wetter conditions including extreme rainfall and flooding more likely during La Niña periods.

Weather patterns in the region are influenced year round by the passage of cold fronts, which bring rainfall and are more frequent during winter months. Winter weather patterns are also influenced by the position of the sub-tropical ridge, which lies over central Australia during winter and results in stable and drier air in the region. Summer weather patterns in the area are influenced by a major trough in the easterly trade-winds located to the west of the Great Dividing Range. Very heavy summer rainfall and extreme precipitation events may be triggered by the enhancement of the major trough by an upper-level trough, southern ocean cold fronts or an east coast low.

These patterns are visible in historical meteorological records for the region, which show that extremes of maximum temperatures and rainfall typically occur during the warm summer months. While the annual pattern of rainfall is characteristic of the continental grasslands of Australia, with a roughly even distribution of rainfall in each season, there is a variation in rainfall intensity throughout the year, with shorter periods of more intense rainfall occurring in spring and summer than in winter and autumn.

The climate and regional meteorological conditions in the region influence the frequency and severity of bush fires and dust storms. While most winds in the region are light, periods of high wind speed coinciding with an unstable atmosphere (e.g. caused by a trough or cold front moving across the region) can generate dust storms. Two to three per year are expected in the Project region, and these are more likely to occur during periods of extreme drought. High winds and lack of rainfall also contribute to an increased fire danger.

7. Local Meteorology

The Approved Methods outline the minimum meteorological data requirements for use in dispersion modelling. These indicate the following:

- Meteorological data must span one year
- Meteorological data must be at least 90% complete
- Meteorological data must be representative of on-site meteorology.

Cristal Mining has installed a meteorological monitoring station at the Atlas-Campaspe Mine. However, the dataset available from the meteorological monitoring station is not yet sufficient for use as part of the assessment.

The nearest BOM automatic weather stations to the Atlas-Campaspe Mine are located at Ivanhoe, Pooncarie and Mildura, approximately 135 km north-east, 80 km north-west and 115 km south-west of the Atlas-Campaspe Mine, respectively. The meteorology at these sites is unlikely to be representative of the localised flows at the Project site. It is for this reason that a coupled approach using the TAPM/CALMET modelling system has been used to develop a meteorological file at the Project site suitable for input into the CALPUFF dispersion model. Details of the model configuration and evaluation are supplied in Attachment A.

Whist there is a meteorological monitoring station operated by the BOM at Ivanhoe, the data from this site covers a single point only. A three-dimensional wind field was required for inclusion in the CALPUFF dispersion modelling of potential impacts from the Ivanhoe Rail Facility. Subsequently, the coupled approach using the TAPM/CALMET modelling system has been used to develop a meteorological file at the Ivanhoe Rail Facility suitable for input into the CALPUFF dispersion model. Details of the model configuration are supplied in Attachment A.

The following sections provide a summary of the site-specific meteorological files for the Atlas-Campaspe Mine and for the Ivanhoe Rail Facility developed using TAPM/CALMET.

7.1 Atlas-Campaspe Mine

7.1.1 Wind speed and wind direction

Wind speed and direction are important aspects that can influence the emission rates of dust. Exposed dust sources, such as stockpiles and dump areas, will have higher dust emissions during strong winds than during light winds. The dust emissions will also have a greater radius of impact during periods of higher wind speeds due to the suspension and long-range transport of dust particles. The seasonal and diurnal variability in the wind speed and wind direction at the Atlas-Campaspe Mine would result in variation in the areas impacted by Atlas-Campaspe Mine activity and may also affect intensity of dust events.

The annual, seasonal and diurnal distributions of winds predicted by TAPM/CALMET are presented as wind roses in Figures 8, 9 and 10. The highest frequencies of winds occur from the south and south-southeast.

The seasonal distribution of wind direction (Figure 9) show that higher impacts are likely to occur to the northeast of the Atlas-Campaspe Mine during the summer as the predominant winds are south-westerly. The wind distribution during autumn is relatively even with a slight predominance of southerlies and north-easterlies. During winter the majority of winds blow from the westerly quadrants. During spring there is an almost even distribution of winds from the westerly and easterly quadrants, although more impacts would be expected to the east of the Atlas-Campaspe Mine as the majority of strong winds are from the westerly directions.

The diurnal distribution of wind direction (Figure 10) shows that winds during the day (6am to 6pm) are typically stronger than during the night, and the strongest winds blow from the westerly quadrants. In the evening (6pm to midnight), the predominant wind direction is south-southwest, and overnight (midnight to 6am) the most frequent winds are from the south-southwest to south-southeast.

A summary of the annual, diurnal and seasonal frequency of wind speeds predicted by CALMET at the Atlas-Campaspe Mine is shown in Table 6. The data shows that the winds at the site are predominantly moderate, with 47% of winds between 2 and 4 metres per second (m/s). The distribution of wind speeds does not vary significantly from season to season, however, higher frequencies of strong winds are predicted during the day.

Table 6 Summary of wind speeds at the Atlas-Campaspe Mine as generated by CALMET

Period	Wind speed				
	Calms	<2 m/s	2 - 4 m/s	4 - 6 m/s	>6 m/s
Annual	0%	26%	47%	21%	7%
Diurnal distribution					
Midnight to 6am	0%	34%	54%	10%	2%
6am to Midday	0%	17%	45%	29%	9%
Midday to 6pm	0%	11%	42%	34%	13%
6pm to Midnight	0%	41%	46%	11%	2%
Seasonal distribution					
Spring	0%	25%	42%	21%	11%
Summer	0%	21%	45%	27%	7%
Autumn	0%	28%	48%	21%	3%
Winter	0%	29%	52%	14%	5%

7.1.2 Atmospheric stability

Stability classification is a measure of the stability of the atmosphere and can be determined from wind measurements and other atmospheric observations. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to F Class stability which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Unstable conditions (Classes A to C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for Class D conditions are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface. During the night, the atmospheric conditions are generally stable (often Classes E and F).

Table 7 shows the percentage of stability classes at the Atlas-Campaspe Mine for the January to December 2007 meteorological data used in the dispersion modelling, where Class A represents the most unstable conditions. There is a high percentage of D and F Class conditions.

Table 7 Frequency distribution of surface atmospheric stability conditions at the Atlas-Campaspe Mine

Pasquill-Gifford Stability Class	Frequency (%)	Classification
A	1.3	Extremely unstable
B	7.9	Unstable
C	18.2	Slightly unstable
D	28.9	Neutral
E	11.3	Slightly stable
F	32.4	Stable

7.1.3 Mixing height

The mixing height refers to the height above ground within which particulates or other pollutants released at or near ground can mix with ambient air. During stable atmospheric conditions, the mixing height is often quite low and particulate dispersion is limited to within this layer. During the day, solar radiation heats the air at the ground level and causes the mixing height to rise. The air above the mixing height during the day is generally cooler. The growth of the mixing height is dependent on how well the air can mix with the cooler upper level air and therefore depends on meteorological factors such as the intensity of solar radiation and wind speed. During strong wind speed conditions the air will be well mixed, resulting in a high mixing height.

Mixing height information has been extracted from the CALMET simulation at the Atlas-Campaspe Mine and is presented in Figure 11. The data shows that the mixing height develops around 7am, peaks at around 3pm before descending sharply after 4pm.

7.2 Ivanhoe Rail Facility

7.2.1 Wind speed and wind direction

The annual, seasonal and diurnal distributions of winds predicted by CALMET at the proposed Ivanhoe Rail Facility are presented as wind roses in Figures 12, 13 and 14.

The figures show that the conditions experienced at the Ivanhoe Rail Facility are predicted to be similar to those experienced at the Atlas-Campaspe Mine; however, the Ivanhoe Rail Facility is predicted to experience a slightly lower frequency of winds from the west-southwest to west and a slightly higher frequency of winds from the north-northeast to east-southeast direction compared to the Atlas-Campaspe Mine.

A summary of the annual, seasonal and diurnal frequency of wind speeds predicted by CALMET at the proposed Ivanhoe Rail Facility is shown in Table 8. The data shows that the winds at the Ivanhoe Rail Facility are similar to those at the Atlas-Campaspe Mine, and are predominantly moderate, with approximately 44% of winds between 2 and 4 m/s, with little seasonal variation, and a higher frequency of strong winds predicted during the day.

Table 8 Summary of wind speeds at the proposed Ivanhoe Rail Facility as generated by CALMET

Period	Wind speed				
	Calms	<2 m/s	2 - 4 m/s	4 - 6 m/s	>6 m/s
Seasonal distribution					
Spring	0%	30.5%	39.0%	22.2%	8.3%
Summer	0%	25.1%	45.4%	22.8%	6.7%
Autumn	0%	32.0%	46.2%	18.8%	3.0%
Winter	0%	34.4%	46.0%	15.9%	3.6%
Annual	0%	30.6%	44.1%	19.9%	5.4%
Diurnal distribution					
Midnight to 6am	0%	41.2%	50.0%	7.4%	1.5%
6am to Midday	0%	22.5%	42.2%	28.1%	7.2%
Midday to 6pm	0%	13.8%	38.7%	35.7%	11.8%
6pm to Midnight	0%	44.7%	45.7%	8.5%	1.1%

7.2.2 Atmospheric stability

Table 9 shows the percentage of stability classes at the proposed Ivanhoe Rail Facility for the January to December 2007 meteorological data used in the dispersion modelling, where Class A represents the most unstable conditions and Class F represent the most stable. As shown at the Atlas-Campaspe Mine, there is a high percentage of D and F Class conditions.

Table 9 Frequency distribution of surface atmospheric stability conditions at the proposed Ivanhoe Rail Facility

Pasquill-Gifford Stability Class	Frequency (%)	Classification
A	1.5	Extremely unstable
B	8.6	Unstable
C	19.1	Slightly unstable
D	26.8	Neutral
E	9.4	Slightly stable
F	34.6	Stable

7.2.3 Mixing height

Mixing height information has been extracted from the CALMET simulation at the proposed Ivanhoe Rail Facility and is presented in Figure 15. As shown at the Atlas-Campaspe Mine, the mixing height develops around 7am, peaks at around 3pm before descending sharply after 4pm.

8. Emissions

Particulate matter (PM) or dust is the primary air pollutant emitted by open-cut mining activities. The vast majority of PM from mining activities consists of coarse particles and particles larger than PM_{10}, generated from mining activities such as mechanical disturbance of rock, soil and sand materials by shovels, excavators and vehicles on dirt roads. Particles are also generated when wind blows over bare ground and different types of stockpiles (NSW Health, 2007). Trace emissions of NO_X and CO would occur due to combustion of fuels through on-site vehicle activity, however, these are expected to be negligible compared to the power generators and would not significantly contribute to the predicted ground-level concentrations of these pollutants and have not been assessed. However, the emission of NO_X, SO_2, CO, PM_{10}, $PM_{2.5}$ and hydrocarbons during the generation of power by on-site by diesel generators has been assessed.

8.1 Construction

Construction has the potential to cause elevated levels of dust if not appropriately managed. The Project includes the construction of the Atlas-Campaspe Mine and the Ivanhoe Rail Facility. Construction activities at the Project site can be broadly described as:

- Site clearance of areas for construction activities, including vegetation clearance, topsoil removal and storage, and earthworks
- Civil works including temporary and permanent drainage works
- Structure and plant erection and installation
- Commissioning and testing of plant and equipment
- Construction site demobilisation.

The major sources of dust during construction are expected to be due to earthworks, such as vegetation clearance, topsoil removal and storage. Emissions during the construction phase of the Project are transient by nature and would not occur continuously over any length of time. Any emissions associated with construction are proposed to be managed through the use of appropriate mitigation measures (Section 10).

8.2 Mining operations

Emissions for activities related to the operation of the Atlas-Campaspe Mine were based on emission factors and methods published by the US EPA and the NPI. Detailed emission estimates and a description of the operational data and methods used in calculating emissions can be found in Attachment C.

Activities associated with mining operations that cause dust emissions are:

- Extraction, transport and dumping of topsoil
- Extraction, transport and dumping of overburden
- Mining, transport and screening of ore
- Wind erosion of stockpiles.

Total emissions of dust from Atlas-Campaspe Mine operations are largely dependent on the site layout, extraction methods, ore/overburden transportation methods, vehicle fleet, and overburden emplacement methods. Other factors that also affect emissions include the ore characteristics such as moisture and silt content, any incident rainfall and any mitigation measures that may be employed.

Dust control measures have also been accounted for in the dispersion modelling study. A summary of key NPI dust control measures and their relative effectiveness is included in Table 10. An additional control factor of 50% for TSP and 5% for PM_{10} has been applied to in-pit activities to account for pit retention (NPI, 2012b). All the factors that account for dust emissions have been accounted for and discussed in more detail in Attachment C.

Table 10 Dust control measures and relative reduction in emissions

Activity	Control Measure	Reduction (%)
Topsoil removal	Watering	50
Haulage	Level 2 watering (> 2 litres/m²/hour)	75
Wind erosion of exposed areas	Stage 1 rehabilitation - stable landform with seed cover/crop application	60
	Stage 2 rehabilitation - established cover crop/revegetation	100
Handling of mineral concentrates post-processing (stacking, road train loading)	Material is assumed to be wet after processing	75

Table note:
litres/m^2/hour = litres per square metre per hour.

A summary of emission rates of TSP, PM_{10} and $PM_{2.5}$ for the representative year of proposed Atlas-Campaspe Mine operations (Year 16) are presented in Table 11. Dust deposition rates were based on size distribution of dust particles from the emission rates estimated for TSP, PM_{10}, and $PM_{2.5}$.

Table 11 Summary of emission rates due to Year 16 of Atlas-Campaspe Mine operations included in the dispersion modelling (g/s)

Activity	Emission rate (g/s)		
	TSP	PM_{10}	$PM_{2.5}$
Topsoil removal	1.8	0.4	0.2
Overburden removal	18.6	7.4	1.6
Ore removal	0.7	0.3	0.1
Ore processing – screening [1]	2.9	1.0	0.1
Stacking of product	0.0018	0.0008	0.0001
Road train loading	0.004	0.002	0.0003
On-site haulage	25.7	7.9	0.8
Grading	0.9	0.3	0.03
Wind erosion	7.7	4.3	0.7
TOTAL	**58.2**	**21.6**	**3.4**

Table note:
[1] All other steps for ore processing are wet and therefore are not a source of dust emissions.
g/s = grams per second.

Dust from the internal haul roads within the active mining area and site access road would be suppressed by routinely spraying water sourced from the groundwater supply borefield (i.e. naturally saline) or from sumps that collect mine runoff water at the Atlas-Campaspe Mine. In addition, as part of ongoing road maintenance works (i.e. for road conditioning and safety purposes) saline water would be applied as required to the internal access roads at the Atlas-Campaspe Mine and to the unsealed sections of the mineral concentrate transport route following completion of the roadworks (i.e. in the order of once a week).

Compared to the total exposed areas of soils, residual saline dust from trafficking along the haul roads, access roads and unsealed sections of the mineral concentrate transport route subject to watering with saline water and/or wind-blown dust from associated road verges would be negligible.

8.3 Ivanhoe Rail Facility

Emissions for activities related to the operation of the Ivanhoe Rail Facility were based on emission factors and methods published by the US EPA and the NPI. Detailed emission estimates and a description of the operational data and methods used in calculating emissions can be found in Attachment C.

Activities at the Ivanhoe Rail Facility that would cause dust emissions are:

- Handling, transport and stockpiling of mineral concentrates
- Wind erosion of mineral concentrates stockpiles
- Vehicle activity on unsealed access road.

A summary of emission rates of TSP, PM_{10} and $PM_{2.5}$ for the operations at the Ivanhoe Rail Facility that were included in the dispersion modelling are presented in Table 12. Dust deposition rates were based on size distributions of dust particles from the emission rates estimated for TSP, PM_{10} and $PM_{2.5}$. The use of runoff captured in the retention basin is proposed to be utilised for dust suppression on mineral concentrate stockpiles; however, in order to provide a conservative assessment, no control factors have been applied for the calculation of dust emissions from operations at the Ivanhoe Rail Facility.

The scale of the operations and the significant distance to nearest sensitive receptors, impacts on air quality are not expected from the Ivanhoe Rail Facility; however, a plan for best practice dust mitigation measures will be put in place in the event that dust impacts occur due to the operation of the facility.

Table 12 Summary of emission rates due to operation of the Ivanhoe Rail Facility

Activity	Emission rate (g/s)		
	TSP	**PM_{10}**	**$PM_{2.5}$**
Wheel generated dust from unpaved haul road	4.17	1.04	0.11
Dumping of mineral concentrates onto stockpiles	0.0056	0.0026	0.0004
FEL transfer of mineral concentrates from stockpile to rail wagon	0.017	0.008	0.001
Wind erosion of mineral concentrate stockpiles	0.007	0.004	0.001
Total emission rate all sources	**4.20**	**1.06**	**0.12**

8.4 Mineral concentrate transport route

Emission rates from the proposed transport of mineral concentrates to the Ivanhoe Rail Facility via the unsealed sections of the mineral concentrate transport route are provided in Table 13. Emission rates have been calculated using the emission factor for vehicles travelling on publicly accessible unpaved roads, published by the US EPA (US EPA, 2006b: equation 1b).

The rate of dust emissions from vehicle activity is highly dependent on vehicle speed, with a reduction in vehicle speed associated with a reduction in dust emissions. A sensitivity analysis has been conducted for from the transport of mineral concentrate on the unsealed sections of the mineral concentrate transport route under vehicle speeds of 100 km/h, 80 km/h, 60 km/h and 40 km/h.

Table 13 Summary of emission rates due to mineral concentrate transport (unsealed sections) to Ivanhoe Rail Facility (g/m²/s)

Activity	Emission rate (g/m²/s)		
	TSP	PM_{10}	$PM_{2.5}$
Haulage on unsealed road: vehicle speed 100 km/h	2.05E-05	6.50E-06	6.50E-07
Haulage on unsealed road: vehicle speed 80 km/h	1.92E-05	5.81E-06	5.81E-07
Haulage on unsealed road: vehicle speed 60 km/h	1.76E-05	5.03E-06	5.03E-07
Haulage on unsealed road: vehicle speed 40 km/h	1.56E-05	4.11E-06	4.11E-07

Table note:
$g/m^2/s$ = grams per square metre per second.

Trailers and rail wagons travelling on the mineral concentrate transport route will be covered to reduce the incidence of fugitive dust emissions from exposed material during transport between the Atlas-Campaspe Mine and Ivanhoe Rail Facility. The assessment has assumed a 100% control factor for the following:

- Covering of trailers in road transport of mineral concentrates
- Covering of rail wagons in rail transport of mineral concentrates
- Transport of MSP process waste in sealed containers.

8.5 On-site power generation

Emissions for the four on-site diesel generators have been based on specifications and stack testing data for Cummins QST30-G4 1,000 kVa generators (prime operation). The stack height and diameter have been assumed based on typical values and typical resulting exit velocities.

A summary of typical values and emission rates resulting from power generation activities are presented in Table 14.

Table 14 Stack characteristics and emission information for the four 1,000 kVa diesel generators used in the air dispersion modelling

Parameter	Unit	Value
Number of generators	Number	4
Stack height	m	6
Stack diameter	m	0.34
Exit velocity	m/s	30.3
Temperature	°C	566
Actual flow rate	m^3/s	2.75
Maximum NO_X concentration[1]	g/HP-Hour	6.6
Maximum CO concentration	g/HP-Hour	1.2
Maximum SO_2 concentration	g/HP-Hour	0.13
Maximum PM concentration	g/HP-Hour	0.11
Prime power rating	kW	880
Hours of operation	hours/day	24
Maximum emission rates calculated per generator		
NO_X	g/s	2.163
CO	g/s	0.393
PM_{10}	g/s	0.036
$PM_{2.5}$	g/s	0.036
SO_2	g/s	0.043
Hydrocarbons (total)	g/s	0.115

Table notes:

[1] Concentrations taken from stack test results published by Cummins.

m^3/s = cubic metres per second.

kW = kilowatt.

g/HP-Hour = grams per horsepower hour.

hours/day = hours per day.

°C = degrees Celsius.

9. Air Quality Assessment

This section presents the results of the dispersion modelling assessment of the proposed activities at the Atlas-Campaspe Mine (Section 9.1), the proposed Ivanhoe Rail Facility (Section 9.2), the mineral concentrate transport route (Section 9.3) and the on-site diesel generators (Section 9.4).

The results of the dispersion modelling include contour plots that are indicative of ground-level concentrations. These are created from the predicted ground-level concentrations at the network of gridded receptors within the modelling domain, which are converted to contours using industry standard interpolation software. Contour plots are presented to illustrate the spatial distribution of ground-level concentrations. However, the process of interpolation causes a smoothing of the base data that can lead to minor differences between the contours and discrete model predictions.

9.1 Atlas-Campaspe Mine

The predicted maximum ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at the nearest sensitive receptor locations due to operations at the Atlas-Campaspe Mine are presented in Table 15. For the 24-hour average concentrations, the maximum predicted ground-level concentrations due to the Project in isolation are presented, as well as the contribution of the contemporaneous background concentrations at the time of this maximum impact. The maximum background values are also presented, for comparison.

Contour plots of the predicted maximum ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates due to operations at the Atlas-Campaspe Mine in isolation are presented in Figure 16 to Figure 21.

9.1.1 Project in isolation

The results of the assessment of TSP show:

- Predicted annual average ground-level TSP concentrations at the nearest sensitive receptor locations are well below the impact assessment criterion of 90 µg/m³
- The area of exceedance of the annual average TSP impact assessment criterion of 90 µg/m³ is localised over the Atlas-Campaspe Mine and off-site impacts are low (Figure 16).

The results of the assessment of PM_{10} show:

- Predicted 24-hour and annual average ground-level PM_{10} concentrations at the nearest sensitive receptor locations are well below the impact assessment criterion of 50 µg/m³ and 30 µg/m³, respectively
- The highest predicted 24-hour average ground-level PM_{10} concentration at a sensitive receptor of 23.6 µg/m³ is predicted to occur at Boree Plains located approximately 7 km north-northeast of the site and is well below the impact assessment criterion of 50 µg/m³
- The highest predicted annual average ground-level PM_{10} concentrations at a nearest sensitive receptor of 1.4 µg/m³ (Boree Plains) is well below the impact assessment criterion of 30 µg/m³.

Table 15 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition at sensitive receptor locations due to operations at the Atlas-Campaspe Mine

Pollutant	Receptors						Criteria
	Wampo	Boree Plains	Magenta	Langleydale	Glen Tilt	Marona	
TSP (µg/m³)							
Annual average							
Project in isolation	0.20	1.81	0.16	0.12	0.23	0.24	90[1,2]
Project with background	52.5	54.1	52.5	52.4	52.6	52.6	
PM_{10} (µg/m³)							
Maximum 24-hour average							
Project in isolation	4.1	23.6	3.2	5.4	5.1	4.7	50[1,2,4]
Project in isolation (number of exceedances)	0	0	0	0	0	0	
Background when maximum impact from Project occurs	22.2	10.2	19.9	23.8	8.7	11.6	
Background only (number of exceedances)	35[3]	35	35	35	35	35	
Project + background	110.3	110.5	110.3	110.3	110.3	110.3	
Project + background (number of exceedances)	35	35	35	35	35	35	
Annual average							
Project in isolation	0.19	1.39	0.14	0.10	0.20	0.20	30[1]
Project with background	26.3	27.5	26.3	26.3	26.4	26.4	
$PM_{2.5}$ (µg/m³)							
Maximum 24-hour average							
Project in isolation	1.3	4.7	1.0	1.4	1.7	1.5	25[5]
Background when maximum impact from Project occurs	4.4	2.0	5.5	4.8	4.2	4.2	
Project with background	22.1	22.1	22.1	22.1	22.1	22.1	
Annual average							
Project in isolation	0.05	0.29	0.04	0.03	0.06	0.05	8[5]
Project with background	5.29	5.52	5.27	5.26	5.29	5.28	

Pollutant	Receptors						Criteria
	Wampo	**Boree Plains**	**Magenta**	**Langleydale**	**Glen Tilt**	**Marona**	
Dust deposition (g/m²/month)							
Annual average							
Project in isolation	0.003	0.055	0.004	0.003	0.005	0.007	2[6]/4[7]
Project with background	1.303	1.355	1.304	1.303	1.305	1.307	

Table notes:

1. Impact assessment criteria defined in the Approved Methods (DEC, 2005).
2. Air NEPM air quality standards for human health and well-being.
3. There is one additional exceedance in the background dataset used for the cumulative assessment compared to the data recorded at Wagga Wagga and reported in Table 4. This is because missing values in the dataset recorded at Wagga Wagga have been interpolated to create a complete dataset for the cumulative assessment, and one of the interpolated values is greater than 50 μg/m^3.
4. Air NEPM air quality standard for 24-hour PM_{10} for human health and well-being allows for five exceedances/year.
5. Air NEPM advisory reporting standard for human health and well-being.
6. NERDDC maximum increase in deposited dust level.
7. NERDDC maximum total deposited dust level.

The results of the assessment of $PM_{2.5}$ show:

- Predicted 24-hour and annual average ground-level $PM_{2.5}$ concentrations at the nearest sensitive receptor locations are low and well below the advisory reporting standards of 25 µg/m³ and 8 µg/m³, respectively
- The highest predicted 24-hour average ground-level $PM_{2.5}$ concentration at a sensitive receptor of 4.7 µg/m³ is predicted to occur at Boree Plains and is well below the advisory reporting standard of 25 µg/m³
- The highest annual average ground-level $PM_{2.5}$ concentration at a sensitive receptor of 0.3 µg/m³ (Boree Plains) is well below the advisory reporting standard of 8 µg/m³.

The results of the assessment of dust deposition rates show:

- The predicted annual average dust deposition rates at the nearest sensitive receptor locations are low and well below the incremental impact assessment criterion of 2 g/m²/month.

9.1.2 Cumulative Impacts

The results of the assessment of TSP show:

- Predicted annual average ground-level TSP concentrations at the nearest sensitive receptor locations are well below the impact assessment criterion of 90 µg/m³ with the inclusion of conservative background concentrations
- The highest predicted annual average ground-level TSP concentration at a nearest sensitive receptor due to the Project with background of 54.1 µg/m³ is well below the impact assessment criterion of 90 µg/m³.

The results of the assessment of PM_{10} show:

- The operation of the Atlas-Campaspe Mine is not predicted to result in any additional exceedances of the 24-hour average PM_{10} impact assessment criterion of 50 µg/m³ at all sensitive receptors
- Predicted annual average ground-level PM_{10} concentrations at the nearest residential sensitive receptor locations are well below the impact assessment criterion of 30 µg/m³ with the inclusion of conservative background concentrations.

The results of the assessment of $PM_{2.5}$ show:

- The predicted 24-hour and annual average ground-level $PM_{2.5}$ concentrations at the nearest sensitive receptor locations are well below the advisory reporting standards of 25 µg/m³ and 8 µg/m³, respectively with the inclusion of conservative background concentrations.

The results of the assessment of dust deposition rates show:

- The predicted annual average dust deposition rates at the nearest sensitive receptor locations are well below the cumulative impact assessment criterion of 4 g/m²/month with the inclusion of existing levels.

9.1.3 Protected lands

Within Mungo National Park, the camp ground closest to the Project is the Belah Campground, which is approximately 4 km inside the eastern boundary of the Mungo National Park. At the Belah Campground, the dispersion modelling has predicted the following concentrations due to the Atlas-Campaspe Mine:

- Maximum 24-hour average PM_{10} concentration of 6.9 µg/m^3
- Maximum 24-hour average $PM_{2.5}$ concentration of 2.0 µg/m^3
- Annual average $PM_{2.5}$ concentration of 0.07 µg/m^3
- Annual average TSP concentration of 0.27 µg/m^3
- Annual average dust deposition of 0.005 g/m^2/month.

The results above indicate that the contribution of particulates and dust from the Atlas-Campaspe Mine at the Belah Campground are minor. Contributions throughout the Willandra Lakes Region World Heritage Area are expected to be lower.

9.1.4 Balranald Mineral Sands Project

It is noted that Iluka Resources Limited lodged a Project Application and Project Scoping Report for the Balranald Mineral Sands Project (SSD-5285) (EMGA Mitchell McLennan, 2012) with the NSW Department of Planning and Infrastructure.

While the Balranald Mineral Sands Project is not approved and no detailed air quality modelling results are available for the proposal, consideration of potential for cumulative impacts is provided below. The Project Scoping Report for the Balranald Mineral Sands Project indicates that mining of the West Balranald and Nepean deposits would be undertaken in series. Whilst mining is being undertaken at the Atlas deposit, operations at the Balranald Mineral Sands Project would be focussed on the West Balranald deposit (approximately 45 km south of the Atlas deposit [Figure 1]). By the time operations at the Balranald Mineral Sands Project progress to the Nepean deposit (northern-most deposit) Project mining operations would be focussed at the Campaspe deposit.

Based on the Project Scoping Report, the Balranald Mineral Sands Project would be operating at its northern-most extent during Year 11 of operations at the Atlas-Campaspe Mine. This would result in a distance between the operational ore extraction areas of the Atlas-Campaspe Mine and the Balranald Mineral Sands Project (Nepean deposit) of approximately 21 km.

Based on this separation distance and the fact that winds that enhance emissions to the south of the Atlas-Campaspe Mine are likely to correspondingly reduce emissions to the north of the Balranald Mineral Sands Project, it is considered unlikely that any cumulative impact would occur from the coincident construction or operation of the Project and the Balranald Mineral Sands Project.

9.2 Ivanhoe Rail Facility

The predicted maximum ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at the nearest sensitive receptor locations due to all operations at the Ivanhoe Rail Facility are presented in Table 16. Predicted concentrations at the receptors are provided for the Project in isolation and with representative contemporaneous background concentrations.

Contour plots of the predicted maximum ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates due to all operations at the Ivanhoe Rail Facility in isolation are presented in Figure 22 to Figure 27.

9.2.1 Project in isolation

The results of the assessment of TSP, PM_{10} and $PM_{2.5}$ from all operations at the Ivanhoe Rail Facility show:

- Predicted maximum ground-level TSP, PM_{10} and $PM_{2.5}$ concentrations at the nearest sensitive receptor locations are low and well below the impact assessment criteria
- Predicted maximum on-site ground-level TSP, PM_{10} and $PM_{2.5}$ concentrations are low and well below the criteria utilised for impact assessment.

The results of the assessment of dust deposition rates from operations at the Ivanhoe Rail Facility show:

- The predicted annual average dust deposition rates at the nearest sensitive receptor locations are low and well below the incremental impact assessment criteria of 2 g/m²/month.

9.2.2 Cumulative Impacts

The results of the assessment of TSP, PM_{10} and $PM_{2.5}$ from all operations at the Ivanhoe Rail Facility with background levels show:

- Predicted annual average ground-level concentrations of TSP and PM_{10} at the nearest sensitive receptor locations are well below the impact assessment criteria with the inclusion of conservative background concentrations
- The operation of the Ivanhoe Rail Facility is not predicted to result in any additional exceedances of the 24-hour average PM_{10} impact assessment criterion of 50 µg/m^3 at any sensitive receptors
- The predicted 24-hour and annual average ground-level concentrations of $PM_{2.5}$ at the nearest sensitive receptor locations are well below the advisory reporting standards of 25 µg/m^3 and 8 µg/m³, respectively. The predicted concentrations of $PM_{2.5}$ include a conservative estimate of the background concentration of $PM_{2.5}$.

The results of the assessment of dust deposition rates from operations at the Ivanhoe Rail Facility with background levels show:

- The predicted annual average dust deposition rates at the nearest sensitive receptor locations are well below the cumulative impact assessment criteria of 4 g/m²/month with the inclusion of existing levels.

Table 16 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition at sensitive receptor locations due to operations at the Ivanhoe Rail Facility

Pollutant	Receptors: Ivanhoe Township	Criteria
TSP (µg/m³)		
Annual average		
Project in isolation	0.22	90[1,2]
Project with background	52.5	
PM_{10} (µg/m³)		
Maximum 24-hour average		
Project in isolation	3.8	50[1,2,3]
Project in isolation (number of exceedances)	0	
Background when maximum impact from Project occurs	21.0	
Background only (number of exceedances)	35	
Project + background	110.3	
Project + background (number of exceedances)	35	
Annual average		
Project in isolation	0.15	30[1]
Project with background	26.3	
$PM_{2.5}$ (µg/m³)		
Maximum 24-hour average		
Project in isolation	0.5	25[4]
Background when maximum impact from Project occurs	4.2	
Project with background	22.1	
Annual average		
Project in isolation	0.02	8[4]
Project with background	5.25	
Dust deposition (g/m²/month): All sources at the Ivanhoe Rail Facility		
Annual average		
Project in isolation	0.01	2[5]/4[6]
Project with background	0.91	

Table notes:

1 Impact assessment criteria defined in the Approved Methods (DEC, 2005).
2 Air NEPM air quality standards for human health and well-being.
3 Air NEPM air quality standard for 24-hour PM_{10} for human health and well-being allows for five exceedances/year.
4 Air NEPM advisory reporting standard for human health and well-being.
5 NERDDC maximum increase in deposited dust level.
6 NERDDC maximum total deposited dust level.

9.3 Mineral concentrate transport route

The mineral concentrate transport route comprises sections of public road between the Atlas-Campaspe Mine and the Ivanhoe Rail Facility. Assessment of the potential air quality impacts of the transport of mineral concentrates is not required by the Approved Methods, as it is outside the boundary of the proposed premises. Notwithstanding, a conservative assessment has been under taken to determine the likely air quality concentrations attributable to mineral concentrate transport using road trains on unsealed roads.

The predicted maximum 1-hour average ground-level PM_{10} concentration at various distances up to 1,500m from the unsealed sections of the mineral concentrate transport route attributable to mineral concentrate transport vehicles are presented in Table 17, along with the proportion of the concentration at 25m for the various distances out from the unsealed sections of the mineral concentrate transport route.

The results show that maximum impacts (i.e. higher predicted ground-level concentrations) are predicted to occur at sections of the haul road with a north-south alignment. Full results for the assessment of sections of the haul road with an east-west and northeast – southwest alignment are provided in Attachment D.

A plot of the predicted maximum 1-hour average ground-level PM_{10} concentration at various distances from 25m up to 1,500m from the unsealed sections of the mineral concentrate transport route is presented in Figure 28 for the worst-case scenario. Figure 29 provides a plot of the predicted proportion of the ground-level PM_{10} concentration relative to the concentration at 25m from the unsealed sections of the mineral concentrate transport route for the various distances and vehicle speeds. The predicted ground-level PM_{10} concentration at various distances from the haul road was compared to the predicted concentration 25m from the road to give an i ndication of the rate of dust drop-out with distance from the haul road. The proportions for each vehicle speed have the same drop-off with distance, so appear as a single line in Figure 29.

Due to the sporadic nature of the road trains as well as the presence of various private vehicles travelling on t he transport route, a c umulative assessment of impacts from all vehicles on t he transport route is not feasible. S ensitive receptors located along the unsealed sections of the haul road would not be exposed to continuous dust emissions, but would experience sporadic dust plumes as each vehicle passes. While background dust levels and sporadic emissions from private vehicles will contribute to dust levels, it is unlikely to result in any exceedances of the air quality criteria at the nearest sensitive receptors, as they are located approximately 800m (Magenta) and 1,300m (Langleydale) from the unsealed sections of haul road.

The results of the assessment show the following:

- The predicted maximum 1-hour average PM_{10} concentration due to vehicle activity on the unsealed sections of the mineral concentrate transport route is below the 24-hour average OEH impact assessment criterion of 50 µg/m³ at a di stance 25m from the haul road for vehicles travelling up to 100 km/h.
- The maximum 1-hour average PM_{10} concentration at a di stance 25m from the unsealed sections of the mineral concentrate transport route is predicted to range from 40.4 µg/m³ for vehicles travelling at 100 km/h, to 25.6 µg/m³ for vehicles travelling at 40 km/h.

Table 17 Results of assessment of PM_{10} emissions from vehicle activity on mineral concentrate transport route

Distance from mineral concentrate transport route (m)	Speed of vehicles travelling on road							
	100 km/h		80 km/h		60 km/h		40 km/h	
	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25m from mineral concentrate transport route
25	40.4	1.00	36.1	1.00	31.3	1.00	25.6	1.00
50	38.4	0.95	34.3	0.95	29.7	0.95	24.3	0.95
75	35.3	0.87	31.6	0.87	27.3	0.87	22.3	0.87
100	32.0	0.79	28.6	0.79	24.8	0.79	20.3	0.79
250	11.8	0.29	10.5	0.29	9.1	0.29	7.4	0.29
500	2.3	0.06	2.1	0.06	1.8	0.06	1.5	0.06
1,000	0.9	0.02	0.8	0.02	0.7	0.02	0.6	0.02
1,500	0.3	0.01	0.3	0.01	0.2	0.01	0.2	0.01

Table note:

Results have been provided for worst-case scenario (north-south road section). Full results for the three road alignments assessed (north-south, east-west and north-east – south-west) are provided in Attachment D.

- The majority of particulate emissions are predicted to drop out in the first 250m from the unsealed sections of the mineral concentrate transport route, with the concentration at a di stance 800m from the unsealed sections of the mineral concentrate transport route predicted to be around 6% of the concentration predicted at 25m, for all vehicle speeds assessed.
- The maximum 1-hour average ground-level PM_{10} concentration at the nearest private receptor (approximately 800m from the haul road) is predicted to be:
    - Between 2.3 µg/m³ and 0.9 µg/m³ for vehicles travelling at 100 km/h
    - Between 2.1 µg/m³ and 0.8 µg/m³ for vehicles travelling at 80 km/h
    - Between 1.8 µg/m³ and 0.7 µg/m³ for vehicles travelling at 60 km/h
    - Between 1.5 µg/m³ and 0.6 µg/m³ for vehicles travelling at 40 km/h.

The results presented above have been pr edicted using a conservative estimate of maximum average vehicle movements per day. It can be implied that the maximum 24-hour average ground-level concentration of PM_{10} at the nearest private receptor would be of similar or lower magnitude as the results presented above, and t herefore compliance with the relevant criteria would be achieved.

As the results of modelling for the unsealed sections of the mineral concentrate transport route indicate that the predicted PM_{10} concentrations at the nearest private receptor (Magenta) readily comply with relevant criteria, it is assumed that compliance with relevant criteria would be achieved for all private receivers along the unsealed sections of the mineral concentrate transport route.

Given the minimal contribution of mineral concentrate transport on unsealed public roads to ground-level concentrations of PM_{10} at the nearest receptor, and given the considerable distance of all sensitive receptors along the mineral concentrate transport route from the Atlas-Campaspe Mine, a c umulative assessment of emissions from mining and m ineral concentrate transport has not been considered.

9.4 On-site diesel generators

Predicted maximum concentrations of NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$ and total hydrocarbons at the nearest sensitive receptors due to the operation of the four 1,000 kVa diesel generators at the Atlas-Campaspe Mine are provided in Table 18.

Ambient air quality monitoring data for NO_2, CO and SO_2 is not available for the Project region, however, due to the absence of any major industrial source in the surrounding region background levels of these pollutants are predicted to be low. Consequently, no background levels have been included in the assessment of these pollutants from the on-site diesel generators.

Contour plots of the predicted maximum 1-hour and annual average NO_2 concentrations due to the diesel generators are provided in Figure 30 and Figure 31, respectively.

The results of the assessment show that the predicted maximum ground-level concentrations of NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$ are below the relevant OEH impact assessment criteria at all sensitive receptors. NO_2 was found to be the most significant pollutant in terms of the percentage of its criteria. The predicted maximum 1-hour average NO_2 concentration at the nearest sensitive receptor is 4.3 $\mu g/m^3$, which is less than 2% of the impact assessment criterion of 246 $\mu g/m^3$. It should also be noted that a conservative NO_X to NO_2 ratio has been used. Emission rates were provided for particulate matter without specifying the component of PM_{10} and $PM_{2.5}$. Predicted ground-level concentrations of PM_{10} have therefore been conservatively estimated by assuming that all particulate matter emissions are PM_{10} and similarly, for $PM_{2.5}$ ground-level concentrations have been estimated by assuming that all particulate matter emissions are $PM_{2.5}$.

The predicted impacts of PM_{10} and $PM_{2.5}$ from the on-site diesel generators are negligible (i.e. less than 0.03 $\mu g/m^3$) in comparison to impacts from fugitive emissions and mining activities (extraction, handling and transport of material), and therefore, do not warrant consideration in the cumulative assessment of the Project.

Table 18 Predicted maximum ground-level concentrations of criteria pollutants at sensitive receptor locations due to the operation of the on-site diesel generators

Pollutant	Receptors						Criteria
	Wampo	Boree Plains	Magenta	Langleydale	Glen Tilt	Marona	
Nitrogen dioxide (µg/m³)							
Maximum 1-hour average							
In isolation	2.6	4.3	3.3	3.2	3.1	3.5	246[1,2]
Annual average							
In isolation	0.004	0.018	0.011	0.009	0.012	0.013	62[1,2]
Carbon monoxide (µg/m³)							
Maximum 15-minute average							
In isolation	2.6	4.5	3.3	3.3	3.2	3.6	100,000[1,2]
Maximum 1-hour average							
In isolation	1.5	2.6	2.0	2.0	1.9	2.1	30,000[1,2]
Maximum 8-hour average							
In isolation	0.3	0.6	0.8	0.4	0.9	0.5	10,000[1,2]
Sulfur dioxide (µg/m³)							
Maximum 10-minute average							
In isolation	0.3	0.6	0.4	0.4	0.4	0.5	712[1,2]
Maximum 1-hour average							
In isolation	0.2	0.3	0.2	0.2	0.2	0.2	570[1,2]
Maximum 24-hour average							
In isolation	0.01	0.02	0.03	0.01	0.03	0.02	228[1,2]
Annual average							
In isolation	0.0002	0.0012	0.0007	0.0006	0.0008	0.0008	60[1,2]

Pollutant	Receptors						Criteria
	Wampo	Boree Plains	Magenta	Langleydale	Glen Tilt	Marona	
PM_{10} (µg/m³)[3]							
	Maximum 24-hour average						
In isolation	0.01	0.02	0.03	0.01	0.03	0.02	50[1,2,4]
	Annual average						
In isolation	0.0002	0.0010	0.0006	0.0005	0.0007	0.0007	30[1,2]
$PM_{2.5}$ (µg/m³)[5]							
	Maximum 24-hour average						
In isolation	0.01	0.02	0.03	0.01	0.03	0.02	25[6]
	Annual average						
In isolation	0.0002	0.0010	0.0006	0.0005	0.0007	0.0007	8[6]
Total hydrocarbons (µg/m³)							
	Annual average						
In isolation	0.0006	0.0032	0.0019	0.0016	0.0022	0.0023	NA

Table notes:
1 Impact assessment criteria defined in the Approved Methods (DEC, 2005).
2 Air NEPM air quality standards for human health and well-being.
3 Predicted concentration assuming all particulate matter emitted is PM_{10}.
4 Air NEPM air quality standard for 24-hour PM_{10} for human health and well-being allows for five exceedances per year.
5 Predicted concentration assuming all particulate matter emitted is $PM_{2.5}$.
6 Air NEPM advisory reporting standard for human health and well-being.

10. Monitoring and Mitigation Measures

Prior to the commencement of Project operations, an Air Quality and Greenhouse Gas Management Plan (AQGHGMP) would be developed for the Project. The AQGHGMP would outline monitoring and mitigation measures for the Project. A summary of the proposed monitoring and mitigation measures is provided in the sub-sections below.

10.1 Operational dust

Air quality mitigation measures currently proposed for implementation at the Atlas-Campaspe Mine include:

- Watering of exposed haul roads within the active mining area (Level 2)
- Watering during topsoil removal
  - Level 1 watering
- Progressive rehabilitation of exposed areas
- Control of the speed of trucks
- Minimisation of travel speed and distance travelled for bulldozing.

The following mitigation measures are proposed for the transport of mineral concentrates and MSP process waste:

- All vehicles transporting mineral concentrates from the Atlas-Campaspe Mine would be covered to minimise potential losses
- All rail wagons transporting mineral concentrates along the Orange-Broken Hill railway would be covered to minimise potential losses
- All MSP process waste transport would be undertaken in sealed containers.

In addition, runoff collected in the sediment basin at the Ivanhoe Rail Facility would be used for dust suppression on the mineral concentrate stockpiles.

10.2 Construction dust

Measures for the management of dust emissions during the construction phase would include, but not necessarily be limited to the following:

- Regular watering of roads and exposed areas to reduce wheel-generated dust and restricting vehicle speeds
- Dust-generating activities such as earthworks would not be carried out during high wind conditions (greater than 10 m/s)
- Establishment of vegetation on stockpiled material to prevent wind erosion
- Minimisation of haul trips and trip distances, where practicable.

Before construction commences, an AQGHGMP is proposed to be developed in conjunction with the construction management plan to assist in minimising nuisance dust. Dust measures to be included are:

- So far as practical, erecting physical barriers such as bunds and or wind breaks around stockpiles or areas where earth moving is required
- Where possible, earth moving activities would be avoided during unfavourable meteorological conditions
- Minimising speed (speed limit of 40 km/h) of on-site traffic, where applicable, to minimise wheel generated dust

- Ensuring all vehicles are suitably fitted with exhaust systems that minimise gaseous and particulate emissions to meet vehicle design standards
- Watering of bunds and stockpiles to minimise dust lift-off
- Watering high use unsealed roads to minimise dust lift-off from the road surface
- Limiting vegetation and soil clearing to approved areas, so as to minimise the area of exposed soil that may generate dust
- Compaction of construction site and stabilisation of vegetation to minimise dust lift-off due to wind erosion.

10.3 Monitoring

It is noted that the DGRs suggest the implementation of real-time air quality monitoring. The predicted impacts of TSP, PM_{10}, $PM_{2.5}$ and dust deposition are all well below the relevant air quality assessment criteria at all sensitive receptors. It is noted that the nearest private receptor is located approximately 7 km from the Atlas-Campaspe Mine. In this context, real-time monitoring is not necessary for the Project.

The existing dust deposition monitoring network will be maintained. However, the predicted dust deposition due to the Project is minimal and it is not expected that the Project will result in any noticeable dust nuisance. It is recommended that the deposition monitoring network be reviewed every two years to evaluate whether it is still necessary to maintain all of the existing monitors.

11. Greenhouse Gas Assessment

This section provides a summary of the greenhouse gas assessment of the Project that has been undertaken with reference to the following DGRs for the Project relating to greenhouse gases:

- A quantitative assessment of potential Scope 1, 2 and 3 greenhouse gas emissions
- A qualitative assessment of the potential impacts of these emissions on the environment
- An assessment of reasonable and feasible measures to minimise greenhouse gas emissions and ensure energy efficiency.

The full greenhouse gas assessment of the Project is provided in Attachment E.

11.1 Overview

The greenhouse gas assessment has assessed the potential impacts of the following aspects of the Project on the state and national greenhouse gas inventories:

- Scope 1 greenhouse gas emissions
  - Consumption of diesel fuel in heavy vehicles at the Atlas-Campaspe Mine and Ivanhoe Rail Facility
  - Consumption of diesel fuel in on-site diesel generators at the Atlas-Campaspe Mine.

- Scope 2 greenhouse gas emissions
  - Consumption of electricity at the Ivanhoe Rail Facility.

- Scope 3 greenhouse gas emissions
  - Extraction, production and transport of diesel fuel consumed at the Atlas-Campaspe Mine and Ivanhoe Rail Facility
  - Consumption of electricity at MSP
  - Consumption of diesel fuel at MSP
  - Consumption of gas at MSP
  - Consumption of diesel during transport between the Ivanhoe Rail Facility and MSP, and between MSP and Port Pirie
  - Extraction, production and transport of electricity consumed at MSP
  - Extraction, production and transport of diesel fuel consumed at MSP
  - Extraction, production and transport of gas consumed at MSP
  - Extraction, production and transport of diesel fuel consumed during transport between the Ivanhoe Rail Facility and MSP, and between MSP and Port Pirie.

11.2 Methodology and reporting tools

The Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) monitors and compiles databases on anthropogenic activities that produce greenhouse gases in Australia and has published greenhouse gas emission factors for a range of anthropogenic activities. The DCCEE methodology for calculating greenhouse gas emissions is published in the National Greenhouse Accounts (NGA) Factors workbook (DCCEE, 2012b) and is based on Australian data. This workbook is updated regularly to reflect current compositions in fuel mixes and evolving information on emission sources.

The scope that emissions are reported under, and the subsequent emission factors used are determined by whether an activity is within an organisation's boundary or not. Direct emission factors are used to calculate Scope 1 emissions from activities within the organisation's boundary. Indirect emission factors are used to calculate Scope 2 emissions from the generation of electricity purchased and consumed by an organisation.

Scope 3 emissions occur as an indirect result of an activity. For an example, Scope 3 emissions are those that occur due to the production of fuel or the losses associated with the transmission of electricity.

The emission factors published in the 2012 NGA Factors workbook have been used to calculate the greenhouse gas emissions from the Project and are summarised in Attachment E.

11.3 Greenhouse gas inventory

The Scope 1, 2 and 3 greenhouse gas emissions estimated for each year of operation of the Project are presented in Table 19, based on the emission factors published in the 2012 NGA Factors workbook and information on energy consumption for each year of the Project. A summary of the Scope 1, 2 and 3 greenhouse emissions is also provided in Table 19 and Figure 32.

11.4 Mitigation measures

Cristal Mining would develop an AQGHGMP that includes:

- Incorporation of best practice mine planning including:
    - Optimisation of haul truck scheduling, routing and idling times to minimise the amount of diesel consumed
    - Design pit access ramps to limit the amount of effort required for fully-laden trucks to climb
    - Optimisation of the location of overburden dumps to limit the distance haul trucks need to cover whilst laden
- Undertake regular maintenance and servicing of the mine fleet and road trains (i.e. mineral concentrate transport trucks)
- Implementation of 'Greenhouse' awareness training at induction
- Installation light sensitive switches on lighting equipment and energy efficient light fittings throughout the Project site where practicable
- Installation energy saving devices within the on-site buildings, where practicable
- Development and maintain an inventory of emissions and sinks.

Table 19 A summary of the Scope 1, 2, 3 and total greenhouse gas emissions for the Project (t CO_2-e)

Year		Scope 1 greenhouse gas emissions (t CO_2-e)	Scope 2 greenhouse gas emissions (t CO_2-e)	Scope 3 greenhouse gas emissions (t CO_2-e)	Total Scope 1, 2 and 3 greenhouse gas emissions (t CO_2-e)
2013	1 (construction)	6,152	0.0	469	6,621
2014	2	7,505	1.2	4,880	12,386
2015	3	31,831	2.8	15,287	47,121
2016	4	26,603	2.7	21,190	47,795
2017	5	44,732	2.6	30,681	75,416
2018	6	17,608	2.6	28,748	46,359
2019	7	28,031	2.6	29,538	57,571
2020	8	29,336	2.6	29,644	58,983
2021	9	26,811	2.7	29,468	56,281
2022	10	30,264	2.7	17,241	47,507
2023	11	37,089	2.9	19,759	56,851
2024	12	27,652	2.7	17,099	44,753
2025	13	30,237	2.8	18,569	48,809
2026	14	33,669	2.7	19,256	52,928
2027	15	38,288	2.8	21,978	60,268
2028	16	36,406	2.6	22,196	58,604
2029	17	38,220	2.8	23,853	62,076
2030	18	37,759	2.8	29,224	66,985
2031	19	36,300	2.7	29,113	65,415
2032	20	13,256	1.0	12,180	25,436
Maximum		***44,732***	***2.9***	***30,681***	***75,416***
Total		***577,746***	***48***	***420,371***	***998,166***

Table notes:

t CO_2-e = tonnes of carbon dioxide equivalent.

Totals may have minor discrepancies due to rounding.

12. Conclusions

The Project components are located at significant distances from potential sensitive receptors, with the closest receptor to the Atlas-Campaspe Mine located at approximately 7 km and the closest receptors to the Ivanhoe Rail Facility located at approximately 4.5 km. The nearest sensitive receptor to potential emission associated with mineral concentrate transport is located some 800 m from the unsealed public road and some 15 km from the Atlas-Campaspe Mine.

The assessment was undertaken using dispersion modelling of emissions expected from Year 16 of operations at the Atlas-Campaspe Mine, a typical worst case operational scenario at the Ivanhoe Rail Facility and also evaluated the transport of mineral concentrates on unsealed roads along the mineral concentrate transport route.

Dispersion modelling indicated no exceedance of any assessment criteria due to Project in isolation at any sensitive receptor. Dispersion modelling also indicated that the addition of a conservative background air quality concentration, the Project would not result in any additional exceedances of any assessment criteria at any sensitive receptors.

The peak annual emission rate of Scope 1 greenhouse gases from the Project is approximately 0.045 million tonnes of carbon dioxide equivalent (Mt CO_2-e) (in year 2017) or 0.008% of Australia's estimated greenhouse gas emissions for the year to March 2012 (546.8 Mt CO_2-e) (DCCEE, 2012a). The proposed greenhouse gas minimisation strategies are consistent with best practice environmental management practises for the mining sector.

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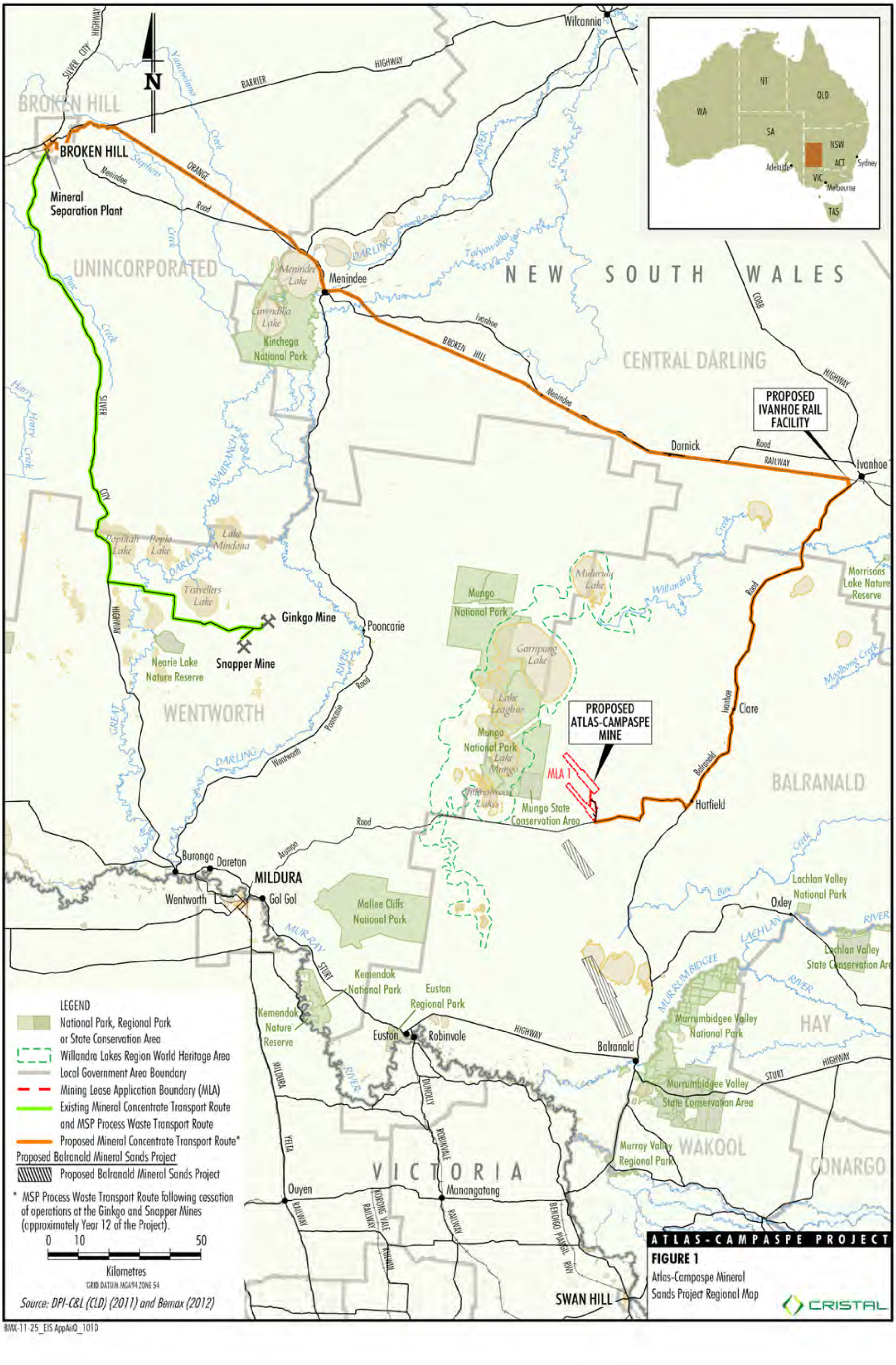

ATLAS-CAMPASPE PROJECT

FIGURE 1

Atlas-Campaspe Mineral Sands Project Regional Map

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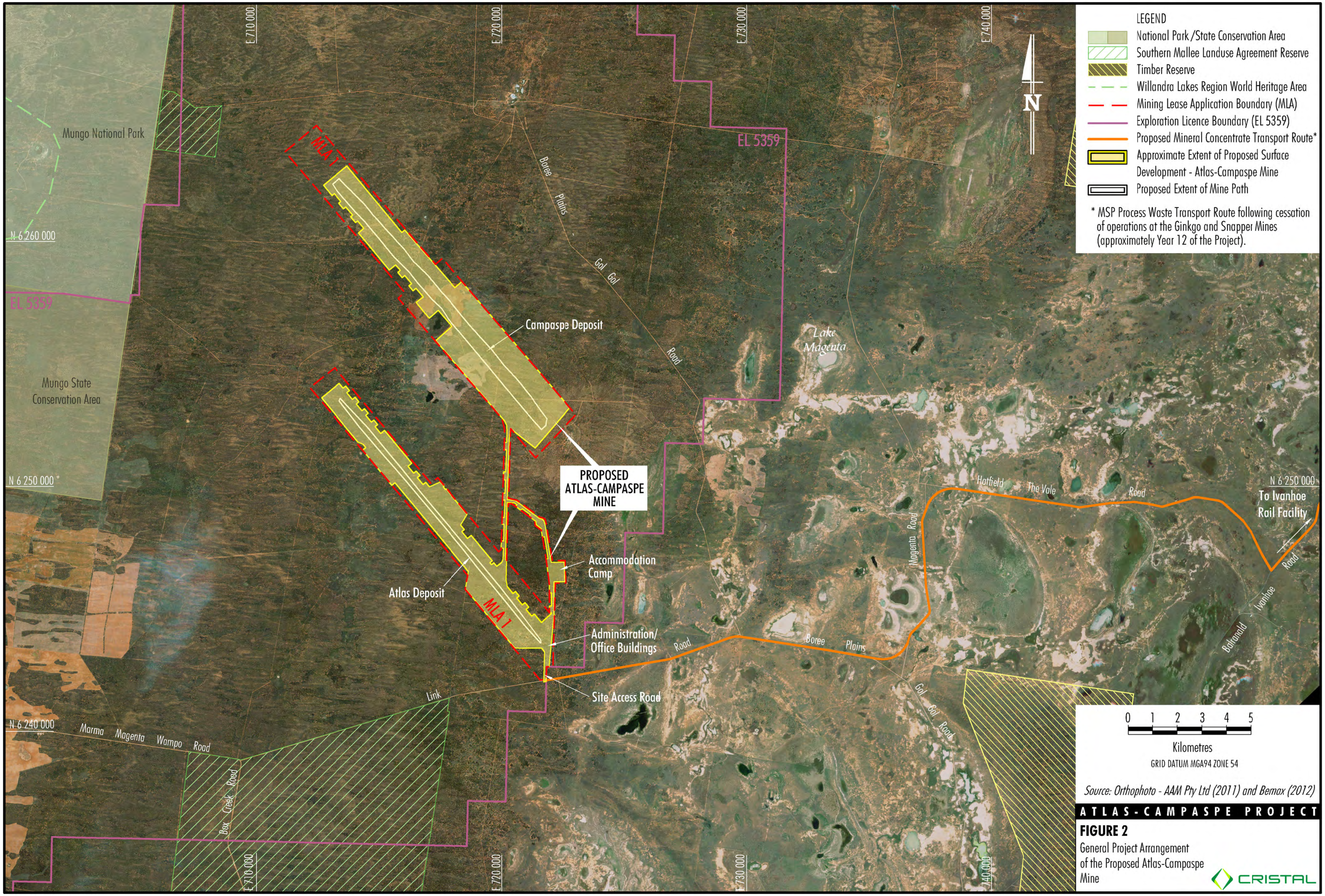

ATLAS-CAMPASPE PROJECT

FIGURE 2
General Project Arrangement of the Proposed Atlas-Campaspe Mine

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ATLAS-CAMPASPE PROJECT

FIGURE 3

General Project Arrangement of the Proposed Ivanhoe Rail Facility

CRISTAL

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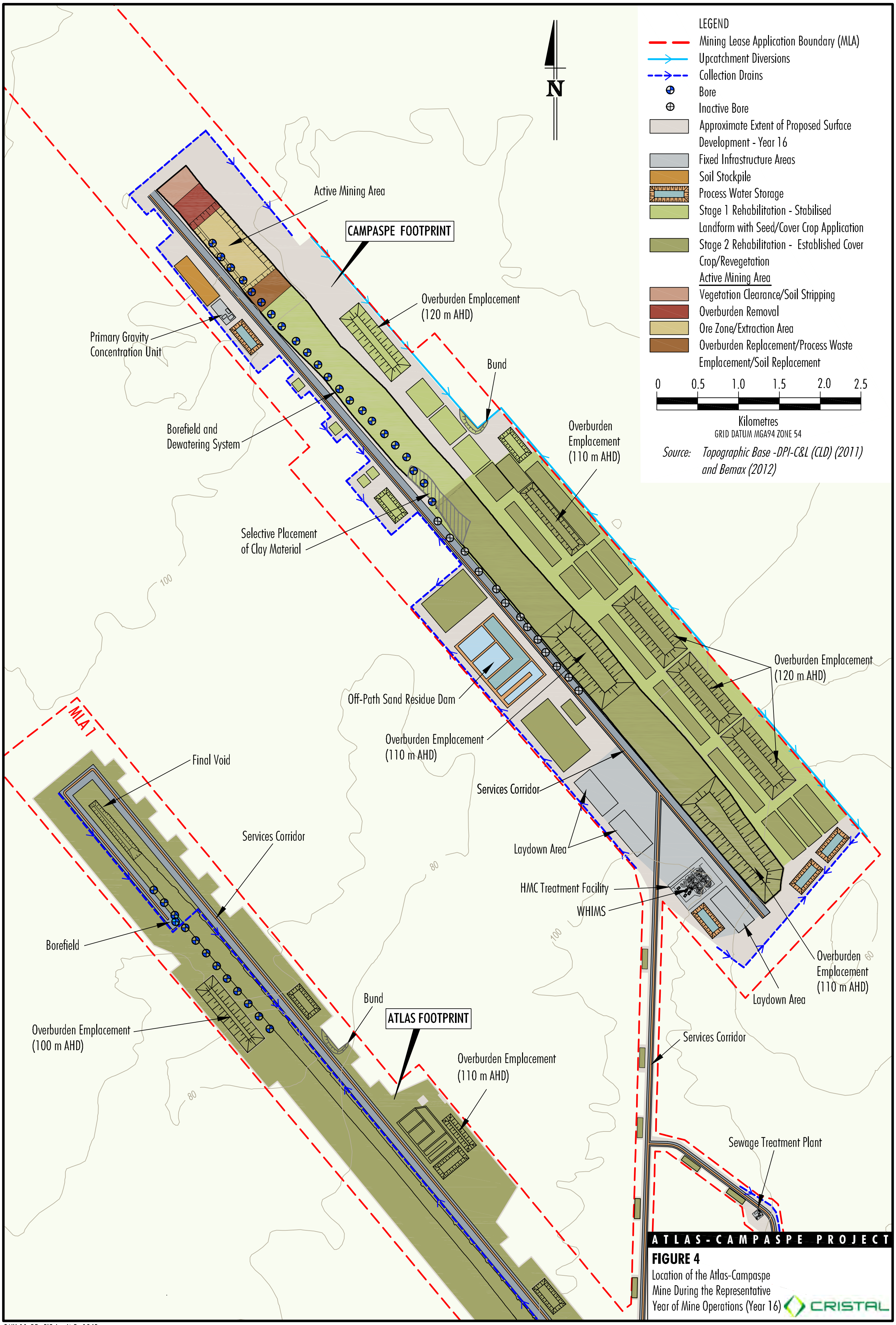

ATLAS-CAMPASPE PROJECT

FIGURE 4

Location of the Atlas-Campaspe Mine During the Representative Year of Mine Operations (Year 16)

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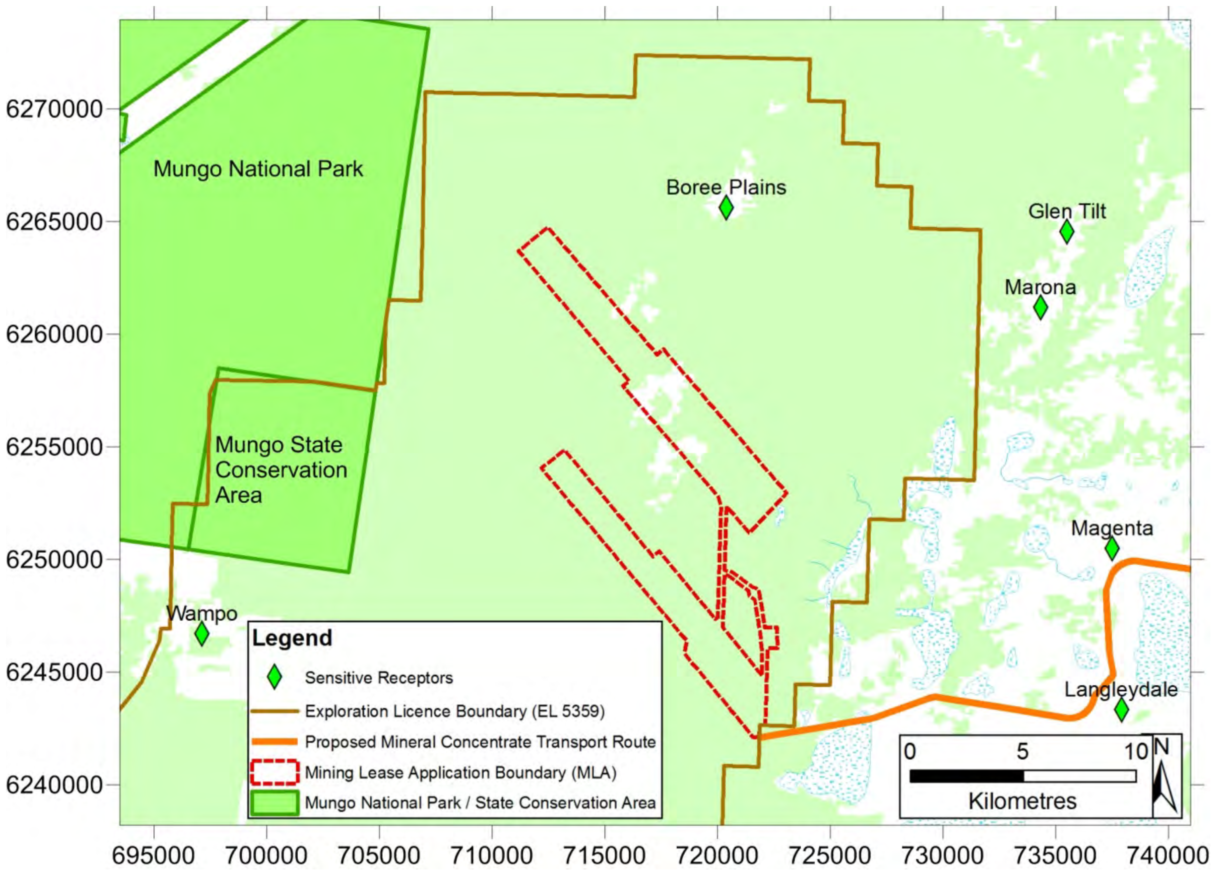


Figure 5 Location of the Atlas-Campaspe Mine and nearest sensitive receptors

Location:	Data source:	Units:
Proposed Atlas-Campaspe Mine, NSW	Google-Earth	Projection WGS84 Zone 54S
Type: Aerial map	**Prepared by:** S. Richardson	**Date:** August 2012

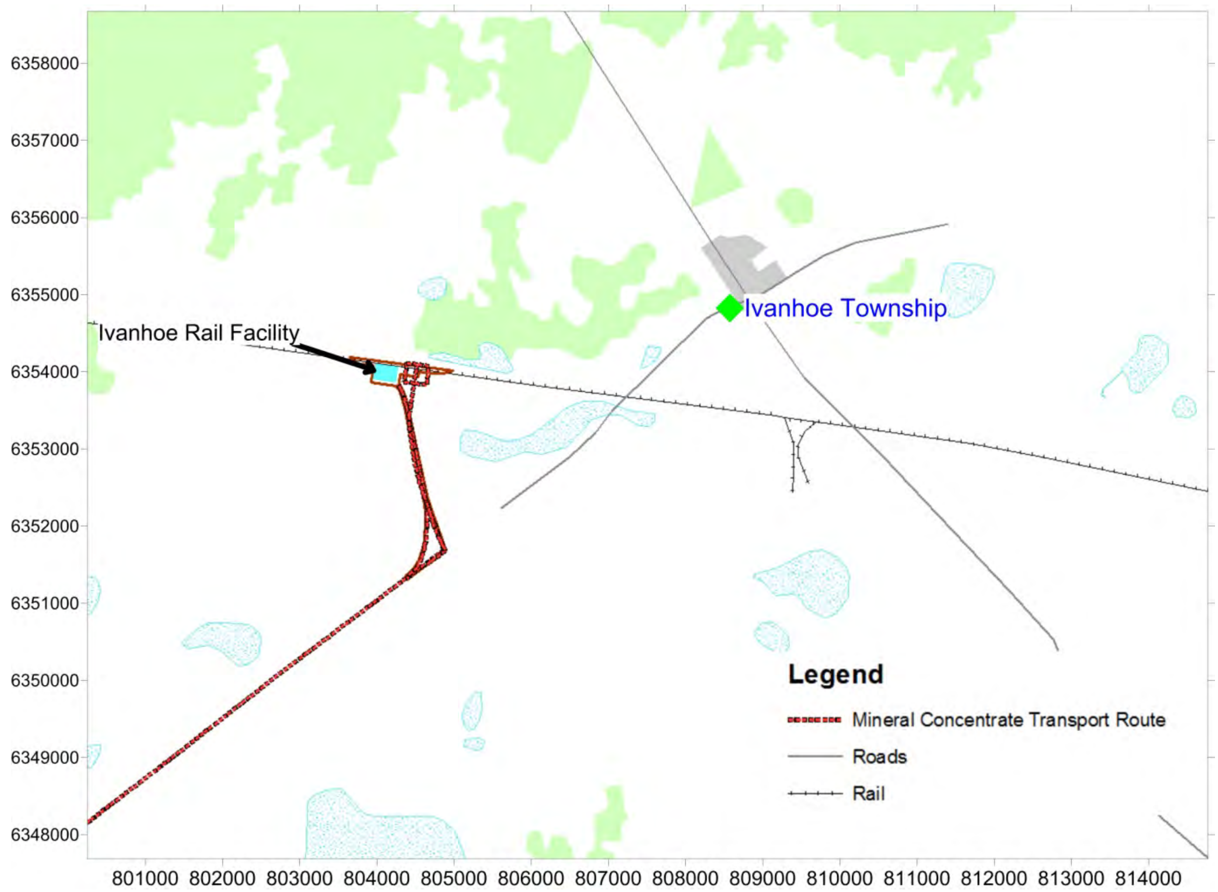


Figure 6 Location of the proposed Ivanhoe Rail Facility and nearest sensitive receptors

Location: Proposed Ivanhoe Rail Facility, NSW	**Data source:** Google-Earth	**Units:** Projection WGS84 Zone 54S
Type: Aerial map	**Prepared by:** S. Richardson	**Date:** September 2012

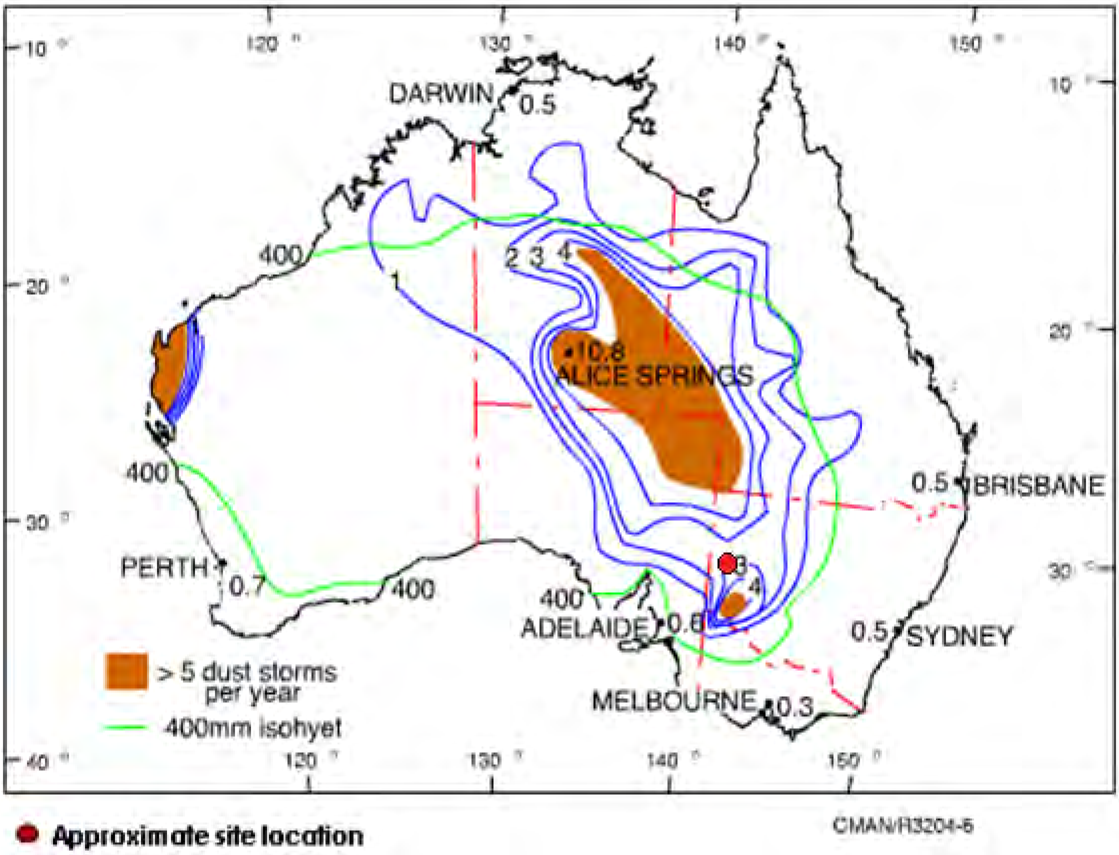


Figure 7 **Estimated frequency of dust storms over Australia**

Location: Australia	**Data source:** Middleton, N.J., 'Dust storms in Australia: frequency, distribution and seasonality.'	**Units:** NA
Type: Dust storm frequency map	**Prepared by:** S. Richardson	**Date:** August 2012

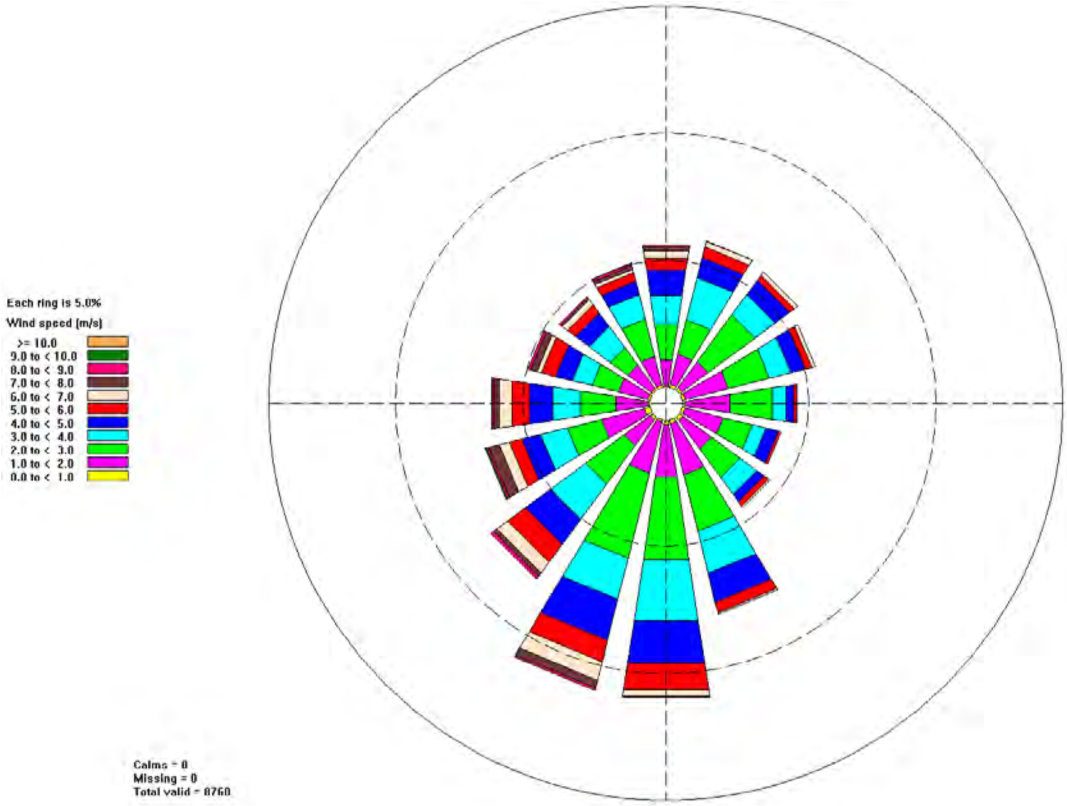


Figure 8 Annual distribution of wind speeds at the Atlas-Campaspe Mine

Location: Proposed Atlas-Campaspe Mine, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m/s and °
Type: Annual wind rose	8760 hourly average records	**Prepared by:** S. Richardson	**Date:** July 2012

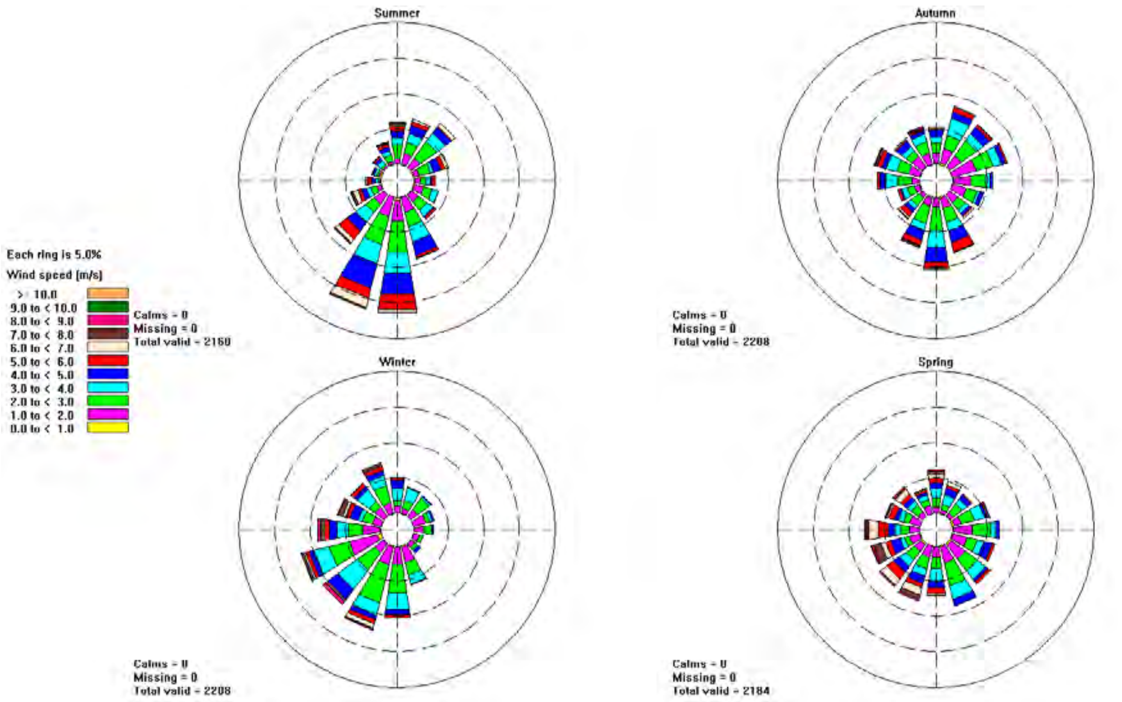


Figure 9 Seasonal distribution of wind speeds at the Atlas-Campaspe Mine

Location: Proposed Atlas-Campaspe Mine, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m/s and °
Type: Seasonal wind rose	8760 hourly average records	**Prepared by:** Tania Haigh	**Date:** July 2012

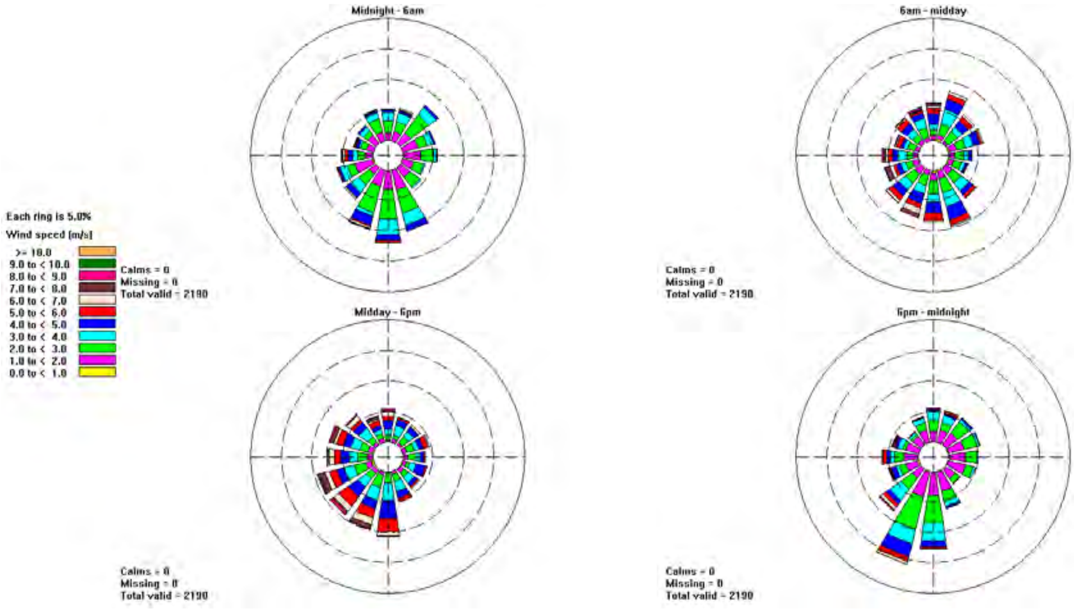


Figure 10 Diurnal distribution of wind speeds at the Atlas-Campaspe Mine

Location: Proposed Atlas-Campaspe Mine, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m/s and °
Type: Diurnal wind rose	8760 hourly average records	**Prepared by:** Tania Haigh	**Date:** July 2012

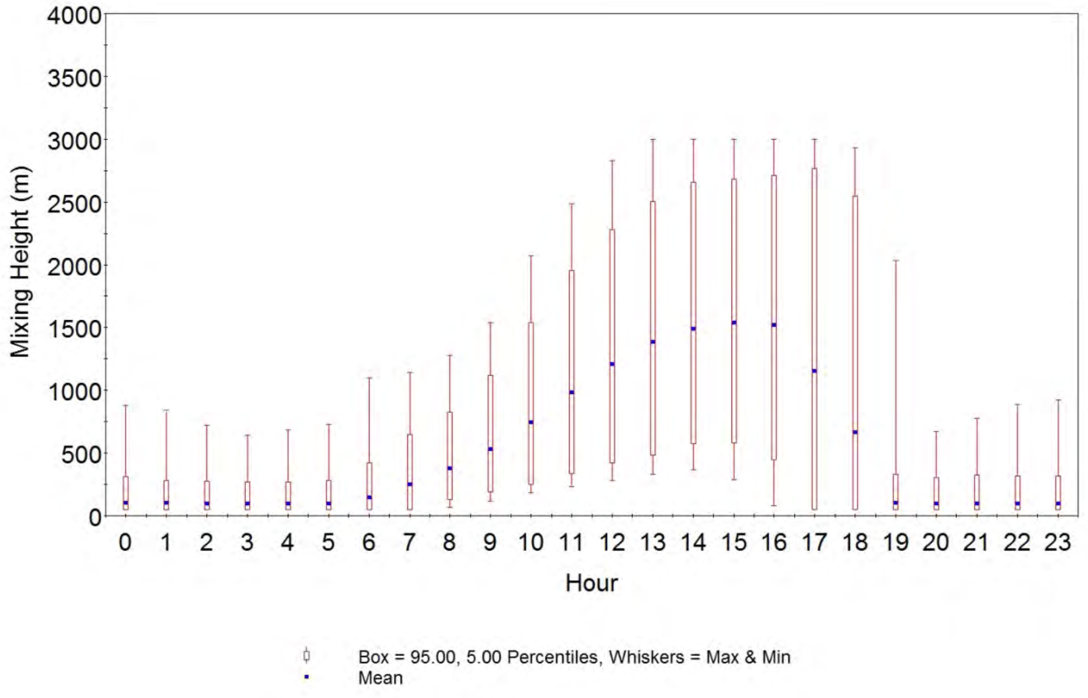


Figure 11 Diurnal distribution of mixing height at the Atlas-Campaspe Mine			
Location: Proposed Atlas-Campaspe Mine, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m
Type: Box and whisker plot	8760 hourly average records	**Prepared by:** Tania Haigh	**Date:** July 2012

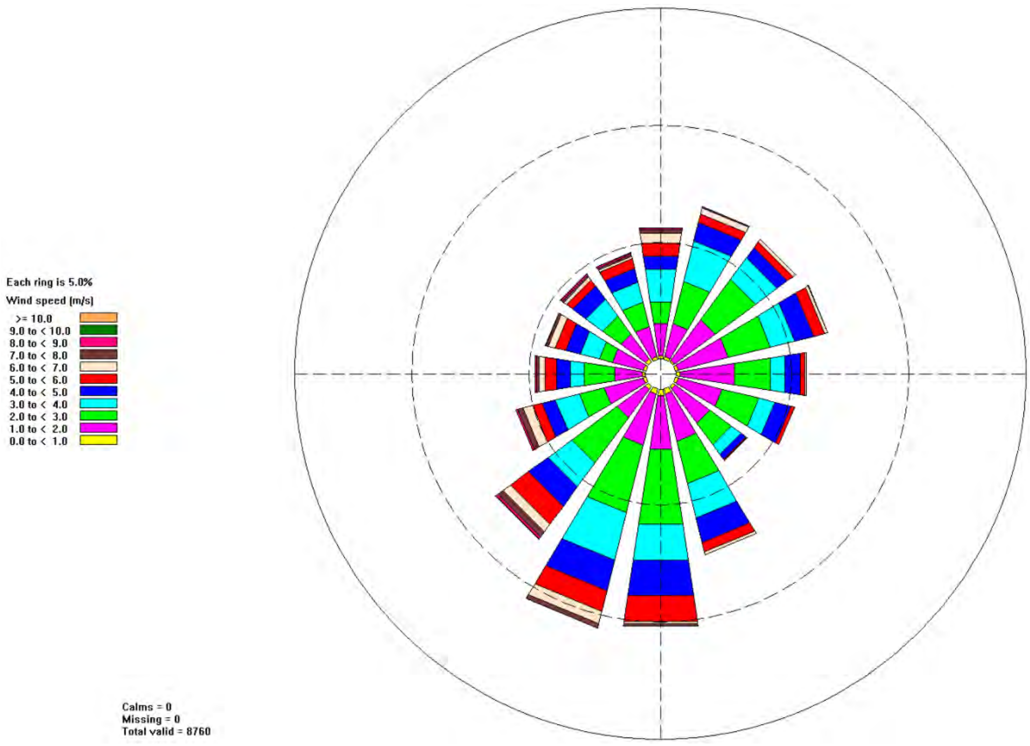


Figure 12 Annual distribution of wind speeds at the proposed Ivanhoe Rail Facility

Location: Proposed Ivanhoe Rail Facility, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m/s and °
Type: Annual wind rose	8760 hourly average records	**Prepared by:** S. Richardson	**Date:** August 2012

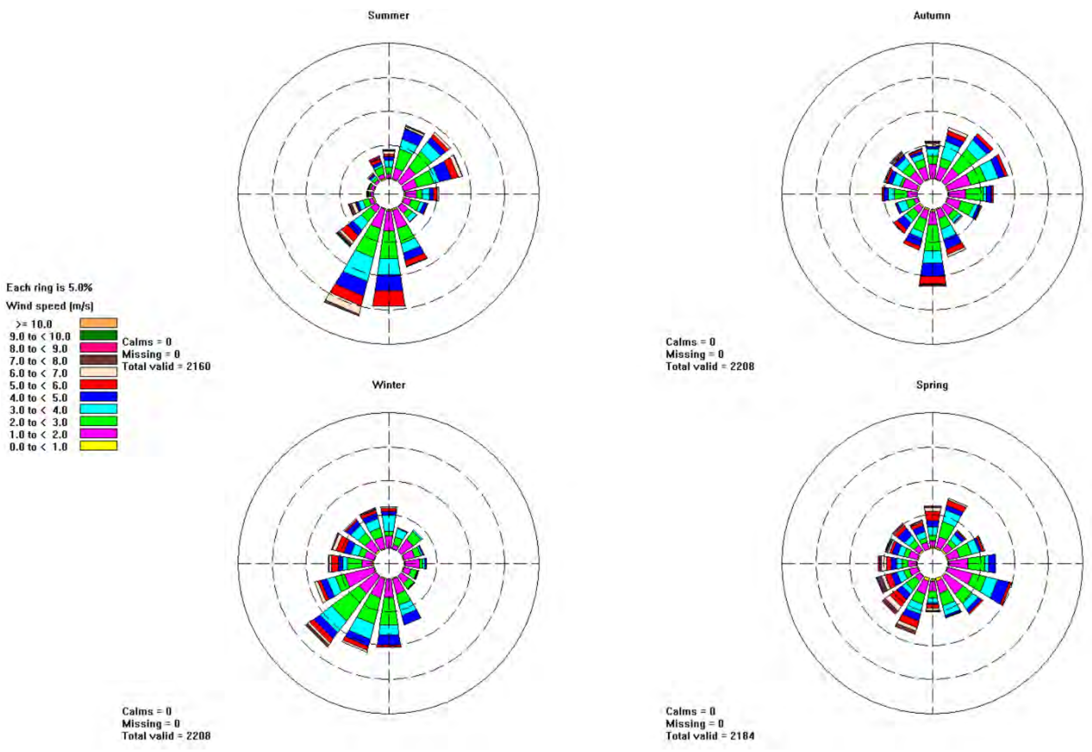


Figure 13 Seasonal distribution of wind speeds at the proposed Ivanhoe Rail Facility

Location: Proposed Ivanhoe Rail Facility, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m/s and °
Type: Seasonal wind rose	8760 hourly average records	**Prepared by:** S. Richardson	**Date:** August 2012

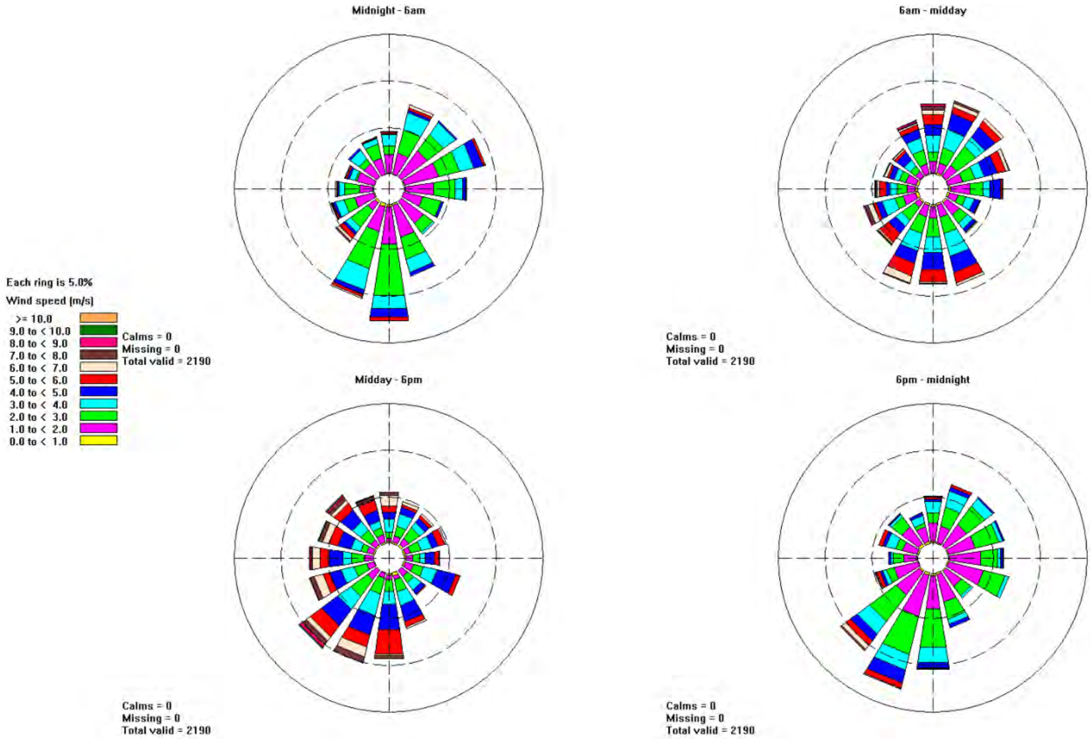


Figure 14 Diurnal distribution of wind speeds at the proposed Ivanhoe Rail Facility

Location: Proposed Ivanhoe Rail Facility, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m/s and °
Type: Diurnal wind rose	8760 hourly average records	**Prepared by:** S. Richardson	**Date:** August 2012

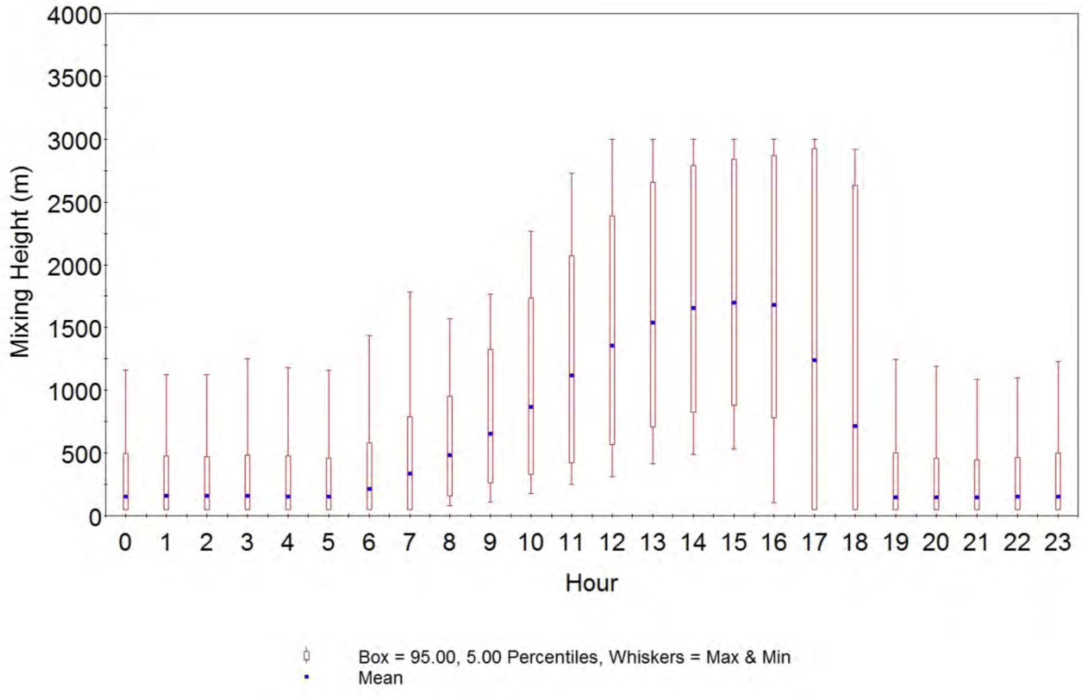


Figure 15 Diurnal distribution of mixing height at the proposed Ivanhoe Rail Facility			
Location: Proposed Ivanhoe Rail Facility, NSW	**Period:** 2007	**Data source:** Generated by TAPM/CALMET	**Units:** m
Type: Box and whisker plot	8760 hourly average records	**Prepared by:** S. Richardson	**Date:** August 2012

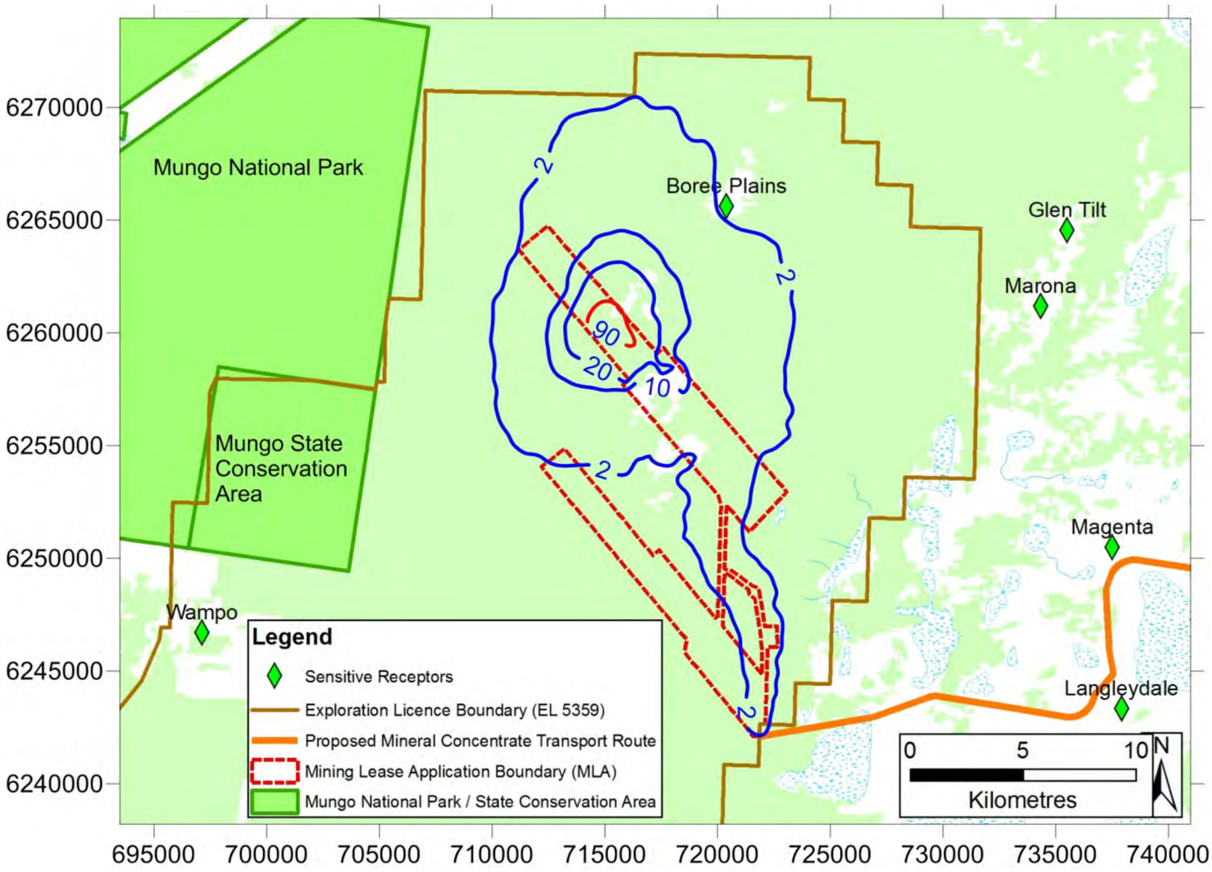


Figure 16 Predicted annual average ground-level concentrations of TSP due to operations at the Atlas-Campaspe Mine (in isolation)

Location:	**Averaging period:**	**Data source:**	**Units:**
Atlas-Campaspe Mine, NSW	Annual	CALPUFF	µg/m³
Type: Annual average contour	**Standard:** 90 µg/m³	**Prepared by:** T. Haigh	**Date:** September 2012

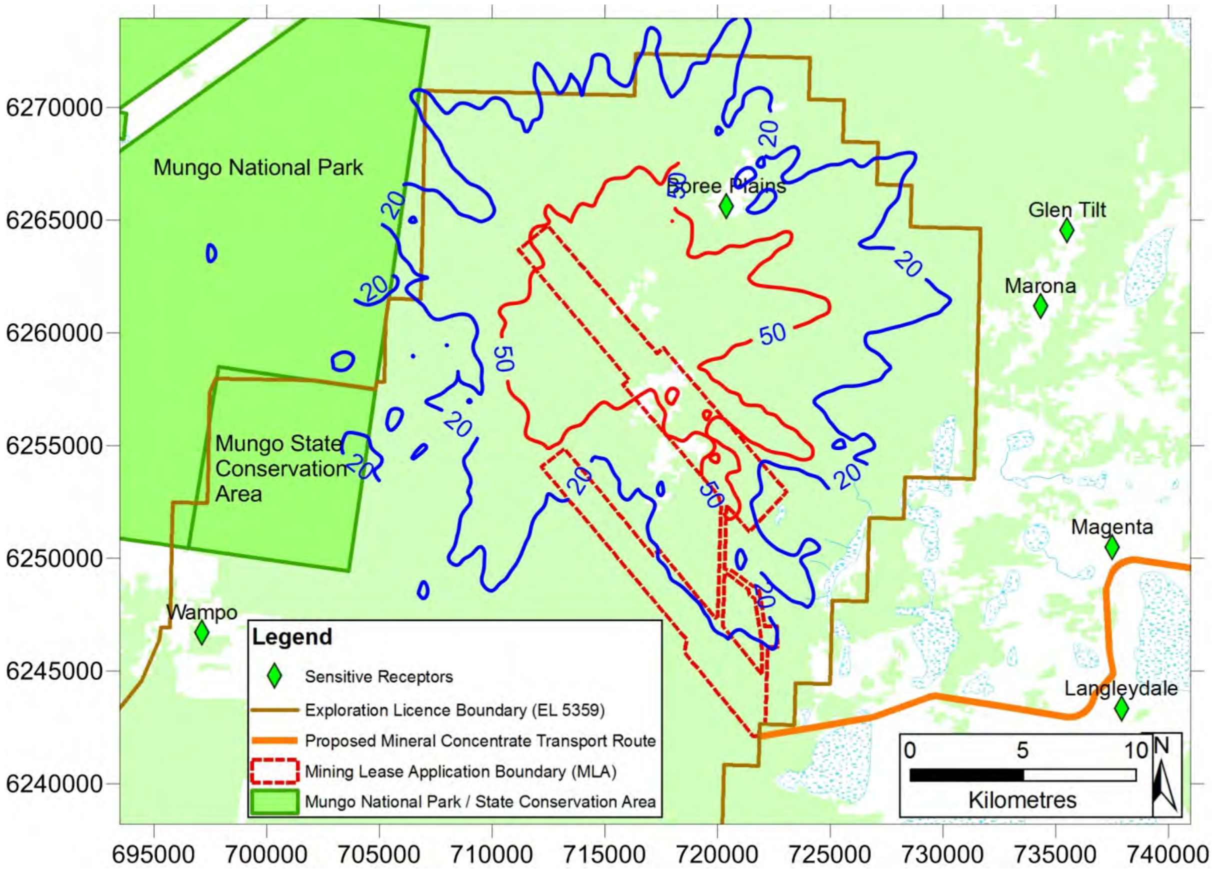


Figure 17 Predicted maximum 24-hour average ground-level concentrations of PM_{10} due to operations at the Atlas-Campaspe Mine (in isolation)

Location: Atlas-Campaspe Mine, NSW	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contour	**Standard:** 50 µg/m³	**Prepared by:** T. Haigh	**Date:** September 2012

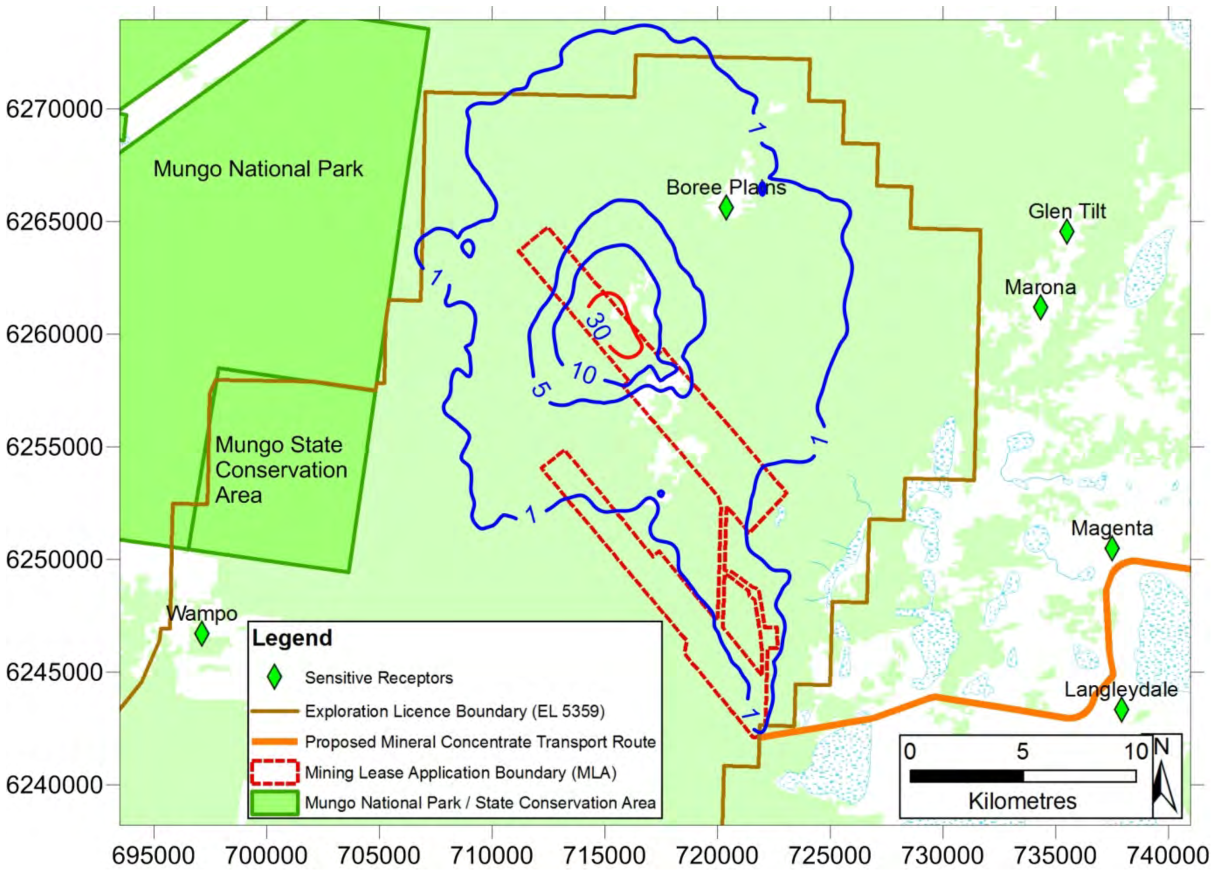


Figure 18 **Predicted annual average ground-level concentrations of PM_{10} due to operations at the Atlas-Campaspe Mine (in isolation)**

Location: Atlas-Campaspe Mine, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual average contour	**Standard:** 30 µg/m³	**Prepared by:** T. Haigh	**Date:** September 2012

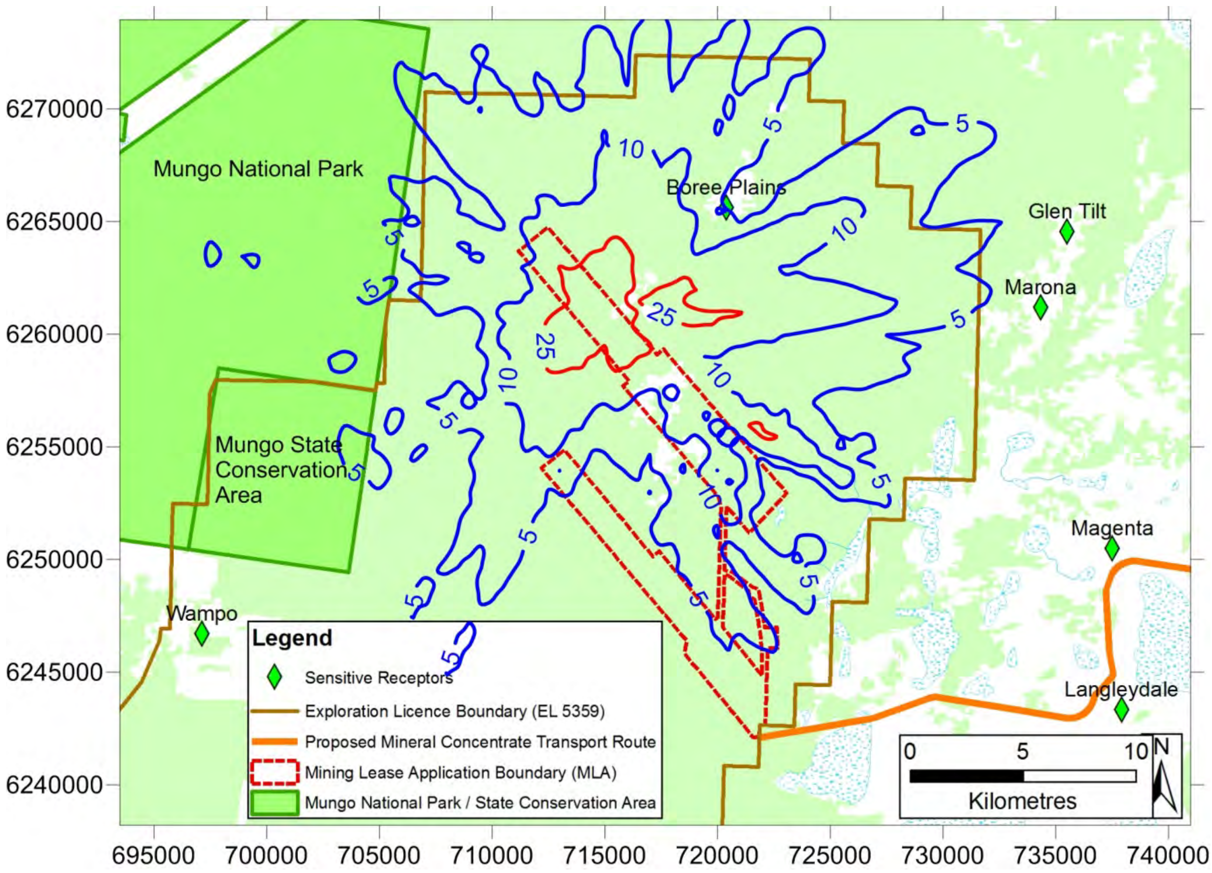


Figure 19	**Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ due to operations at the Atlas-Campaspe Mine (in isolation)**

Location: Atlas-Campaspe Mine, NSW	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contour	**Standard:** 25 µg/m³	**Prepared by:** T. Haigh	**Date:** September 2012

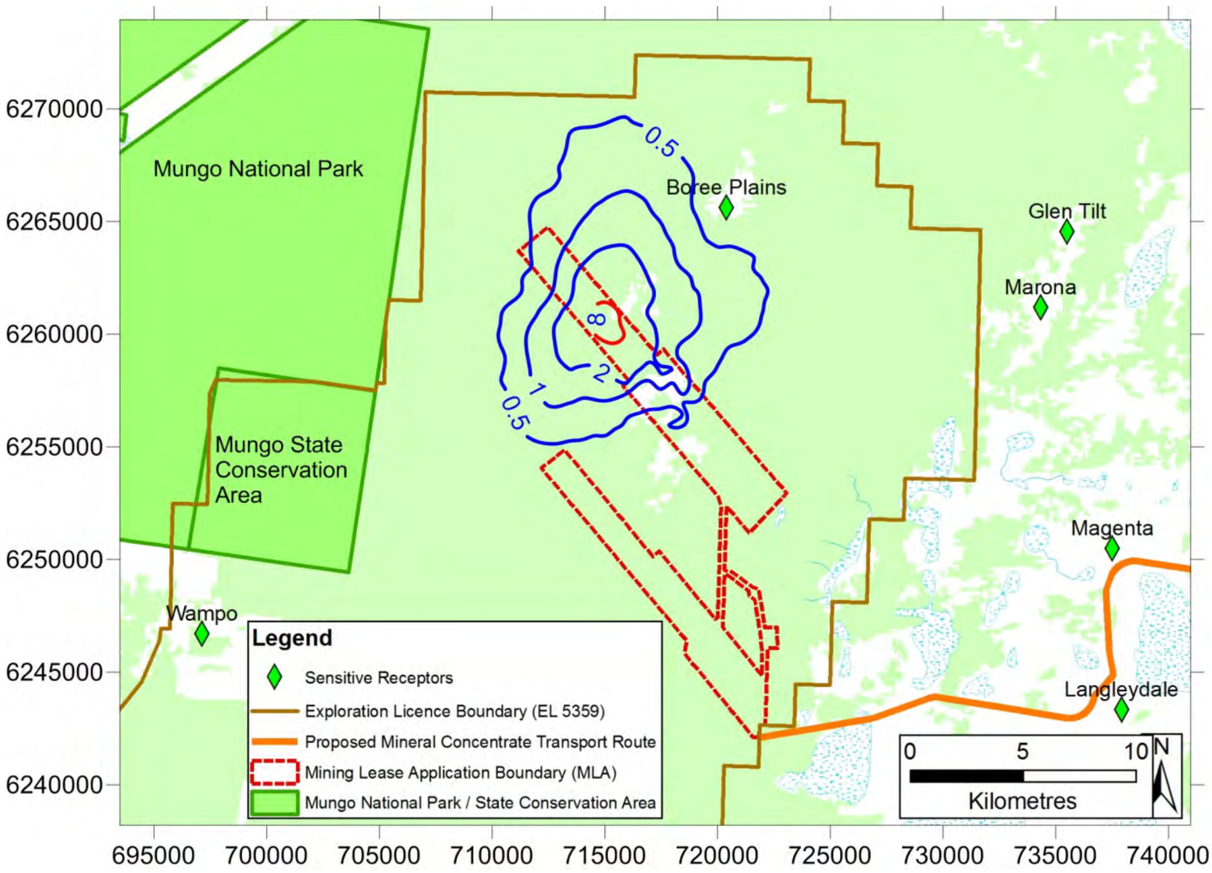


Figure 20	**Predicted annual average ground-level concentrations of $PM_{2.5}$ due to operations at the Atlas-Campaspe Mine (in isolation)**		
Location: Atlas-Campaspe Mine, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual average contour	**Standard:** 8 µg/m³	**Prepared by:** S. Richardson	**Date:** September 2012

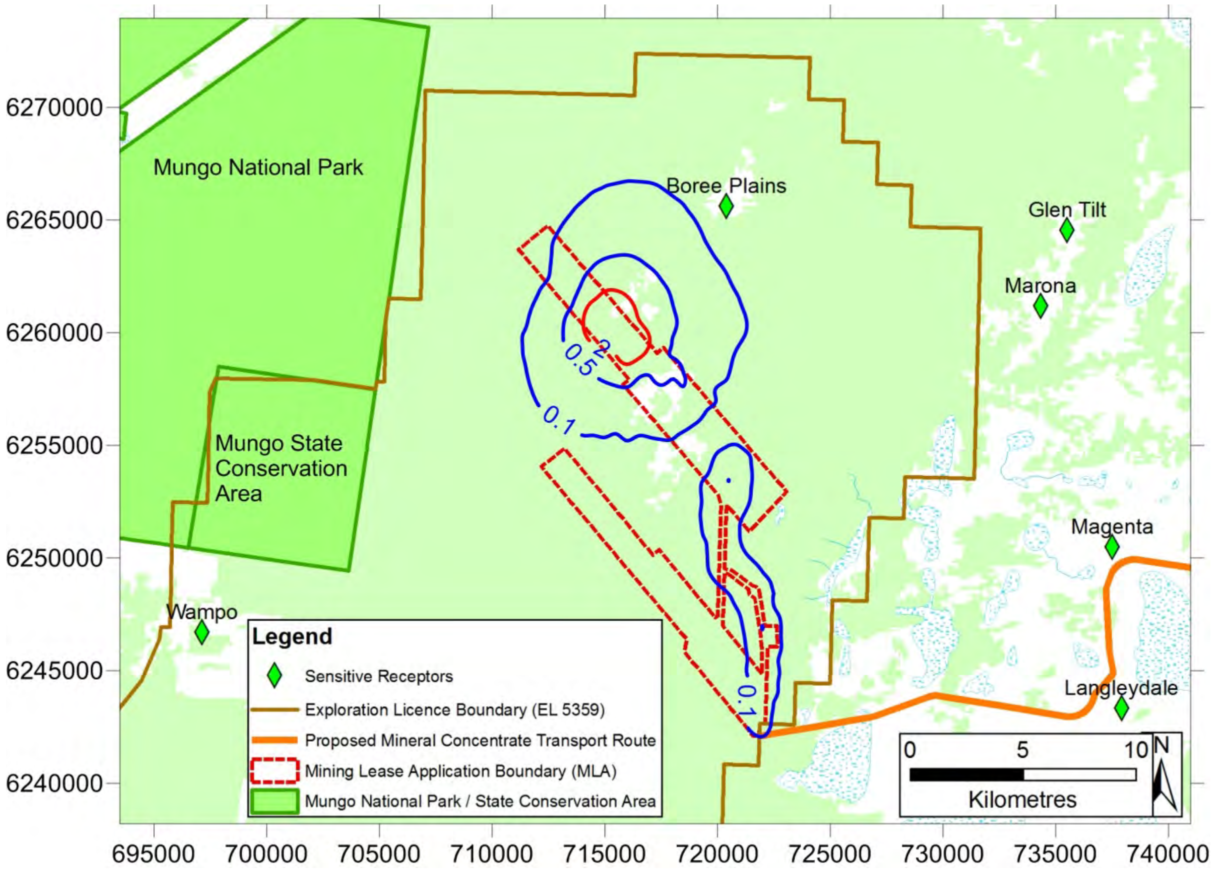


Figure 21 Predicted annual average ground-level dust deposition due to operations at the Atlas-Campaspe Mine (in isolation)

Location: Atlas-Campaspe Mine, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** g/m2/month
Type: Annual average contour	**Standard:** 2 $g/m^2/month$	**Prepared by:** T. Haigh	**Date:** November 2012

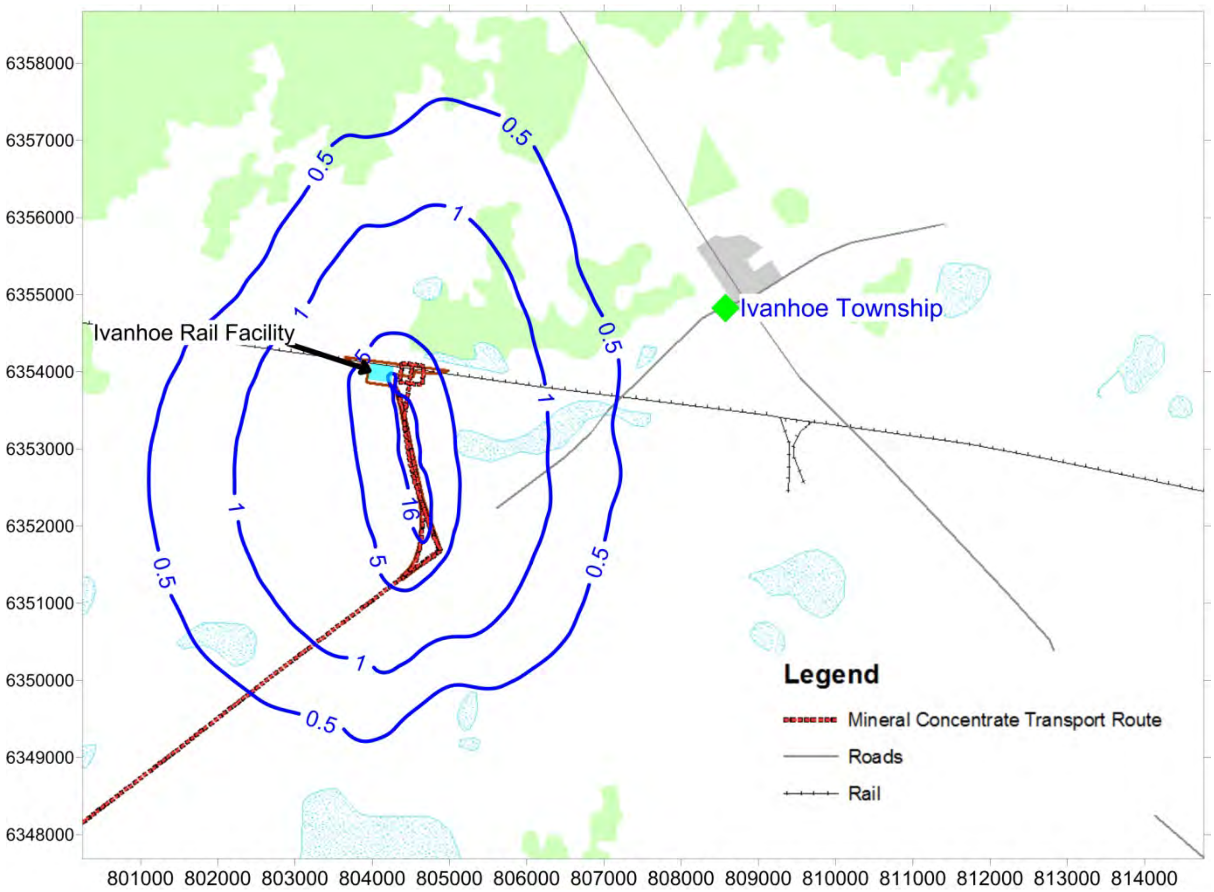


Figure 22	**Predicted annual average ground-level concentrations of TSP due to all operations at the Ivanhoe Rail Facility (in isolation)**		
Location: Ivanhoe Rail Facility, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual average contour	**Standard:** 90 µg/m³	**Prepared by:** S. Richardson	**Date:** September 2012

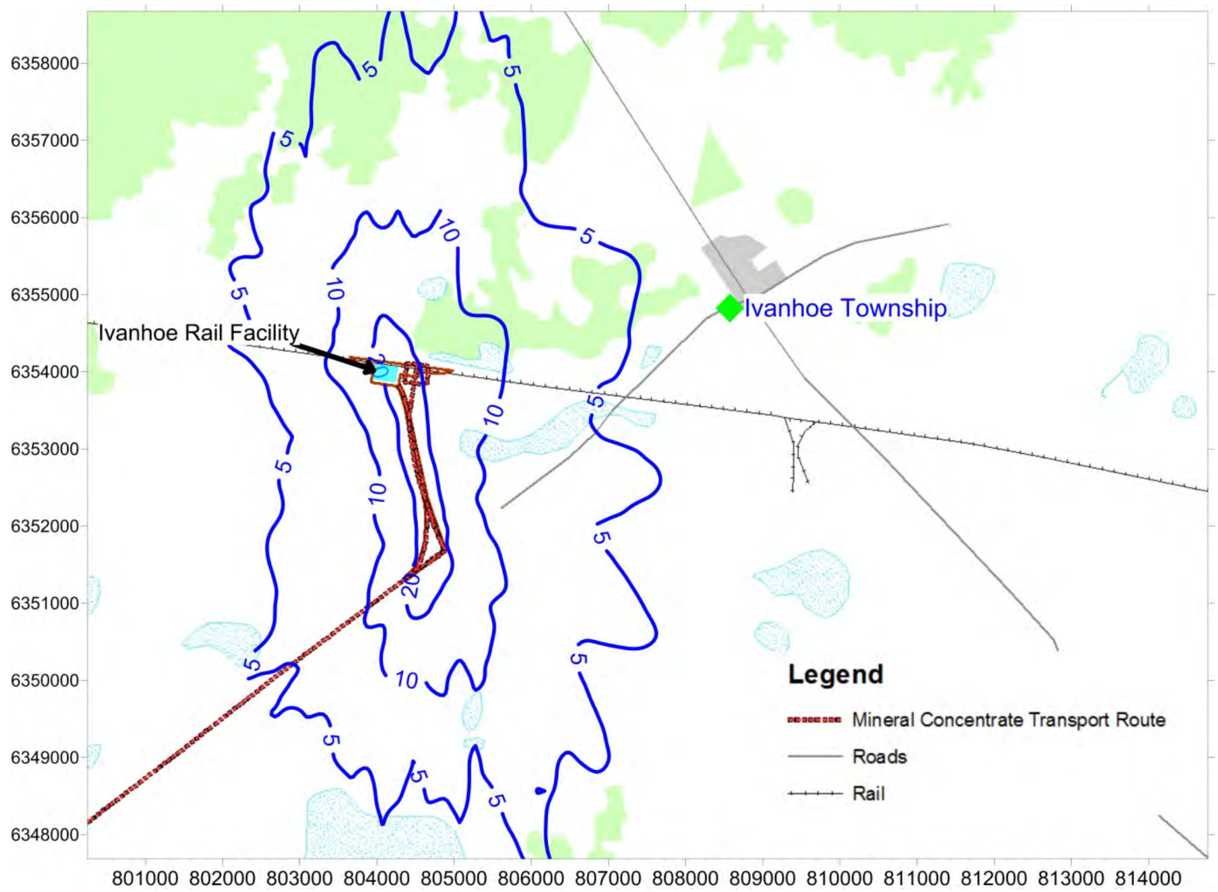


Figure 23	**Predicted maximum 24-hour average ground-level concentrations of PM_{10} due to all operations at the Ivanhoe Rail Facility (in isolation)**		
Location: Ivanhoe Rail Facility, NSW	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contour	**Standard:** 50 µg/m³	**Prepared by:** S. Richardson	**Date:** September 2012

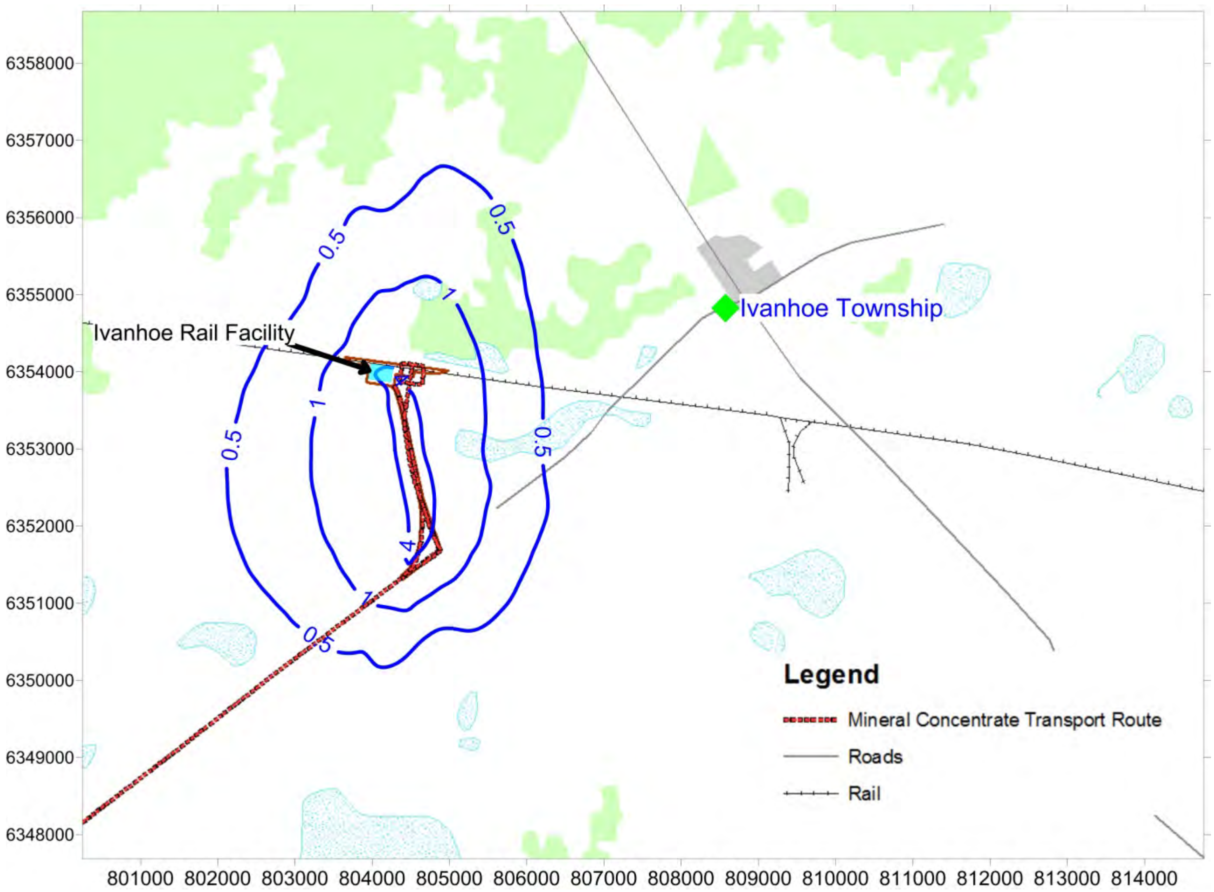


Figure 24 Predicted annual average ground-level concentrations of PM_{10} due to all operations at the Ivanhoe Rail Facility (in isolation)

Location: Ivanhoe Rail Facility, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual average contour	**Standard:** 30 µg/m³	**Prepared by:** S. Richardson	**Date:** September 2012

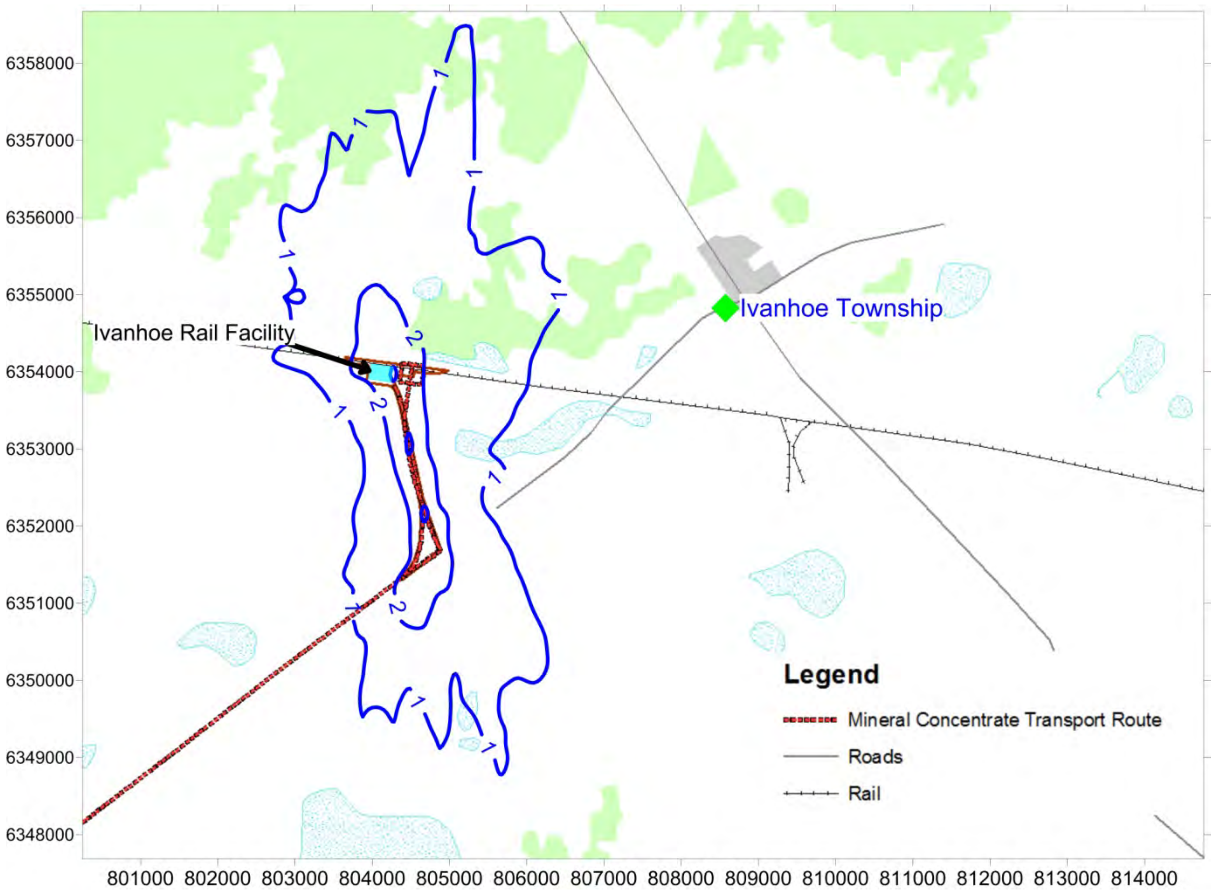


Figure 25 Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ due to all operations at the Ivanhoe Rail Facility (in isolation)

Location: Ivanhoe Rail Facility, NSW	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contour	**Standard:** 25 µg/m³	**Prepared by:** S. Richardson	**Date:** September 2012

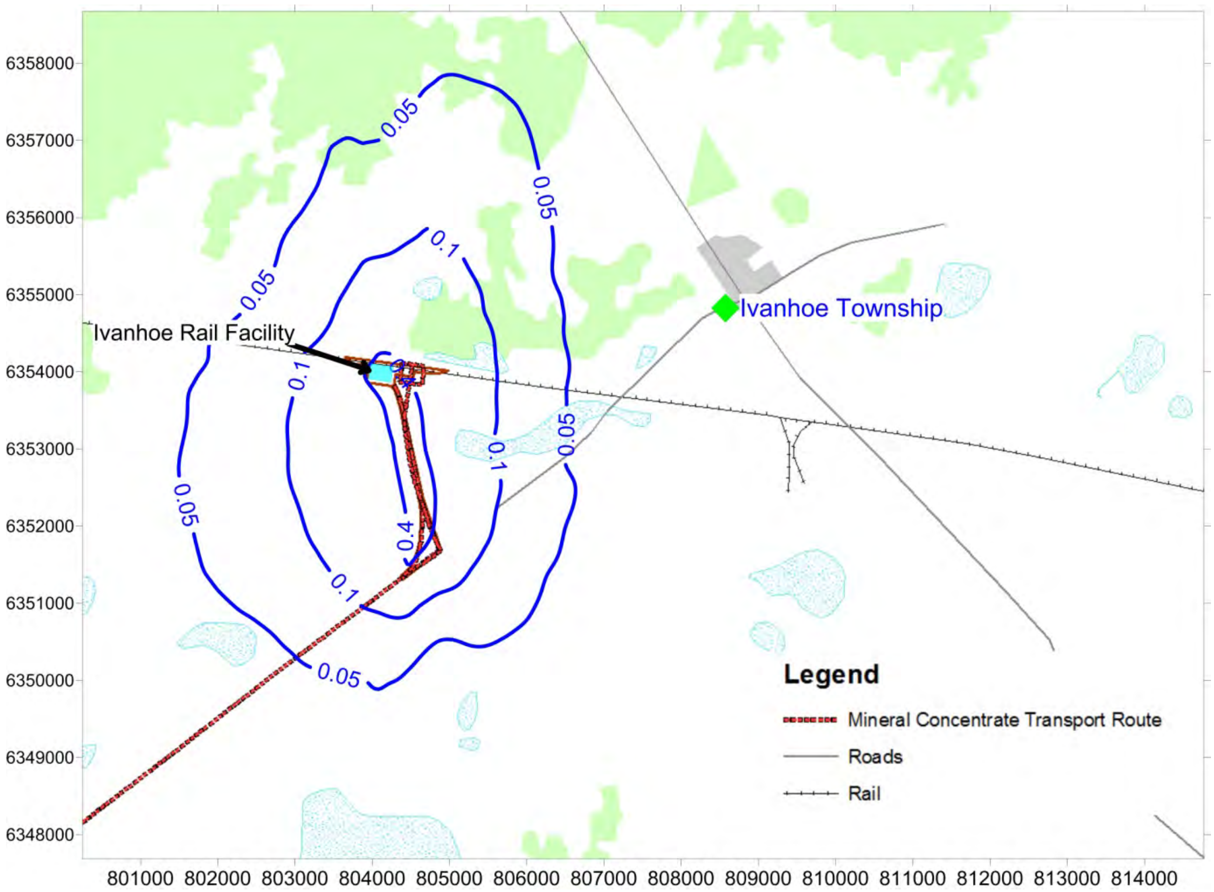


Figure 26	**Predicted annual average ground-level concentrations of $PM_{2.5}$ due to all operations at the Ivanhoe Rail Facility (in isolation)**

Location:	**Averaging period:**	**Data source:**	**Units:**
Ivanhoe Rail Facility, NSW	Annual	CALPUFF	µg/m³
Type: Annual average contour	**Standard:** 8 µg/m³	**Prepared by:** S. Richardson	**Date:** September 2012

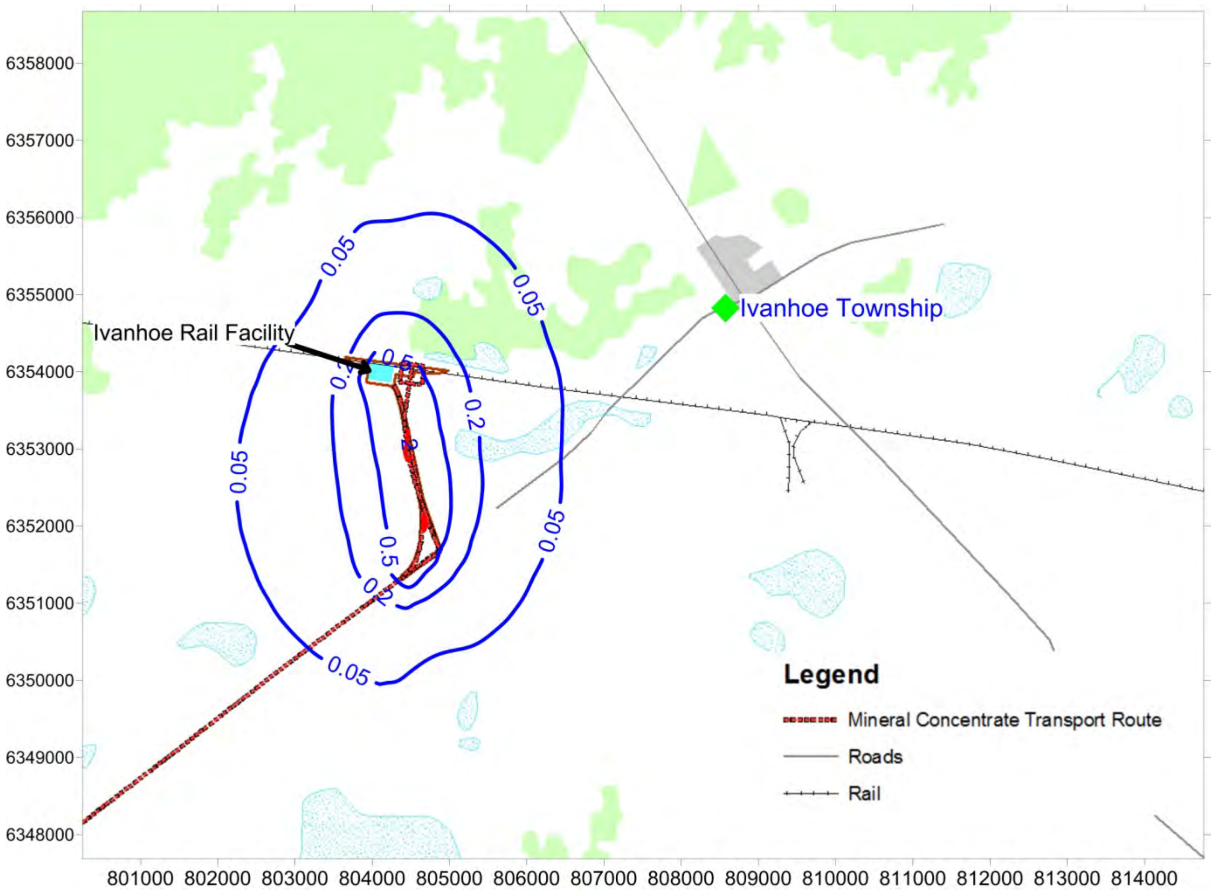


Figure 27 Predicted annual average dust deposition due to all operations at the Ivanhoe Rail Facility (in isolation)

Location: Ivanhoe Rail Facility, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** g/m2/month
Type: Annual average contour	**Standard:** 2 g/m²/month	**Prepared by:** T. Haigh	**Date:** September 2012

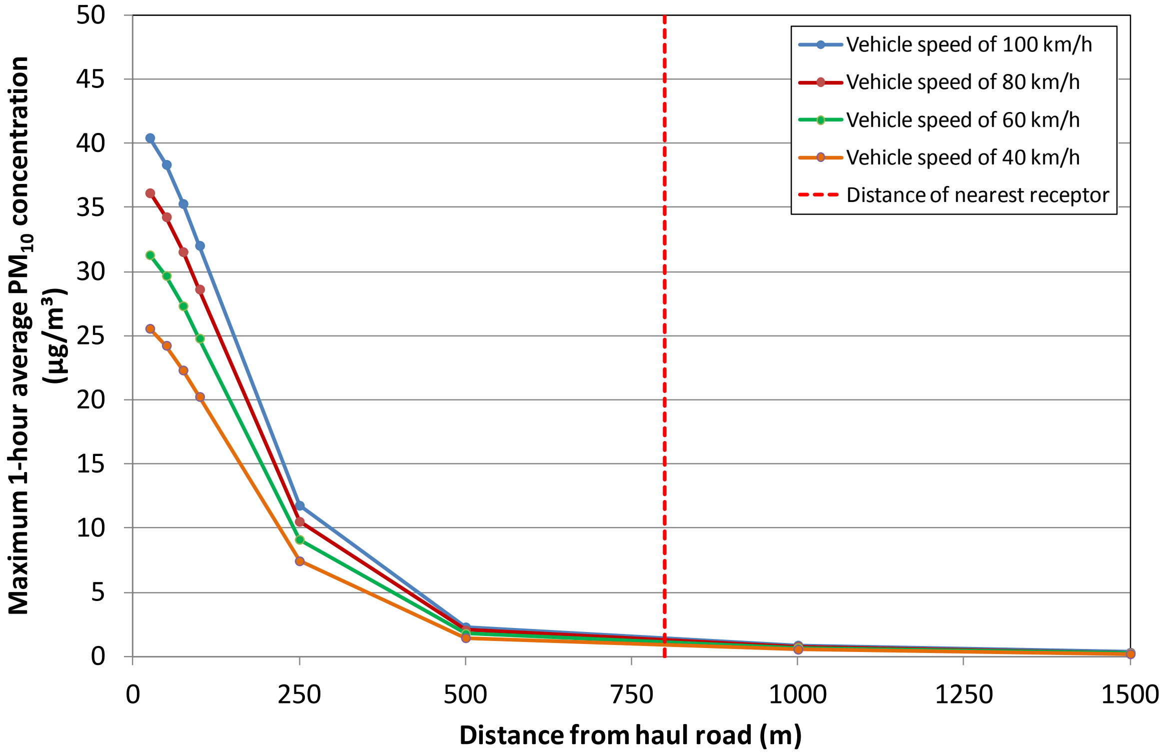


Figure 28	**Predicted maximum 1-hour average ground-level concentrations of PM_{10} at various distances from the haul road due to vehicle activity on the mineral concentrate transport route**		
Location: Mineral concentrate transport route, NSW	**Averaging period:** 1-hour	**Data source:** CALPUFF	**Units:** µg/m³ and metres
Type: Line graph		**Prepared by:** S. Richardson	**Date:** August 2012

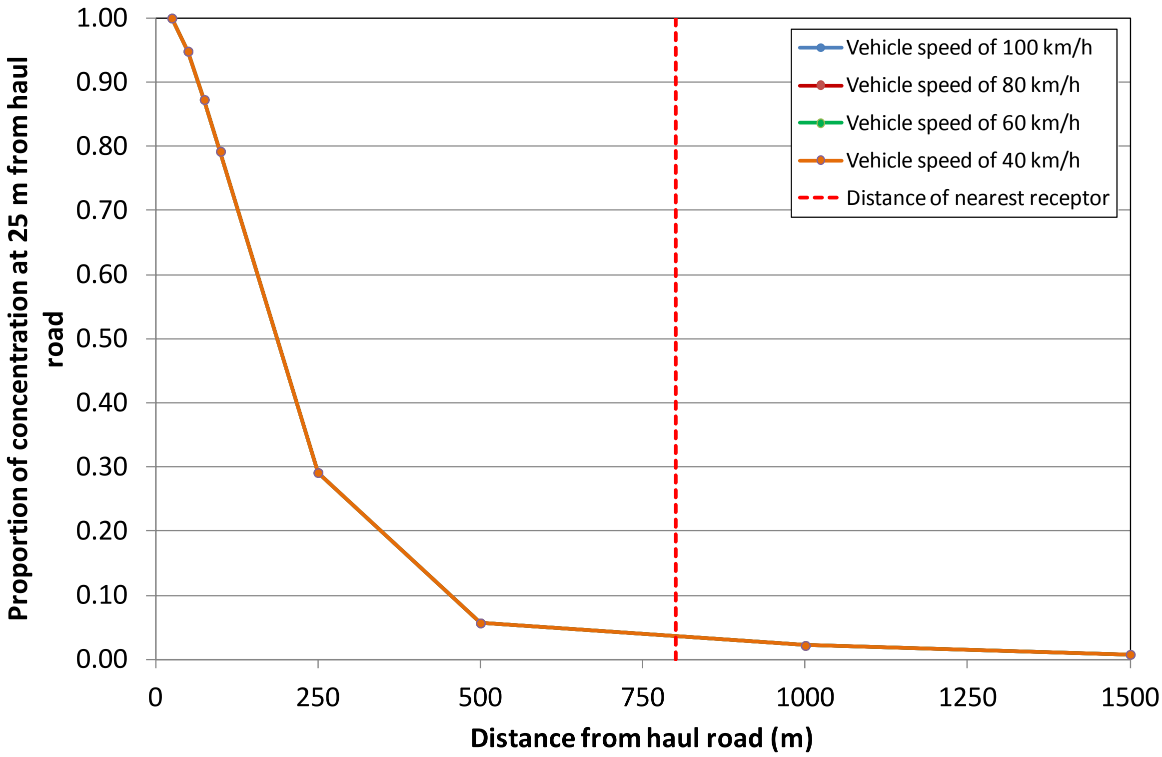


Figure 29 Predicted proportion of ground-level concentrations of PM_{10} at 25 metres from the haul road at various distances from the haul road due to vehicle activity on the mineral concentrate transport route (results for all vehicle speeds are the same so appear as a single line)

Location: Mineral concentrate transport route, NSW	**Averaging period:** 1-hour	**Data source:** CALPUFF	**Units:** metres
Type: Line graph		**Prepared by:** S. Richardson	**Date:** August 2012

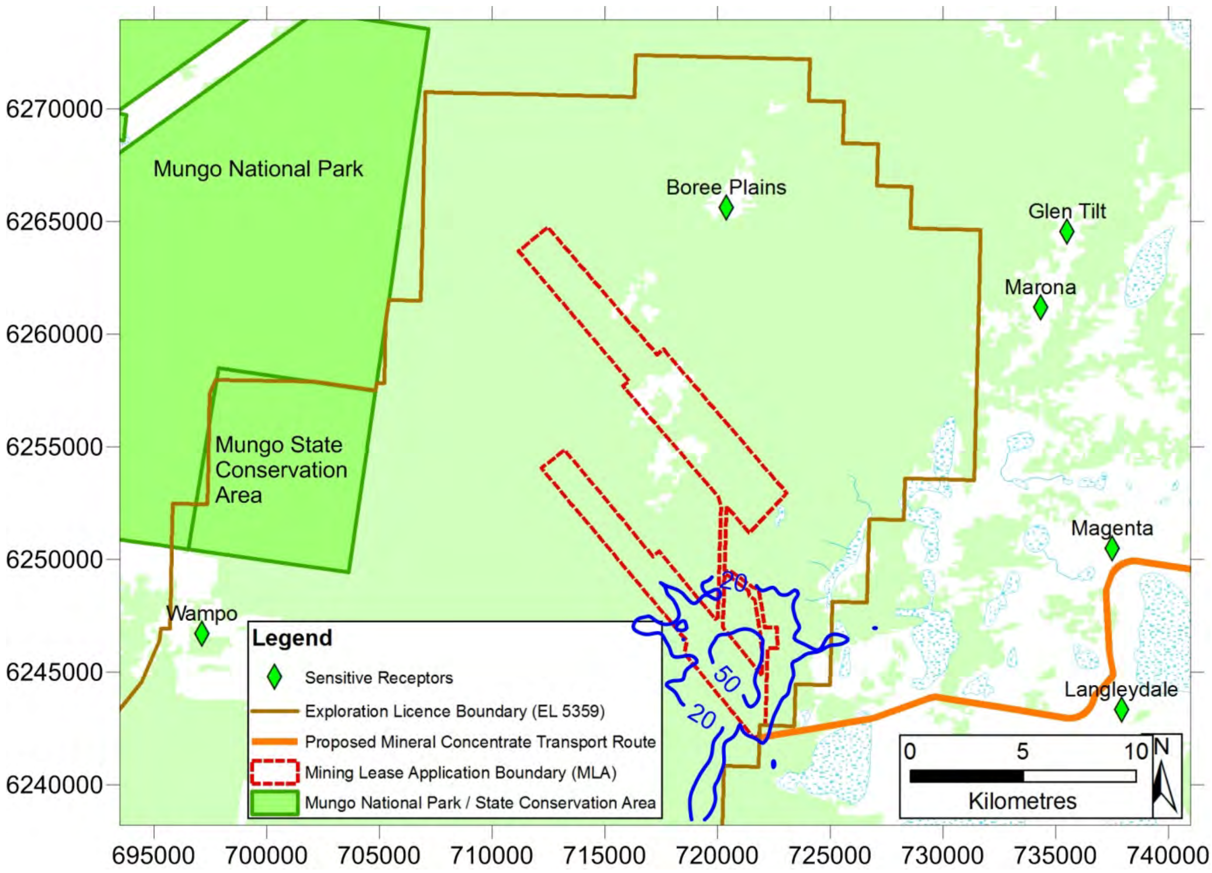


Figure 30 Predicted maximum 1-hour average ground-level concentrations of nitrogen dioxide due to the operation of diesel generators at the Atlas-Campaspe Mine (in isolation)

Location: Atlas-Campaspe Mine, NSW	**Averaging period:** 1-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contour	**Standard:** 246 µg/m³	**Prepared by:** S. Richardson	**Date:** August 2012

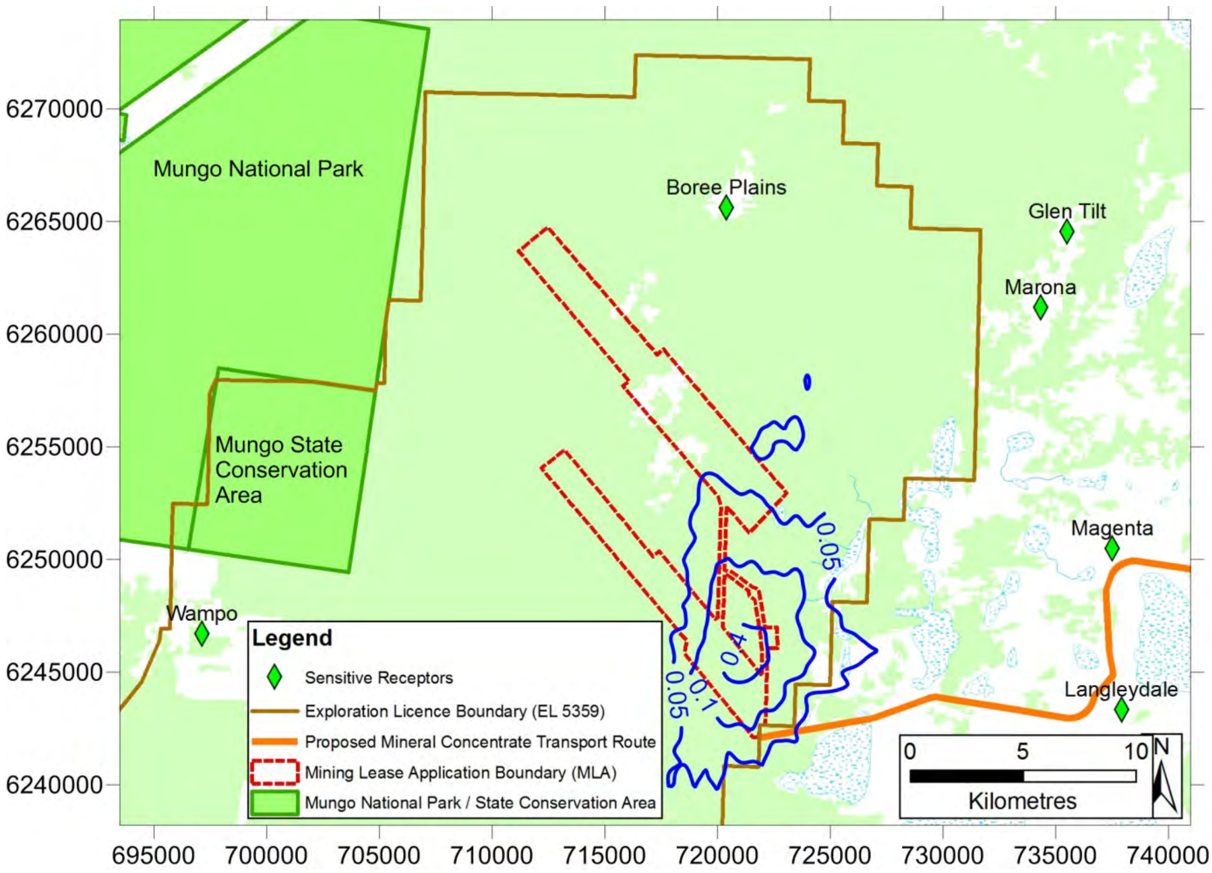


Figure 31 **Predicted annual average ground-level concentrations of nitrogen dioxide due to the operation of diesel generators at the Atlas-Campaspe Mine (in isolation)**

Location: Atlas-Campaspe Mine, NSW	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual average contour	**Standard:** 62 µg/m³	**Prepared by:** S. Richardson	**Date:** August 2012

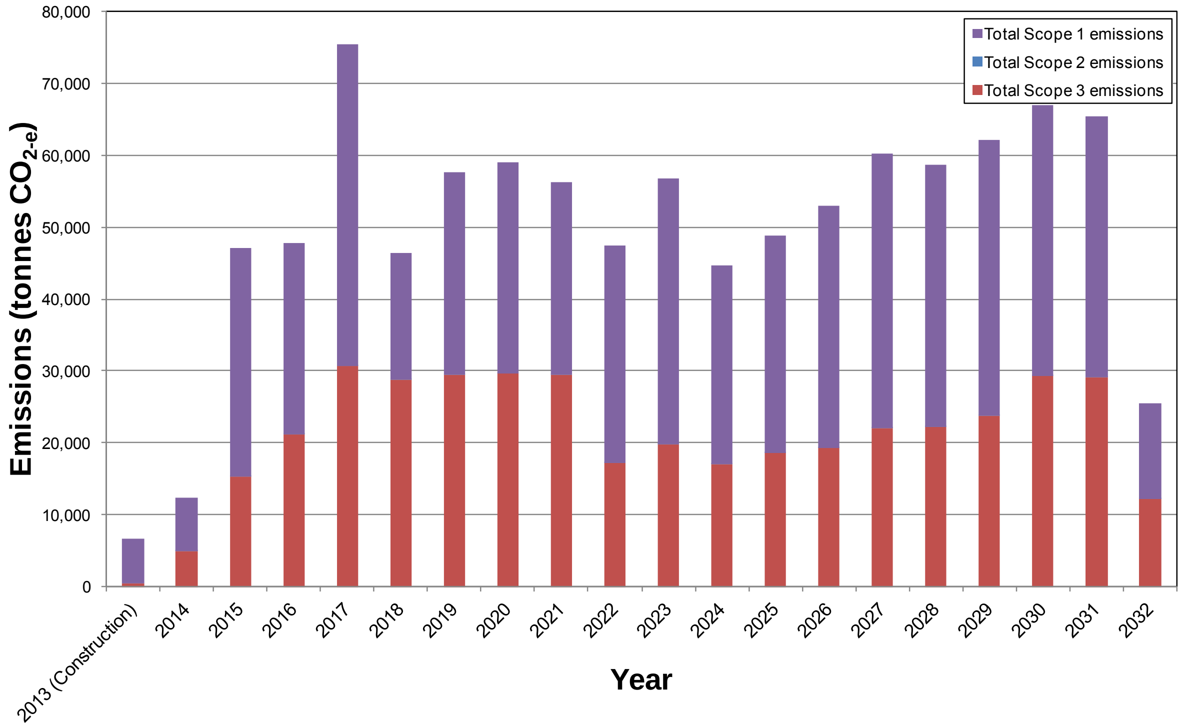


Figure 32	**Projected annual greenhouse gas emissions for the lifetime of the Atlas-Campaspe Mineral Sands Project. (Scope 2 emissions are not visible as they are less than 3 tonnes CO_2-e/year.)**	
Location: NSW	**Data source:** Cristal Mining Australia Limited	**Units:** Tonnes CO_2-e
Type: Bar chart	**Prepared by:** T. Haigh	**Date:** October 2012

Attachment A

Meteorological and dispersion modelling methodology

Contents

Figures

Tables

A1 Meteorological modelling

The meteorological data for this study was generated by coupling The Air Pollution Model (TAPM), a prognostic mesoscale model to CALMET, a diagnostic meteorological model. The coupled methodology for the TAPM/CALMET modelling system was developed by Katestone Environmental Pty Ltd (Katestone) to enable high resolution modelling capabilities for regulatory and environmental assessments. The modelling system can incorporate synoptic, mesoscale and local atmospheric conditions, detailed topography and land use categorisation schemes to simulate synoptic and regional scale meteorology for input into pollutant dispersion models, such as CALPUFF. Details of the model configuration and evaluation are supplied in the following sections.

Due to the significant distance between the proposed active mining area and the Ivanhoe Rail Facility, a separate set of meteorological data was generated for each site.

A1.1 TAPM meteorological modelling

The meteorological model, TAPM, was developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and has been validated by the CSIRO, Katestone and others for many locations in Australia, in southeast Asia and in North America (see www.cmar.csiro.au/research/tapm for more details on the model and validation results from the CSIRO). TAPM has proven to be a useful model for simulating meteorology in locations where monitoring data is unavailable.

TAPM is a prognostic meteorological model that predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by the synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 kilometres [km] to 200 km) and at a local scale (down to a few hundred metres [m]). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the Atlas-Campaspe Mineral Sands Project (the Project) region. This information is generated by a global model similar to the large-scale models used to forecast the weather. The data are supplied on a grid resolution of approximately 75 km, and at elevations of 100 m to 5 km above the ground. TAPM uses this synoptic information, along with specific details of the location such as surrounding terrain, land-use, soil moisture content and soil type to simulate the meteorology of a region as well as at a specific location.

A1.1.1 Model validation and selection of representative model year

In accordance with the requirements of the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW) (Department of Environment and Conservation [DEC], 2005) (Approved Methods), the TAPM meteorological model was run for a five year consecutive period to allow the selection of the most representative model year for use in the assessment. A detailed analysis of the TAPM simulated meteorology for each year during 2005 to 2009 period was carried out to identify the model period that adequately describes the expected meteorological patterns at the Project site.

TAPM was configured as specified in Section A1.1.2.1 at the Atlas-Campaspe Mine using synoptic data for five years (2005, 2006, 2007, 2008 and 2009) in order to examine the model performance against meteorological data gathered at the Pooncarie Mail Agency and Ivanhoe Post Office Bureau of Meteorology (BOM) stations during the same period.

Figure A1, Figure A2 and Figure A3 contain probability density function (PDF) plots of the wind speed, wind direction and temperature for the entire period from 2005 to 2009 and for each individual year. Data recorded at the Pooncarie Mail Agency and Ivanhoe Post Office meteorological stations are shown, as well as the data generated by TAPM for each period.

By comparing the PDF plots for each year of observed and modelled data to the completed 2005 to 2009 period, it can be seen that most of the individual years are a reasonable representation of the period. With regards to wind speed and direction, from the years modelled, 2005 and 2007 can be considered the most representative. With regards to temperature 2007 appears to be the most representative of the period modelled and shows the highest correlation with the observations. It is for these reasons that 2007 has been chosen as the representative year for dispersion modelling.

Comparison of the wind direction, modelled using TAPM, to the same period of observational data from Pooncarie Mail Agency and Ivanhoe Post Office shows that the model captures the general distribution of wind directions reasonably well. The dominant wind directions in the TAPM data are between the southeast and the southwest, with the majority of winds from the south to south-southwest direction. The southeast to southwest quadrant is the direction that the majority of winds at Pooncarie and Ivanhoe flow from. The extreme peaks and troughs in the PDF curves of the observed wind direction, when compared to the modelled data, are an artefact of the poor temporal fidelity of the observational data.

Comparison of the wind speed, modelled using TAPM, to the same period of observational data from Pooncarie Mail Agency and Ivanhoe Post Office shows that the model captures the overall distribution of wind speeds reasonably well, however; the model does not capture the higher wind speeds. The maximum speed recorded during the period at Pooncarie was 20.6 metres per second (m/s) and at Ivanhoe 19.2 m/s. The maximum wind speed produced from the TAPM modelling was around half these values at 10.3 m/s. Under prediction of wind speeds is a well know issue with TAPM. Once again the extreme peaks and troughs in the PDF curves of the observed wind speed, when compared to the modelled data, are an artefact of the poor temporal fidelity of the observational data.

Comparison of the temperature, modelled using TAPM, to the same period of observational data from Pooncarie Mail Agency and Ivanhoe Post Office shows that the model captures the overall distribution of temperatures reasonably well. Both Pooncarie and Ivanhoe demonstrate a slight bias towards higher temperatures than those obtained from TAPM. Again this is most likely an artefact of the poor temporal fidelity of the observational data. Since temperature observations are only recorded at 9am and 3pm at both Pooncarie and Ivanhoe it is likely that the daily maximum temperatures would be captured (at 3pm) but unlikely that the daily minimum would be captured.

A1.1.2 TAPM configuration

A1.1.2.1 Atlas-Campaspe Mine

TAPM (version 4.0.5) was configured as follows:

- 52 x 40 grid point domain with an outer grid of 26 km and nesting grids of 10 km, 3 km and 1 km
- Grid centred near the proposed Atlas-Campaspe Mine (latitude -33° 49.0', longitude 143° 20.5')
- Geoscience Australia 9-second digital elevation model terrain data
- 25 vertical grid levels.

A1.1.2.2 Ivanhoe Rail Facility

TAPM (version 4.0.5) was configured as follows:

- 40 x 40 grid point domain with an outer grid of 30 km and nesting grids of 10 km, 3 km and 1 km
- Grid centred near the proposed Ivanhoe Rail Facility (latitude -32° 55.0', longitude 144° 17.0')
- Geoscience Australia 9-second digital elevation model terrain data
- 25 vertical grid levels.

A1.2 CALMET meteorological modelling

CALMET is an advanced non-steady-state diagnostic three-dimensional meteorological model with micro-meteorological modules for overwater and overland boundary layers. The model is the meteorological pre-processor for the CALPUFF Modelling system. CALMET is capable of reading hourly meteorological data as data assimilation from multiple sites within the modelling domain; it can also be initialised with the gridded three-dimensional prognostic output from other meteorological models such as TAPM. This can improve dispersion model output, particularly over complex terrain as the near surface meteorological conditions are calculated for each grid point.

CALMET (version 6.327) was used to simulate meteorological conditions in the region. The CALMET simulation was initialised with the gridded TAPM three-dimensional wind field data from the 1 km grid. CALMET treats the prognostic model output as the initial guess field for the CALMET diagnostic model wind fields. The initial guess field is then adjusted for the kinematic effects of terrain, slope flows, blocking effects and 3-dimensional divergence minimisation.

CALMET was set up with 12 vertical levels with heights at 0, 20, 40, 80, 130, 180, 230, 330, 500, 800, 1600, 2600 and 4600 m at each grid point. The geophysical data (land use and terrain heights) were generated from TAPM 1 km terrain. All default options and factors were selected except where noted below.

Key features of CALMET used to generate the wind fields are as follows:

- 365 days modelled (1 January 2007 to 31 December 2007)
- Prognostic wind fields input as MM5/3D.dat for "initial guess" field only (as generated from TAPM)
- Cloud cover determined from prognostic input data
- No extrapolation of surface wind observations to upper layers
- Mixing height parameters all set as default
- Step 1 wind field options include kinematic effects, divergence minimisation, Froude adjustment to a critical Froude number of 1 and slope flows
- Terrain radius of influence set at 5 km
- No data assimilation.

A grid of 60 x 60 at 400 m spacing (southwest corner located at (795.073, 6341.167)) was used to generate data for the Ivanhoe Rail Facility, and a grid of 96 by 72 at 500 metre spacing (southwest corner located at (693.234, 6238.203)) was used to generate data for the Atlas-Campaspe Mine.

A2 Dispersion modelling

A2.1 CALPUFF dispersion modelling

The CALPUFF dispersion model utilises the three-dimensional wind fields developed by TAPM and CALMET to simulate the dispersion of air pollutants to predict ground-level concentration across a network of receptors spaced at regular intervals, and at identified discrete locations. CALPUFF is a non-steady-state Lagrangian Gaussian puff model containing parameterisations for complex terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal, and simple chemical transformation. CALPUFF employs the three dimensional meteorological fields generated from the CALMET model by simulating the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF contains algorithms that can resolve near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as the long range effects of removal, transformation, vertical wind shear, overwater transport and coastal interactions. Emission sources can be characterised as arbitrarily-varying point, area, volume and lines or any combination of those sources within the modelling domain.

CALPUFF (version 6.627) was configured as follows:

- 365 days modelled (1 January 2007 to 31 December 2007)
- Gridded 3-D hourly-varying meteorological conditions generated by CALMET
- Partial plume path adjustment for terrain modelled
- Dispersion coefficients calculated internally from sigma v and sigma w using micrometeorological variables
- Dry depletion on
- All other options set to default.

A domain area of 80 by 80 grids at 200 m spacing was used for the Ivanhoe Rail Facility, and a domain area of 96 by 72 grids at 500 m spacing was used for the Atlas-Campaspe Mine.

A3 Impact assessment

A3.1 Ambient backgrounds used in air quality assessment

The cumulative assessment of particulate emissions from the Project has been conducted in accordance with the Approved Methods. The Approved Methods states that background concentrations must be included in the assessment to assess the total impact of a proposed project on the air environment.

Ideally background concentrations of air pollutants are obtained from ambient air quality monitoring data collected at the project site; however, as with the Project, on-site monitoring data is not available in most locations, particularly in regional areas. When on-site data is not available, ambient monitoring data should be obtained from a monitoring site as close as possible to the proposed location where the sources of air pollution resemble existing sources at the site. In some circumstances background air quality concentrations can be inferred from data from other sites; however, consideration must be given to the variation in the sources of air pollution, as well as other environmental factors at the site.

The Approved Methods specifies two methods of accounting for background concentrations. Level 1 assessment requires the inclusion of the maximum background concentration of the pollutant being assessed for each relevant averaging period. Level 2 assessment requires the addition of hourly contemporaneous data to ground-level concentrations of pollutants at each receptor. A Level 2 assessment has been conducted for this Project.

In some circumstances ambient air quality monitoring data show existing levels of some pollutants exceed the New South Wales (NSW) Office of Environment and Heritage (OEH) impact assessment criteria on occasions. The Approved Methods states that, when such exceedances occur, a proposed development must demonstrate that no additional exceedances will occur as a result of their operation. This can be demonstrated by adding the contemporaneous background level to the impacts from a proposal at sensitive receptor locations.

A3.1.1 PM_{10}

As discussed in the Existing Environment section of the main Air Quality Report, the nearest monitoring stations measuring ambient PM_{10} levels is the site operated by Cristal Mining Australia Limited (Cristal Mining) at the Mineral Separation Plant at Broken Hill (high volume air sampler), and the site operated by the OEH at Wagga Wagga. The location of these monitoring sites in relation to the Project is shown in Figure A4. While the Broken Hill and Wagga Wagga sites are located a significant distance (270 km northwest and 400 km southeast, respectively) from the Project site, a detailed review of the monitoring data recorded at these sites as well as the localised sources of air pollutants and other environmental factors has been conducted to determine the suitability of the monitoring data for the cumulative assessment of the Project.

The range and statistics for the ambient PM_{10} monitoring data for the Broken Hill and Wagga Wagga monitoring stations during the 2007 assessment year is provided in Table A1. A time-series of the 24-hour average PM_{10} data measured at the two sites during this period is provided in Figure A5. While the data measured at Pooncarie, Ivanhoe and Penarie as part of the OEH DustWatch program is not suitable for use in an Impact Assessment, a summary of the data has been included in Table A1 and Figure A5, and the locations of the monitoring sites shown in Figure A4 to assess the suitability of the monitoring data at Broken Hill and Wagga Wagga for use in the cumulative assessment of the Project.

Table A1 Statistics for ambient PM_{10} monitoring data measured at the Broken Hill (Cristal Mining), Wagga Wagga (OEH), Pooncarie (OEH DustWatch program), Ivanhoe (OEH DustWatch program) and Penarie (OEH DustWatch program) monitoring sites during the 2007 assessment year (24-hour average data)

Statistic	Monitoring site				
	Broken Hill Cristal Mining	Wagga Wagga OEH	Pooncarie OEH DustWatch program [2]	Ivanhoe OEH DustWatch program [2]	Penarie OEH DustWatch program [2]
Count	58 [1]	356	365	365	365
Min	1.0	3.8	0.0	0.0	0.0
Mean	22.3	26.1	6.8	4.2	4.1
Max	105.3	110.3	294.3	19.6	45.0
99.9%	103.8	102.5	294.3	19.6	45.0
99.5%	97.8	83.9	218.8	17.3	28.9
99%	90.3	80.3	45.0	15.0	20.2
90%	39.8	47.3	10.3	8.0	7.3
80%	30.5	35.7	7.0	6.4	6.1
70%	25.5	29.6	5.5	5.3	5.2
50%	18.3	21.7	4.1	3.7	4.0

Table note:

1 Measured using a high volume air sampler once every six days.

2 Measured using DustTrak device as part of DustWatch program operated by the OEH Lower Murray Darling Catchment Management Authority and Commonwealth of Australia 2012 and not suitable for use in Impact Assessment. Program is designed to monitor wind erosion levels across Australia and is not designed to report on air quality and health related issues.

The data show that the range and statistics measured at the Broken Hill and Wagga Wagga sites are similar, with the Wagga Wagga site generally shown to have slightly higher PM_{10} concentrations.

In addition to natural sources such as wind erosion of exposed areas of soil or land (particularly during dry periods) and occasional bush fires and dust storms, additional localised sources of particulates at Broken Hill include the Mineral Separation Plant and the Perilya Broken Hill Mine.

Wagga Wagga is an urban town and is less isolated compared to the site at Broken Hill. Due to the increased vegetation cover at Wagga Wagga the contribution of localised dust emissions due to wind erosion of exposed areas of soil or land is likely to be lower at the site at Wagga Wagga compared to the site at Broken Hill. Minor particulate emissions associated with power generation, meat processing and waste oil refining are currently reported to the National Pollutant Inventory (NPI, 2012a). Predominant localised sources of particulate emissions at Wagga Wagga are likely to be associated with urban activity (vehicle emissions, residential and commercial practices, etc) as well as agricultural and horticultural activity.

While the Broken Hill and Wagga Wagga monitoring sites will experience differences in localised sources of dust, due to the geographic features of the central NSW region and the synoptic weather patterns, both monitoring sites are likely to experience similar regional dust influences. The climate of the region is characterised by the year round passage of cold fronts which generally move across southern Australia from west to east. Consequently, regional dust influences, such as dust storms, are likely to be move across the central NSW region and be experienced at Broken Hill followed by Wagga Wagga, with the Project site located in between likely to experience similar levels. The similar range and statistics shown in the ambient PM_{10} monitoring data recorded at the two sites indicates that regional dust influences are important contributors to the dust levels recorded at the two sites. The incidence of regional dust is evident in the time-series in Figure A5, showing peak events at Broken Hill correlating with peak events at Wagga Wagga, particularly during February and October.

The OEH DustWatch monitoring data measured at Pooncarie, Ivanhoe and Penarie shows that dust levels recorded at these sites are significantly lower than those measured at Broken Hill and Wagga Wagga. This is to be expected due to the isolated location of the Pooncarie, Ivanhoe and Penarie sites and the absence of any significant nearby industrial or residential dust sources.

As discussed in the Existing Environment Section of the main Air Quality Report, the frequency of dust storms in the region is likely to contribute to elevated levels of suspended particulates not representative of natural ambient background concentrations. The Approved Methods provides methods for dealing with elevated background concentrations through the use of a contemporaneous background at sensitive receptor locations to demonstrate that no additional exceedances will occur as a result of a facility.

The monitoring sites at Pooncarie, Ivanhoe and Penarie are likely to be more representative of the background dust levels at the Project site due to the isolated location of these sites and the absence of any significant industrial or residential dust source; however, as the data at these sites is measured using a DustTrak device, the monitoring data is not suitable for use in the cumulative assessment of the Project.

The monitoring site at Broken Hill is also likely to be more representative of the Project site due to similarities in geographical features and fewer industrial and residential sources compared to the site at Wagga Wagga; however, as the data is recorded using a high volume air sampler once every six days a complete dataset is not available suitable for use as a contemporaneous background in the assessment.

Subsequently, the cumulative assessment of the Project has been carried out using the 24-hour average PM_{10} concentrations recorded at the OEH site at Wagga Wagga during the 2007 assessment period and can be considered conservative due to higher concentrations from anthropogenic sources as well as natural.

The data capture rate of 24-hour average PM_{10} concentrations at Wagga Wagga was 97.5%. In order to include every 24-hour period of predicted ground-level concentrations in the cumulative assessment, the nine missing data points in the dataset of monitoring results from Wagga Wagga were filled in by averaging the concentrations on the day before and after the missing values. Where two consecutive values were missing a weighted average was used that favoured the observational data on the day immediately following or preceding the missing data point. Using the average of days surrounding the missing data points is more conservative than using the average of the entire dataset. The interpolated data points did not alter the outcome of the assessment, however, one of the interpolated 24-hour average PM_{10} concentrations was greater than 50 micrograms per cubic metre ($\mu g/m^3$).

A3.1.2 TSP

Previous assessments by Katestone and standard conversion ratios detailed in the US EPA's Compilation of Air Pollution Emission Factors Volume 1 (AP-42) and in the NPI Handbooks have found that PM_{10} is usually 50% of the TSP concentration. Due to the absence of any measurements of TSP, this ratio has been employed for this study. The 24-hour average contemporaneous data were then added to the ground-level concentrations of TSP as predicted by the model.

A3.1.3 $PM_{2.5}$

To account for background, levels of $PM_{2.5}$ are assumed to be 20% of the total PM_{10}. This is a conservative assumption as $PM_{2.5}$ levels reported by the different facilities in the greater NSW region to the NPI are found to be significantly less than this. Due to the absence of any measurements of TSP or $PM_{2.5}$, these ratios have been employed for this study. The 24-hour average contemporaneous data were then added to the ground-level concentrations of $PM_{2.5}$ as predicted by the model.

A3.1.4 Dust deposition rate

Available dust deposition data were provided by Cristal Mining for the six sites operated near to the Atlas-Campaspe Mine during November 2011 and June 2012. Excluding outliers at two of the sites, the maximum average insoluble solids level was 1.3 grams per square metre per month ($g/m^2/month$). This level was used as background dust deposition rate for the air quality assessment.

A3.2 Assessment of impacts from mineral concentrate transport route

Assessing air quality impacts from haul road emissions is calculated from the total emission rate, based on the length of haul road, the number of vehicle movements and the average mass of the vehicles. The total emission rate is spread along the length of the road and modelled as a constant dust emission rate (as grams per square metre per second). Using this approach to model haul road emissions may be overly conservative and not a realistic representation of the activity on the haul road. In reality the dust emissions from this source are not constant along the entire length of the road. Sensitive receptors located along the length of the haul road would not be exposed to continuous dust emissions from this source, but would experience sporadic dust plumes as each vehicle passes.

The assessment of air quality impacts from the mineral concentrate transport route has been based on the dispersion modelling of dust emissions from a representative section of haul road. The results of the dispersion modelling are presented as dust concentrations and the proportion of dust drop-out as a function of distance from the haul road. The results of the assessment have been used predict compliance with the relevant air quality criteria at the nearest sensitive receptors, located approximately 800 m (Magenta) and 1,300 m (Langleydale) from the haul road.

To provide a worst-case assessment of the Transport Corridor, the dispersion modelling was conducted for the full 12 months of meteorological data to incorporate all meteorological conditions likely to be experienced at the site. In addition, the dispersion modelling was conducted for three representative sections of the transport corridor across different alignments, including a north-south section, east-west section and northeast-southwest section (Figure A6).

For each of the three road alignment model scenarios, emissions were run for four scenarios to simulate the emissions of dust from the road under vehicle speeds of 100 kilometres per hour (km/h), 80 km/h, 60 km/h and 40 km/h as a sensitivity analysis on the impact of reducing vehicle speed as a control factor.

A3.3 Method for the conversion of NO_X to NO_2

Nitric oxide (NO) that is emitted by diesel generators can undergo chemical transformation in the atmosphere to form nitrogen dioxide (NO_2). NO_2 is more toxic than NO and therefore it is important to quantify the transformation of NO to NO_2 in the atmosphere. Measurements around power stations in central Queensland show, under worst possible cases, a conversion of 25-40% of the NO to NO_2 occurs within the first 10 km of plume travel. During days with elevated background levels of hydrocarbons (generally originating from bush-fires, hazard reduction burning or other similar activities), the resulting conversion is usually below 50% in the first 30 km of plume travel (Bofinger et al 1986).

For the air dispersion modelling assessment of the emissions from the on-site diesel generators a ratio of 30% conversion of the oxides of nitrogen to NO_2 has been assumed, which is very conservative considering the short travel time of the plume to the maximum ground-level concentrations.

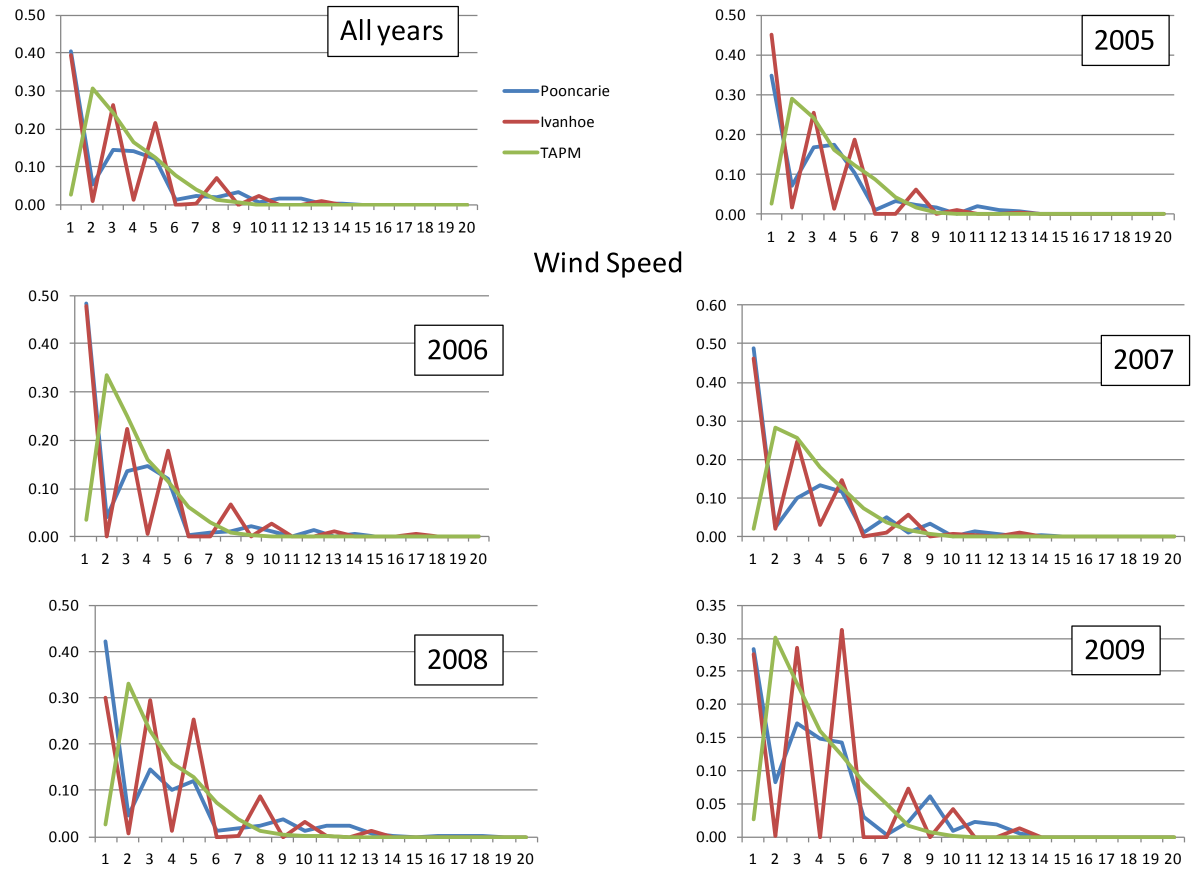


Figure A1 PDF plots of observed and modelled wind speeds

Location: Atlas-Campaspe Mine	**Period:** 2005 – 2009	**Data source:** BOM, TAPM	**Units:** m/s and %
Type: PDF plot		**Prepared by:** B. Lilley	**Date:** July 2012

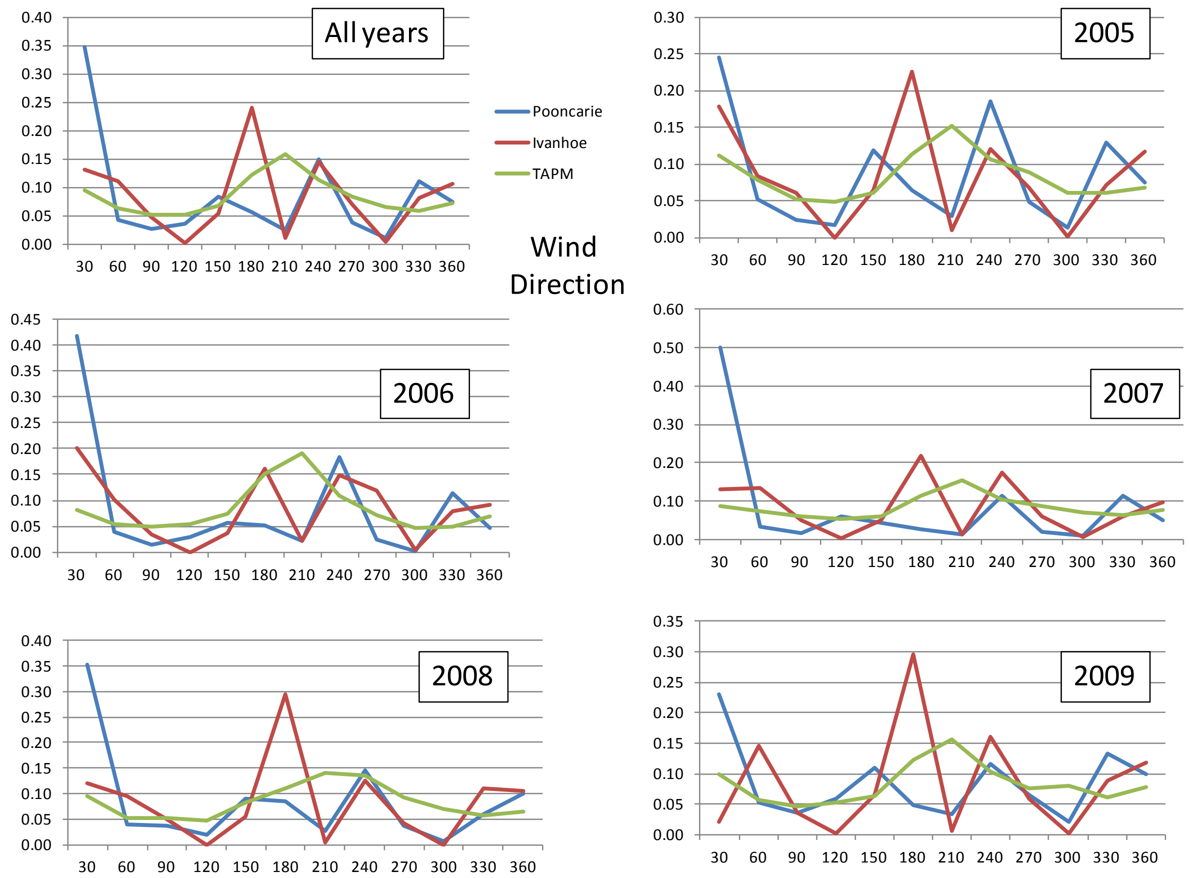


Figure A2 PDF plots of observed and modelled wind direction

Location: Atlas-Campaspe Mine	**Period:** 2005 – 2009	**Data source:** BOM, TAPM	**Units:** ° and %
Type: PDF plot		**Prepared by:** B. Lilley	**Date:** July 2012

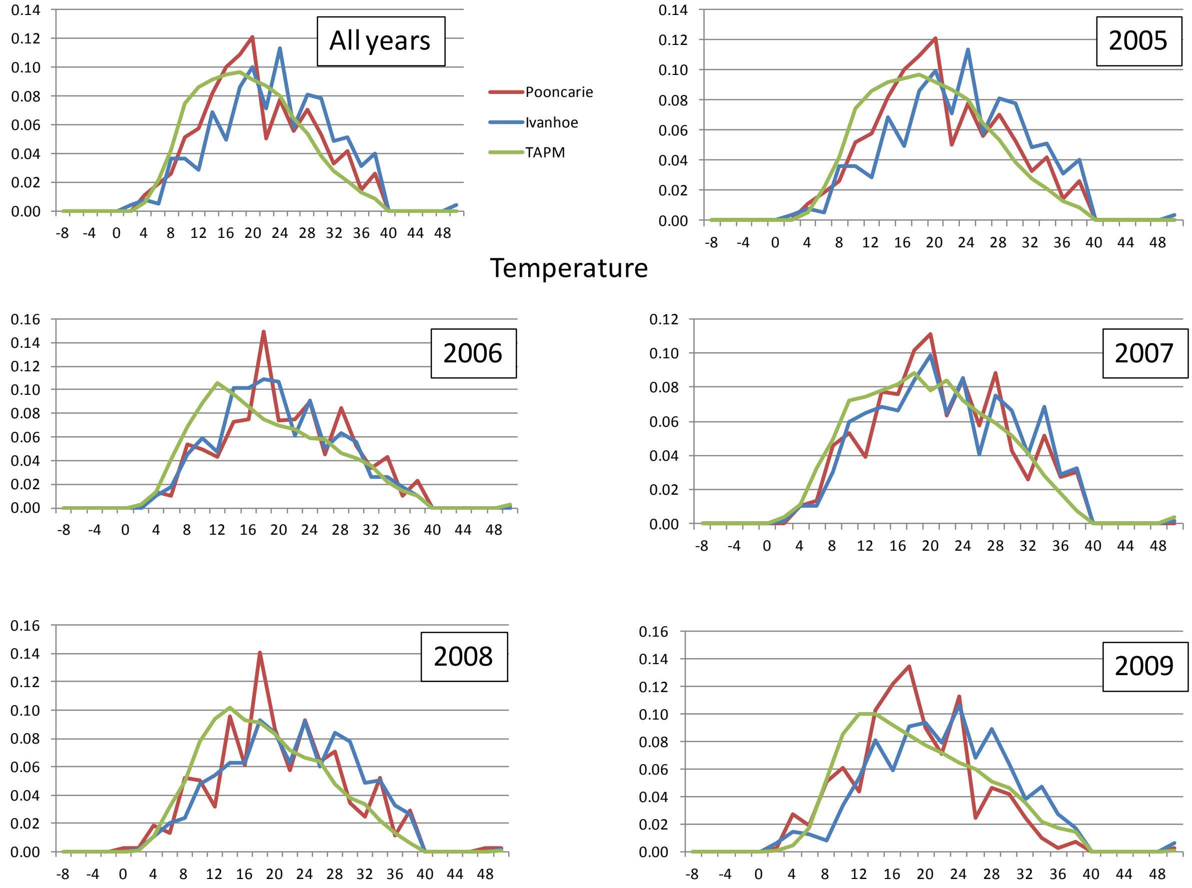


Figure A3	**PDF plots of observed and modelled temperatures**		
Location: Atlas-Campaspe Mine	**Period:** 2005 – 2009	**Data source:** BOM, TAPM	**Units:** °C and %
Type: PDF plot		**Prepared by:** B. Lilley	**Date:** July 2012

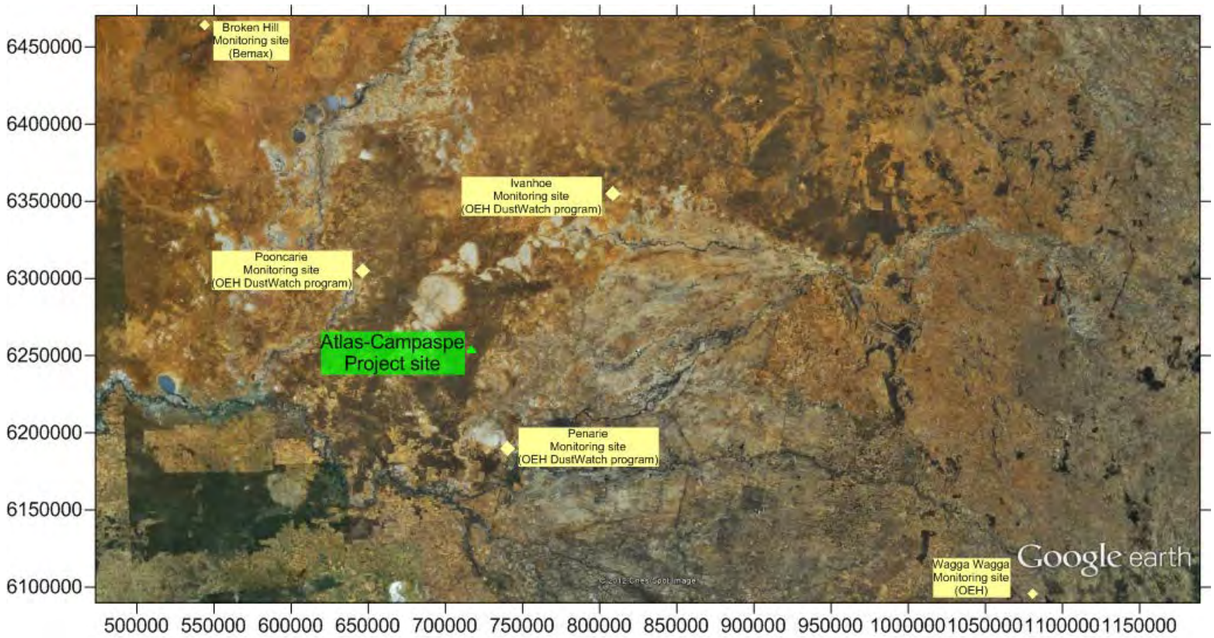


Figure A4 Location of the ambient air quality monitoring sites at Broken Hill and Wagga Wagga and the Atlas-Campaspe Mineral Sands Project		
Location: NSW	**Data source:** Google-Earth	**Units:** Projection WGS84 Zone 54S
Type: Aerial map	**Prepared by:** S. Richardson	**Date:** September 2012

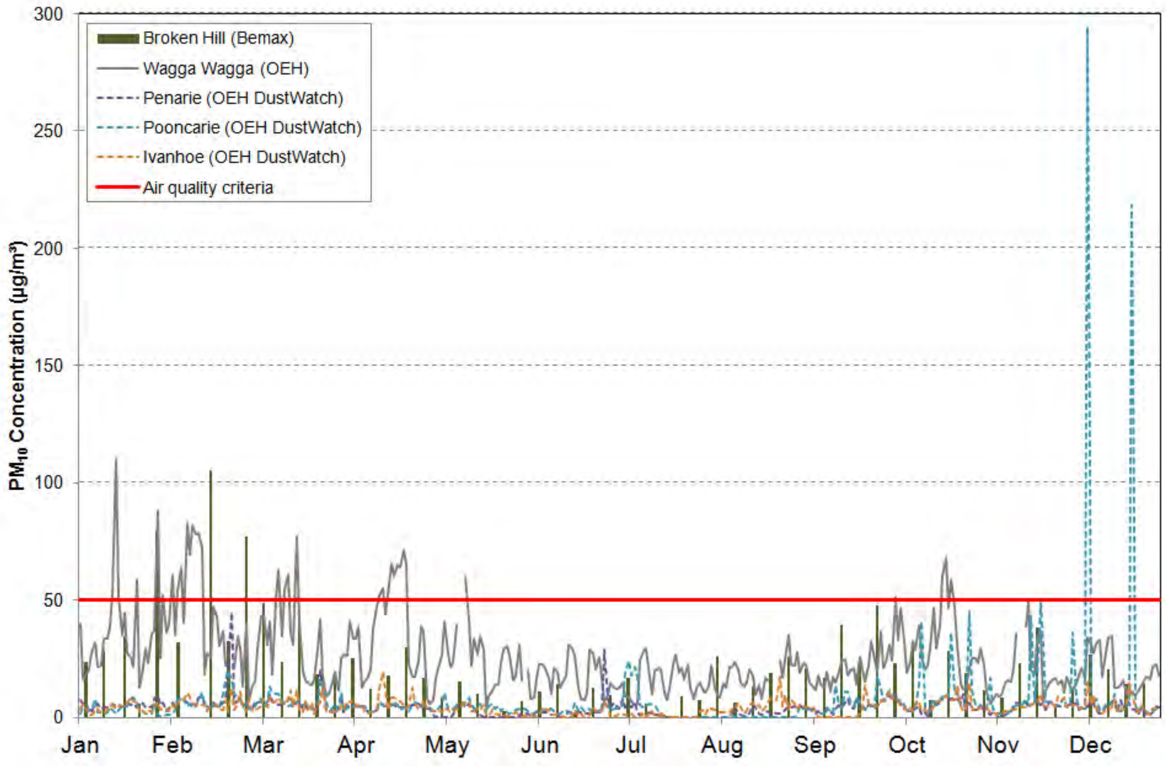


Figure A5 Comparison of PM_{10} monitoring data at Broken Hill, Pooncarie, Ivanhoe, Penarie and Wagga Wagga

Location: NSW	**Data source:** Cristal Mining and OEH	**Units:** µg/m³
Type: Histogram	**Prepared by:** S. Richardson	**Date:** September 2012

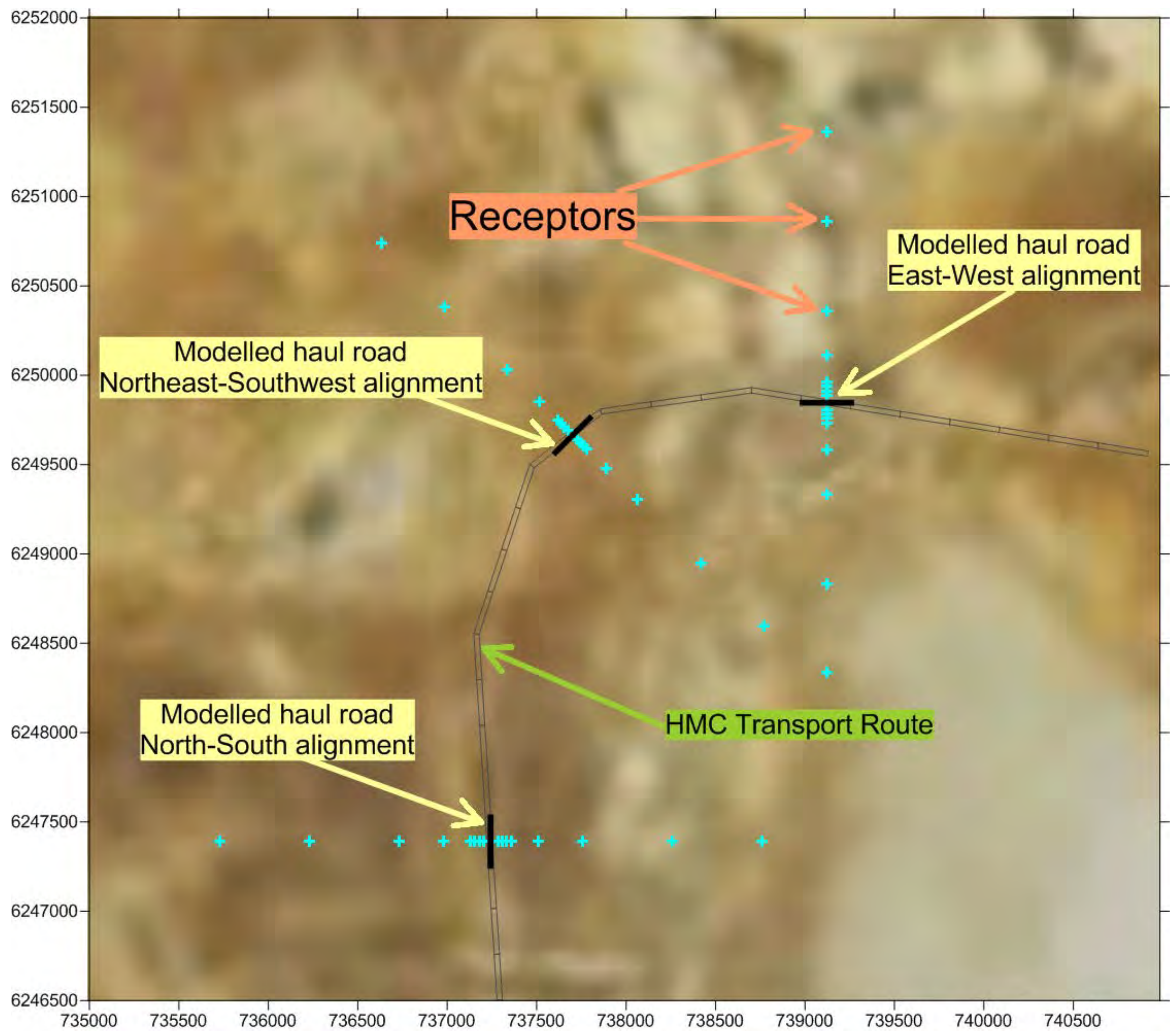


Figure A6 Diagram of modelled sections of the mineral concentrate transport corridor at an east-west, north-south and northeast-southwest alignment with receptors at 25m, 50m, 75m, 100m, 250, 500m, 1000m and 1500m spacing from haul road

Location: NSW	**Data source:** Google-Earth	**Units:** Projection WGS84 Zone 54S
Type: Site map	**Prepared by:** S. Richardson	**Date:** August 2012

Attachment B

Climate and regional meteorology

Contents

Tables

Figures

B1 Climate

A summary and analysis of the climate and meteorology in the Atlas-Campaspe Mineral Sands Project (the Project) region has been based on available monitoring information and is presented in Table B1. The analysis includes a description of both climatic trends and extreme meteorological events that characterise the region's weather patterns and may influence the development of the mine and its potential impact on the environment.

B1.1 General Climate Classification

Under a modified Köppen system (Bureau of Meteorology [BOM], 2011a) (Figure B1), based on a standard 30 year climatology the region is classified as "Grassland", with a warm, persistently dry climate (Modified Köppen classification system of Australian climate classes). This typically indicates that the region will experience very low average annual rainfall. This is illustrated in (Figure B2), which shows the region receives, on average, around 300mm of rainfall each year (BOM, 2011b). Average monthly rainfall is relatively uniform throughout the year with no obvious seasonal variation. The six major seasonal rainfall climate zones are based on the median annual rainfall (based on the 100 year period from 1900 to 1999) and seasonal incidence (the ratio of the median rainfall over the period November to April to the period May to October) (BOM, 2011a).

The region is located within a temperature and humidity zone typified by hot dry summers and cold winters (Figures B3 and B4) (BOM, 2011a). As the site is located approximately 730 kilometres (km) inland, west of the Great Dividing Range, the ranges will act as a barrier to much of the moist on-shore flow. Therefore the region will, on average, be relatively drier and less humid than a coastal location at a similar latitude.

B1.2 Major Climate Influences

The climate of the region is influenced by various short- and long-term cyclical climate patterns. Short-term cycles such as the passage of cold fronts and the movement of high pressure systems influence daily weather patterns. The longer-term El Niño Southern Oscillation cycle has a strong influence on seasonal rainfall patterns in this region. During El Niño periods when the Southern Oscillation Index (SOI) is negative the climate tends to be drier and periodically extends to drought conditions. Conversely, during the La Niña cycle the SOI is positive and wetter conditions prevail, periodically resulting in extreme precipitation events (intense and long duration of rainfall) and flooding.

Weather patterns of this region are influenced year round by the passage of cold fronts. A cold front is formed when cold dense air advances equatorwards, causing warm air to be forced aloft over its sloping surface. Frontal systems affect all of southern Australia. They can occur at any time of year, however they have the greatest impact during the winter months. Fronts generally move across southern Australia from west to east, and can be in the region from a couple of days to a week. Frontal systems bring rainfall to southern Australia. These frontal systems vary in their intensity and speed, and the stronger systems are generally associated with heavier rainfall. If frontal systems are slower moving, then rainfall may occur for extended periods and may be heavy at times (BOM, 2011c). While cold fronts can affect the region at any time of the year, they are more frequent during the winter months.

Table B1 Meteorological Summary – Long Term Average Temperature, Rainfall and Evaporation

Period of Record	Average Monthly Temperature (°C)[1] [Minimum-Maximum]			Average Monthly Rainfall (mm)[1]									Average Monthly Evaporation (mm)[1,2]	
	Pooncarie Mail Agency [47029]	Balranald (RSL) [49002]	Ivanhoe Post Office [49019]	Hatfield (Clare) [49008]	Euston (Turlee) [49111]	Hatfield (The Vale) [49047]	Hatfield (Benikie) [49049]	Pooncarie (Mulurulu) [47024]	Pooncarie (Top Hut) [47018]	Oxley (Walmer Downs) [49055]	Ivanhoe (Kilfera) [49063]	Ivanhoe Post Office [49019]	Menindee Post Office [47019]	Mildura Airport [76031]
	1882-2012	**1879-2012**	**1884-2012**	**1873-2012**	**1960-2012**	**1924-2012**	**1876-2012**	**1882 - 2012**	**1920-2012**	**1922-2012**	**1872-2012**	**1884-2012**	**1968-2012**	**1965-2012**
January	33.4-38.5	29.5-38.1	29.5-39.5	25.6	33.1	28.0	23.6	24.0	22.9	28.2	20.7	30.0	332.6	328.6
February	31.8-37.0	28.6-37.1	30.1-38.4	25.9	22.7	24.7	25.0	22.7	27.0	29.4	29.0	28.4	268.3	274.0
March	27.6-33.4	25.3-33.8	26.3-37.6	27.4	21.2	24.1	22.1	23.2	20.1	24.9	24.5	29.8	225.1	229.4
April	22.9-30.0	16.3-28.6	22.1-31.2	21.5	20.1	20.4	18.9	19.1	16.7	23.0	19.4	19.1	143.1	141.0
May	18.8-23.4	16.4-23.3	17.1-23.6	29.0	24.9	25.5	27.9	29.0	22.7	29.1	27.7	27.1	85.3	83.7
June	14.8-18.5	13.2-20.0	14.8-19.0	26.1	20.2	24.0	25.6	25.7	19.7	26.6	27.6	26.6	57.7	57.0
July	16.0-19.6	12.4-20.8	13.7-19.5	22.9	25.1	21.6	21.6	21.8	23.5	26.1	20.1	22.9	64.7	62.0
August	16.8-21.4	14.7-25.4	15.8-23.4	24.0	25.8	23.7	24.0	23.8	22.5	26.1	22.7	23.5	99.5	93.0
September	20.5-24.7	16.9-24.9	18.5-25.8	22.9	24.8	21.2	22.6	23.4	19.7	22.7	22.3	22.0	147.0	138.0
October	23.3-28.9	19.8-30.0	21.9-30.2	26.6	28.1	28.2	27.2	26.7	29.1	31.7	25.4	28.4	212.2	201.5
November	27.2-33.9	23.4-32.8	25.2-35.1	23.7	25.9	25.0	23.2	23.2	19.3	26.1	25.3	24.0	260.4	255.0
December	30.9-35.4	24.5-34.9	29.5-37.1	22.0	22.9	22.5	21.8	23.7	20.8	26.4	20.6	26.1	319.9	310.0
Average Annual	**25.1-26.9**	**22.1-26.6**	**24.8-28.1**	**299** ***[297.6]***	**300** ***[294.8]***	**286** ***[288.9]***	**281** ***[283.6]***	**282** ***[286.3]***	**268** ***[264.0]***	**323** ***[320.6]***	**284** ***[285.6]***	**306** ***[308.3]***	**2,208** ***[2,215.8]***	**2,190** ***[2,173.2]***

1 Source: BOM (2012).
2 As measured by Class A Evaporation Pan
[ ] Sum of average monthly records
mm = millimetres
°C = degrees Celsius

The summer weather pattern across much of New South Wales (NSW) is also influenced by a major trough in the easterly trade-winds located to the west of the Great Dividing Range at an average meridional position of 700 km from the coast (Sturman and Tapper, 2002). This feature is shown in Figure B5 (BOM, 2011d), with the average mean sea level pressure for January being chosen as representative of a typical summer pressure pattern. The effects of the east coast trough can often be enhanced by the presence of an upper-level trough, southern ocean cold fronts or an east coast low. These can increase convection along the trough which can lead to very heavy summer rainfall and may trigger extreme precipitation events, such as flash flooding.

The winter weather pattern across this region of New South Wales is influenced by the position of the sub-tropical ridge. The sub-tropical ridge is a dynamic feature of the atmospheric circulation, which is present all year round. During the warmer part of the year in southern Australia, the ridge is located to the south of the continent. As southern Australia cools and winter approaches, the sub-tropical ridge moves northward over central Australia. This feature is shown in Figure B6 (BOM, 2011d), with the average mean sea level pressure for July being chosen as representative of a typical winter synoptic pressure pattern. Conditions along the ridge, under the influence of the high pressure systems dry and descending air, tend to be stable and drier.

B1.3 Thunder-days and Lightning Ground Flash Density

According to BOM records the region can expect between 10 to 15 thunder-days per year (based on ten years of data from 1990 to 1999) (Figure B7) (BOM, 2005). A thunder-day is defined as is a calendar day which thunder is heard at least once at a given location. The region can also expect around one ground strike of lightning per square kilometre per year (based on approximately 8 years of data, 1995 – 2002) (Figure B8) (BOM, 2005).

B1.4 Dust Storms

Dust storms affect the drier inland areas of Australia, such as the Project region. Major dust storm events are more likely to occur during periods of extreme drought. In order for a dust storm to develop the wind has to be strong enough to firstly dislodge the dust particles from the surface and then lift them up into the atmosphere. The minimum wind speed depends on the size of the dust particles, with larger particles needing higher wind speeds to become airborne. In Australia, the minimum wind speed required is about 30 kilometres per hour. Once airborne, to lift the dust to high levels, the atmosphere must be unstable. This instability can often be created by intense surface heating or the passage of a trough or cold front across the region. Once aloft the dust particles move away from the source region under the influence the pre-dominant upper level winds (BOM, 2006). Figure B9 shows an estimated frequency of dust storms over Australia (Middleton, 1984). From this figure it can be seen that the region of the Project site can expect approximately two to three dust storms per year. However, this graphic has not been updated since 1984 and as such does not include recent significant dust events such as the dust storms of 2002, 2009 and 2011 which severely impacted a number of major regional centres in NSW.

B1.5 Bushfires

Large areas of Australia suffer from the risk of bushfires. Low relative humidity, high winds and lack of rain all contribute to increased fire danger. Severe bushfire seasons can often occur after wetter than average periods. Above average rainfall encourages increased plant growth. During subsequent dry spells the plant matter dries out, increasing the fuel loading for a region and therefore increasing the risk of bushfires.

It can be seen in Figure B10 the highest risk of bushfire for the Project area occurs during summer (BOM, 2009). The greatest risk occurs during periods dominated by moderate to strong westerly to northerly winds, as this generally results in hot, dry conditions over the region.

B2 Regional meteorology

The relevant meteorological conditions in the Project area are discussed in the following sub-sections.

B2.1 Wind speed and direction

Wind speed and direction are important parameters for the transport and dispersion of air pollutants. Due to the data sparse nature of the region of the Project site data from two BOM automatic weather stations (AWS) have been used to characterise the wind profile of the area; Pooncarie Mail Agency and Ivanhoe Post Office. This provides a description of the wind fields based on available AWS observations over the period from 01 January 2005 to 31 December 2010. As this is a relatively short period on which to base a climatology the data presented may not include extremes. Also as the two stations are some distance from the Atlas-Campaspe Mine, data presented may not be entirely representative of the long term average at the Atlas-Campaspe Mine. This is due to the influence of local features such as terrain, land use and land cover.

The annual distribution of wind speed and direction for the period are presented as wind rose diagrams in Figure B11 for Pooncarie and Figure B12 for Ivanhoe. The distributions are also presented separately as Probability Density Function (PDF) charts for both wind speed and direction in Figure B13 for Pooncarie and Figure B14 for Ivanhoe. The seasonal distributions of wind speed and direction for the same period are presented as wind rose diagrams in Figure B15 for Pooncarie and Figure B16 for Ivanhoe and PDF charts in Figure B17 for Pooncarie and Figure B18 for Ivanhoe.

Analysis of the annual wind distributions shows three wind directions are dominant at the Pooncarie Mail Agency site. Winds from the southwest direction are the most dominant with approximately 20.6 percent (%) of all winds from the southwest. Northwest and southeast winds are the next most dominant with 15.8% and 12.8% respectively. The winds at Pooncarie are generally light to moderate in strength, with 61.4% between 2 metres per second (m/s) to 5 m/s.

At Ivanhoe Post Office, analysis of the annual wind distributions shows two dominant wind directions. Winds from the south are the most dominant, with 27.9% of all winds from this direction. Southwest is the next most dominant with 16.2%. The winds at Ivanhoe, like Pooncarie, are generally light to moderate in strength, with 55.6% between 2 m/s to 5 m/s.

The seasonal wind distributions at Pooncarie generally reflect those of the annual distributions. Southwest winds are a dominant direction year round. It is only in autumn that the northwest winds are more dominant, with 24.5% of winds from the northwest versus 23.4% from the southwest. Spring sees a slightly more even distribution to the wind directions, with winds from the southwest and southeast dominant, at 17.5% and 16.2% respectively. Light to moderate winds dominate year round, with the majority of winds in each season between 2 m/s to 5 m/s. There is a slight increase in the proportion of light winds during the autumn months.

The seasonal wind distributions at Ivanhoe also generally reflect the annual distributions. Winds from the south are dominant year round, but particularly during the autumn months, when they make up 32.8% of all winds. Spring and summer both see a slightly more even distribution to the wind directions, with a significant increase in the frequency of north and northwest winds. Light to moderate winds also dominate year round, with the majority of winds in each season between 2 m/s to 5 m/s.

The annual distributions of wind speeds and directions at the two sites are summarised in Table B2.

Table B2 Summary of the annual distribution of wind speed and direction at Pooncarie Mail Agency and Ivanhoe Post Office

Location	Wind direction sector	Total proportion from direction (%)	Wind speed range (m/s)	Breakdown by wind speed range (%)
Pooncarie Mail Agency	Southwest	20.6	< 2	17.9
			2 – 5	59.8
			> 5	22.3
	Northwest	15.8	< 2	17.4
			2 – 5	59.9
			> 5	22.7
	Southeast	12.8	< 2	20.4
			2 – 5	68.0
			> 5	11.6
	All other directions	50.8	< 2	18.3
			2 – 5	60.9
			> 5	20.8
Ivanhoe Post Office	South	27.9	< 2	26.4
			2 – 5	60.0
			> 5	13.6
	Southwest	16.2	< 2	31.2
			2 – 5	51.6
			> 5	17.2
	All other directions	55.9	< 2	35.4
			2 – 5	54.5
			> 5	10.1

Table note:
The description of wind speed has been categorised as follows -
< 2 m/s is described as calm to light winds
Between 2-5 m/s is described as a moderate breeze
> 5 m/s is described as a strong breeze
Source: NCDC, 2011

B2.2 Temperature

The closest BOM meteorological stations to the Project recording temperature data are located in Pooncarie, Balranald and Ivanhoe (BOM, 2012).

Long-term, monthly-average daily maximum and minimum temperatures from the Pooncarie Mail Agency, Balranald (RSL) and Ivanhoe Post Office meteorological stations show that temperatures are warmest from November to March and coolest in the winter months of June, July and August (Table B1).

Monthly-average daily maximum temperatures are highest in January (38.5, 38.1 and 39.5ºC at the Pooncarie Mail Agency, Balranald [RSL] and Ivanhoe Post Office meteorological stations, respectively) and monthly-average daily minimum temperatures are lowest in either June or July (14.8, 12.4 and 13.7ºC for the Pooncarie Mail Agency, Balranald [RSL] and Ivanhoe Post Office meteorological stations, respectively) (Table B1). This seasonal variation in temperature can be seen in Figure B19, which illustrates the range of temperatures for each month recorded at the Ivanhoe Post Office BOM monitoring station from 1939 to 2011.

B2.3 Rainfall

The long-term average annual rainfall at meteorological stations proximal to (i.e. less than approximately 50 km) the Atlas-Campaspe Mine varies from approximately 268 mm at the Pooncarie (Top Hut) meteorological station to approximately 323 mm at the Oxley (Walmer Downs) meteorological station (Table B1).

The long-term average annual rainfall at meteorological stations at Ivanhoe varies from approximately 284 mm at the Ivanhoe (Kilfera) meteorological station to approximately 306 mm at the Ivanhoe Post Office meteorological station (Table B1).

A plot of the average and highest monthly rainfall recorded at the Ivanhoe Post Office BOM monitoring station is illustrated in Figure B20. The highest monthly rainfalls have occurred during the warmer months of the year. Average monthly rainfall is relatively uniform throughout the year and no seasonal variation is obvious (Table B1 and Figure B20).

B2.4 Relative humidity

The seasonal availability of moisture is another important factor in influencing the climate, by affecting the transfer of heat in the atmosphere through the balance between sensible and latent heat fluxes, and the occurrence of precipitation. Relative humidity is one of several measures used to describe the amount of moisture in the atmosphere, and is the ratio of the actual amount of moisture in the atmosphere to the maximum amount that could be held, at a given temperature.

A plot of the mean 9am and 3pm relative humidity for Ivanhoe Post Office is presented in Figure B21 (BOM, 2011e). Analysis of this plot reveals that June is the month with the highest average 9am and 3pm relative humidity at 82% and 55% respectively. December has the lowest average 9am and 3pm relative humidity at 39% and 25% respectively.

B2.5 Evaporation

Long-term evaporation records are available from the Menindee Post Office and Mildura Airport meteorological stations, which have recorded an average annual evaporation of approximately 2,208 and 2,190 mm, respectively (Table B1). A plot of the Monthly average daily evaporation rate for Mildura Airport is presented in Figure B22 (BOM, 2012).

The highest monthly-average evaporation is in January (332.6 and 328.6 mm at Menindee Post Office and Mildura Airport, respectively) (Table B1). The lowest monthly evaporation is in June (57.7 and 57.0 mm for Menindee Post Office and Mildura Airport, respectively) (Table B1).

Based on the available datasets, measured monthly-average evaporation exceeds the measured monthly-average rainfall in all months (Table B1).

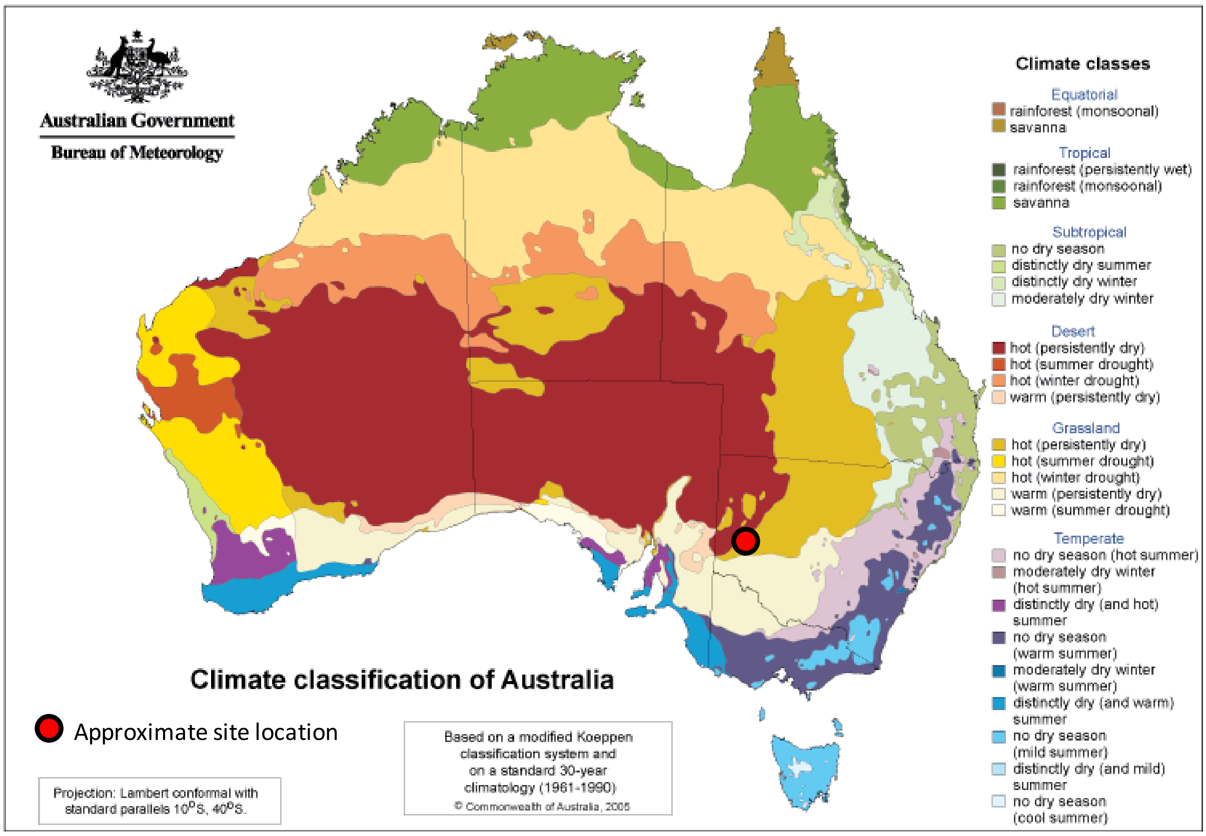


Figure B1	**Modified Köppen classification system of Australian climate classes**

Location: Australia	**Data source:** BOM	**Units:** Projection Lambert conformal
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

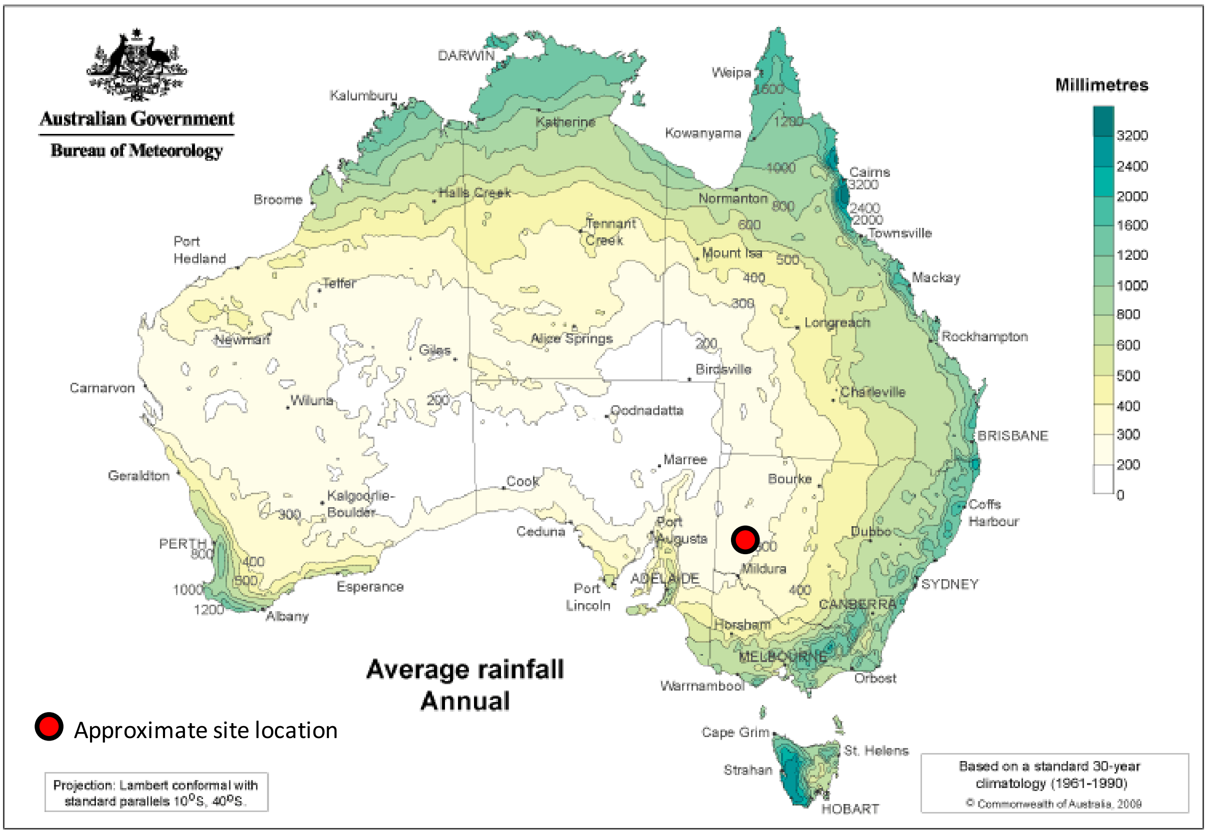


Figure B2 Australian average annual rainfall

Location:	Data source:	Units:
Australia	BOM	Mm
Type:	**Prepared by:**	**Date:**
Climate map	B. Lilley	2012

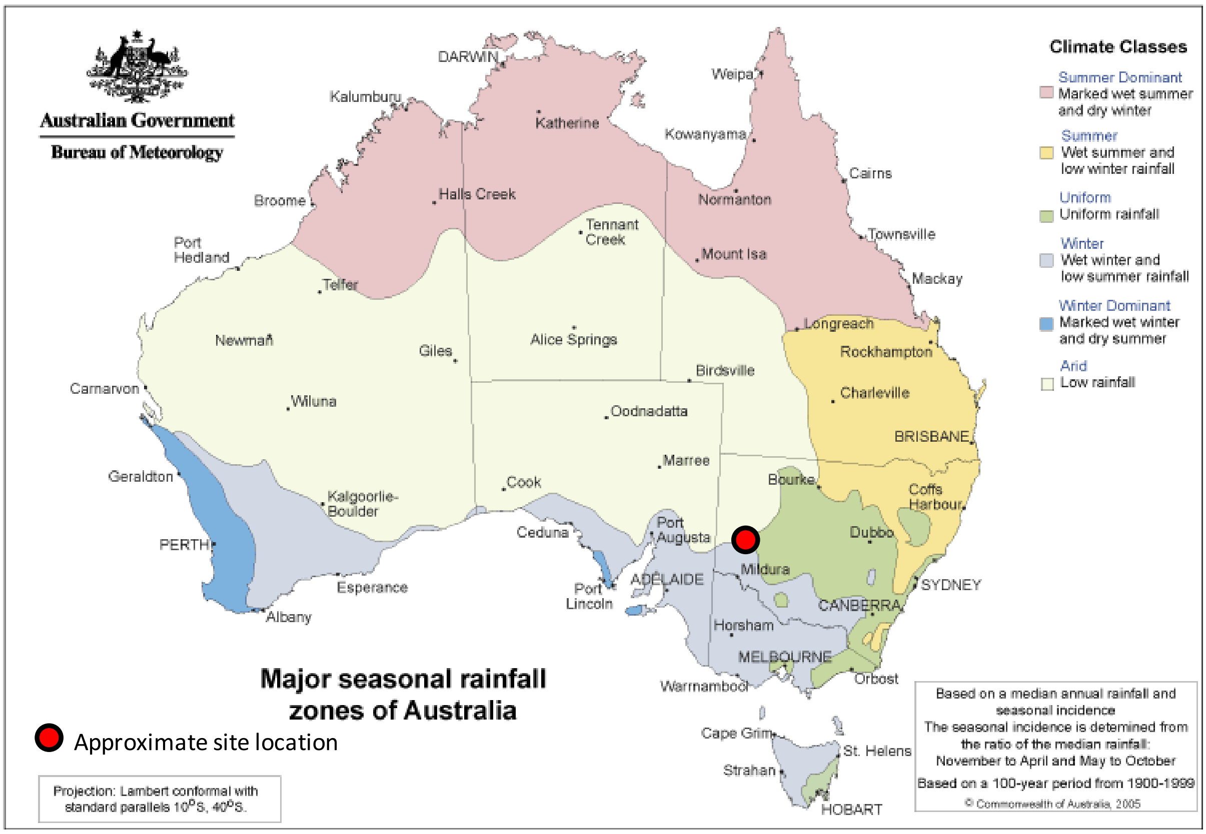


Figure B3	**Australian seasonal rainfall climate map**	
Location: Australia	**Data source:** BOM	**Units:** NA
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

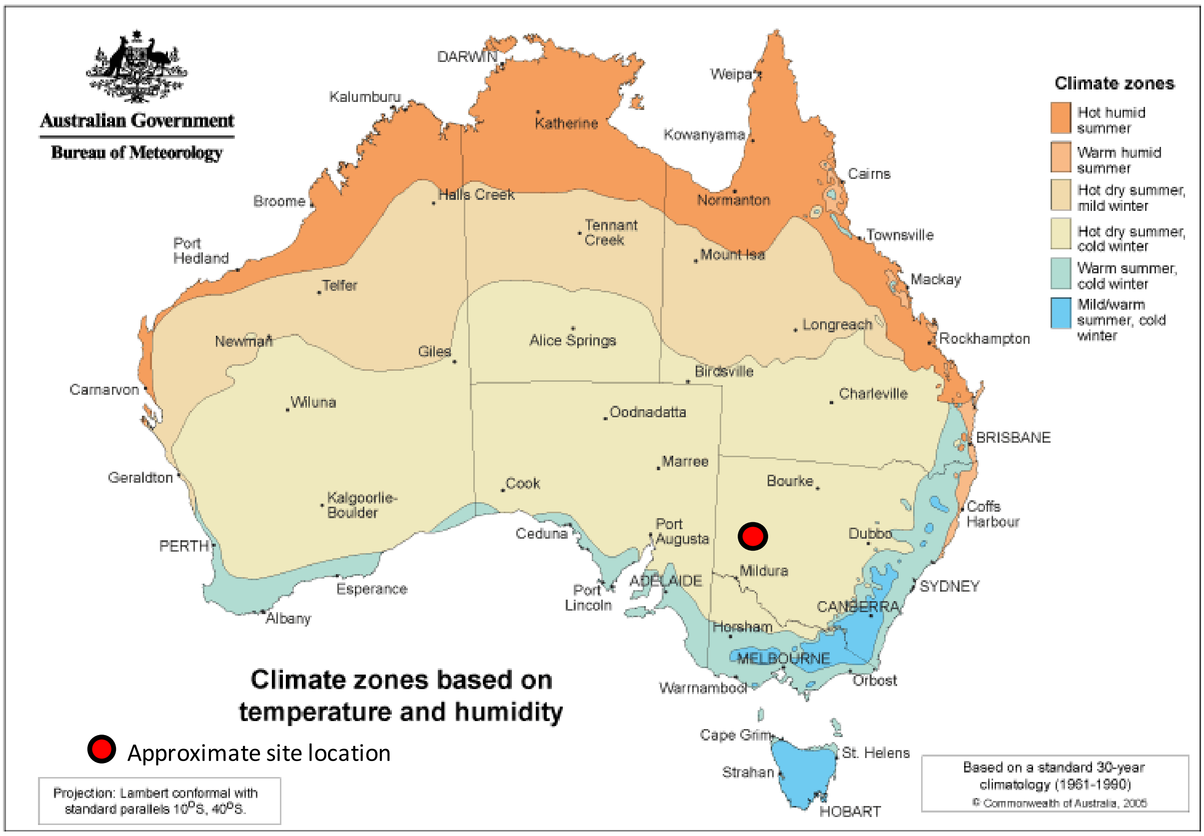


Figure B4 Australian climate zones for temperature and humidity		
Location: Australia	**Data source:** BOM	**Units:** NA
Type: Climate map	**Prepared by:** T. Haigh	**Date:** 2012

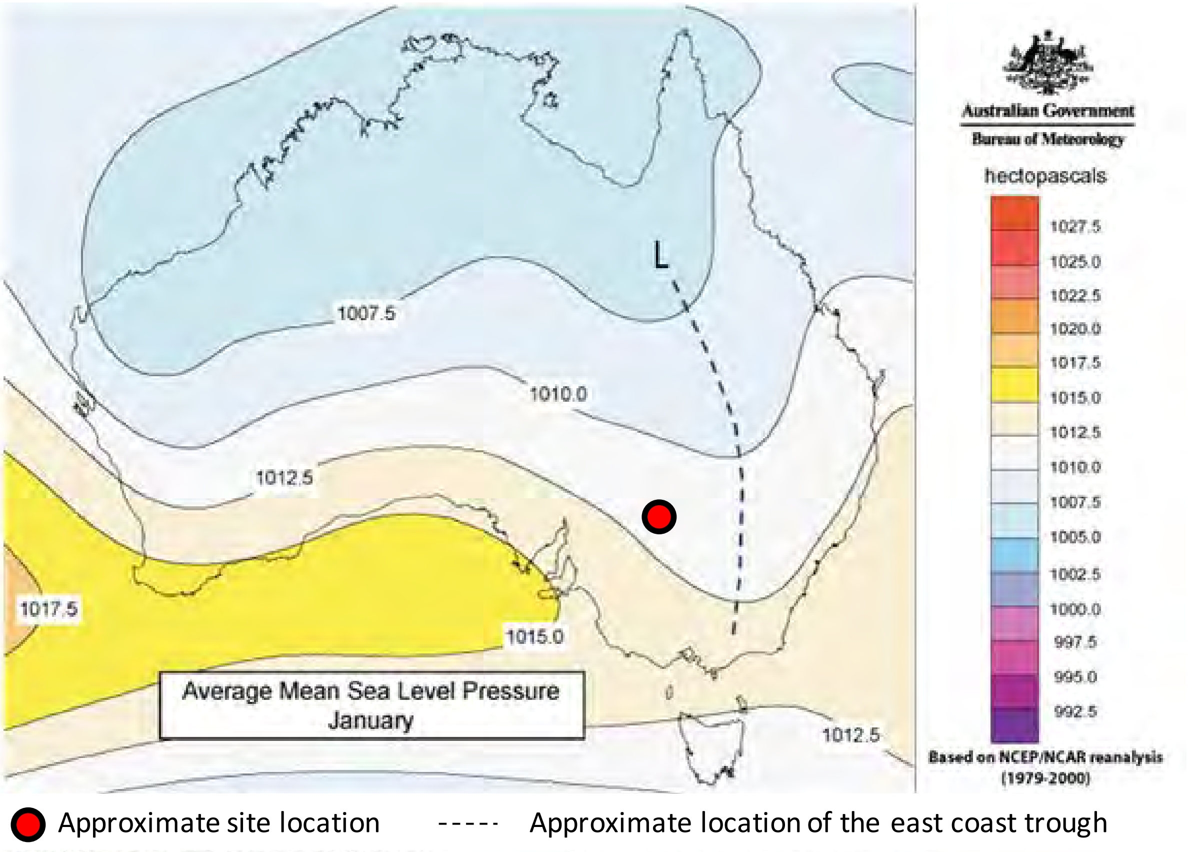


Figure B5	Average mean sea level pressure - January	
Location: Australia	**Data source:** BOM	**Units:** hPa
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

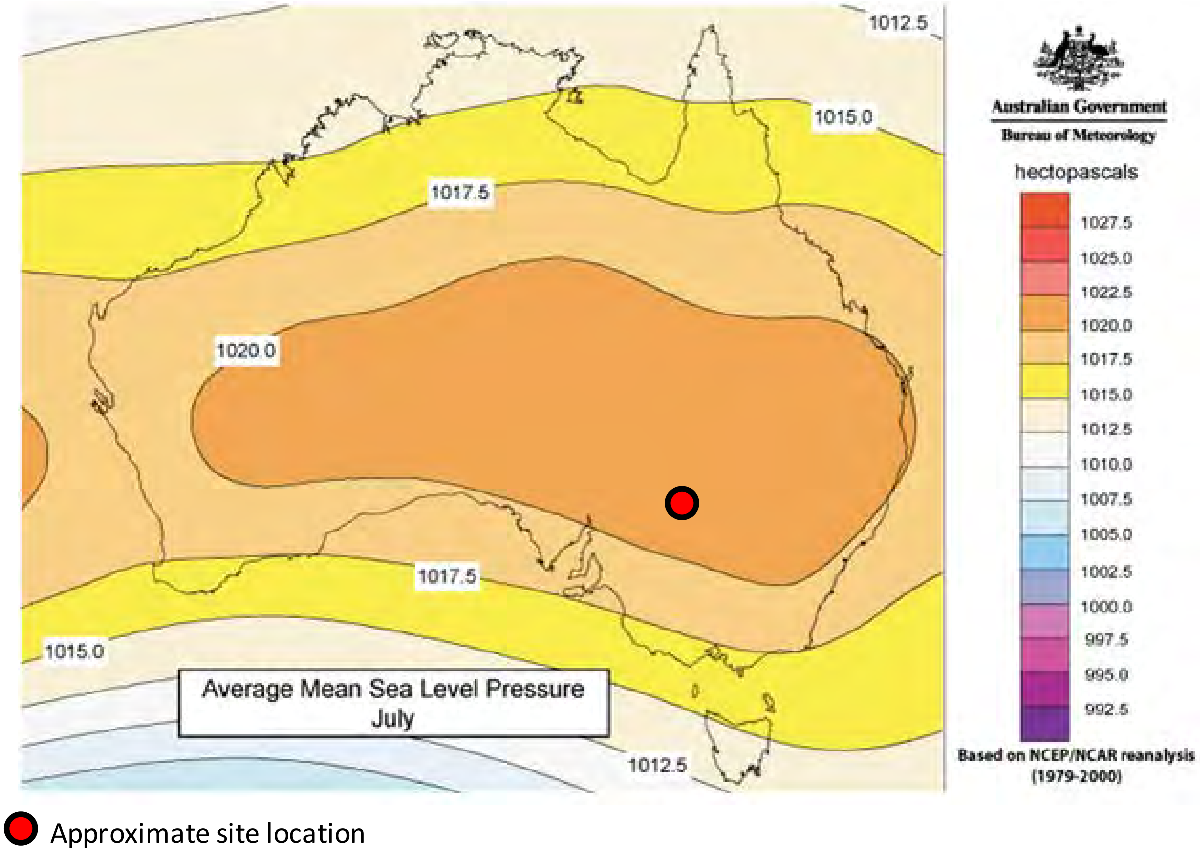


Figure B6 **Average mean sea level pressure - July**

Location: Australia	**Data source:** BOM	**Units:** hPa
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

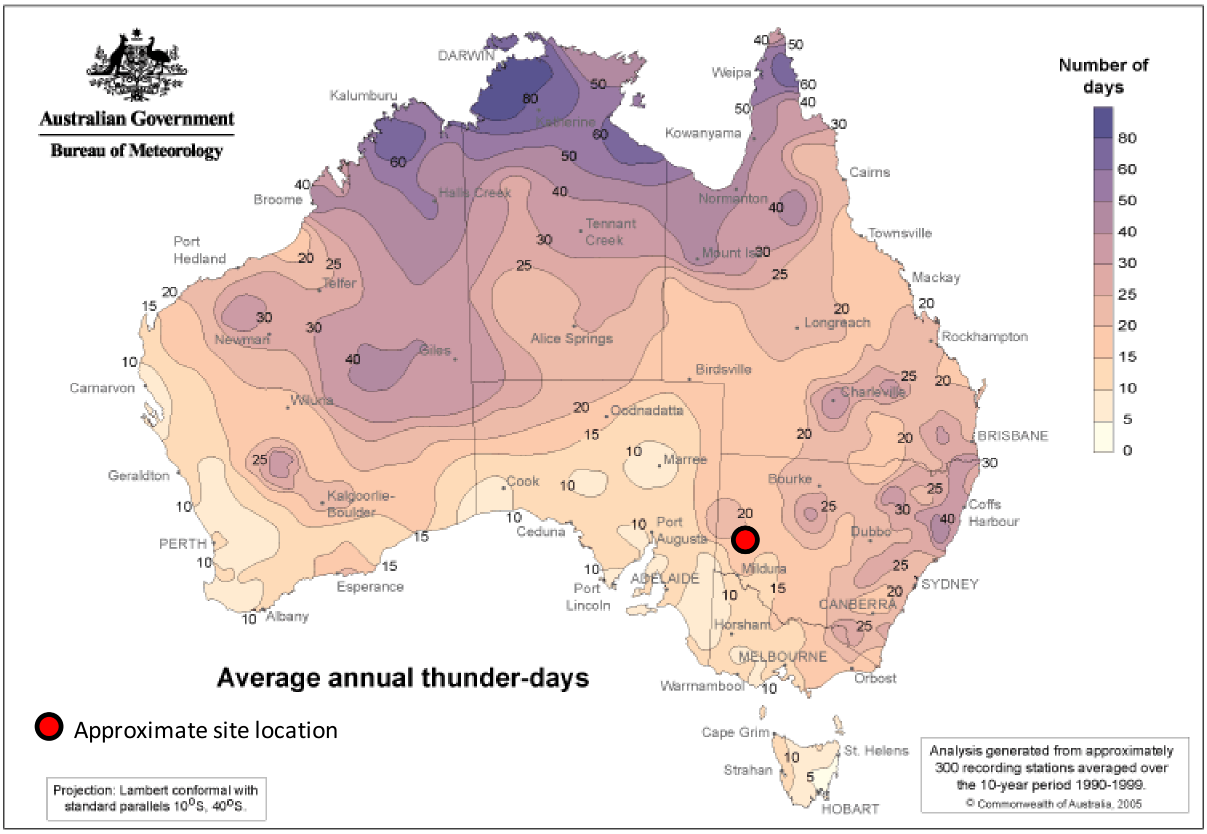


Figure B7 **Average annual thunder-days**

Location: Australia	**Data source:** BOM	**Units:** Projection Lambert conformal
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

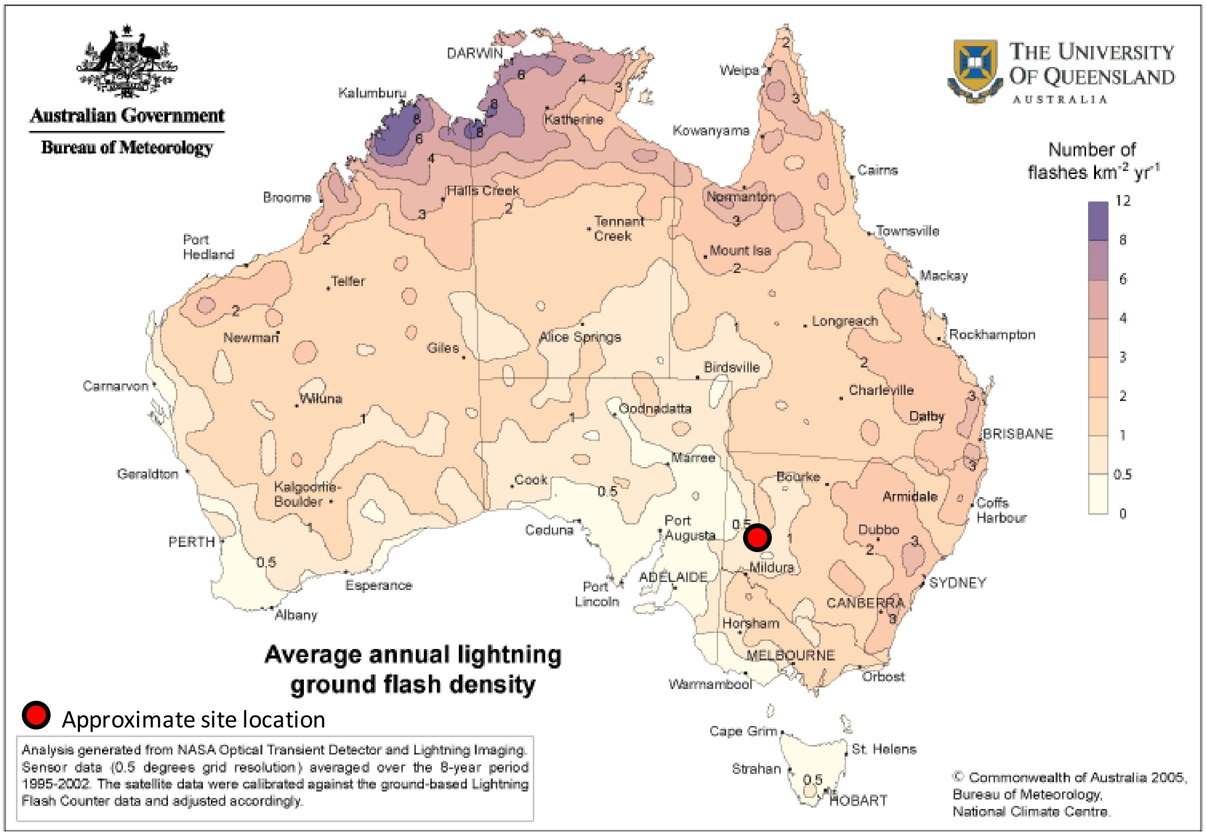


Figure B8 Average annual lightning ground flash density

Location: Australia	**Data source:** BOM and the University of Queensland	**Units:** --
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

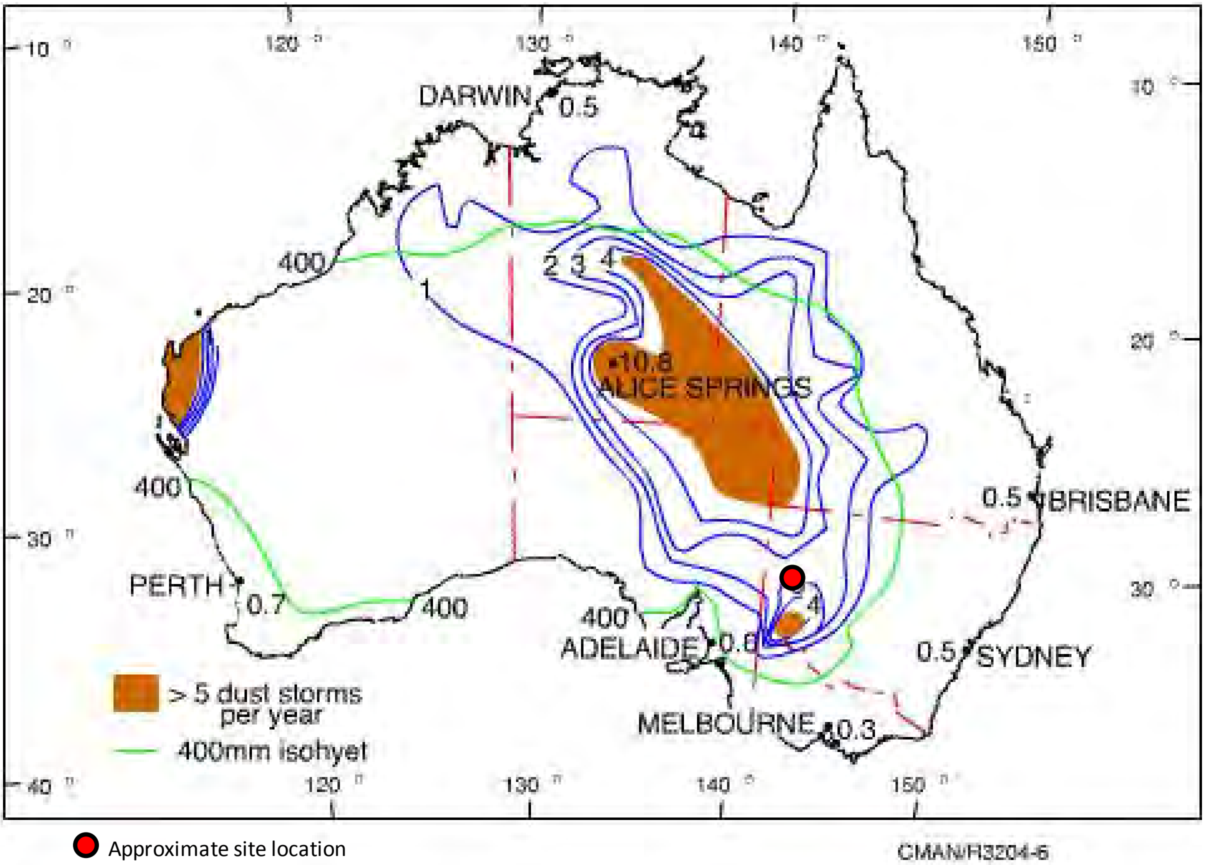


Figure B9 **Estimated frequency of dust storms over Australia**

Location: Australia	**Data source:** Middleton, N.J., 'Dust-storms in Australia: frequency, distribution and seasonality.'	**Units: --**
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

Figure B10 Australian bushfire seasons

Location: Australia	**Data source:** BOM (2009)	**Units:** --
Type: Climate map	**Prepared by:** B. Lilley	**Date:** 2012

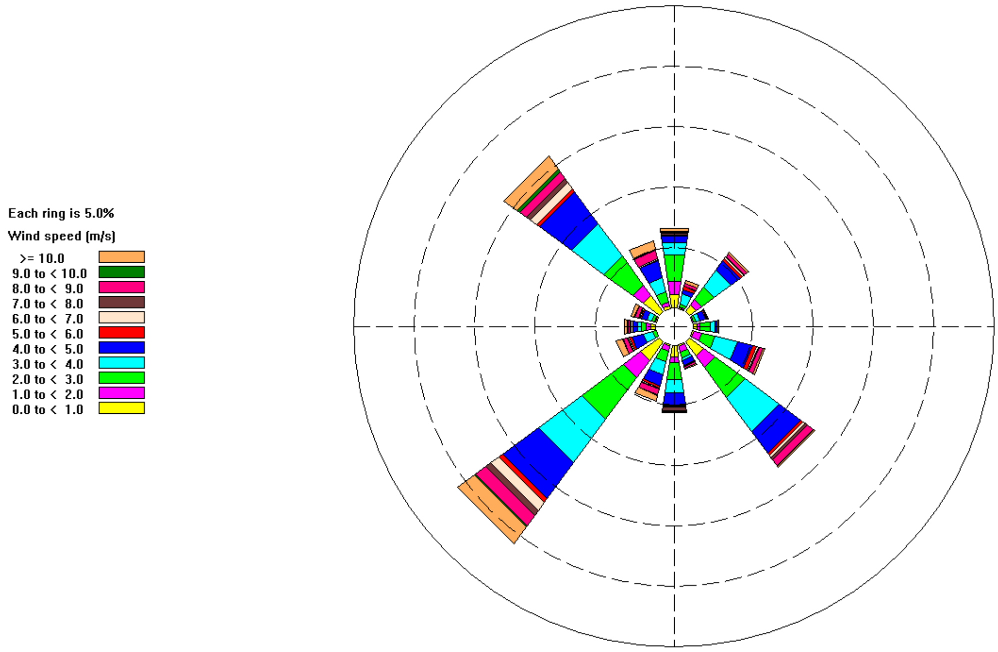


Figure B11	**Annual distribution of measured winds at the Pooncarie monitoring station**		
Location: Pooncarie, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Annual wind rose		**Prepared by:** B. Lilley	**Date:** November 2011

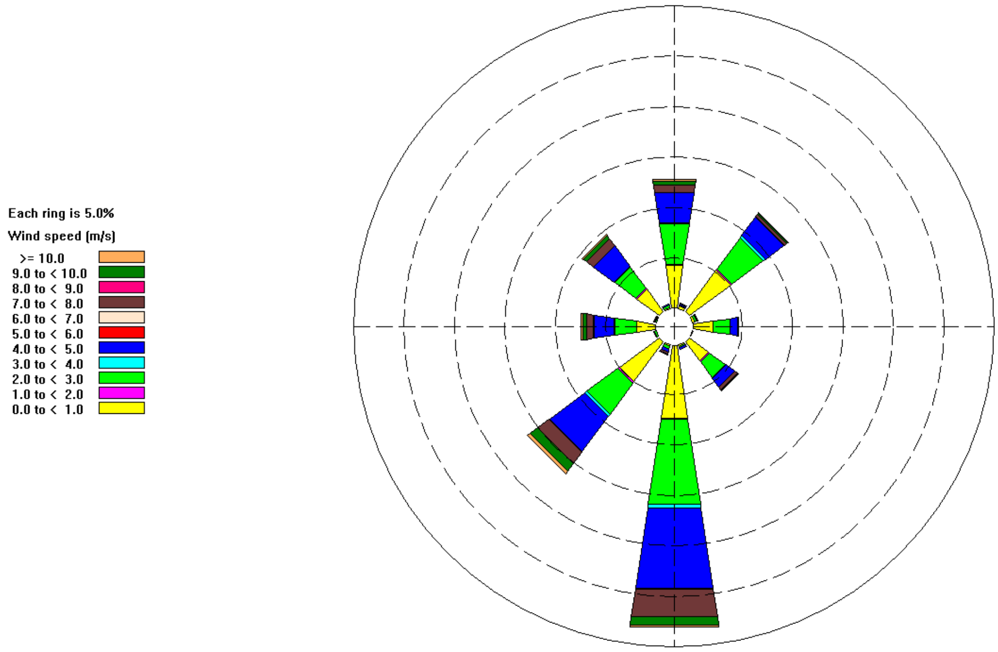
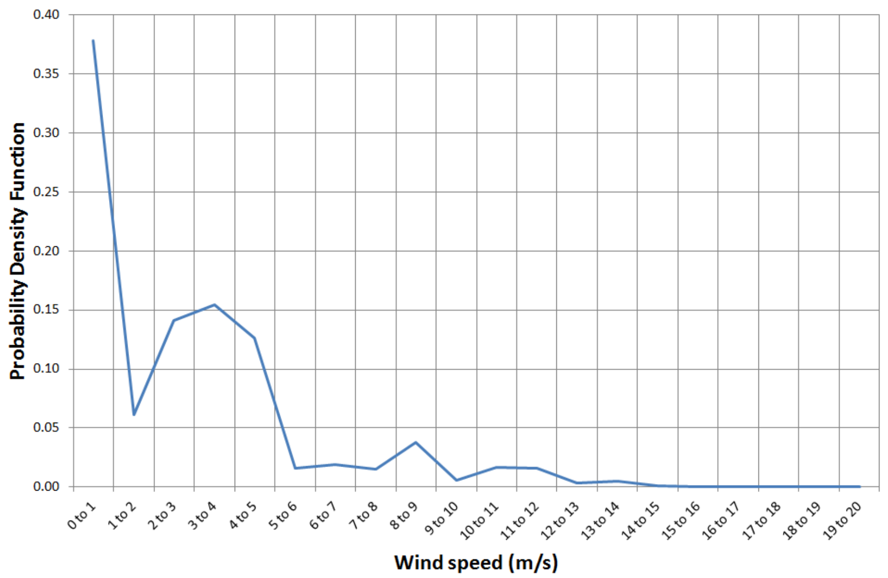


Figure B12 Annual distribution of measured winds at the Ivanhoe monitoring station			
Location: Ivanhoe, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Annual wind rose		**Prepared by:** B. Lilley	**Date:** November 2011



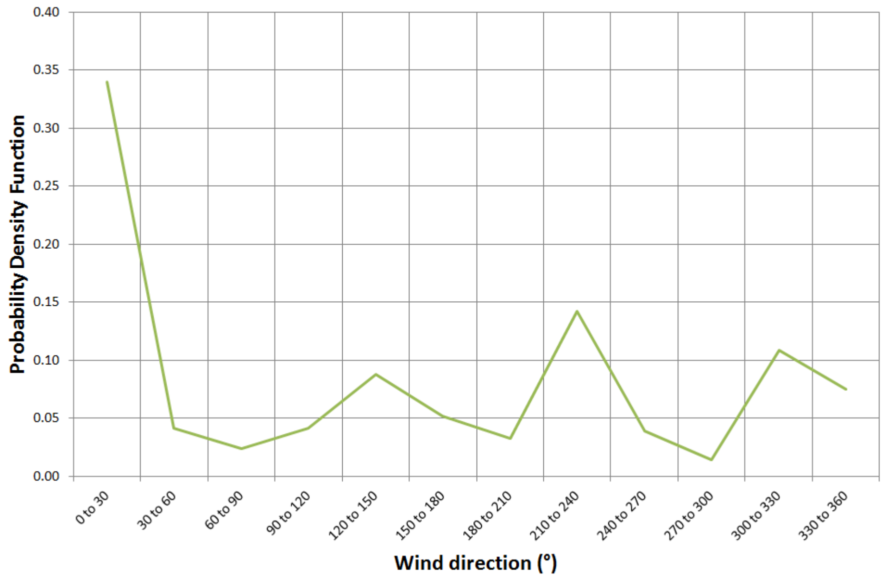
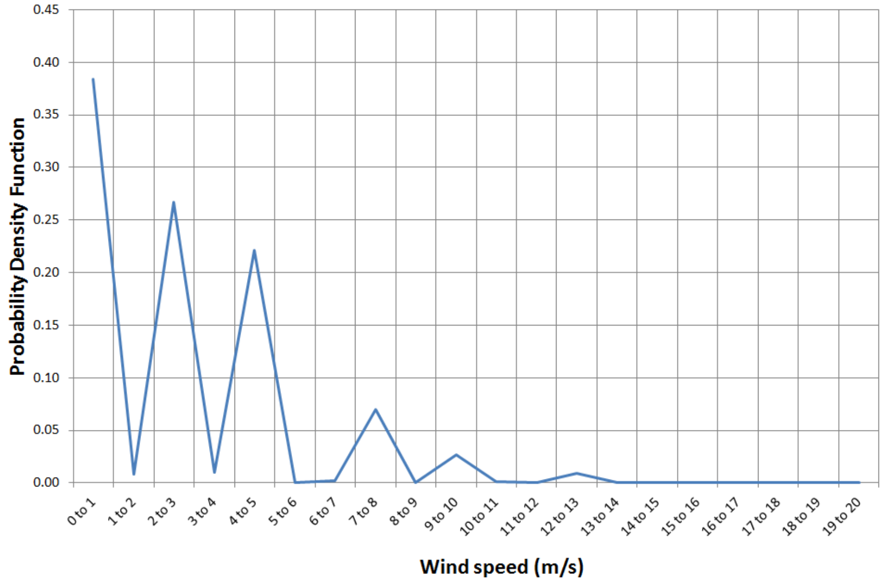


Figure B13 Annual distribution of measured wind speed and wind direction at the Pooncarie monitoring station

Location: Pooncarie, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Probability density function (PDF)		**Prepared by:** B. Lilley	**Date:** November 2011



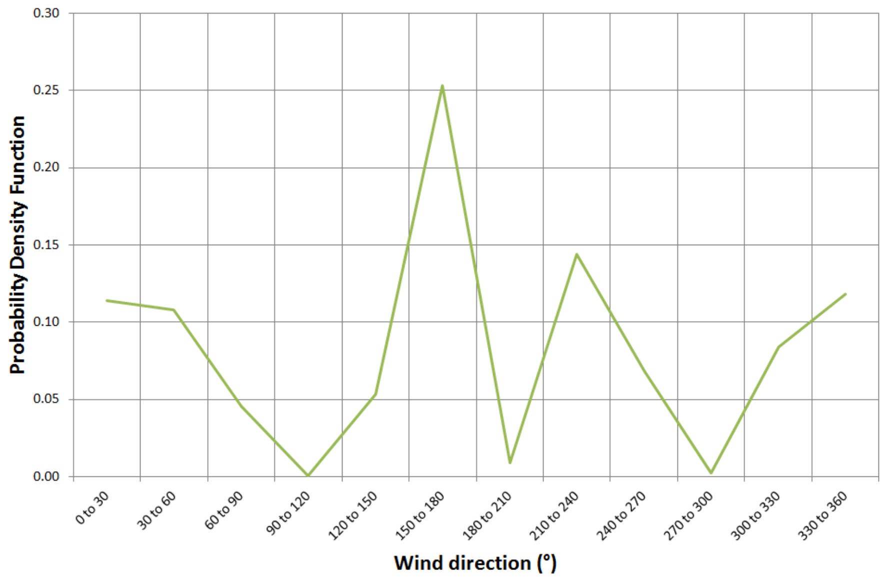


Figure B14 **Annual distribution of measured wind speed and wind direction at the Ivanhoe monitoring station**

Location: Ivanhoe, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Probability density function (PDF)		**Prepared by:** B. Lilley	**Date:** November 2011

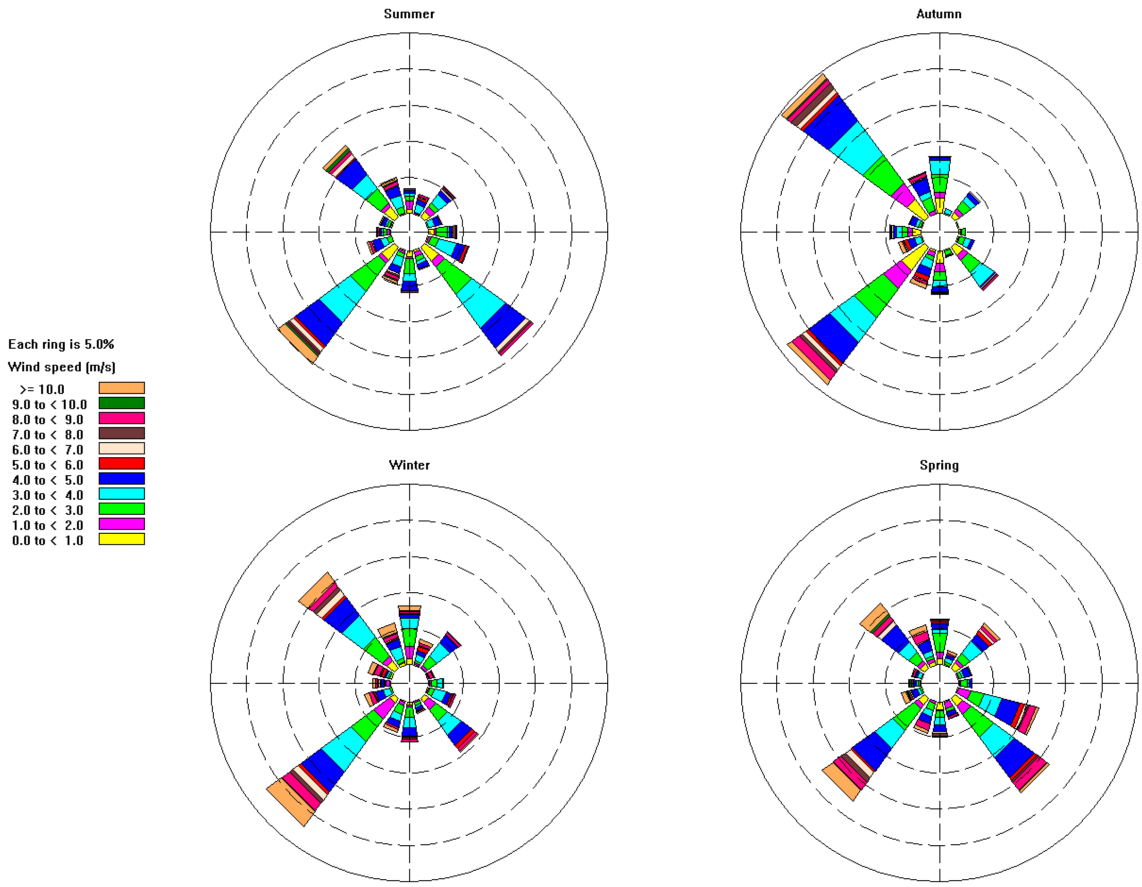


Figure B15 **Seasonal distribution of measured winds at the Pooncarie monitoring station**

Location: Pooncarie, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Seasonal wind rose		**Prepared by:** B. Lilley	**Date:** November 2011

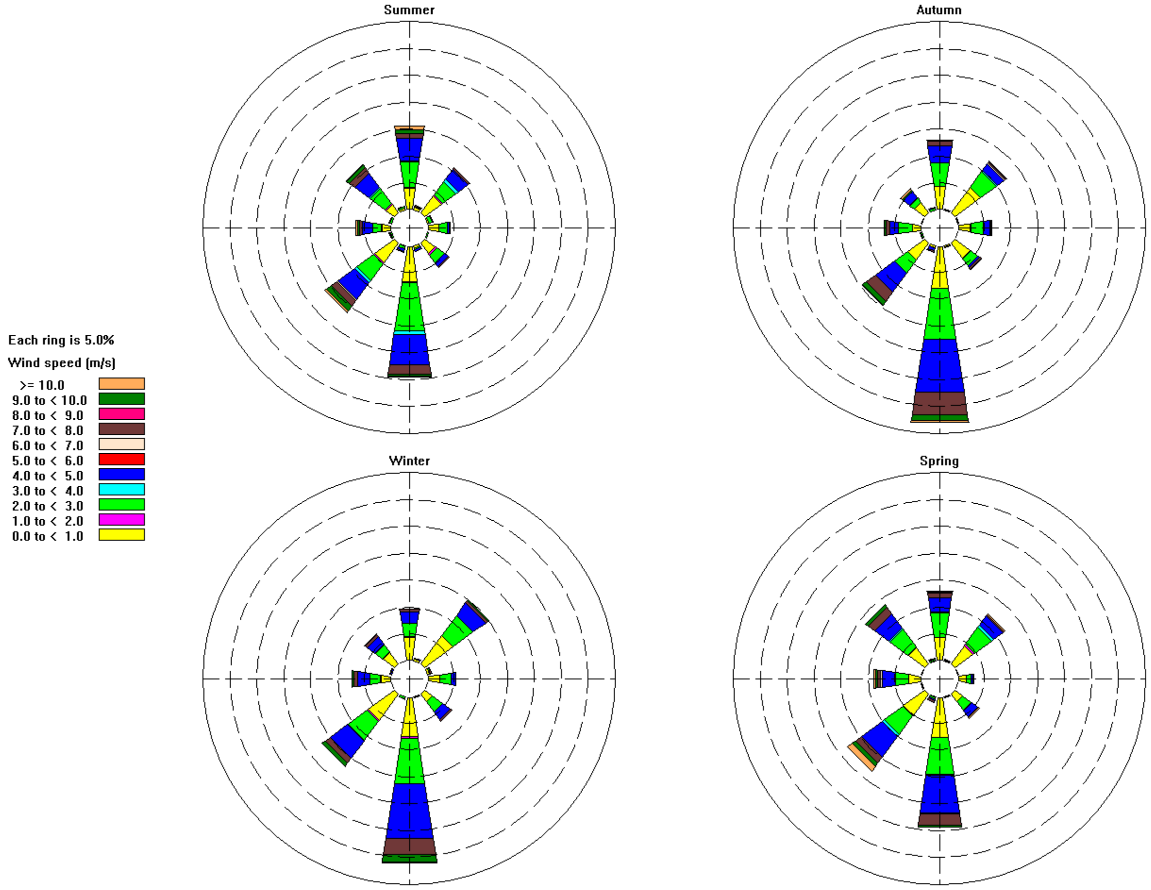


Figure B16 **Seasonal distribution of measured winds at the Ivanhoe monitoring station**

Location: Ivanhoe, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Seasonal wind rose		**Prepared by:** B. Lilley	**Date:** November 2011

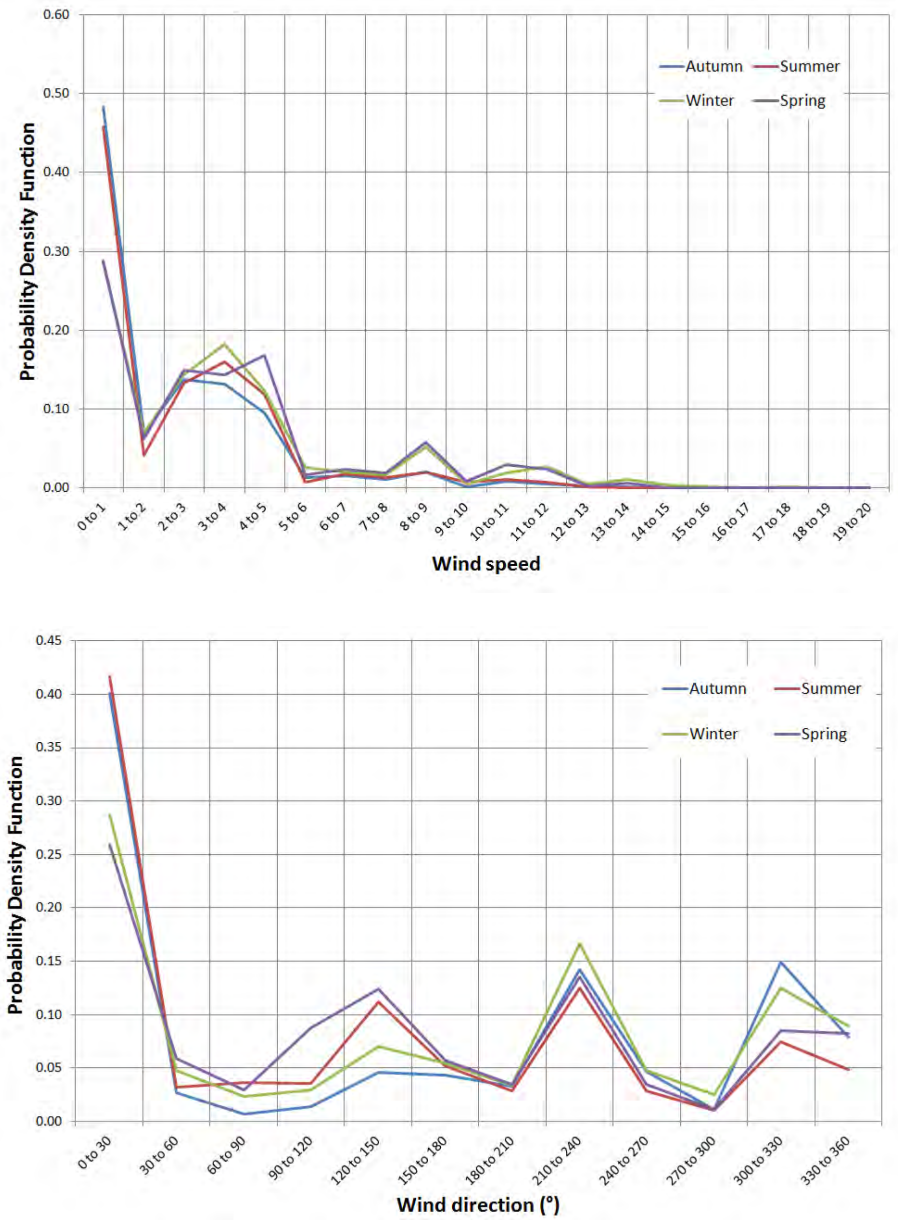
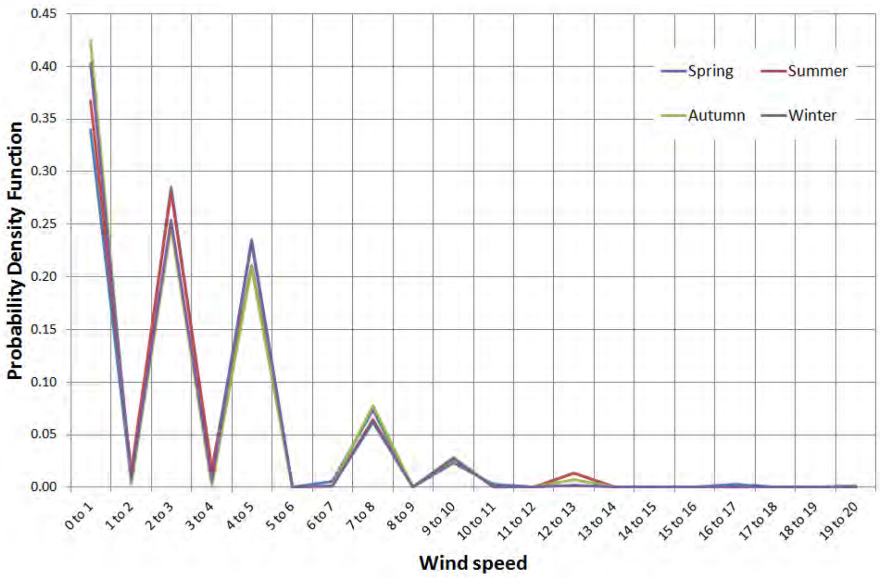


Figure B17 Seasonal distribution of measured wind speed and wind direction at the Pooncarie monitoring station

Location: Pooncarie, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Probability density function (PDF)		**Prepared by:** B. Lilley	**Date:** November 2011



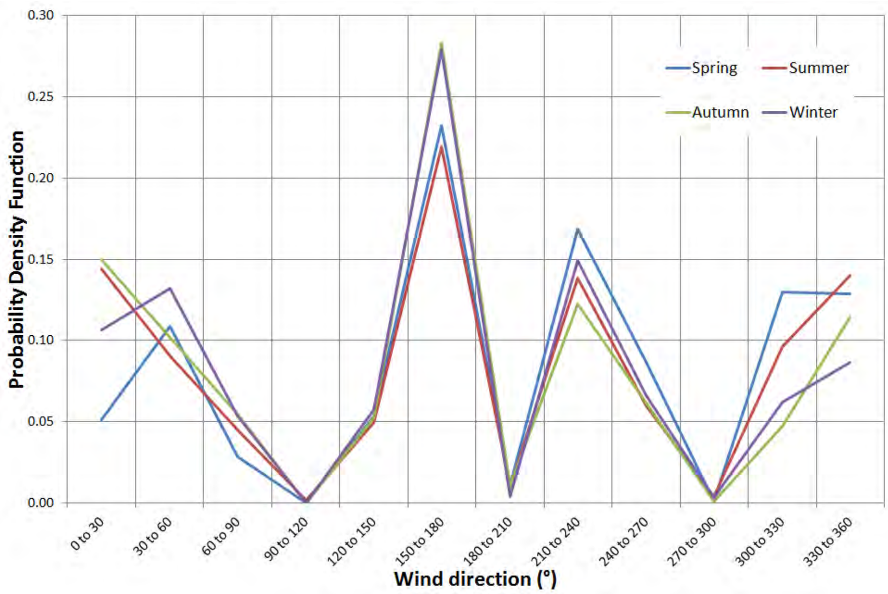


Figure B18 **Seasonal distribution of measured wind speed and wind direction at the Ivanhoe monitoring station**

Location: Ivanhoe, New South Wales	**Period:** 2005 to 2010	**Data source:** BOM	**Units:** m/s and °
Type: Probability density function (PDF)		**Prepared by:** B. Lilley	**Date:** November 2011

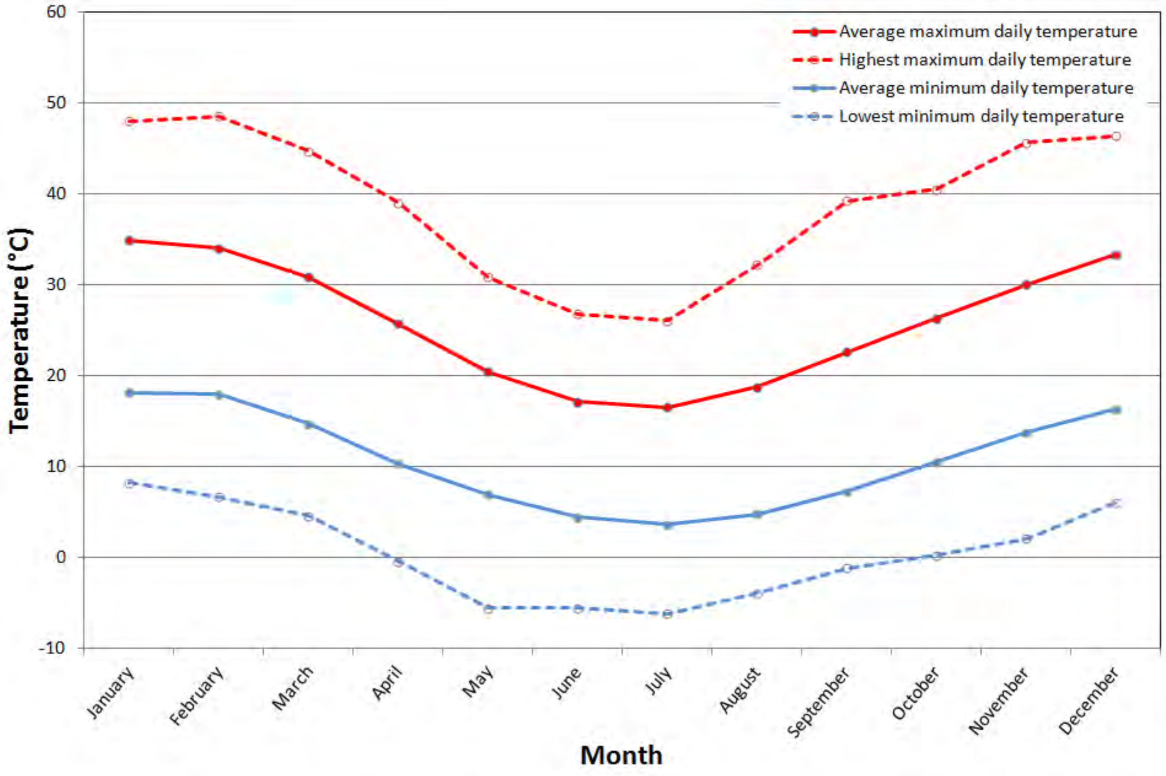


Figure B19	**Temperature statistics by month at the Ivanhoe monitoring station**		
Location: Ivanhoe, New South Wales	**Period:** 1939 to 2011	**Data source:** BOM	**Units:** °C
Type: Line graph		**Prepared by:** S. Richardson	**Date:** July 2012

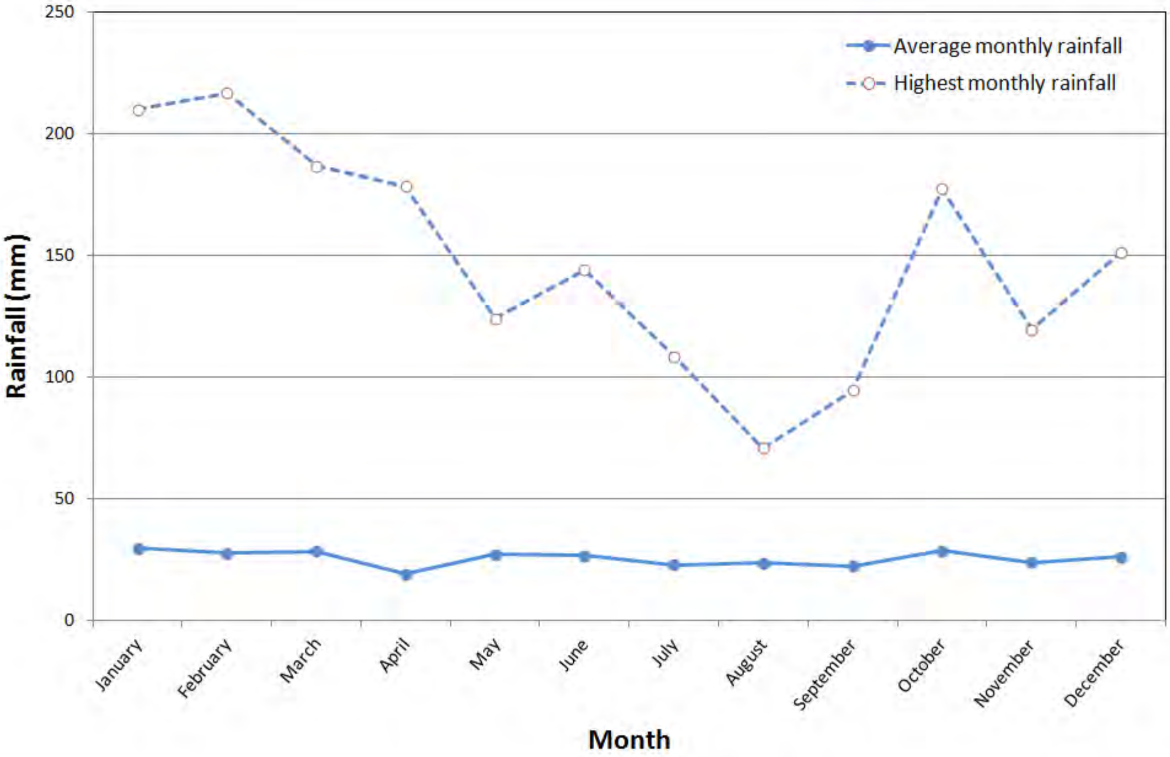


Figure B20	**Average and highest monthly rainfall at the Ivanhoe monitoring station**		
Location: Ivanhoe, New South Wales	**Period:** 1884 to 2011	**Data source:** BOM	**Units:** mm
Type: Line graph		**Prepared by:** S. Richardson	**Date:** July 2012

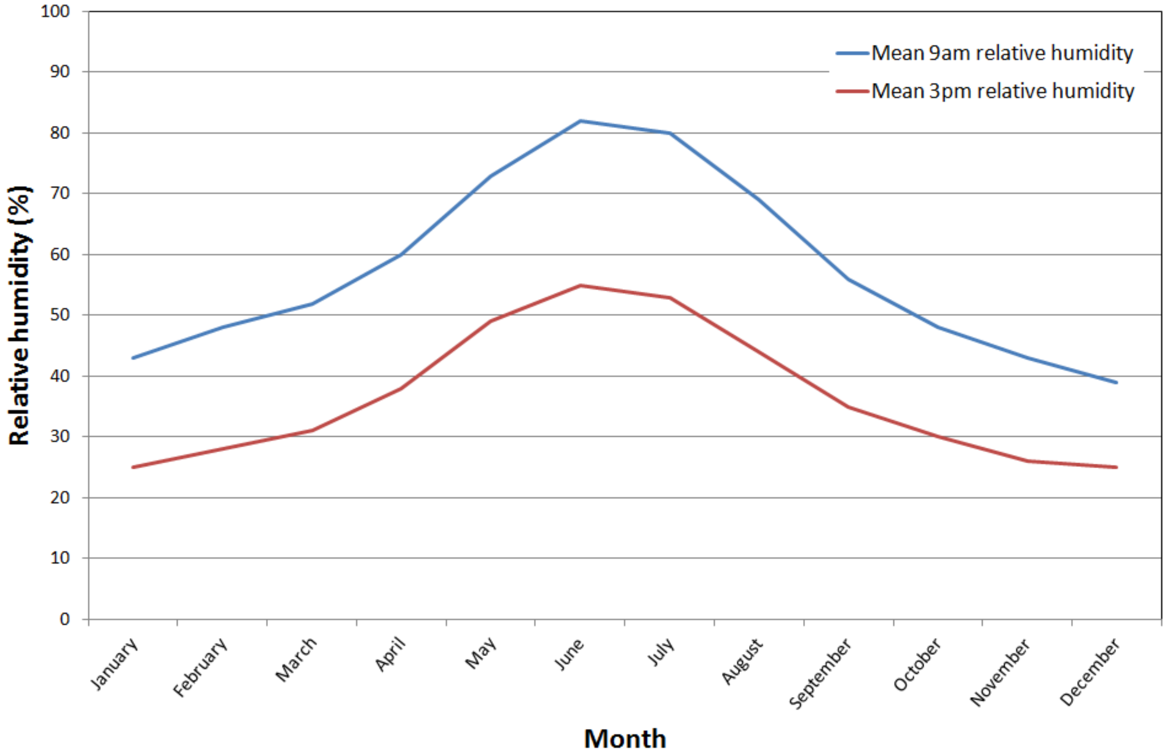


Figure B21 **Average 9am and 3pm relative humidity at the Ivanhoe monitoring station**

Location: Ivanhoe, New South Wales	**Period:** 1939 to 2010 (9am) and 1945 to 2010 (3pm)	**Data source:** BOM	**Units:** %
Type: Line graph		**Prepared by:** S. Richardson	**Date:** July 2012

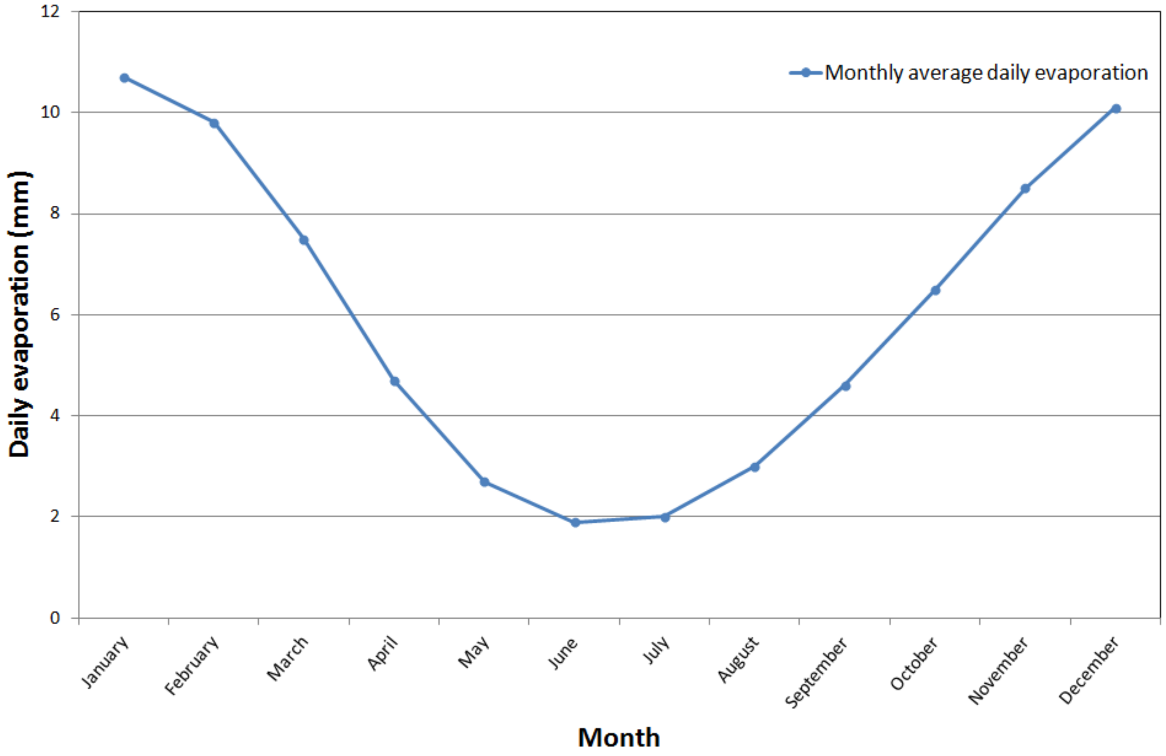


Figure B22 Monthly average daily evaporation rate at the Mildura Airport monitoring station			
Location: Mildura Airport, New South Wales	**Period:** 1965 to 2011	**Data source:** BOM	**Units:** mm
Type: Line graph		**Prepared by:** S. Richardson	**Date:** July 2012

Attachment C

Emissions

Contents

Tables

C1 Particulate emissions as TSP, PM_{10} and $PM_{2.5}$

This section provides a description of the emission rates of particulate matter (as total suspended particulates [TSP], particulate matter with a diameter less than 10 microns [PM_{10}] and less than 2.5 microns [$PM_{2.5}$]) from the following activities:

- Atlas Campaspe Mine Site:
  - Overburden/ore extraction
  - Transport of overburden
  - Transport of ore
  - Handling and stockpiling of overburden/ore
  - Wind erosion of stockpiles
  - Wind erosion of exposed areas
  - Truck loading
  - On-site transport of heavy mineral concentrate to site boundary.
- Mineral concentrate transport route to the Ivanhoe Rail Facility:
  - Transport of mineral concentrate on unsealed haul road.
- Ivanhoe Rail Facility:
  - Transport of mineral concentrate on unsealed haul road
  - Unloading and loading of mineral concentrate onto stockpiles
  - Wind erosion of stockpiles.

C1.1 Emission rates

Dust emissions rates for activities related to the operation of the proposed Atlas-Campaspe mineral sands mine were based on emission factors and methods published by the United States Environment Protection Agency (US EPA) and by the National Environment Protection Council (NEPC) for the National Pollutant Inventory (NPI) (US EPA, 1998; US EPA, 2004; US EPA, 2006a; US EPA, 2006b; US EPA, 2006c; NPI, 2012b).

Emission rates from the proposed activities at the Atlas-Campaspe Mine for the modelled scenario are summarised in Table C1.

Emission rates from the proposed transport of mineral concentrate to the Ivanhoe Rail Facility via the unsealed haul road for vehicles travelling at different speeds are provided in Table C2. Emission rates have been calculated using the emission factor for vehicles travelling on publicly accessible unpaved roads dominated by light duty vehicles, published by the US EPA (US EPA, 2006b: equation 1b). The rate of dust emissions from vehicle activity is highly dependent on vehicle speed, with a reduction in vehicle speed associated with a reduction in dust emissions. A sensitivity analysis has been carried out to show the air quality impacts from the transport of mineral concentrate on the unsealed road with vehicles travelling at speeds of 100 kilometres per hour (km/h), 80 km/h, 60 km/h and 40 km/h, with the emission rates under these four scenarios provided in Table C2 as grams of particulate emission (TSP, PM_{10} and $PM_{2.5}$) per square metre per second.

Emission rates from the proposed activities at the Ivanhoe Rail Facility for the modelled scenario are summarised in Table C3.

The size distribution of dust particles was derived from the emission rates estimated for TSP, PM_{10}, and $PM_{2.5}$. These were used to assess dust deposition rates at a network of evenly-spaced grid receptors and at sensitive receptors throughout the region.

Table C1 Estimated total dust emission rates for the mine site (g/s)

Activity	Emission Rate (g/s)		
	TSP	PM_{10}	$PM_{2.5}$
Topsoil Removal	1.8	0.4	0.2
Overburden Removal	18.6	7.4	1.6
Ore Removal	0.7	0.3	0.1
Ore Processing	2.9	1.0	0.1
Stacking of product	0.0018	0.0008	0.0001
Road train loading	0.004	0.002	0.0003
On-site haulage	25.7	7.9	0.8
Grading	0.9	0.3	0.03
Wind Erosion	7.7	4.3	0.7
TOTAL	**58.2**	**21.6**	**3.4**

Table note:
g/s = grams per second

Table C2 Estimated dust emission rates from mineral concentrate transport route ($g/m^2/s$)

Activity	Emission Rate ($g/m^2/s$)		
	TSP	PM_{10}	$PM_{2.5}$
Haulage on unsealed road: vehicle speed 100 kph	2.05E-05	6.50E-06	6.50E-07
Haulage on unsealed road: vehicle speed 80 kph	1.92E-05	5.81E-06	5.81E-07
Haulage on unsealed road: vehicle speed 60 kph	1.76E-05	5.03E-06	5.03E-07
Haulage on unsealed road: vehicle speed 40 kph	1.56E-05	4.11E-06	4.11E-07

Table note:
$g/m^2/s$ = grams per square metre per second

Table C3 Estimated total dust emission rates from Ivanhoe Rail Facility (g/s)

Activity	Emission rate (g/s)		
	TSP	PM_{10}	$PM_{2.5}$
Wheel generated dust from unpaved haul road	4.17	1.04	0.11
Dumping of mineral concentrate onto stockpiles	0.0056	0.0026	0.0004
FEL transfer of mineral concentrate from stockpile to rail wagon	0.017	0.008	0.001
Wind erosion of mineral concentrate stockpiles	0.007	0.004	0.001
Total emission rate all sources	**4.20**	**1.06**	**0.12**

C1.2 Activity data

Information on mine operations was supplied by Cristal Mining Australia Limited (Cristal Mining) and is summarised in Table C4 for the modelled scenario at the Atlas-Campaspe Mine and mineral concentrate transport route, and in Table C5 for the modelled scenario at the Ivanhoe Rail Facility. Where information was not available, ore and o verburden characteristics from the US EPA AP-42 documents were used.

The following control factors have been applied:

- 50 percent (%) during topsoil removal due to watering
- Pit retention for all in-pit activities - 50% for TSP, 5% for PM_{10} (NPI for Mining, 2012)
- 60% for Stage 1 rehabilitation
- 100% for Stage 2 rehabilitation
- 75% for haulage on-site due to Level 2 watering
- No controls for haulage along mineral concentrate transport route to Ivanhoe Rail Facility
- No controls applied at Ivanhoe Rail Facility.

Dust emissions from the Atlas pit area have been assumed to be negligible by Year 16 as the eleven year period after mining operations cease should be sufficient for the area to be completely rehabilitated.

Table C4 Activity data and assumptions used in emissions estimation for Year 16 of operations at the Atlas-Campaspe mineral sands mine and mineral concentrate transport route

Parameter	Units	Value	Comments
Haul road lengths - one way			
From active pit to inpit overburden dump	km	0.6	
Haul from active pit to topsoil stockpiles	km	0.5	
From active pit to overburden	km	2.2	
Haul from mineral concentrate product area to site boundary	km	13.27	
Asasessed section of mineral concentrate transport route to the Ivanhoe Rail Facility	km	0.3	
Stockpile heights			
Overburden emplacements	m	20	
Topsoil/subsoil stockpiles	m	5	
Mineral concentrate stockpiles	m	5	
Stockpile lengths and widths			
Overburden emplacement - width	m	310	
Overburden emplacement - length	m	1,000	
Areas			
Topsoil stockpiles	ha	110.3	Surface areas estimated from supplied dbf
Mineral concentrate stockpiles	ha	2.2	
Exposed ground - Stage 1 rehabilitation	ha	271.1	
Exposed ground - Stage 2 rehabilitation	ha	866.1	
Active pit area	ha	88.1	
Overburden emplacement	ha	62.1	Calculated assuming surface area consists mostly of two long rectangular slopes
Hours of Operation			
On-site Fleet	days/year	243	On-site fleet operates on 10 days on, 5 days off roster
	hours/day	22	

Parameter	Units	Value	Comments
All Atlas-Campaspe Operations	days/year	365	
	hours/day	24	
Material throughput			
Ore	Mtpa	7.2	
Mineral concentrate	ktpa	546	
Overburden production	Mt/month	3.13	
	Mtpa	37.6	
Overburden dumped in-pit	%	75	
Overburden dumped in emplacement area	%	25	
Reject material	Mtpa	6.9	
MSP waste	tpa	50,000	
Topsoil removed	tpa	1,452,990	
Vehicles and equipment			
Haul truck - CAT 777D empty weight	tonnes	73.0	As per manufacturer's specifications in Caterpillar Performance Handbook, Edition 38 (2008)
Haul truck - CAT 777D - full weight	tonnes	163.3	
Haul truck - CAT 777D payload	tonnes	90.3	
Haul truck - average weight	tonnes	118	
Kenworth T650 road train - empty weight	tonnes	28	
Kenworth T650 road train - full weight	tonnes	83	
Kenworth T650 road train - payload	tonnes	55	
Road train - average weight	tonnes	59	Weighted average to account for the 1 in 9 trucks that return from Ivanhoe with MSP waste after Year 12
Number of trips between mineral concentrate stockpile and Ivanhoe Rail Facility	Number /day	24	
Mean vehicle speed on transport corridor to Ivanhoe Rail Facility	km/h	100	Sensitivity analysis conducted for vehicles travelling at varied speeds
	km/h	80	
	km/h	60	
	km/h	40	
Scraper - payload	tonnes	18	
Scraper - empty weight	tonnes	35.5	
Scraper - full weight	tonnes	54	
Scraper - average weight	tonnes	45	
Number of graders (CAT 16G)	number	2	
Average speed of graders	km/h	10	Caterpillar Performance Handbook, Edition 38 (2008) states that typical grader speed on haul roads is 5-16 km/h
Number of dozers	number	4	
Hours of operation of dozers	hours/day	22	
Number of dozers operating on ore	number	3	
Number of dozers on overburden	number	1	

Parameter	Units	Value	Comments
Number of stackers	number	7	
Meteorological parameters			
Number of days/year with rainfall > 0.25 mm	days/year	46	Taken from data recorded at BOM Euston (Turlee) monitoring station
Percentage of time of wind speeds > 5.4 m/s	%	10.4	Extracted from output of CALMET meteorological modelling
Mean wind speed	m/s	3.2	
Material characteristics			
Moisture content of Ore	%	6.0	
Moisture content of ore - before processing	%	2.0	
Moisture content of overburden	%	2.0	Assumed to be the same as pre-processed ore
Silt content of overburden	%	10.0	Upper bound of values given in email from Tara Smith at Bemax on 11 July
Silt content of Ore before and after processing	%	1.0	Upper bound of values given in email from Tara Smith at Bemax on 11 July
Silt content of unpaved road between active pit and overburden dump	%	4.8	Chapter 13.2 of AP42 documents - mean values for sand and gravel processing industry
Silt content of unpaved mineral concentrate transport route	%	4.8	Assumed to be the same as unpaved road on-site
Moisture content of unpaved mineral concentrate transport route	%	0.2	Default value for publicly accessible unpaved roads (NPI, 1999)

Table notes:
km = kilometres.
m = metres.
ha = hectares.
days/year = days per year.
hours/day = hours per day.
Mt/month = million tonnes per month.
Mtpa = million tonnes per annum.
ktpa = kilotonnes per annum.
tpa = tonnes per annum.
number/day = number per day.
m/s = metres per second.
MSP = Broken Hill Mineral Separation Plant.

Table C5 Activity data and assumptions used in emissions estimation for operations at the Ivanhoe Rail Facility

Parameter	Units	Value	Comments
Haul road lengths - one way			
Length of unsealed haul road up to Ivanhoe Rail Facility gate	km	2.605	
Length of turning circle on paved road	km	0.66	Assume trucks travel around circle once for each load
Stockpile			
Stockpile length	m	50	
Stockpile width	m	20	
Stockpile height	m	1.5	
Stockpile surface area (per stockpile)	m^2	1,041	
Number of stockpiles	Number	3	

Parameter	Units	Value	Comments
Hours of Operation			
Hours of operation (all activities)	days/year	24	
	hours/day	365	
Material throughput			
Mineral Concentrate throughput	ktpa	450	
Vehicles and equipment			
Road train payload	tonne	55	Based on specifications for Kenworth T650
Road train empty weight	tonne	28	
Road train full weight	tonne	83	
Meteorological parameters			
Number of days/year with rainfall > 0.25 mm	days/year	46	Taken from data recorded at BOM Euston (Turlee) monitoring station
Percentage of time of wind speeds > 5.4 m/s	%	8.7	Extracted from output of TAPM meteorological modelling
Mean wind speed	m/s	3.1	
Material characteristics			
Moisture content of stockpiled mineral concentrate	%	6.0	
Silt content of unpaved road	%	4.8	Chapter 13.2 of AP42 documents - mean values for sand and gravel processing industry
Silt content of mineral concentrate	%	1	Upper bound of values given in email from Tara Smith at Bemax on 11 July
Silt loading of unsealed pad at Ivanhoe Rail Facility	g/m²	12	Chapter 13.2 of AP42 documents – mean value for concrete batching

Table notes:
m^2 = square metres.
g/m^2 = grams per square metre.

C1.3 Emission factors

Emission factors were calculated using the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b), and the AP24 documents. Tables C6, C7 and C 8 list the emission factors used to estimate dust emissions from the Atlas-Campaspe Mine and Ivanhoe Rail Facility operations. Details of the calculations of each emission factor are provided following the table.

Table C6 Summary of emission factors used for emissions estimation of activities at the Atlas-Campaspe Mine

Activity	Units	TSP	PM_{10}	$PM_{2.5}$
Topsoil removal	kg/tonne	0.029	0.0073	0.0030
Wheel generated dust from scraper in travel mode	kg/VKT	0.84	0.12	0.09
Dumping of topsoil onto stockpiles	kg/tonne	0.012	0.004	0.0009
Front end loader on pre-processed ore	kg/tonne	0.0019	0.0009	0.0001
Front end loader on post-processed ore	kg/tonne	0.0004	0.0002	0.00003
Bull dozer on ore in active pit	kg/h/vehicle	1.06	0.13	0.11
Bull dozer on overburden	kg/h/vehicle	16.7	4.1	1.8
Truck and shovel on overburden	kg/tonne	0.0019	0.0009	0.0001
Dumping of overburden by truck	kg/tonne	0.012	0.0043	0.0009
Grading	kg/VKT	1.08	0.34	0.03
Wind erosion of ore and exposed areas	mg/ha/yr	0.74	0.37	0.06
Wheel generated dust form haul trucks on unpaved road (haul truck - CAT 777D)	g/VKT	3969	1011	101
Wheel generated dust from haul trucks on unpaved road (road train)	g/VKT	2894	738	74
Screening of ore	kg/tonne	0.013	0.004	0.0003
Stacking of mineral concentrate	kg/tonne	0.0004	0.0002	0.00003

Table notes:
kg/tonne = kilograms per tonne.
kg/h/vehicle = kilograms per hour per vehicle.
g/VKT = grams per vehicle kilometre travelled.
mg/ha/yr = milligrams per hectare per year.
kg/VKT = kilograms per vehicle kilometre travelled.

Table C7 Summary of emission factors used for emissions estimation of the transport of mineral concentrate via the mineral concentrate transport route

Activity	Units	TSP	PM_{10}	$PM_{2.5}$
Haulage on unsealed road[1]: vehicle speed 100 km/h	g/VKT	1108	351	35
Haulage on unsealed road[1]: vehicle speed 80 km/h	g/VKT	1036	314	31
Haulage on unsealed road[1]: vehicle speed 60 km/h	g/VKT	951	272	27
Haulage on unsealed road[1]: vehicle speed 40 km/h	g/VKT	842	222	22

Table note:
1 Emission factor for vehicles traveling on publicly accessible roads, dominated by light duty vehicles (US EPA, 2006b: equation 1b).

Table C8 Summary of emission factors used for emissions estimation of activities at the Ivanhoe Rail Facility

Activity	Units	TSP	PM_{10}	$PM_{2.5}$
Wheel generated dust from paved truck loop on-site	g/VKT	2059	395	96
Wheel generated dust from unpaved road	g/VKT	2825	720	72
Dumping of mineral concentrate from road train onto stockpile	kg/t	0.0004	0.0002	0.00003
Front end loader transfer from stockpile to container	kg/t	0.0004	0.0002	0.00003
Wind erosion of mineral concentrate stockpiles	mg/ha/yr	0.74	0.37	0.06
Front end loader stockpile management	kg/t	0.0004	0.0002	0.0000
Table note: kg/t = kilograms per tonne.				

C1.3.1 Topsoil Scraping

The emission factors for topsoil removal via scraper were calculated from the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b) and the AP42 documents, chapter 11.9 "Western Surface Coal Mining" (October 1998).

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Topsoil	kg/t	0.029	0.0073	TSP * 0.105 (assumed the $PM_{2.5}$ fraction of TSP for bulldozing overburden from the AP42 chapter 11.9)

C1.3.2 Scraper in Travel Mode

The emission factors for topsoil removal via scraper were calculated from the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b) and the AP42 documents, chapter 11.9 "Western Surface Coal Mining" (October 1998).

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Unpaved road	kg/t	$9.6E10^{-6} \times s^{1.3} \times W^{2.4}$	$1.32E10^{-6} \times s^{1.3} \times W^{2.4}$	TSP x 0.105 (assumed the $PM_{2.5}$ fraction of TSP for bulldozing overburden from the AP42 chapter 11.9)

Where s = silt content of unpaved road (%).
W = vehicle gross mass in tonnes.

C1.3.3 Transfers

The AP42 documents, Chapter 13.2.4 "Aggregate Handling and Storage Piles" (US EPA, 2006a) provides the following equation to calculate the emission factor for miscellaneous transfers.

$$E = k0.0016\left(\frac{U}{2.2}\right)^{1.3}\left(\frac{M}{2}\right)^{-1.4} kg/t$$

Where k = 0.74 for particles less than 30 micrometres (µm).
k = 0.35 for particles less than 10 µm.
k = 0.053 for particles less than 10 µm.
U = mean wind speed in m/s.
M = material moisture content.

The transfer emission factor was equation was used to calculate emissions due t o the following activities:

- Front end loaders on ore
- Truck and shovels on overburden
- Stacking of mineral concentrate.

C1.3.4 Bulldozing

The emission factors for bulldozing were calculated from the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b) and the AP42 documents, chapter 11.9 "Western Surface Coal Mining" (October 1998).

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Overburden/ore	kg/h/vehicle	$\frac{2.6(s)^{1.2}}{(M)^{1.3}}$	$\frac{0.34(s)^{1.5}}{(M)^{1.4}}$	TSP x 0.105 ($PM_{2.5}$ fraction of TSP for bulldozing overburden from the AP42 chapter 11.9)

Where s = material silt content (%).
M = material moisture content (%).

C1.3.5 Truck dumping

The emission factors for truck dumping of overburden were calculated from the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b) and t he AP42 documents, chapter 11.9 "Western Surface Coal Mining" (October 1998).

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Overburden	kg/t	0.012	0.0043	TSP x $\frac{0.053}{0.74}$ (ratio of $PM_{2.5}$ and TSP particle size fractions for transfers from the AP42 documents, Chapter 13.2.4)

C1.3.6 Grading

The emission factors for grading were calculated from the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b) and the AP42 documents, chapter 11.9 "Western Surface Coal Mining" (October 1998).

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Overburden	kg/VKT	$0.0034\ (S)^{2.5}$	$0.0034\ (S)^{2}$	TSP x 0.031 ($PM_{2.5}$ fraction of TSP for grading from the AP42 documents, Chapter 11.9)

Where S = mean vehicle speed (km/h).

C1.3.7 Wind erosion

The emission factors for ore and exposed areas were calculated from AP42 documents, chapter 11.9 "Western Surface Coal Mining" (October 1998) and the NPI Emission Estimation Technique Manual for Mining Version 3.1 (2012b). An additional factor has also been incorporated to account for the natural control due to rainfall.

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Ore, overburden, exposed area	t/ha/yr	$0.85 \times \frac{365 - p}{365}$	TSP x 0.5 (assumed from the NPI mining version 2.3 where a 50 % ratio of TSP to PM_{10} was found.	TSP x 0.075 (assumed from the AP42 documents, chapter 13.2.5 "Industrial wind erosion").

Where p = the number of days per year with more than 0.25 millimetres of rainfall.

C1.3.8 Haulage on unpaved Roads

The emission factors for unpaved roads on-site were calculated from the AP42 documents, chapter 13.2.2 titled "unpaved roads" (US EPA, 2006b), Equation 1a.

The equation used in the assessment is as follows:

$$E = 289.1 \times k\ (s/12)^{a}\ (W/3)^{b}$$

Where s = surface material silt content (%).
W = mean vehicle weight (tons).

The factor 289.1 converts the emission factor from lb/VMT to g/VKT, and the following constants were assumed.

Constant	TSP (assumed from PM_{30})	PM_{10}	$PM_{2.5}$
k (lb/VMT)	4.9	1.5	0.15
a	0.7	0.9	0.9
b	0.45	0.45	0.45

The emission factors for the unpaved mineral concentrate transport route were calculated from the AP42 documents, chapter 13.2.2 titled “unpaved roads” (US EPA, 2006b), Equation 1b.

The equation used in the assessment is as follows:

$$E = 281.9 \times \frac{\left(k\ (s/12)^{a}(S/30)^{d}\right)}{(M/0.5)^{c}} - C$$

Where s = surface material silt content (%).
S = mean vehicle speed (mps).
M = surface material moisture content (%).
C = emission factor for 1980’s vehicle fleet exhaust, break wear and tyre wear (set as 0 in this assessment).

The factor 281.9 converts the emission factor from lb/VMT to g/VKT, and the following constants were assumed.

Constant	**TSP (assumed from PM_{30})**	**PM_{10}**	**$PM_{2.5}$**
k (lb/VMT)	6.0	1.8	0.18
A	1	1	1
C	0.3	0.2	0.2
D	0.3	0.5	0.5

C1.3.9 Haulage on paved Roads

The emission factors for paved roads at the Ivanhoe Rail Facility were calculated from the AP42 documents, chapter 13.2.1 titled “paved roads” (US EPA, 2006c), Equation 1.

The equation used in the assessment is as follows:

$$E = k\ (sL)^{0.91}(W)^{1.02}$$

Where *k* = particle size multiplier.
sL = road surface silt loading (g/m^2).
W = mean vehicle weight (tons).

The following constants were assumed.

Constant	**TSP (assumed from PM_{30})**	**PM_{10}**	**$PM_{2.5}$**
k (g/VKT)	3.23	0.62	0.15

C1.3.10 Screening

Emission factors for crushing of coal at the processing plant were calculated using the AP42 documents, chapter 11.19.2 "Crushed Stone Processing and Pulverized Mineral processing” (US EPA, 2004).

Material	Units	TSP	PM_{10}	$PM_{2.5}$
Ore	kg/t	0.0013	0.0043	TSP x 0.000025 / 0.00037 (using the ratio of controlled screening $PM_{2.5}$ and TSP emission factors as a scaling factor)

C2 Emissions from on-site diesel generators

Emissions and stack characterstics for the four 1,000 kilovolt ampere kVa) diesel generators located at the Atlas-Campaspe Mine have been based on specifications and stack testing data for Cummings QST30-G4 1,000 kVa generators (prime operation). Stack heights and diameter have been assumed based on typical values and exit velocities.

Stack characteristics and emissions information for the on-site diesel generators used in the dispersion modelling are provided in Table C9.

Table C9 Stack characteristics and emission information for the four diesel generators used in the air dispersion modelling

Parameter	Unit	Value
Number of generators	Number	4
Stack height	m	6
Stack diameter	m	0.34
Exit velocity	m/s	30.3
Temperature	°C	566
Actual flow rate	m^3/s	2.75
Maximum NO_X concentration[1]	g/HP-Hour	6.6
Maximum CO concentration	g/HP-Hour	1.2
Maximum SO_2 concentration	g/HP-Hour	0.13
Maximum PM concentration	g/HP-Hour	0.11
Prime power rating	kW	880
Hours of operation	Hours/day	24
Maximum emission rates calculated per generator		
NO_X	g/s	2.163
CO	g/s	0.393
PM_{10}	g/s	0.036
$PM_{2.5}$	g/s	0.036
SO_2	g/s	0.043
Hydrocarbons (total)	g/s	0.115

Table note:

[1] Concentrations taken from stack test results published by Cummins.

°C = degrees Celsius

kW = kilowatt

m^3/s = cubic metres per second

hours/day = hours per day

g/HP-Hour = grams per horsepower hour

m/s = metres per second

Attachment D

Full results: Assessment of Mineral Concentrate Transport Route

Contents

Tables

The predicted maximum 1-hour average ground-level PM_{10} concentration at various distances up to 1,500 metres (m) from the haul road due to vehicle activity on the mineral concentrate transport route are presented in Tables D1, D2, D3 and D4 for the assessment of particulate emissions during vehicles travelling at 100 kilometres per hour (km/h), 80 km/h, 60 km/h and 40 km/h, respectively. Ground-level concentrations of pollutants were predicted at a network receptors set at the defined distances at either side of the road. Results presented are the maximum predicted ground-level concentrations at the receptors. Results have been provided for the worst-case scenario, identified as the haul road sections with a north-south alignment, as well as for the assessment of emissions from the haul road sections with an east-west and northeast-southwest alignment.

The results have been provided for the Project in isolation only. No background concentrations have been included.

Table D1 Results of assessment of PM_{10} emissions from vehicle activity on the mineral concentrate transport route to Ivanhoe Rail Facility, with vehicles travelling at 100 km/h

Distance from mineral concentrate transport route (m)	Assessment of various haul road-alignments					
	Haul road east-west alignment		Haul road north-south alignment		Haul road northeast-southwest alignment	
	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route
25	35.6	1.00	40.4	1.00	31.4	1.00
50	17.4	0.49	38.4	0.95	32.8	1.04
75	6.9	0.19	35.3	0.87	33.5	1.07
100	3.1	0.09	32.0	0.79	33.8	1.08
250	0.2	0.00	11.8	0.29	28.0	0.89
500	0.0	0.00	2.3	0.06	9.0	0.28
1,000	0.0	0.00	0.9	0.02	1.5	0.05
1,500	0.0	0.00	0.3	0.01	0.6	0.02

Table note:
µg/m³ = micrograms per cubic metre

Table D2 Results of assessment of PM_{10} emissions from vehicle activity on the mineral concentrate transport route to Ivanhoe Rail Facility, with vehicles travelling at 80 km/h

Distance from mineral concentrate transport route (m)	Assessment of various haul road-alignments					
	Haul road east-west alignment		Haul road north-south alignment		Haul road northeast-southwest alignment	
	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route
25	31.9	1.00	36.1	1.00	28.1	1.00
50	15.6	0.49	34.3	0.95	29.4	1.04
75	6.2	0.19	31.6	0.87	30.0	1.07
100	2.8	0.09	28.6	0.79	30.3	1.08
250	0.1	0.00	10.5	0.29	25.1	0.89
500	0.0	0.00	2.1	0.06	8.0	0.28
1,000	0.0	0.00	0.8	0.02	1.4	0.05
1,500	0.0	0.00	0.3	0.01	0.5	0.02

Table D3 Results of assessment of PM_{10} emissions from vehicle activity on the mineral concentrate transport route to Ivanhoe Rail Facility, with vehicles travelling at 60 km/h

Distance from mineral concentrate transport route (m)	Assessment of various haul road-alignments					
	Haul road east-west alignment		Haul road north-south alignment		Haul road northeast-southwest alignment	
	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route
25	27.6	1.00	31.3	1.00	24.3	1.00
50	13.5	0.49	29.7	0.95	25.4	1.04
75	5.3	0.19	27.3	0.87	25.9	1.07
100	2.4	0.09	24.8	0.79	26.2	1.08
250	0.1	0.00	9.1	0.29	21.7	0.89
500	0.0	0.00	1.8	0.06	6.9	0.28
1,000	0.0	0.00	0.7	0.02	1.2	0.05
1,500	0.0	0.00	0.2	0.01	0.5	0.02

Table D4 Results of assessment of PM_{10} emissions from vehicle activity on the mineral concentrate transport route to Ivanhoe Rail Facility, with vehicles travelling at 40 km/h

Distance from mineral concentrate transport route (m)	Assessment of various haul road-alignments					
	Haul road east-west alignment		Haul road north-south alignment		Haul road northeast-southwest alignment	
	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route	Max 1-hour PM_{10} concentration (µg/m³)	Proportion of concentration at 25 m from mineral concentrate transport route
25	22.5	1.00	25.6	1.00	19.9	1.00
50	11.0	0.49	24.3	0.95	20.8	1.04
75	4.4	0.19	22.3	0.87	21.2	1.07
100	1.9	0.09	20.3	0.79	21.4	1.08
250	0.1	0.00	7.4	0.29	17.7	0.89
500	0.0	0.00	1.5	0.06	5.7	0.28
1,000	0.0	0.00	0.6	0.02	1.0	0.05
1,500	0.0	0.00	0.2	0.01	0.4	0.02

Attachment E

Greenhouse gas assessment

Contents

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Figures

Glossary

Term	Definition
Units of measurement	
GJ	Gigajoule
kg	Kilogram
kL	Kilolitre
Mt	Million tonnes
PJ	Petajoule
t	Tonne
t CO_2-e	Tonnes of CO_2 equivalent
Air pollutants and chemical nomenclature	
CH_4	Methane
CO_2	Carbon dioxide
N_2O	Nitrous oxide
Other abbreviations	
CPM	Carbon Pricing Mechanism
DCCEE	Commonwealth Department of Climate Change and Energy Efficiency
EEO	Energy Efficiency Opportunities
LULUCF	Land Use, Land Use Change and Forestry
NGA	National Greenhouse Accounts
NGER	National Greenhouse and Energy Reporting Act 2007
UNFCCC	United Nations Framework Convention on Climate Change
MSP	Mineral Separation Plant

E1 Introduction

Katestone Environmental Pty Ltd was commissioned to conduct a greenhouse gas assessment for inclusion in the Atlas-Campaspe Mineral Sands Project (the Project) Environmental Impact Statement.

This report has been prepared to address the Director-General's Requirements for the Project relating to greenhouse gases, including:

- A quantitative assessment of potential Scope 1, 2 and 3 greenhouse gas emissions
- A qualitative assessment of the potential impacts of these emissions on the environment and
- An assessment of reasonable and feasible measures to minimise greenhouse gas emissions and ensure energy efficiency.

The greenhouse gas assessment has assessed the potential impacts of the Project on the state and national greenhouse gas inventories and the proposed best practice greenhouse gas abatement measures.

E2 Greenhouse gas assessment

E2.1 Background

This greenhouse gas assessment considers the potential impact of the Project on the global climate system by changes that it may cause to net greenhouse gas emissions. Climate change is an environmental concern at a global level. Any source or sink of greenhouse gases has a nominally equivalent effect no matter where it occurs in the world. While few if any individual projects would make a noticeable change to the Earth's climate, the summation of human activities that are increasing the concentrations of greenhouse gases in the upper atmosphere does. Governments and the global scientific community have established conventions for accounting for greenhouse gas emissions to enable pollution control among all global jurisdictions. This assessment employs these established conventions so that the relative impact of the Project can be properly understood.

The term greenhouse gases comes from the 'greenhouse effect', which refers to the process whereby greenhouse gases in the atmosphere absorb the radiation released by the Earth's surface and then radiate some heat back towards the ground, increasing the surface temperature (Raupach and Fraser, 2011). Human activity, especially burning fossil fuels, is increasing the concentration of greenhouse gases and hence increasing the absorption of outgoing heat energy. Even a small increase in long-term average surface temperatures has numerous direct and indirect consequences for climate.

The main greenhouse gases influenced directly by human activities and included in carbon accounting are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and synthetic gases, such as sulphur hexafluoride (SF_6) perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs) (Raupach and Fraser 2011; pp. 15-20). These gases vary in effect and longevity in the atmosphere, but scientists have developed a system called Global Warming Potential to allow them to be described in equivalent terms to CO_2 (the most prevalent greenhouse gas) called equivalent carbon dioxide emissions (CO_2-e). A unit of one tonne of CO_2-e (t CO_2-e) is the basic unit used in carbon accounting. An emissions inventory, or 'carbon footprint', is calculated as the sum of the emission rate of each greenhouse gas multiplied by the global warming potential. For example:

$$\text{tonnes } CO_2\text{-e} = \text{tonnes } CO_2 \times 1.0 + \text{tonnes } CH_4 \times 21 + \text{tonnes } N_2O \times 310$$

CO_2 and CH_4 are part of the carbon cycle, which refers to the natural movement of carbon among the ocean, plants, soil and the atmosphere. Fossil fuels such as coal, oil and natural gas are the product of ancient deposits of organic matter. When combusted, their stored carbon is released again to the atmosphere at an extremely rapid rate in comparison to the rate at which it became stored.

Burning fossil fuels always causes greenhouse gas emissions and energy from fossil fuels underpins the global economy and the human development gained from it. Consequently, changing this pattern to reduce emissions and protect climate is extremely difficult. The need for a global solution to this problem has led to the United Nations Framework Convention on Climate Change (UNFCCC), the associated Kyoto Protocol and the world scientific body, the Intergovernmental Panel on Climate Change (IPCC). In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below two degrees Celsius (UNFCCC, 2011). Australia is an active participant in these global arrangements and this has a strong effect on domestic economic and environmental policy.

E2.2 Emission scopes

The process for accounting for greenhouse gas emissions involves dividing emissions among three 'scopes' to assign responsibility for emissions and manage potential double-counting. The Australian Government Clean Energy Regulator defines two emission categories for calculating greenhouse gas emissions in legislation. These are as follows:

- Direct emissions, including:
    - Scope 1 emissions:
        - In relation to a facility, means the release of greenhouse gas into the atmosphere as a direct result of an activity or series of activities (including ancillary activities) that constitute the facility.

- Indirect emissions, including:
    - Scope 2 emissions:
        - In relation to a facility, means the release of greenhouse gas into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam that is consumed by a facility but that do not form part of the facility.

A third emission category is defined under the Greenhouse Gas Protocol (World Business Council on Sustainable Development, 2009) for calculating greenhouse gas emissions that are a consequence of the activities of a facility but occur from sources owned or controlled by another organisation. This category is termed Scope 3 emissions and covers sources such as:

- Employee business travel
- Transportation of products, materials and waste
- Outsourced activities, contract manufacturing and franchises
- Emissions from waste generated by the reporting facility when the point of greenhouse gas emissions occurs at sources or sites that are owned or controlled by another company
- Emissions from the use and end-of-life phases of products and services produced by the reporting facility
- Employees commuting to and from work
- Production of imported materials.

E2.3 Australian policy and regulation

E2.3.1 Australian international commitments

The following discussion of Australia's global commitments to respond to climate change is derived from information published by the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) on its website (DCCEE, 2012c).

The UNFCCC provides the basis for global action 'to protect the climate system for present and future generations'. Australia ratified the Convention in 1992. The Convention entered into force in 1994 after a requisite 50 countries had ratified it. There are now 193 Parties to the UNFCCC - almost all of the members of the United Nations.

Parties to the Convention have agreed to work towards stabilising 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.

Under the convention, Australia is committed to:

- Submitting a national inventory of emissions and removals of greenhouse gases
- Implementing national programs to mitigate climate change and adapt to its impacts
- Conducting research related to the climate system and promoting relevant technologies
- Raising public awareness about climate change
- Submitting comprehensive National Communications (i.e. reports).

The Kyoto Protocol is an international agreement created under the UNFCCC in Kyoto, Japan in 1997. Australia's ratification of the protocol came into effect on 11 March 2008. The protocol aims to reduce the collective greenhouse gas emissions of developed country parties by at least five per cent below 1990 levels during 2008 to 2012 – referred to as the first commitment period. Australia has a target for emissions of 108 percent (%) of estimated emissions for 1990 or 591.5 million tonnes of carbon dioxide equivalent (Mt CO_2-e).

At the United Nations climate change negotiations in Durban, South Africa in 2011, Parties to the Kyoto Protocol decided to establish a second commitment period from 1 January 2013. There will be further negotiations in 2012 to finalise the emission reductions targets to be taken by countries who participate in the second commitment period. The 18th Conference of the Parties of the UNFCCC is set for Doha, Qatar from 26 November to 7 December 2012.

The Australian Government has a constitutional power to ensure that Australia meets its international commitments, including those made under the UNFCCC. There are several related national policies, statutes and regulations that may be important to the development and operation of the Project, including:

- The *National Greenhouse and Energy Reporting Act 2007* (NGER Act) and regulations
- The *Clean Energy Act 2011*
- The *Energy Efficiency Opportunities Act 2006.*

This legislation is enforced by Australian Government agencies and penalties apply for non-compliance.

E2.3.2 National greenhouse and energy reporting

The NGER Act established a national framework for corporations to report greenhouse gas emissions and energy consumption. Registration and reporting is mandatory for corporations that have energy production, energy use or greenhouse gas emissions that exceed specified thresholds. The current National Greenhouse and Energy Reporting (NGER) thresholds for facilities and operations are:

- Total greenhouse gas emissions: 25,000 t CO_2-e per year
- Energy produced: 100,000 gigajoules (GJ) per year
- Energy consumed: 100,000 GJ per year.

In relation to a facility, 'energy produced' means:

- *the extraction or capture of energy from natural sources for final consumption by or from the operation of the facility or for use other than in the operation of the facility, or*
- *the manufacture of energy by the conversion of energy from one form to another form for final consumption by or from the operation of the facility or for use other than in the operation of the facility.*

The NGER Act is administered by the Clean Energy Regulator and the scheme also provides the basis for the *Clean Energy Act 2011* and associated Carbon Pricing Mechanism (CPM).

The Project would exceed the thresholds for energy consumed, energy produced and greenhouse gas emissions for NGER reporting. The diesel used to fuel heavy vehicles alone is equivalent to an energy consumption of 585,253 GJ, which exceeds the reporting threshold of 100,000 GJ.

As the Project exceeds the NGER thresholds, Cristal Mining Australia Limited (Cristal Mining) would be required to report.

E2.3.3 Clean Energy Act (Carbon Pricing Mechanism)

The *Clean Energy Act 2011* has established a carbon emissions trading system for Australia including a fixed price period, a 'collar' period (with ceiling and floor prices) and full emissions trading from 1 July 2015, where the market will determine prices (with some restrictions). The floor price component was later removed when Australia reached an agreement with the European Union (EU) over use of EU emission credits for the CPM.

The CPM is on a facility basis only, with the potential liability to Cristal Mining of the Project determined distinct from all other operations.

In the case of the Atlas-Campaspe Mineral Sands Project - using the language of the legislation – Cristal Mining will not become a 'liable entity' under section 20 of the Act because although it will have 'operational control' of a 'facility', the 'covered emissions' (s. 30) will be below the threshold of 25,000 t CO_2-e.

Covered emissions are essentially those that the facility directly emits (Scope 1), with liquid transport fuels (e.g. diesel) excluded. Similarly, the use of transport fuels for other purposes including the running of diesel generators on the Atlas-Campaspe Mine are excluded. Diesel is typically taxed separately by adjustments to the applicable excise (fuel tax credit scheme).

The total Scope 1 emissions for the Project associated with the on-site combustion of diesel fuel in heavy vehicles and on-site diesel generators are approximately 577,746 t CO_2-e. Provided the applicable excise is paid on the fuel used, these emissions will not count towards the threshold.

E2.3.4 Energy Efficiency Opportunities

The Energy Efficiency Opportunities (EEO) program encourages large energy-using businesses to improve their energy efficiency. It does this by requiring businesses to identify, evaluate and report publicly on cost effective energy savings opportunities (Commonwealth Department of Resources, Energy and Tourism, 2011). Participation in EEO is mandatory for corporations that use more than 0.5 petajoules (PJ) of energy per year.

The controlling corporation of a facility is required to participate in EEO. As Cristal Mining is 100% owned and controlled by Cristal Australia Pty Ltd, Cristal Mining is required to participate in EEO reporting for the facility. As part of its annual EEO reporting, Cristal Mining will be required to include energy use from the Project, including an evaluation of cost effective energy savings opportunities.

E2.3.5 Reporting tools

The DCCEE monitors and compiles databases on anthropogenic activities that produce greenhouse gases in Australia. The DCCEE has published greenhouse gas emission factors for a range of anthropogenic activities. The DCCEE methodology for calculating greenhouse gas emissions is published in the National Greenhouse Accounts (NGA) Factors workbook (DCCEE, 2010, 2011a and 2012a) and is based on Australian data. This workbook is updated regularly to reflect current compositions in fuel mixes and evolving information on emission sources.

E3 Sources of Greenhouse Gas Emissions

E3.1 Construction

The construction phase will include the construction of the mining infrastructure at the Atlas-Campaspe Mine and at the Ivanhoe Rail Facility. Processing of the mineral concentrate from the mine will occur at the existing infrastructure at the Broken Hill Mineral Separation Plant (MSP), with no significant construction work required at the MSP.

Construction phase activities at the Atlas-Campaspe Mine and Ivanhoe Rail Facility include the following:

- Site clearance of areas for construction activities, including vegetation clearance, topsoil removal and storage, and earthworks
- Civil works including temporary and permanent drainage works
- Structure and plant erection and installation
- Commissioning and testing of plant and equipment
- Construction site demobilisation.

These activities will emit greenhouse gas emissions through the consumption of diesel fuel to power construction vehicles and equipment. The emissions associated with the construction phase have been quantified using details of the quantity of diesel fuel.

E3.2 Operations

Cristal Mining has provided details of annual diesel fuel consumption at the Atlas-Campaspe Mine and Ivanhoe Rail Facility, and annual diesel fuel, gas fuel and electricity consumption at the MSP for each year of the operational Project life. The data are summarised in Table E1.

Electricity for the Atlas-Campaspe Mine will be supplied by the on-site diesel generators. Electricity at the Ivanhoe Rail Facility and MSP is purchased from the New South Wales grid. Diesel fuel at the Atlas-Campaspe Mine is used for both heavy vehicles and the operation of the generators. Diesel fuel at the MSP is used for heavy vehicles only. Liquefied Petroleum Gas (LPG) is used at the MSP for the mineral dryers and ilmenite kiln circuits. No explosives will be used at the Project site. Diesel fuel is also used for transport of mineral concentrate between the Ivanhoe Rail Facility and MSP, and from the MSP to Port Pirie.

Greenhouse gas emissions have been calculated for the following activities associated with the Atlas-Campaspe Mineral Sands Project:

- Scope 1 greenhouse gas emissions
  - Consumption of diesel fuel in heavy vehicles at the Atlas-Campaspe Mine and Ivanhoe Rail Facility
  - Consumption of diesel fuel in on-site diesel generators at the Atlas-Campaspe Mine.

- Scope 2 greenhouse gas emissions
  - Consumption of electricity at the Ivanhoe Rail Facility.

- Selected Scope 3 greenhouse gas emissions
  - Extraction, production and transport of diesel fuel consumed at the Atlas-Campaspe Mine and Ivanhoe Rail Facility
  - Consumption of electricity at MSP
  - Consumption of diesel fuel at MSP
  - Consumption of gas at MSP
  - Consumption of diesel during transport between the Ivanhoe Rail Facility and MSP, and between MSP and Port Pirie
  - Extraction, production and transport of electricity consumed at MSP
  - Extraction, production and transport of diesel fuel consumed at MSP
  - Extraction, production and transport of gas consumed at MSP
  - Extraction, production and transport of diesel fuel consumed during transport between the Ivanhoe Rail Facility and MSP, and between MSP and Port Pirie.

Table E1 Summary of fuel and electricity consumption for the life of the Project

Year		Atlas-Campaspe Mine and Ivanhoe Rail Facility		Ivanhoe Rail Facility	Broken Hill Mineral Separation Plant			
		Diesel fuel heavy vehicles (kL)	Diesel fuel generators (kL)	Electricity consumption (kWh)	Diesel fuel heavy vehicles (kL)	LPG fuel (kL)	Electricity consumption (kWh)	Diesel fuel for transport of mineral concentrates between Ivanhoe Rail Facility and MSP, and from MSP to Port Pirie (kL)
2013	1 (Construction)	403	1,888	0	0	0	0	0
2014	2	2,159	626	1,314	28	297	556,128	1,083
2015	3	10,309	1,497	3,141	85	886	1,660,660	3,234
2016	4	8,411	1,457	3,056	125	1,311	2,456,232	4,829
2017	5	15,162	1,425	2,988	177	1,855	3,475,800	6,889
2018	6	5,100	1,434	3,008	177	1,855	3,475,800	6,931
2019	7	8,971	1,426	2,992	177	1,855	3,475,800	6,931
2020	8	9,448	1,433	3,007	177	1,855	3,475,800	6,934
2021	9	8,489	1,456	3,054	177	1,855	3,475,800	6,939
2022	10	9,762	1,463	3,069	97	1,014	1,900,104	3,775
2023	11	12,209	1,546	3,244	110	1,150	2,154,996	4,280
2024	12	8,768	1,489	3,124	97	1,018	1,907,828	3,789
2025	13	9,717	1,498	3,142	105	1,105	2,070,032	4,111
2026	14	11,004	1,483	3,111	108	1,134	2,124,100	4,219
2027	15	12,690	1,509	3,165	124	1,295	2,425,336	4,817
2028	16	12,091	1,410	2,957	126	1,319	2,471,680	4,909
2029	17	12,656	1,518	3,185	136	1,422	2,664,780	5,292
2030	18	12,504	1,499	3,145	171	1,789	3,352,216	6,658
2031	19	12,018	1,444	3,028	171	1,789	3,352,216	6,658
2032	20	4,387	529	1,111	72	759	1,421,216	2,822

Table notes: kL = kilolitres kWh = kilowatt hours HMC = heavy mineral concentrate

E4 Method used to estimate greenhouse gas emissions

DCCEE has published greenhouse gas emission factors for a range of anthropogenic activities. The DCCEE methodology for calculating greenhouse gas emissions is published in the NGA Factors workbook (DCCEE, 2010, 2011a and 2012a) and is based on Australian data. This workbook is updated regularly to reflect current compositions in fuel mixes and evolving information on emission sources.

The greenhouse gas intensity of each activity has been calculated using the simplified equation as follows:

$$GHG = E \text{ x } EF$$

Where:

GHG: Annual greenhouse gas emissions in t CO_2-e

E: Annual fuel input energy (gigajoules per year [GJ/yr])

EF: Emission factors for CO_2, CH_4 and N_2O (kilograms per carbon dioxide equivalent per gigajoule [kg CO_2-e /GJ])

The total annual CO_2-e emissions are the sum of the CO_2-e emissions for each of the three greenhouse gases, CO_2, CH_4 and N_2O. The emission factors that have been used to calculate greenhouse gas emissions are presented in Table E2 to Table E6.

Table E2 Fuel combustion emission factors for liquid fuels and certain petroleum based products for stationary sources (Table 3, NGA factors; DCCEE 2012a)

Fuel combusted	Energy content GJ/kL	Emission factor kg CO_2-e/GJ		
		CO_2	CH_4	N_2O
Diesel oil	38.6	69.2	0.10	0.20
Liquefied Petroleum Gas (LPG)	25.7	59.6	0.10	0.20

Table note:
GJ/kL = gigajoules per kilolitre

Table E3 Fuel combustion factors for fuels used for transport energy purposes (Table 4, NGA factors; DCCEE 2012a)

Fuel combusted	Energy content GJ/kL	Emission factor kg CO_2-e/GJ		
		CO_2	CH_4	N_2O
Diesel oil for heavy vehicles	38.6	69.2	0.20	0.50

Table E4 Indirect emission factors for consumption of purchased electricity from the grid (Table 5, NGA factors; DCCEE 2012a)

State, Territory or grid description	Scope 2 emission factor kg CO_2-e/kWh
New South Wales	0.88

Table E5 Indirect emission factors for the combustion of liquid fuels and certain petroleum based products (Table 39, NGA factors; DCCEE 2012a)

Liquid fuels combusted	Scope 3 emission factor kg CO_2-e/GJ
Diesel oil	5.3
LPG	5.0

Table E6 Indirect emission factors for the consumption of purchased electricity by end users (Table 40, NGA factors; DCCEE 2012a)

State, Territory or grid description	Scope 3 emission factor kg CO_2-e/kWh
New South Wales	0.18

Table note:
kg CO_2-e/kWh = kilogram carbon dioxide equivalent per kilowatt hour

E5 Greenhouse gas inventory

E5.1 Project greenhouse gas inventory

The greenhouse gas emissions estimated for each year of operation of the mine are presented in Table E7 (Scope 1 emissions), Table E811 (Scope 2 emissions), Table E9 (Scope 3 emissions) and Table E10 (total Scope 1, 2 and 3 emissions).

Figure E1 shows the projected annual greenhouse gas emissions for the lifetime of the Project for each of the Scope 1, Scope 2 and Scope 3 emissions provided in Table E7, Table E8 and Table E9.

It can be seen from Figure E1 that the Scope 1 emissions from the consumption of diesel fuel in heavy vehicles at the Atlas-Campaspe Mine and Ivanhoe Rail Facility are expected to have the greatest contribution to the total greenhouse gas emissions from the Project. Scope 3 greenhouse gas emissions from the consumption of diesel fuel during transport of heavy mineral concentrate between the Ivanhoe Rail Facility and the MSP, and between the MSP and Port Pirie are the next largest contributor.

The peak annual emission rate of Scope 1 greenhouse gases from the Atlas-Campaspe Mineral Sands Project is 0.045 Mt CO_2-e (in year 2017) or 0.008% of Australia's estimated greenhouse gas emissions for 2012 of 546.8 Mt CO_2-e (DCCEE, 2012c).

The total greenhouse gas emissions reported for New South Wales were 152.5 Mt CO_2-e in the 2009/2010 reporting period (DCCEE, 2012d), excluding emissions and removals from Land Use, Land Use Change and Forestry (LULUCF). With the inclusion of emissions and removals from LULUCF, the total greenhouse gas emissions were 157.4 Mt CO_2-e. The peak annual emission rate of Scope 1 greenhouse gases from the Atlas-Campaspe Mineral Sands Project would contribute approximately 0.03% to this total.

Table E7 Estimated Scope 1 greenhouse gas emissions for the Project (t CO_2-e)

Year		Scope 1 greenhouse gas emissions (t CO_2-e)		Total Scope 1 greenhouse gas emissions (t CO_2-e)
		Atlas-Campaspe Mine and Ivanhoe Rail Facility		
		Consumption of diesel fuel heavy vehicles	Consumption of diesel fuel generators	
2013	1 (Construction)	1,087	5,065	6,152
2014	2	5,825	1,679	7,505
2015	3	27,815	4,016	31,831
2016	4	22,694	3,909	26,603
2017	5	40,909	3,823	44,732
2018	6	13,761	3,847	17,608
2019	7	24,205	3,826	28,031
2020	8	25,492	3,844	29,336
2021	9	22,905	3,906	26,811
2022	10	26,339	3,925	30,264
2023	11	32,942	4,147	37,089
2024	12	23,657	3,995	27,652
2025	13	26,218	4,019	30,237
2026	14	29,690	3,978	33,669
2027	15	34,239	4,048	38,288
2028	16	32,623	3,783	36,406
2029	17	34,148	4,072	38,220
2030	18	33,738	4,021	37,759
2031	19	32,426	3,874	36,300
2032	20	11,837	1,419	13,256

Table E8 Estimated Scope 2 greenhouse gas emissions for the Project (t CO_2-e)

Year		Scope 2 greenhouse gas emissions (t CO_2-e)	Total Scope 2 greenhouse gas emissions (t CO_2-e)
		Ivanhoe Rail Facility	
		Consumption of electricity	
2013	1 (Construction)	0.0	0.0
2014	2	1.2	1.2
2015	3	2.8	2.8
2016	4	2.7	2.7
2017	5	2.6	2.6
2018	6	2.6	2.6
2019	7	2.6	2.6
2020	8	2.6	2.6
2021	9	2.7	2.7
2022	10	2.7	2.7
2023	11	2.9	2.9
2024	12	2.7	2.7
2025	13	2.8	2.8
2026	14	2.7	2.7
2027	15	2.8	2.8
2028	16	2.6	2.6
2029	17	2.8	2.8
2030	18	2.8	2.8
2031	19	2.7	2.7
2032	20	1.0	1.0

Table E9 Estimated Scope 3 greenhouse gas emissions for the Project (t CO_2-e)

Year		Scope 3 greenhouse gas emissions (t CO_2-e)									Total Scope 3 greenhouse gas emissions (t CO_2-e)
		Atlas-Campaspe Mine and Ivanhoe Rail Facility	Broken Hill Mineral Separation Plant						Transport of mineral concentrate between Ivanhoe Rail Facility and MSP, and from MSP to Port Pirie		
		Extraction, production and transport of diesel fuel consumed	Consumption of electricity	Consumption of diesel fuel heavy vehicles	Consumption of gas	Extraction, production and transport of electricity consumed	Extraction, production and transport of diesel fuel consumed	Extraction, production and transport of gas consumed	Consumption of diesel fuel	Extraction, production and transport of diesel fuel consumed	
2013	1 (Construction)	469	0	0	0	0	0	0	0	0	469
2014	2	570	489	76	457	100	6	38	2,923	222	4,880
2015	3	2,415	1,461	229	1,364	299	17	114	8,725	662	15,287
2016	4	2,019	2,161	337	2,018	442	26	168	13,030	988	21,190
2017	5	3,393	3,059	478	2,856	626	36	238	18,587	1,409	30,681
2018	6	1,337	3,059	478	2,856	626	36	238	18,702	1,418	28,748
2019	7	2,127	3,059	478	2,856	626	36	238	18,701	1,418	29,538
2020	8	2,226	3,059	478	2,856	626	36	238	18,708	1,418	29,644
2021	9	2,035	3,059	478	2,856	626	36	238	18,721	1,420	29,468
2022	10	2,296	1,672	262	1,561	342	20	130	10,185	772	17,241
2023	11	2,814	1,896	297	1,770	388	23	148	11,548	876	19,759
2024	12	2,098	1,679	262	1,567	343	20	131	10,223	775	17,099
2025	13	2,294	1,822	283	1,701	373	21	142	11,092	841	18,569
2026	14	2,555	1,869	291	1,746	382	22	146	11,382	863	19,256
2027	15	2,905	2,134	335	1,994	437	25	166	12,997	985	21,978
2028	16	2,762	2,175	340	2,031	445	26	169	13,244	1,004	22,196

Year		Scope 3 greenhouse gas emissions (t CO_2-e)									Total Scope 3 greenhouse gas emissions (t CO_2-e)
		Atlas-Campaspe Mine and Ivanhoe Rail Facility	Broken Hill Mineral Separation Plant						Transport of mineral concentrate between Ivanhoe Rail Facility and MSP, and from MSP to Port Pirie		
		Extraction, production and transport of diesel fuel consumed	Consumption of electricity	Consumption of diesel fuel heavy vehicles	Consumption of gas	Extraction, production and transport of electricity consumed	Extraction, production and transport of diesel fuel consumed	Extraction, production and transport of gas consumed	Consumption of diesel fuel	Extraction, production and transport of diesel fuel consumed	
2029	17	2,900	2,345	367	2,189	480	28	183	14,279	1,083	23,853
2030	18	2,865	2,950	461	2,754	603	35	230	17,963	1,362	29,224
2031	19	2,754	2,950	461	2,754	603	35	230	17,963	1,362	29,113
2032	20	1,006	1,251	194	1,168	256	15	98	7,615	577	12,180

Table E10 A summary of the total greenhouse gas emissions for the Project (t CO_2-e)

Year		Total Scope 1 greenhouse gas emissions (t CO_2-e)	Total Scope 2 greenhouse gas emissions (t CO_2-e)	Total Scope 3 greenhouse gas emissions (t CO_2-e)	Total greenhouse gas emissions (t CO_2-e)
2013	1 (Construction)	6,152	0.0	469	6,621
2014	2	7,505	1.2	4,880	12,386
2015	3	31,831	2.8	15,287	47,121
2016	4	26,603	2.7	21,190	47,795
2017	5	44,732	2.6	30,681	75,416
2018	6	17,608	2.6	28,748	46,359
2019	7	28,031	2.6	29,538	57,571
2020	8	29,336	2.6	29,644	58,983
2021	9	26,811	2.7	29,468	56,281
2022	10	30,264	2.7	17,241	47,507
2023	11	37,089	2.9	19,759	56,851
2024	12	27,652	2.7	17,099	44,753
2025	13	30,237	2.8	18,569	48,809
2026	14	33,669	2.7	19,256	52,928
2027	15	38,288	2.8	21,978	60,268
2028	16	36,406	2.6	22,196	58,604
2029	17	38,220	2.8	23,853	62,076
2030	18	37,759	2.8	29,224	66,985
2031	19	36,300	2.7	29,113	65,415
2032	20	13,256	1.0	12,180	25,436
Maximum		***44,732***	***2.9***	***30,681***	***75,416***
Total		***577,746***	***48.3***	***420,371***	***998,166***

E6 Greenhouse gas minimisation strategies

Cristal Mining is a participant in the EEO program and as part of its annual EEO reporting will include the results of energy efficiency assessments for the Project as well as an evaluation of cost effective energy savings opportunities.

Cristal Mining's participation in the NGER reporting would include the monitoring of all greenhouse gas emissions and energy consumption as part of the Project.

In addition to the participation in the EEO program and the NGER reporting, Cristal Mining would develop an Air Quality and Greenhouse Gas Management Plan which includes:

- Incorporation of best practice mine planning including:
  - Optimisation of haul truck scheduling, routing and idling times to minimise the amount of diesel consumed
  - Design pit access ramps to limit the amount of effort required for fully-laden trucks to climb
  - Optimisation of the location of overburden dumps to limit the distance haul trucks need to cover whilst laden
- Undertake regular maintenance and servicing of the mine fleet and road trains (i.e. mineral concentrate transport trucks)
- Implementation of 'Greenhouse' awareness training at induction
- Installation light sensitive switches on lighting equipment and energy efficient light fittings throughout the Project site where practicable
- Installation energy saving devices within the on-site buildings, where practicable
- Development and maintain an inventory of emissions and sinks.

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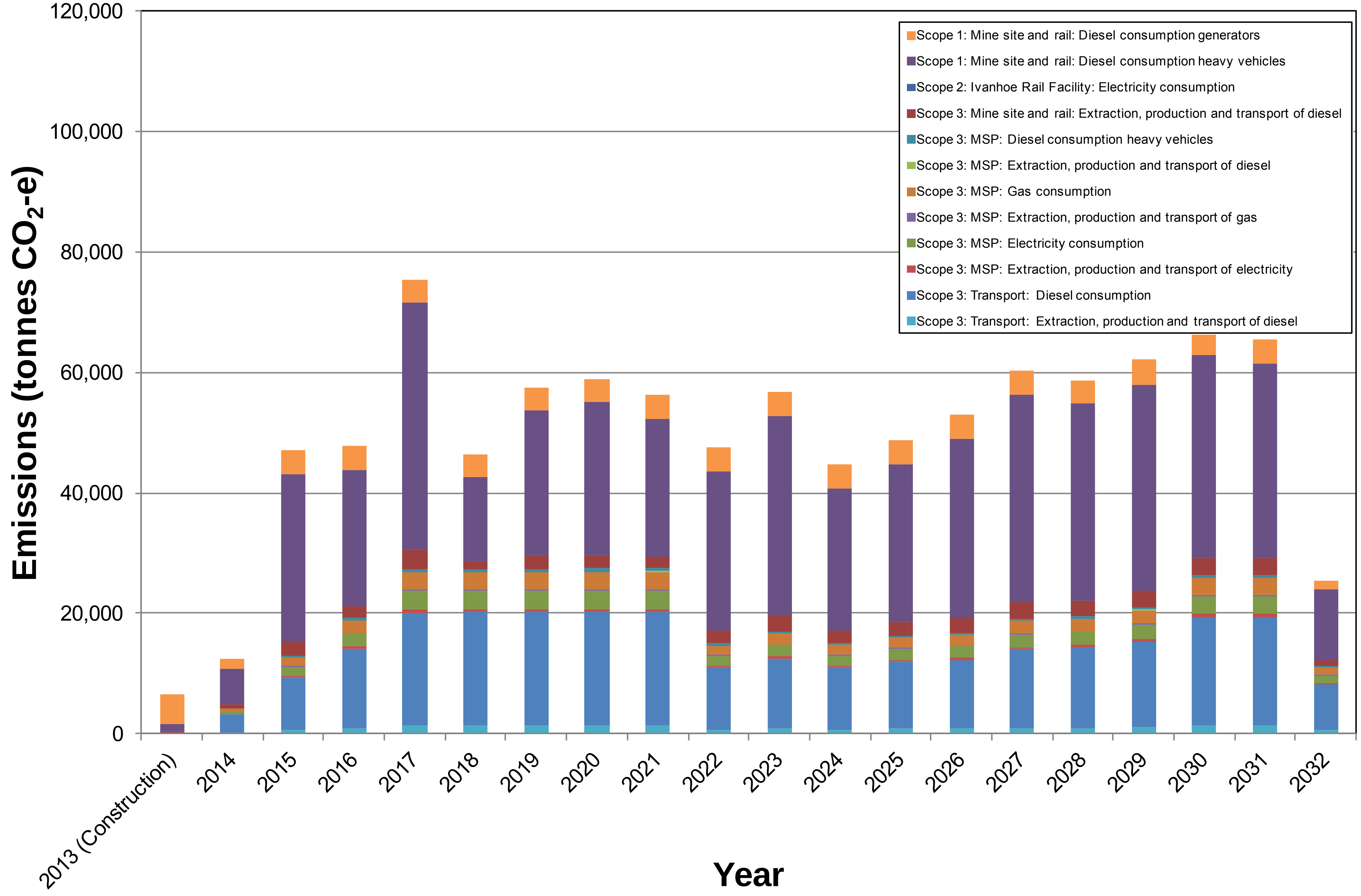

Figure E1	**Projected annual greenhouse gas emissions for the lifetime of the Atlas-Campaspe Mineral Sands Project**	
Location: New South Wales	**Data source:** Cristal Mining	**Units:** Tonnes CO_2-e
Type: Bar chart	**Prepared by:** T. Haigh	**Date:** October 2012