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Air Quality Assessment of the Yeelirrie Uranium Project

Prepared for

Cameco Australia Pty Ltd

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Prepared by:	Tania Haigh, Natalie Shaw
Reviewed by:	Simon Welchman
Approved by:	Simon Welchman 19/12/2014

Katestone Environmental Pty Ltd
Ground Floor, 16 Marie Street, Milton, QLD.
PO Box 2217, Milton, QLD. 4064, Australia
ABN 92 097 270 276

Phone: +61 7 3369 3699
Fax: +61 7 3369 1966
Email: us@katestone.com.au

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Term	Definition
$\mu g/m^3$	micrograms per cubic metre
µm	microns
°C	degrees Celsius
ha	hectare
km	kilometre
km/h	kilometre per hour
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mg	milligram
Mt	Million tonnes
t	tonnes
tpa	tonnes per annum
Nomenclature	
PM	Particulate matter (fine dust)
$PM_{2.5}$ and PM_{10}	Particulate matter less than 2.5 or 10 microns, respectively
TSP	Total suspended particles
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
SO_2	Sulfur dioxide
CO	Carbon monoxide
Abbreviations	
EPA	Western Australia Environment Protection Authority
Cameco	Cameco Australia Pty Ltd
DER	Department of Environment Regulation
EM Plan	Environmental Management Plan
HG ore	High grade ore
MG ore	Medium grade ore
NPI	National Pollutant Inventory
UHG ore	Ultra high grade ore
UOC	Uranium oxide concentrate
US EPA	United States Environmental Protection Agency
VHG ore	Very high grade ore

EXECUTIVE SUMMARY

Cameco Australia Pty Ltd (Cameco) proposes to develop an open pit uranium mine and associated processing facility at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie and 60 km west of Mt Keith. The proposed Yeelirrie Uranium Project would provide approximately 7,500 tpa of uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), through the development and operation of an open pit mine and on-site Metallurgical Plant.

Katestone Environmental Pty Ltd has been commissioned by Cameco to prepare the air quality assessment of the proposed Yeelirrie Uranium Project, as part of a Public Environmental Review. The air quality assessment investigates the potential for air quality impacts to occur due to mining operations for a scenario representing a stage in the development that is likely to result in the highest ground-level concentrations at the closest sensitive receptors.

The assessment used meteorological and dispersion models to assess the potential impact associated with dust emissions (TSP, PM_{10}, $PM_{2.5}$ and dust deposition) from the proposed Yeelirrie Uranium Project in isolation (operationally contributed) and with the inclusion of ambient background levels of dust representative of the region.

The air quality assessment demonstrates that ground-level concentrations of the key mining related air pollutants: $PM_{2.5}$, PM_{10}, TSP and dust deposition would be below the relevant criteria at all sensitive receptors.

The Yeelirrie Uranium Project also includes onsite power generation using diesel generators. The potential air quality impact associated with the diesel generators was also assessed. The key air pollutants associated with diesel power generators include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and particulates (as PM_{10}).

Emission rates of NOx have been based on rich-burn engines with no emission controls. Rich burn engines can employ catalytic controls that will reduce NOx, CO and hydrocarbon emissions significantly. Alternatively, lean-burn engines can also produce lower emissions of NOx compared with uncontrolled rich burn engines.

The air quality assessment of the power generation plant demonstrates that NO_2, SO_2 and CO concentrations are predicted to comply with the air quality criteria at all sensitive receptors. One exceedance day of the 1-hour average NO_2 criterion of 250 $\mu g/m^3$ was predicted at the nearest receptor (Yeelirrie Pool, which is located 16.4 km southeast of the ore body); however, one exceedance day is allowed for by the Air NEPM.

It is expected that available contemporary NOx control technology can be employed to significantly reduce the NO_2 impacts in practice.

1. INTRODUCTION

Katestone Environmental Pty Ltd (Katestone) was commissioned by Cameco Australia Pty Ltd (Cameco) to undertake an air quality impact assessment of the proposed Yeelirrie Uranium Project in Western Australia.

Cameco is currently proposing to submit a Public Environmental Review for the project that includes an increase in uranium ore production from 1.2 million tonnes per annum (Mtpa) to 2.4 Mtpa. Katestone completed an air quality assessment for BHP Billiton in 2011 and the modelling system developed for the Yeelirrie Uranium Project during that study has been utilised for this revised assessment.

1.1 Project description

Cameco proposes to develop an open pit uranium mine and associated processing facility at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie, 60 km west of Mt Keith, 70 km southwest of Wiluna and 110 km northwest of Leinster (Figure 1). The proposed Yeelirrie Uranium Project would involve mining of up to 14 Mtpa of mineralised uranium ore and waste material using open cut mining techniques over an anticipated mine life of over 30 years. Processing of the uranium ore will be carried out at the on-site metallurgical Plant. The project will produce approximately 7,500 tpa of uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), through the development and operation of an open pit mine and on-site Metallurgical Plant.

Associated mine infrastructure, including ore processing facilities, water supply infrastructure, roads, accommodation, offices and workshops, stockpile and lay down areas and evaporation pond will also be constructed. Tailings will be discharged back into the mine open pit. A quarry will be established approximately 8km north of the project. Extracted quarry material will be used in the construction of the processing plant and infrastructure. The quarry is expected to operate during the first three years of mining. A schematic of the final project layout is shown in Figure 2.

The key characteristics of the proposed development that are important to the air quality impact assessment are summarised in Table 1.

Table 1 Key characteristics of the proposed Yeelirrie Uranium Project important to the air quality assessment

Element	Description
Project operating life	About two years of pre-production mining and construction followed by a further 15 years of mining and up to 15 years of processing
Operations summary	Open pit mining and on-site processing of uranium mineralised ore to produce uranium oxide concentrate
Mining method	Open pit mining using conventional equipment such as excavators, front-end loaders and haul trucks or scrapers
Nature of mineralisation	Shallow-depth alluvial deposit about 10 m below ground level with a thickness of between 1 – 7 m
Mining rate	Up to 14 Mtpa of mineralised ore and non-mineralised material (annual average of approximately 8 Mt)
Processing method	Alkali leach and direct precipitation
Production rate	Up to 7,500 tpa of uranium oxide concentrate produced
Tailings management	In-pit disposal to an engineered Tailings Storage Facility
Maximum electricity demand (MW)	15
Average electricity consumption (MWh/a)	150,000
Project footprint - mine open pit	Clearing of no more than 726 ha within a 4557 ha development envelope
Project footprint - associated infrastructure	Clearing of no more than 1363 ha within a 4557 ha development envelope
Accommodation village	A village would be constructed about 20 km east of the processing plant, with sufficient accommodation for up to 1,200 people
Quarry	A quarry supplying approximately 500,000 tonnes of basic raw material would be located about 8 km north of the processing plant

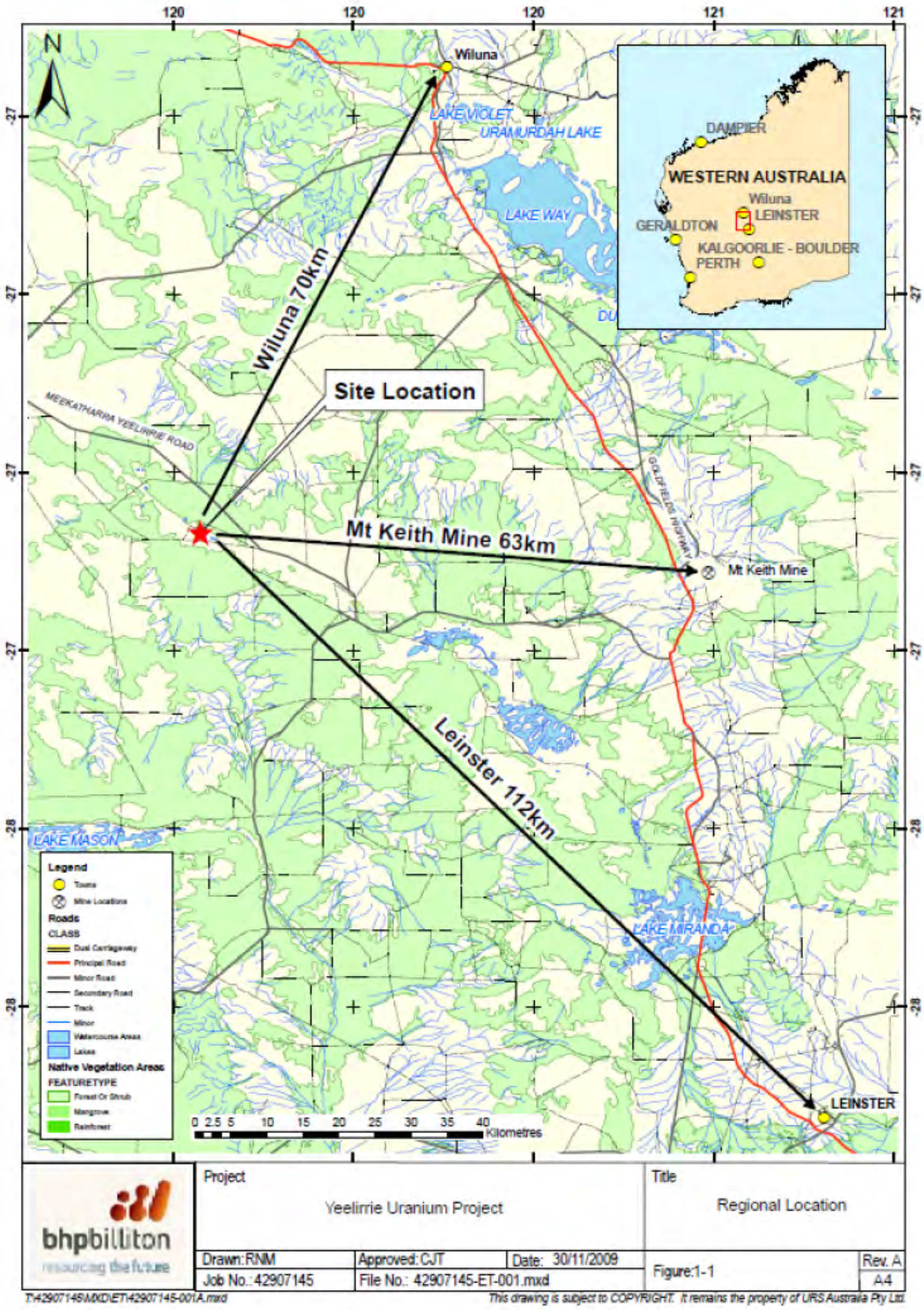
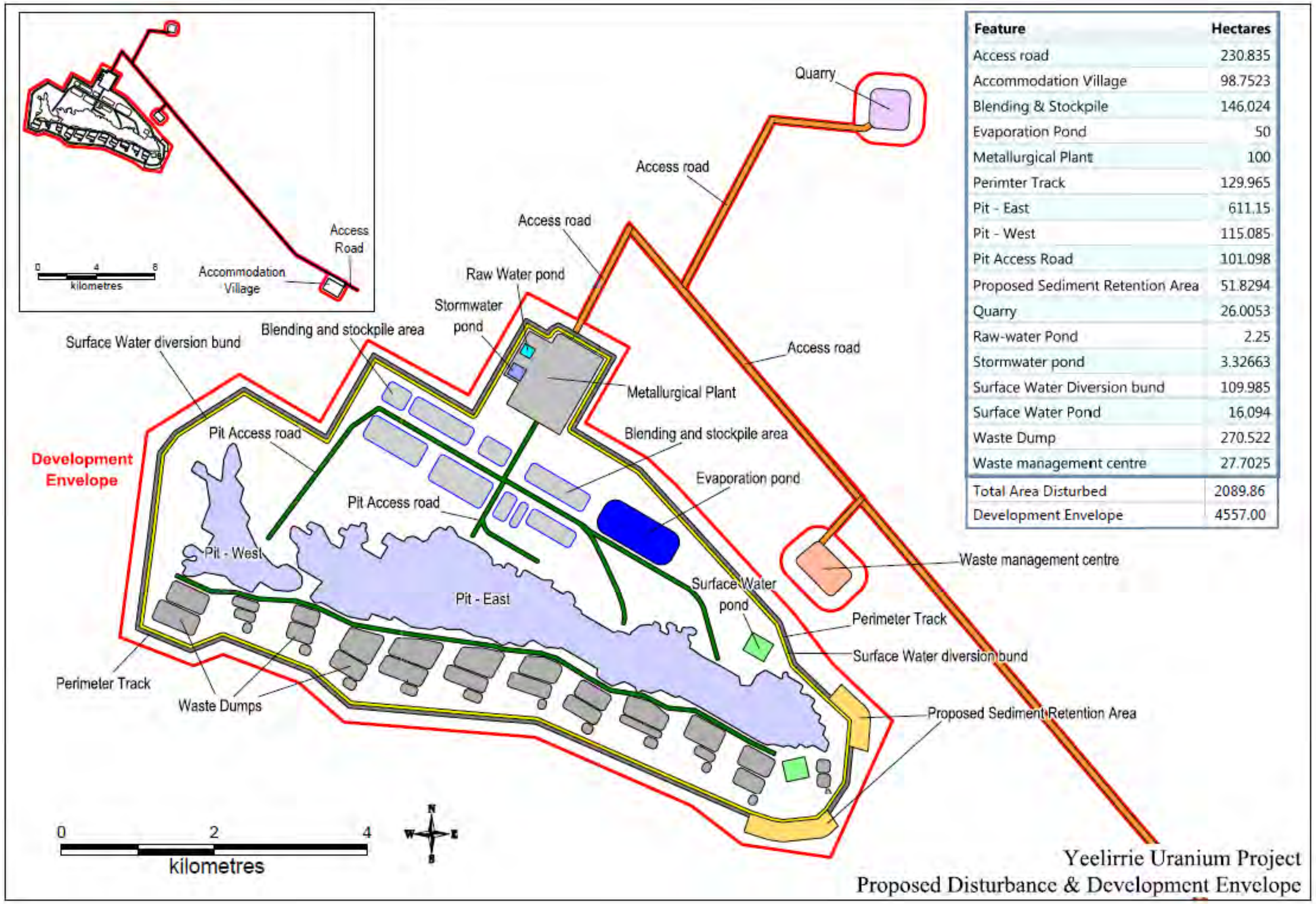


Figure 1 Proposed Yeelirrie Uranium Project site location



Feature	Hectares
Access road	230.835
Accommodation Village	98.7523
Blending & Stockpile	146.024
Evaporation Pond	50
Metallurgical Plant	100
Perimter Track	129.965
Pit - East	611.15
Pit - West	115.085
Pit Access Road	101.098
Proposed Sediment Retention Area	51.8294
Quarry	26.0053
Raw-water Pond	2.25
Stormwater pond	3.32663
Surface Water Diversion bund	109.985
Surface Water Pond	16.094
Waste Dump	270.522
Waste management centre	27.7025
Total Area Disturbed	2089.86
Development Envelope	4557.00

Figure 2 **Proposed disturbance footprint and final project layout**

1.2 Scope of work

The purpose of this air quality assessment is to:

- Describe the climate, local meteorology and existing air environment in the development area
- Quantify emissions of dust (TSP, PM_{10} and $PM_{2.5}$) from all mine related sources
- Quantify emissions of other air pollutants from all mine related sources, including onsite power generation
- Conduct air dispersion modelling using accepted techniques
- Evaluate the incremental and cumulative air quality impacts of the proposed Yeelirrie Uranium Project on the air environment
- Present the results in relation to relevant ambient air criteria
- Recommend dust management and mitigation strategies where applicable

This study summarises the aspects of the project that may result in emissions to the atmosphere, as well as the legislation, policies and guidelines that are relevant to the assessment and management of air emissions in Western Australia and Australia. The key air pollutant that is likely to be emitted to the atmosphere from the mining operations is dust; however, there will also be emissions of other pollutants, including oxides of nitrogen (NOx), carbon monoxide (CO) and sulfur dioxide (SO_2), due to onsite power generation.

Dust emissions will occur as a result of both the construction and operation of the mine. Elevated levels of dust can adversely impact the amenity and health of people living in the vicinity. Emissions of dust have been estimated for a scenario that is representative of a stage in the life of the mine with the highest potential to impact the air environment. Dispersion modelling has been used to predict ground-level concentrations of dust as TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates due to the project. The cumulative ground-level concentrations (operationally contributed plus background) have been compared with the health and amenity guidelines.

Emissions from the on-site power generation have also been estimated and modelled. The predicted increases in ground-level concentrations of NO_2, CO, SO_2 and particulates as PM_{10} have been compared with the relevant air quality criteria.

The assessment has been conducted in accordance with the Department of Environment Regulation's (DER) Air Quality Modelling Guidance Notes (DER, 2006). Relevant details can be found in the following sections:

- Identify emissions and secondary pollutants (Section 5.1)
- Modelling to predict impacts (Section 3.3)
- Presentation of modelling results (Section 7)
- Modelling cumulative impacts (Section 7)
- Emissions estimates (Section 5.4 and Appendix B)
- Model capability (Appendix A)
- Meteorological data for modelling (Section 6 and Appendix A)
- Advanced models (Section 3.3 and Appendix A)
- Model acceptability and verification (Appendix A)
- Reporting

As this is a uranium mine, radon is also emitted. Radon has been assessed in a separate report.

2. AIR QUALITY STANDARDS

Air quality in Western Australia is assessed against the standards specified in the *National Environment Protection (Ambient Air Quality) Measure 1998* (Air NEPM), which has been enacted through the *National Environmental Protection Council (Western Australia) Act 1996*. The National Environmental Protection Council defines national ambient air quality standards and goals in consultation with, and agreement from, all state governments. The Air NEPM standards for the most significant air pollutants that may arise from the proposed Yeelirrie Uranium Project are presented in Table 2.

Table 2 Air quality standards relevant to the Yeelirrie Uranium Project

Pollutant	Averaging period	Air NEPM standard (µg/m³)	Air NEPM goal – maximum allowable exceedances
Particulate matter less than 10 µm (PM_{10})	24-hour	50	5 days per year
NO_2	1-hour	246	1 day per year
	Annual	62	None
SO_2	1-hour	572	1 day per year
	24-hour	229	1 day per year
	Annual	57	None
CO	8-hour	11,000	1 day per year

For other significant air pollutants not covered by the Air NEPM, for impact assessment purposes the DER adopts the World Health Organisation's Guidelines for Air Quality or air quality guidelines from other jurisdictions where appropriate, with appropriate amendments to suit the Western Australian context (Department of Environment, Government of Western Australia, 2004). Air quality assessment criteria for the most significant air pollutants that may arise from the proposed Yeelirrie Uranium Project that are not covered by the Air NEPM are summarised in Table 3. The *Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1999* specifies a 24-hour average TSP standard in the Kwinana area of 90 µg/m³ (limit of 150 µg/m³) for an isolated residential dwelling. This standard has been applied as an impact assessment criterion to the Yeelirrie Uranium Project.

Table 3 **Relevant air quality guidelines**

Pollutant	Averaging period	Air quality guidelines	Units	Source
Total suspended particulates (TSP)	24-hour	90	µg/m³	Kwinana
	Annual	90	µg/m³	NSW EPA
Particulate matter less than 10 µm (PM_{10})	24-hour	50	µg/m³	Air NEPM
	Annual	25	µg/m³	WHO guideline
Particulate matter less than 2.5 µm ($PM_{2.5}$)	24-hour	25	µg/m³	Air NEPM advisory reporting standard
	Annual	8	µg/m³	Air NEPM advisory reporting standard
Dust deposition rate	Annual	2 [a]	g/m²/month	NSW EPA[c]
		4 [b]		

Table note:

[a] Maximum increase in deposited dust level

[b] Maximum total deposited dust level

[c] Amenity dust guideline

3. METHODOLOGY

This air quality assessment was conducted in accordance with recognised techniques for dispersion modelling and emission estimation. The air quality assessment is based on a dispersion modelling study that incorporates source characteristics and air pollution emission rates, local meteorology, terrain, land use and the geographical location of sensitive receptors.

3.1 Meteorological modelling

The Yeelirrie site has operated an automatic weather station (AWS) approximately half way between the proposed development and the Yeelirrie Homestead, with data available from the AWS from 7 February 2010 to 19 January 2011. The monitoring data is likely to be representative of the local area surrounding the monitoring station, whereas the dispersion modelling requires a three dimensional wind field across the broader region. To produce the required wind field for dispersion modelling, a coupled approach using the TAPM/CALMET modelling system and the AWS measurements has been used.

The meteorological data for this study was generated by coupling TAPM, a prognostic mesoscale model, to CALMET, a diagnostic dispersion model. The available monitoring data from the Yeelirrie AWS was assimilated into the TAPM model to improve the model's predictions. The coupled TAPM/CALMET modelling system was developed by Katestone to enable detailed air dispersion modelling capabilities for regulatory and environmental assessments. The modelling system incorporates 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. Complete details of the model configuration and a review of the models performance are provided in Appendix A.

3.2 Emissions

3.2.1 Mine

Dust emissions from the proposed Yeelirrie Uranium Project have been estimated based on representative emission factors from the National Pollutant Inventory (NPI) mining handbook and USEPA AP-42 documents and detailed source characteristics and operational activity data provided by Cameco. Emissions have been estimated for one year of operations, based on operational activities at the mine that have the potential to cause the highest ground-level concentrations at the closest sensitive receptors.

Technical descriptions of the emissions model are outlined in Section 5.1.2 for the mining operations, Section 5.1.3 for the metallurgical plant and 5.1.4 for the quarry and in detail in Appendix B.

3.2.2 Power generation

Emissions from power generation have been estimated based on the engine manufacturer's specifications. Details of the emissions data are provided in Appendix B. Section 5.1.5 provides all emission rates used in the assessment.

3.3 Dispersion modelling

Atmospheric dispersion modelling was carried out using the CALPUFF Version 6.4 dispersion model (EarthTec) to predict the ground-level concentrations of particulate matter, SO_2, CO and NO_2 and dust deposition rates.

The CALPUFF dispersion model utilises the three-dimensional wind fields from CALMET to simulate the dispersion of air pollutants to predict ground-level concentrations across a gridded domain. CALPUFF is a non-steady-state Lagrangian Gaussian puff model containing parameterisations to simulate 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.

Dust dispersion modelling was carried out for the scenario representing the operations at the mine likely to result in the greatest impacts to the air environment surrounding the proposed Yeelirrie Uranium Project. The model was configured to predict the potential impact of emissions on ambient levels of TSP, PM_{10}, $PM_{2.5}$ and dust deposition within the modelling domain. For dust deposition modelling, a particle size distribution was included based on size fractions of TSP, PM_{10} and $PM_{2.5}$ reported for the various mine sources in AP-42.

The model was also configured to assess the dispersion and predict the potential impact of SO_2, CO, NO_2 and particulates as PM_{10} from the onsite diesel generators within the modelling domain.

Details of the CALPUFF model configuration are provided in Appendix A.

3.3.1 Method for the conversion of oxides of nitrogen to nitrogen dioxide

The nitric oxide (NO) that will be emitted from the onsite diesel generators will undergo chemical transformation in the atmosphere to form NO_2. As NO_2 is more toxic than NO, it is important to quantify the transformation of NO to NO_2 to assess the predicted ground-level NO_2 concentrations against the air quality criteria. NO and NO_2 are collectively termed NO_X.

The actual degree of conversion of NO to NO_2 in a plume will depend on atmospheric conditions at the time that the emissions occur. 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 this assessment a conservative ratio of 30% conversion of the NO to NO_2 has been assumed to estimate the ground-level concentrations of NO_2 resulting from the operation of the onsite diesel generators.

3.3.2 Limitations of dispersion modelling

This study necessarily relies on the accuracy of a number of data sets including, but not limited to:

- Meteorological information
- Calculation of emission rates from mining activities

Where uncertainty exists in important properties of the proposed activities within the project or the environment, this assessment has erred on the side of caution and selected inputs that would provide for overestimates of ground-level concentrations of air pollutants. A number of assumptions have been applied.

It is important to note that numerical models are based on an approximation of governing equations and will inherently be associated with some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included.

There will be physical processes that are not explicitly accounted for in the model and, in general, these approximations tend to lead to an over prediction of air pollutant levels. For example, in the real world when a plume of dust reaches an area of sloping terrain, mass from the plume will be removed through impaction on the surface. In a dust model, however, the dust plume is treated as a gas and the plume will pass over or around the obstacle with no loss of mass. This difference in characterisation can lead to an over prediction of dust levels downwind from the source.

The approach adopted for emission estimation and dispersion modelling has been in accordance with accepted industry practice. Whilst DER suggests that modelling "...is not suitable to assess the environmental risk associated with a project...", modelling is routinely used in Western Australia and in other Australian state jurisdictions to demonstrate that projects involving fugitive dust can be approved.

Noting the potential for uncertainty in modelling fugitive dust emissions, the following approach has been adopted:

- Emission rates estimated in accordance with recommendations of other environmental regulators e.g. US EPA and NSW EPA
- Emission factors published by US EPA and Australian Government
- Site specific information on meteorological conditions and material properties will be used where available
- Selection of project year represents understanding of worst-case year
- Efficiency of dust emission controls have been based on literature values and dust emission controls will be based on Cameco's proposed approach.

In Katestone's experience, this approach provides a conservative, but reliable estimate of dust levels suitable for impact assessment studies:

3.4 Presentation of results

Modelling results have been presented as ground-level concentrations or dust deposition rates at sensitive receptors as well as contours across the modelling domain.

4. EXISTING ENVIRONMENT

The existing environment in the region surrounding the project is discussed in this section. Important aspects of the existing environment include existing sources of air pollutants, the location of sensitive receptors and proximity to activities producing air pollutants, geographical features, climate and meteorological conditions.

4.1 Local terrain and land use

The land use of the Wiluna Shire in central Western Australia is predominantly pastoral rangeland, with regions of hummock grassland, woodland, shrub land and low open forest (Figure 3).

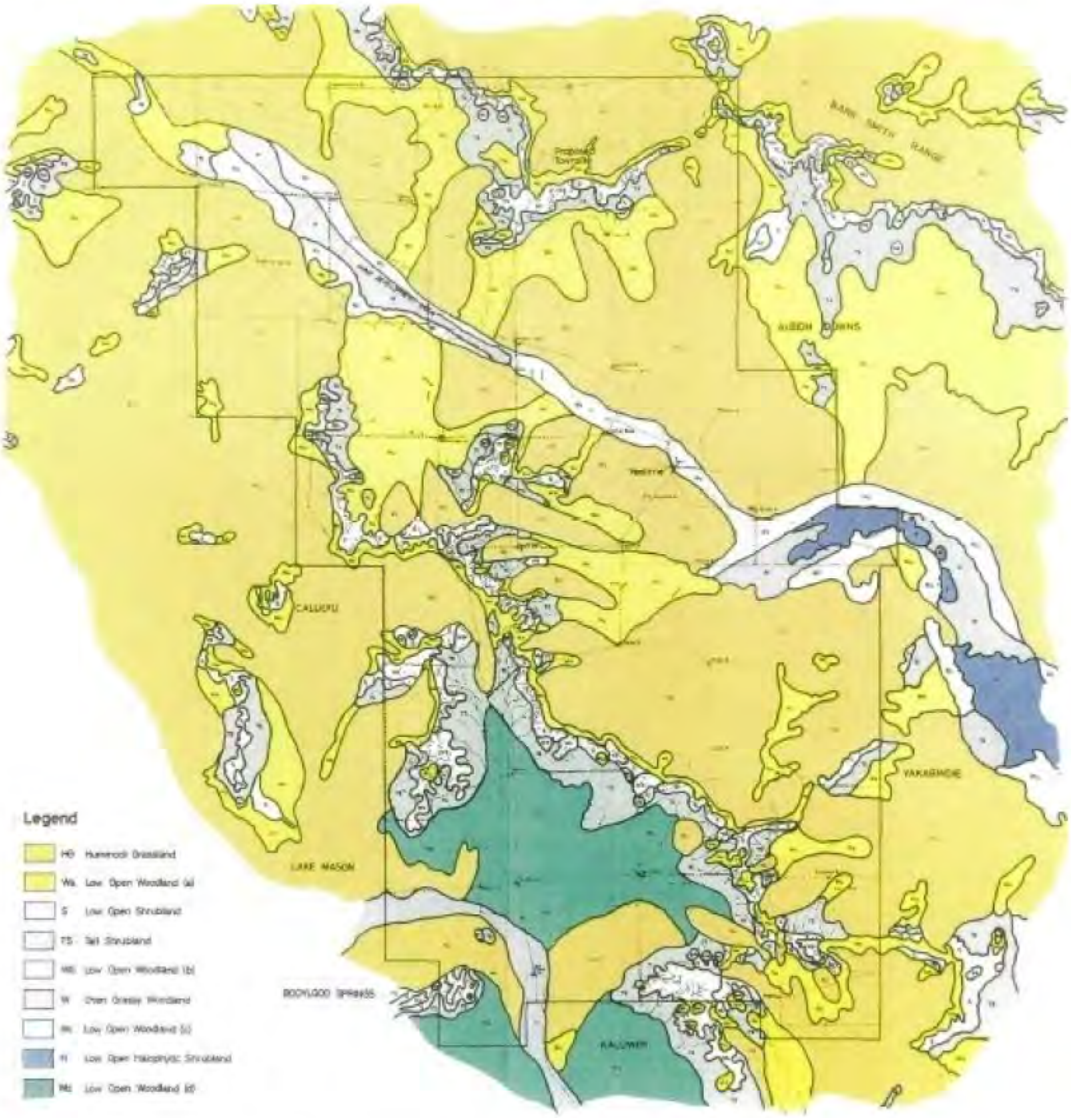


Figure 3 **Proposed Yeelirrie Uranium Project site vegetation**

The uranium deposit occurs in carbonated sediments in the central drainage channel of a wide, flat and long valley that is flanked by granite breakaways of low topographic relief, some 50 to 100 metres and an elevation of 480 to 595 metres above sea level.

The current land uses in the region surrounding the proposed Yeelirrie Uranium Project are predominantly fenced pastoral land. Trial mining activities were performed in the area by Western Mining Corporation (WMC) between 1978 and 1983. The open-cut trial pits were closed in 1994 and decommissioned and revegetated in 2000 and 2004.

4.2 Sensitive receptors

The proposed Yeelirrie Uranium Project is located on the Yeelirrie pastoral property in the East Murchison pastoral region. This region is sparsely populated with homesteads approximately 30 km and more apart. The proposed project site is relatively isolated, with the nearest receptors located more than 10 km from the ore body. The nearest sensitive receptors identified in the air quality impact assessment are the Yeelirrie Pool, Accommodation Village and Yeelirrie Homestead located approximately 10.2 km, 15.6 km and 16.4 km, respectively, from the ore body. The nearest sensitive receptors to the proposed Yeelirrie Uranium Project are presented in Table 4 and Figure 4.

Table 4 Nearest sensitive receptors to the proposed Yeelirrie Uranium Project

Receptor	Distance and direction from ore body
Accommodation Village	15.6 km southeast, adjacent to the Yeelirrie Homestead
Yeelirrie Homestead	16.4 km southeast
Ululla Homestead	28.5 km north
Albion Downs Homestead	44.2 km west-southwest
Youno Downs	61.8 km west-northwest
Yeelirrie Pool	10.2 km northeast
Palm Springs	50.4 km east-southeast

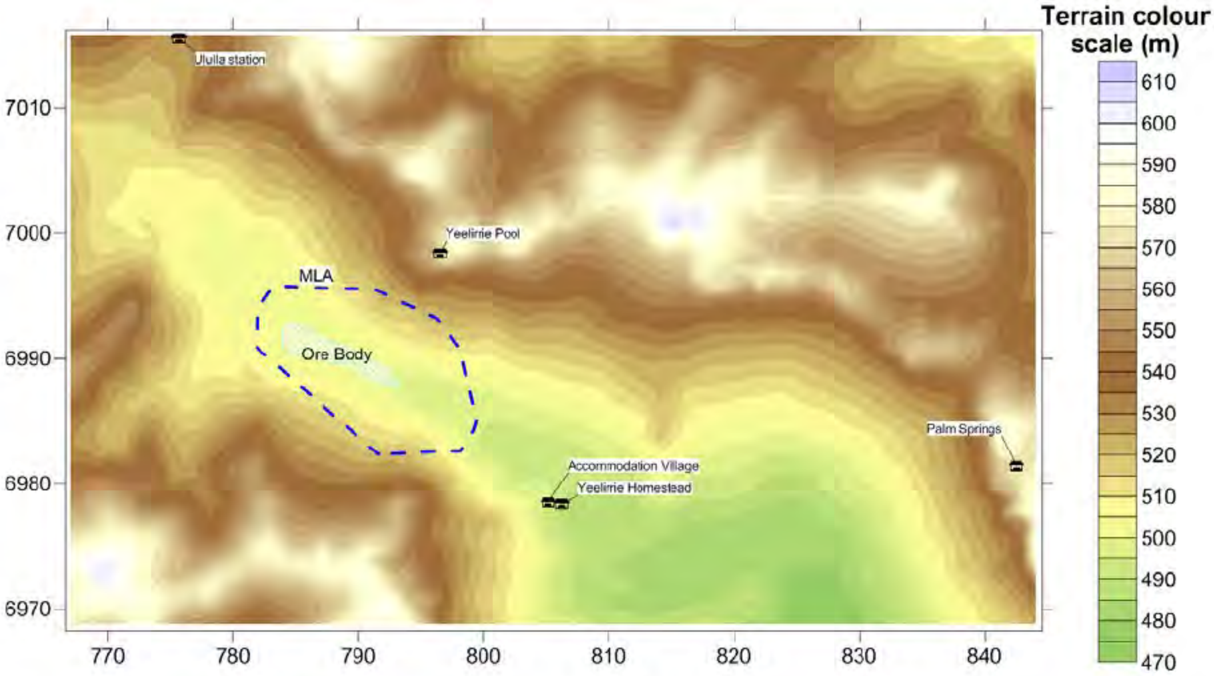


Figure 4 Location of the proposed Yeelirrie Uranium Project and nearest sensitive receptors

4.3 Climate and meteorology

4.3.1 Climate overview

The Western Australian climate varies significantly throughout the state. While the southern regions of Western Australia experience the four typical seasons (spring, summer, autumn and winter), in the northern areas of the state the seasons are generally described as either wet or dry. In addition, there is a reduction in rainfall and an increase in temperature extremes and variability with an increase in distance from the Western Australian coastline. The climate of Western Australia is strongly influenced by the size of the Australian land mass, as well as large scale synoptic processes such as warm/cold frontal systems, cut-off lows, the west coast trough, blocking highs, the southern annual mode, the Indian ocean dipole, cloud bands and tropical lows (DAFF, 2008).

The extent and detail of the description of climate is relative to the spatial and temporal scale of the assessment. The proposed Yeelirrie Uranium Project site is situated near the geographic centre of Western Australia and, as such, is influenced by the large scale synoptic situation; which encompasses most of the Indian and Southern Ocean as well as the Australian land mass; the regional scale weather of the arid inland regions of Australia and the local scale atmospheric environment of the proposed development site itself.

The most important aspect of the Yeelirrie climate in terms of air quality is the frequency and intensity of hot, dry north-easterly winds, as these are most likely to generate dust from the erosion of stockpiles and disturbed areas. Also of importance is the frequency and intensity of night-time inversions particularly in winter characterised by a stable atmosphere and the formation of a low level jet, as these conditions can cause pollutants to remain suspended in the atmosphere for long periods of time.

The inland areas of the Western Australian region show a predominance of east to southwest winds during spring and summer, shifting to a distinct alternating westerly and easterly flow during autumn and winter. Coastal locations observe a high frequency of moderate to strong winds from the north-northeast to northeast during winter, shifting to winds predominantly from the south during spring and summer.

4.3.2 Temperature, rainfall and relative humidity

The Bureau of Meteorology (BoM) also operates a meteorological monitoring station at Yeelirrie, near the on-site AWS. Data from this BoM station has been used to summarise long-term rainfall, temperature, solar exposure and humidity for the region as the station has been operating since 1928. A summary of the historical rainfall, temperature, solar radiation and humidity data for the BoM site at Yeelirrie is provided in Table 5 (BoM, 2014).

The annual average rainfall for the site is 239 mm. The monthly averages indicate that the summer, autumn and winter months of December through June tend to be wetter, with around 77 % of annual rainfall recorded during this period. The winter and spring months of July through November tend to be drier, with around 23 % of annual rainfall recorded during these months.

The data show that the maximum temperatures at the site average around 38 °C during January and 19.3 °C during July, while the minimum temperatures average around 3.5 °C during July and 22.2 °C during January. Temperature extremes include a maximum of 47.9°C recorded at the site during January 2013, and a minimum of -5.1 °C recorded at the site during July 2000.

The BoM data illustrate the typical seasonal pattern of solar exposure, with the average solar radiation greater during the warm summer months of October through to March compared to the cool winter months of April through to September.

The BoM data show that the spring, summer and autumn months of September through March tend to be less humid, with 9am relative humidity ranging from 32% to 44% at the site. A higher relative humidity was measured during the autumn and winter months of April through August, with 9am relative humidity ranging from 52% to 68% at the site. The data also show that, on average, the relative humidity is 64% higher at 9am than at 3pm.

Table 5 Summary of monitoring data from Bureau of Meteorology monitoring station at Yeelirrie

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm) – For years 1928 to 2014													
Average rainfall	29.7	31	31.4	24.4	25.3	22.8	17.4	12.4	4.8	9.7	10.1	20.4	239
Temperature (°C) – For years 1973 to 2014													
Mean maximum temperature	37.9	35.9	33.2	29.0	23.5	19.5	19.3	21.7	25.8	30.1	33.0	36.1	28.8
Mean minimum temperature	22.2	21.3	18.2	13.9	8.3	4.7	3.5	4.7	7.9	12.6	16.3	19.9	12.8
Maximum temperature	47.9	46.0	44.0	38.5	36.8	29.9	28.6	33.4	37.5	41.5	43.2	45.4	47.9
Minimum temperature	12.0	10.0	6.0	3.0	-2.8	-5.0	-5.1	-4.8	-2.2	-0.4	1.9	7.6	-5.1
Solar exposure (MJ/m²) – For years 1990 to 2014													
Mean daily solar exposure	27.8	24.5	21.6	17.3	14.3	12.3	13.5	17.4	21.8	25.4	28.0	28.8	21.1
Relative humidity (%) – For years 1973 to 2010													
Mean 9am relative humidity	34	42	43	52	59	68	66	56	44	36	33	32	47
Mean 3pm relative humidity	21	27	27	34	37	42	41	33	26	20	19	19	29

4.3.3 On-site meteorology

Data from an automatic weather station (AWS) located half way between the proposed development and the Yeelirrie Homestead from 7 February 2010 to 19 January 2011 has been used to characterise the meteorology at the project site. The Yeelirrie AWS records 1-hour average wind speed, wind direction, relative humidity, temperature, barometric pressure and radiation as well as evaporation and rainfall totals. The data from the Yeelirrie AWS for the period 7 February 2010 to 19 January 2011 have been used to characterise the meteorology at the site of the Yeelirrie Uranium Project.

A monthly summary of the monitoring data from the Yeelirrie AWS is presented in Table 6, and includes rainfall, temperature, wind speed, relative humidity, barometric pressure and solar radiation.

The data show that the annual rainfall for the region was 290.4 mm, with 43 % of the rainfall recorded during November and December 2010 and a further 23% recorded during March 2010. Relatively low rainfall levels were recorded during April through to September 2010, while no rain was recorded at the site during February and October 2010.

The monthly average temperature ranged from 11.1 °C during July to 33.2 °C during February. The lowest daily average temperature of 7.6 °C was recorded during July, while the highest daily average temperature of 37.1 °C was recorded during February. The monitoring data illustrate the typical seasonal pattern of solar exposure, with the monthly average solar radiation greater during the warm summer months of October through March compared to the cool winter months of April through September.

The annual average wind speed recorded at the site was 2.7 m/s, with the monthly average wind speed ranging from 1.7 m/s (April and July) to 2.9 m/s (January). Daily average wind speeds of up to 6.0 m/s were recorded at the site during December, while a daily average wind speed of 0.2 m/s was recorded at the site during April.

Monthly average relative humidity ranged from around 60 % during June and July to 24 % during February and November. The peak daily average relative humidity level of 95 % was recorded at the site during June, while the lowest humidity level of 10 % was recorded at the site during March.

The monthly average barometric pressure data show that the months of November through to April were dominated by low pressure synoptic conditions that are typically associated with wetter summer conditions, while the months of May through to October were dominated by high pressure systems that are typically associated with clear, drier conditions.

The annual, seasonal and diurnal distributions of winds recorded at the Yeelirrie AWS are presented as wind roses in Figure 5, Figure 6 and Figure 7, respectively. The data show that winds were predominantly from the east-northeast to south-southeast, with 68 % of the winds recorded from this sector. The remaining winds were recorded from the south to northwest (26 %) and north-northeast to northeast (6 %) directions. As shown in Figure 6 and Figure 7, the winds from the east-northeast to south-southeast were predominant during all seasons and during all periods of the day, with the strength of these winds increasing during the spring and summer months, and during the morning (6am to midday) and afternoon (midday to 6pm) periods.

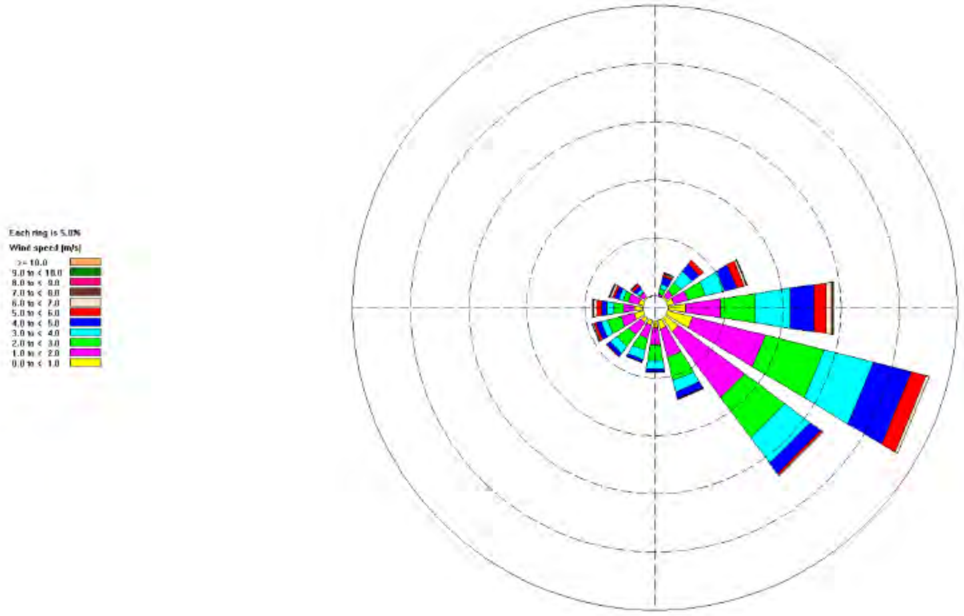


Figure 5 Annual wind distribution for Yeelirrie AWS (7 February 2010 - 19 January 2011)

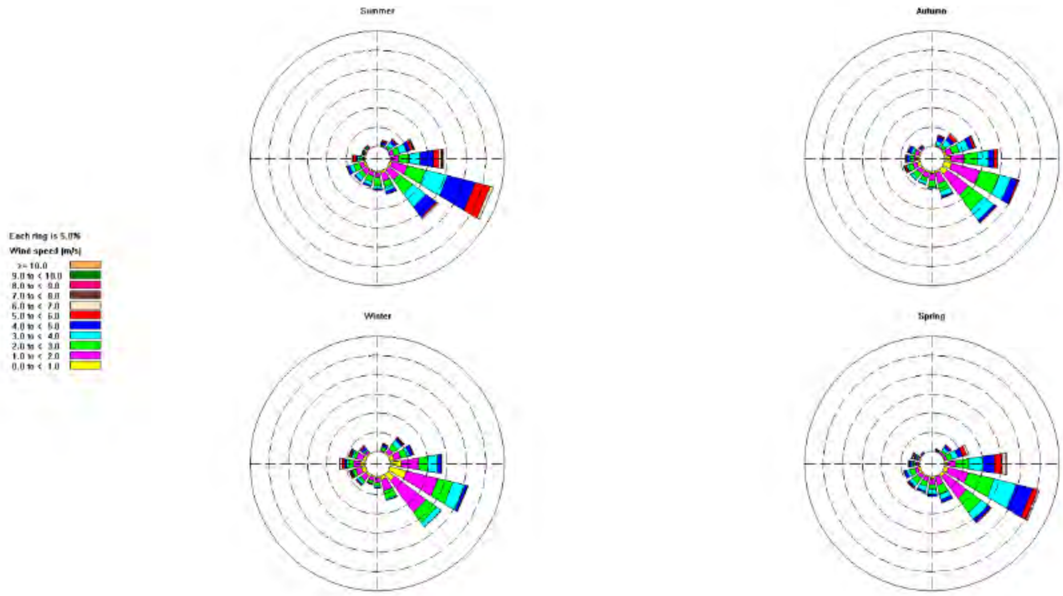


Figure 6 Seasonal wind distribution for Yeelirrie AWS (7 February 2010 - 19 January 2011)

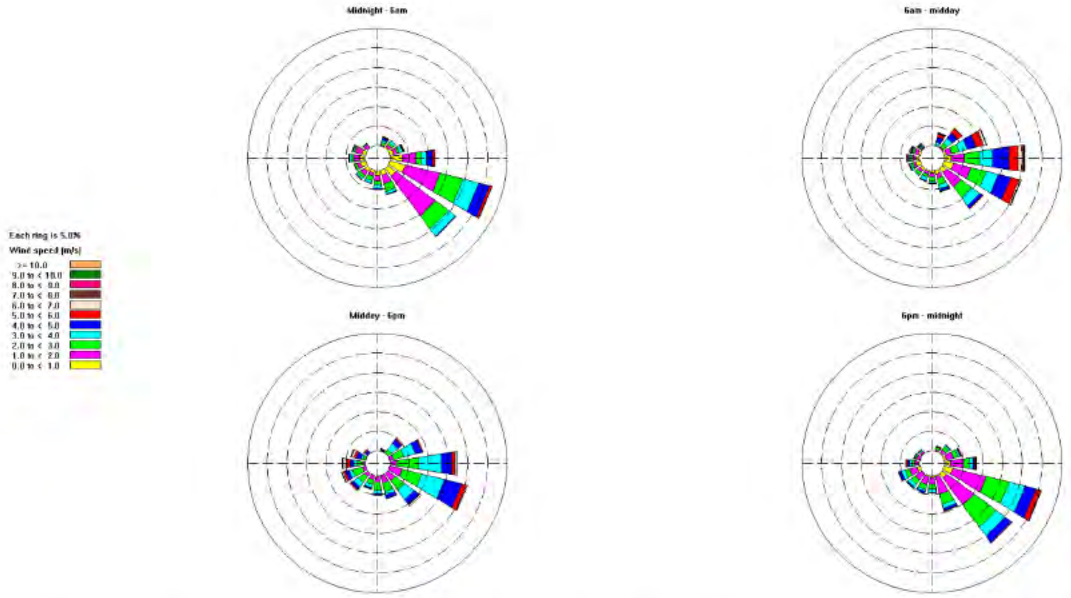


Figure 7 Diurnal wind distribution for Yeelirrie AWS (7 February 2010 - 19 January 2011)

Table 6 **Summary of monitoring data from Yeelirrie AWS during February 2010 to January 2011**

Parameter[1]	Feb[2]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Annual[4]
Rainfall (mm)													
Monthly rainfall total	1.0	68.0	15.8	10.4	15.0	14.6	27.6	8.4	0.0	29.8	94.0	5.8	290.4
Temperature (°C)													
Minimum daily temperature	28.9	22.4	18.3	11.5	7.7	7.6	9.5	9.7	16.1	19.4	17.7	27.0	16.3
Maximum daily temperature	37.1	32.1	28.3	23.1	19.2	15.3	23.7	27.3	31.3	33.1	36.8	36.0	28.6
Average daily temperature	33.2	27.4	23.7	16.8	13.7	11.1	14.0	16.2	22.2	26.2	28.3	29.9	21.9
Wind speed (m/s)													
Minimum daily wind speed	0.5	0.5	0.2	0.6	0.3	0.6	0.5	0.7	0.8	0.6	0.6	0.8	0.6
Maximum daily wind speed	4.6	4.1	4.0	3.8	2.8	5.5	4.4	4.3	4.7	5.1	6.0	4.6	4.5
Average daily wind speed	2.6	2.4	1.7	2.0	1.8	1.7	1.8	2.3	2.6	2.7	2.6	2.9	2.3
Relative humidity (%)													
Minimum daily relative humidity	13.9	9.9	29.5	30.5	35.8	39.8	29.9	17.3	15.2	11.9	10.5	22.6	22.2
Maximum daily relative humidity	41.5	85.6	78.0	81.8	94.8	80.2	76.1	83.6	53.3	68.2	89.6	67.0	75.0
Average daily relative humidity	24.9	34.3	48.3	54.0	61.1	60.0	45.0	45.4	31.0	24.2	36.2	37.9	41.8
Barometric pressure (hPa)													
Minimum daily pressure	947.0	950.2	949.2	948.8	956.3	949.0	947.1	950.4	950.8	947.5	941.6	939.3	948.1
Maximum daily pressure	955.2	960.7	966.0	964.5	968.4	969.3	971.7	969.4	963.1	959.6	954.8	949.2	962.7
Average daily pressure	951.3	955.9	956.0	958.4	963.7	963.2	960.7	961.3	957.1	952.8	946.6	945.7	956.1
Solar radiation (Watts/m²)													
Minimum daily solar radiation	143.9	76.6	60.2	67.6	26.7	56.2	52.0	58.6	80.2	156.8	45.2	120.7	78.7
Maximum daily solar radiation	276.8	285.3	219.6	169.4	141.3	148.7	181.4	280.6	265.8	283.8	295.4	284.5	236.0
Average daily solar radiation	227.7	223.3	170.4	139.3	99.4	124.4	146.5	195.7	222.0	252.2	232.3	221.9	187.9

Table note:

1 Minimum, maximum and average values are based on the 24-hour average data for each month
2 Data available from 7 February 2010 only
3 Data available to 19 January 2011 only
4 Annual values are based on the average of all months, with the exception of rainfall which is presented as a total

4.4 Ambient air quality

The air quality in the region of the proposed Yeelirrie Uranium Project is characterised in this section through a review of existing industrial sources of emissions, other likely natural and anthropogenic sources of emissions, and representative monitoring data. This information has been used to select representative ambient background levels for use in the cumulative air quality assessment.

4.4.1 Existing sources of emissions

The NPI database identifies a number of industrial sources within the central Western Australia region reporting emissions of PM_{10}, $PM_{2.5}$, SO_2, CO and NOx. The existing industries within a 100 km radius of the proposed Yeelirrie Uranium Project and the reported emissions of PM_{10}, $PM_{2.5}$, SO_2, CO and NO_X for the 2008 – 2009 year are presented in Table 7. The closest mining activity in the region is at Mount Keith approximately 70 km east of the proposed Yeelirrie Uranium Project.

The area immediately surrounding the proposed Yeelirrie Uranium Project is mostly pastoral rangeland with scattered residencies. The main regional dust source is wind erosion of exposed soil surfaces. With the exception of pastoral activities there are no significant nearby anthropogenic gaseous emission sources affecting air quality in the vicinity of the site. Localised sources of dust are likely to be predominantly naturally occurring, associated with wind erosion of exposed areas of soil or land, particularly during dry periods. Air quality in the vicinity of the site is also affected by occasional bush fires and scrub fires.

Minor anthropogenic sources of dust are likely to come from vehicles passing on the nearby unsealed roads and any vehicular activity on the pastoral lease. Daily background-levels of dust are expected to be low and will vary significantly depending on location, topography, meteorological conditions and proximity to sources.

Table 7 Inventory of emission sources of particulate matter (as PM_{10} and $PM_{2.5}$), SO_2, CO and NO_X reported for 2012-2013 reporting year (NPI)

Faculty name	Locality	Main activity	Distance and direction from project	Total kg/year				
				PM_{10}	$PM_{2.5}$	SO_2	CO	NO_X
Agnew Gold Mine	Leinster	Gold ore mining and processing	110 SSE	1,891,320	5,678	82	44,885	86,671
Bronzewing Operations	Lake Darlot	Gold ore mining and processing	110 E	1,567,009	29,583	297	225,340	512,819
Burnakura Gold Mine	Reedy	Underground and open pit gold mining	140 W	157,863	6,231	70	54,686	107,948
Cliffs Nickel Project	Sir Samuel	Nickel mining	70 E	850,000	5,400	46	36,000	58,000
Cosmos Nickel Project	Leinster	Nickel mining and processing	80 SE	390,067	4,665	73	64,391	128,976
Jundee Operations	Wiluna	Gold ore mining and processing	120 NE	2,144,487	20,101	755	207,127	553,864
Lawlers Operations	Agnew	Gold ore mining	110 SSE	1,193,805	7,233	89	63,783	123,736
Leinster Nickel Operation	Leinster	Nickel mining and concentrating	110 SE	3,323,000	14,130	1,050	122,000	410,000
Leinster Power Station	Leinster	Electricity generation	110 SE	14,552	14,096	711	159,468	552,291
Mt Keith Nickel Operation	Wiluna	Nickel ore mining	70 E	8,600,000	110,000	1,200	810,000	1,800,000
Mt Keith Power Station	Leinster	Electricity generation	130 SSE	21,950	21,282	969	233,798	780,358
Paroo Station Mine	Wiluna	Mining and processing of lead concentrate	70 N	457,250	5,150	44	36,362	90,355
Wiluna	Wiluna	Electricity generation using mineral gas	70 NNE	1,280	1,250	13	11,000	24,400
Wiluna Compressor Station	Wiluna	Gas compression	80 NNE	78	78	21	3,392	13,082
Wiluna Operations	Wiluna	Gold ore mining and processing	70 NNE	298,469	9,597	423	67,211	246,261

4.4.2 Monitoring data

Due to the remote location of the proposed Yeelirrie Uranium Project, there are currently no long-term air quality monitoring stations in the region that monitor ambient dust levels. However, monitoring of SO_2, NO_2, CO and particulates is currently carried out by the DER in the Perth metropolitan and southwest regions of Western Australia. The network of monitoring stations have been selected to monitor wind-blown crustal material and smoke from bushfires, hazard reduction or stubble burning and wood-fired heaters in the industrial and residential areas of Western Australia.

The DER monitoring stations are generally located within the urbanised coastal regions of Western Australia, with the closest monitoring station (Geraldton) located over 500 km west of the proposed Yeelirrie Uranium Project site. The DER monitoring stations are influenced by urban activities and industrial emission sources that tend to emit a higher proportion of fine particles to total suspended particles (TSP) than occurs in the natural environment. The sources of CO, NO_2 and SO_2 are also expected to be significantly greater than those in the pastoral Yeelirrie region. Consequently, measurements of particulates, CO, NO_2 and SO_2 at the DEC sites would be higher than those occurring at the proposed Yeelirrie Uranium Project site, which is a significant distance from any industrialised, urban environments. Notwithstanding this, the monitoring data can be used to provide a conservative estimate of ambient background concentrations at the proposed Yeelirrie Uranium Project site.

A summary of the monitoring data recorded in recent years at the sites most representative of the site of the Yeelirrie Uranium Project site is presented in Table 8, Table 9 and Table 10 for PM_{10}, $PM_{2.5}$ and other key pollutants emitted by the proposed power generation, respectively.

Table 8 Particulates (as PM_{10}) summary for Perth and Geraldton in Western Australia

Monitoring station	Year	6th Highest (µg/m³)	99th Percentile (µg/m³)	95th Percentile (µg/m³)	90th Percentile (µg/m³)
Geraldton	2011	45.7	47	40.2	33.8
	2012	44.5	45.9	38.9	34.6
	2013	41.3	45.4	35.8	32.2
Caversham, Perth	2011	40.3	49.2	27.2	24.4
	2012	31.3	34.4	26.2	23.6
	2013	31.2	33.2	27.3	23.8
Duncraig, Perth	2011	29.9	35.5	26.1	23.0
	2012	31.1	32.1	25.6	22.8
	2013	29.7	30.1	25.7	23.2

Table note:

Data sources: Government of Western Australia Department of Environment Regulation, Air Monitoring Report (2011, 2012, 2013)

Table 9 **Particulates (as PM$_{2.5}$) summary for Perth in Western Australia**

Monitoring station	Year	Maximum (μg/m^3)	95th Percentile (μg/m^3)	90th Percentile (μg/m^3)	Annual Average (μg/m^3)
Caversham, Perth	2011	41.5	10.8	9.8	7.0
	2012	45.9	12.3	10.6	7.8
	2013	22.6	13.6	11.6	7.9
Duncraig, Perth	2011	52.1	11.5	10.4	7.8
	2012	77.3	12.7	11	8.2
	2013	18.7	12.7	11.4	7.6

Table note:

Data sources: Government of Western Australia Department of Environment Regulation, Air Monitoring Report (2011, 2012, 2013)

Table 10 **Air quality data summary for the Perth metropolitan and southwest regions of Western Australia during 2013**

Pollutant	Averaging Period	Monitoring station	95th Percentile	75th Percentile	50th Percentile
Carbon monoxide	8-hour	Duncraig (north metropolitan region)	1380 μg/m^3 (1.2 ppm)	460 μg/m^3 (0.4 ppm)	345 μg/m^3 (0.3 ppm)
Nitrogen dioxide	1-hour	Rolling Green (outer east rural)	28.2 μg/m^3 (0.02 ppm)	24.4 μg/m^3 (0.01 ppm)	11.1 μg/m^3 (0.006 ppm)
Sulfur dioxide	1-hour	Rockingham (south coast)	96.9 μg/m^3 (0.04 ppm)	36.7 μg/m^3 (0.01 ppm)	13.1 μg/m^3 (0.005 ppm)
	24-hour		13.1 μg/m^3 (0.005 ppm)	7.9 μg/m^3 (0.003 ppm)	2.6 μg/m^3 (0.001 ppm)

Table note:

Data source: Government of Western Australia Department of Environment and Conservation, 2008 Western Australia Air Monitoring Report (December 2009)

4.4.3 Background levels

The background levels selected for the assessment are presented in Table 11. The values selected for 24-hour average concentrations of PM_{10} and $PM_{2.5}$ and annual average $PM_{2.5}$ were based on the range of values shown in Table 8 and Table 9. Annual PM_{10} concentrations are taken as 50% of the 24 hour based on the relationship the 95th percentile and the 50th percentile for PM_{10} at the monitoring stations.

There are currently no known measurements of TSP in the region. The standard conversion ratios detailed in the United States Environmental Protection Agencies (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. In accordance with standard industry practice, this ratio has been employed for this assessment.

Currently monitoring of dust deposition levels is not conducted in the surrounding region. The New South Wales Environmental Protection Authority (NSW EPA) has set dust deposition impact assessment criterion to prevent impacts to residential amenity. The impact assessment criterion is expressed as an incremental increase in dust deposition levels over background due to the operation of a facility of 2.0 g/m²/month (DEC, 2006). Due to the absence of dust deposition monitoring data in the vicinity of the proposed Yeelirrie Uranium Project, the impact assessment criterion specified by the NSW EPA has been used in this assessment.

The background concentrations will provide a conservative estimate of the accumulative impact from the proposed Yeelirrie Uranium Project. As the background estimates are based on monitoring data from regions subject to anthropogenic pollution sources as well as natural (fugitive) sources, the concentrations will be significantly higher than those likely to be experienced at Yeelirrie. Monitoring of ambient dust levels at the proposed Yeelirrie Uranium Project site prior to and during operation of the mine will confirm background levels of particulates at the site.

This assessment has not included a background concentration for CO, NO_2 or SO_2 due to the lack of significant existing sources of these pollutants in the region, with all sources located greater than 60 km from the proposed Yeelirrie Uranium Project site.

Table 11 TSP, PM_{10} and $PM_{2.5}$ concentrations used as background concentrations for the proposed Yeelirrie Uranium Project

Pollutant	Averaging period	Concentration (µg/m³)
TSP	24-hour	50
	Annual	25
PM_{10}	24-hour	25
	Annual	12.5
$PM_{2.5}$	24-hour	10.8
	Annual	7.7

5. EMISSIONS

5.1 Sources of emissions

The vast majority of dust from mining activities consists of coarse particles (around 40 percent) and particles larger than PM_{10}, generated from natural activities such as mechanical disturbance of rock and soil materials by dragline or shovel, bulldozing, blasting and vehicles on dirt roads. Particles are also generated when wind blows over bare ground and different types of stockpiles (NSW Government, 2010). The potential sources of dust from the proposed Yeelirrie Uranium Project are outlined in the following sections.

5.1.1 Construction

Construction has the potential to cause elevated levels of dust if not appropriately managed. Construction phase activities at the project site can be broadly described as:

- Preparation of the site for mining and the construction of the Metallurgical Plant, including the initial clearing of vegetation and stockpiling of topsoil for subsequent reuse
- Establishment of mine infrastructure
- Establishment of the quarry
- Commencement of pit dewatering
- Construction of initial water management infrastructure

The major sources of dust during construction are expected to be earthworks, such as vegetation clearance, topsoil removal and storage.

5.1.2 Mining operations

The major source of dust emissions from conventional open-cut mining is the truck and excavator operation to remove overburden and ore. Sources of emissions associated with the extraction process include the following:

- Dozer ripping of overburden
- Excavator on overburden and ore and loading into trucks
- Transport of overburden and ore to stockpiles
- Dumping of overburden and ore to stockpiles
- Wind erosion of exposed pits and storage stockpiles

The ore stockpiles will be managed so that stocks of high-grade material will be exposed for no more than 18 months and medium-grade materials up to twenty years. Low-grade materials and overburden may be exposed for the life of the operation, depending on the progress of rehabilitation activities and the economics associated with the processing of the lower-grade ore.

Mining will initially target areas of higher grade uranium ore, with the Metallurgical Plant continuing to treat ore from stockpiles until the economic material has been processed. In this assessment ore are defined as either ultra high grade (UHG), very high grade (VHG), high grade (HG), medium grade (MG) or low grade (LG).

5.1.3 Metallurgical Plant

The dust emissions from the Metallurgical Plant will be minimal, with the leaching, precipitation, refining and packaging processes occurring within a closed environment. The predominant sources of dust emissions will be associated with the ore preparation phase, and will include:

- Dumping of ore to ROM stockpiles
- Wind erosion of ROM stockpiles
- Loading of ore into crushing unit by front end loader (FEL)
- Crushing unit
- Conveyor between crushing unit and semi autogenous grinding (SAG) mill
- Transfer points (crusher to conveyor and conveyor to SAG)
- SAG mill

5.1.4 Quarry operations

Dust will be emitted from the quarry proposed to be located approximately 8km north of the project. The quarry will supply material to the project during the first three years of operation to assist in construction. The sources of dust emissions from the quarry will include:

- Wind erosion of exposed area
- Haulage of material from the quarry to the project
- Material transfers at the quarry

5.1.5 On-site power generation

A series of diesel-fired electricity generators and local electricity transmission infrastructure will be installed to meet the proposed electricity demand of 15 Megawatts (MW) and an estimated average annual electricity consumption of around 150,000 MWh. Twelve diesel-fired generators will be installed at the Metallurgical Plant.

Emissions from the operation of the diesel-fired generators will include NOx, CO, SO_2, hydrocarbons and particulates (PM_{10} and $PM_{2.5}$). Exhaust gases from the generators will be collected and conveyed via a waste heat boiler and blower fan to the carbonation stage of the Metallurgical Plant where the carbon dioxide content will be utilised to convert sodium hydroxide to sodium carbonate and bicarbonate. It has been assumed that NOx, CO, SO_2, hydrocarbons and particulate emissions are unchanged as a result of this to provide a worst-case assessment of potential impacts.

Details of stack characteristics and the emission rates of SO_2, NOx, CO, hydrocarbons and particulates (PM_{10} and $PM_{2.5}$) from the onsite diesel generators used in the dispersion modelling are presented in Section 5.4. Emission rates of NOx have been based on rich-burn engines with no emission controls. Rich burn engines can employ catalytic controls that will reduce NOx, CO and hydrocarbon emissions significantly. Alternatively, lean-burn engines can also produce lower emissions of NOx compared with uncontrolled rich burn engines.

5.2 Representative operations

The air quality impact assessment has assessed the emissions from the Yeelirrie Uranium Project during one year of mine operations. The scenario has been selected to represent the mining activities that will have the highest potential for causing offsite impacts.

For the majority of dust producing activities the dust emission rate is dependent on the estimated quantities of overburden and ore to be extracted and processed. Mining will occur for up to 15 years at a rate of up to 14 Mtpa and would initially occur for 24-hours per day, with the subsequent mining schedule being as necessary to achieve production targets. Processing on-site may occur for up to 15 years after mining ceases.

The proposed mining sequence will begin targeting the highest grade ore within the ore body and will then progress east and west until the entire pit area shown in Figure 8 has been mined. Pit dewatering will occur approximately one year in advance of the mining schedule. Tailings will be disposed of in previously mined pit areas, and after the tailings have dried out, rehabilitation will take place.

It has been assumed that the worst-cast potential impacts, in terms of ground-level concentrations at nearest sensitive receptors, will occur during operation of the mine during Year 3 of operations, as the proposed volume of overburden and total material mined are both at a maximum and operations are assumed to be 24-hours per day. While the milling rate is not at its maximum, this is typically not the most significant source of emissions.

Figure 8 illustrates the layout of the mine and Metallurgical Plant in Year 3, including the ore body, open pit, previously used pits and storage stockpiles. Mining in Year 3 occurs on the eastern half of the project boundary, with dewatering occurring on either side of the excavated pit area in preparation for the next year of mining.

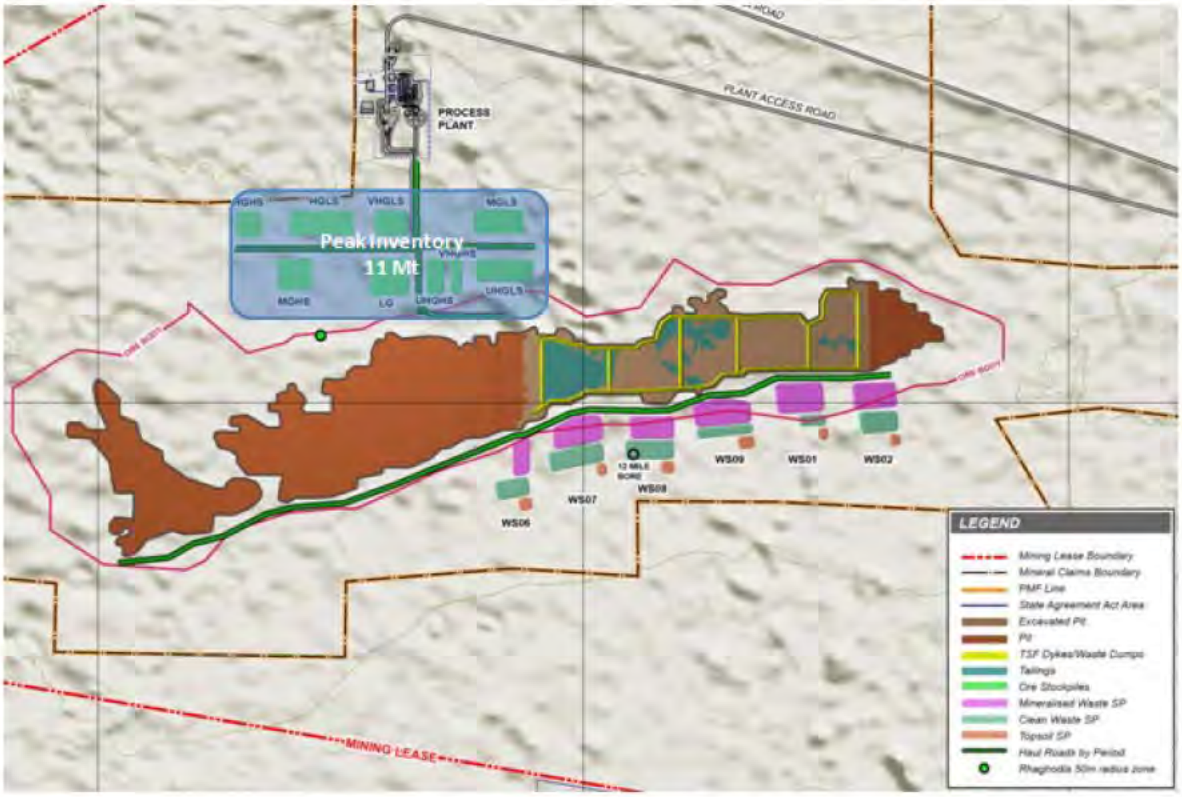


Figure 8 Mine layout during Year 3

A breakdown of the material extracted from the pits during Year 3 is presented in Table 12.

Table 12 Estimated tonnes of material extracted from open pit during Year 3

Material	Tonnes extracted from open pit
UHG ore	1,018,850
VHG ore	943,889
HG ore	1,489,466
MG ore	1,120,011
LG ore	-
Overburden	7,441,137
Topsoil	330,317
Total	**12,343,671**

In Year 3 approximately 1.3 Mt of ore will be processed. This consists of ultra and very high grade ore and includes a quantity of ore extracted during prior years and stockpiled near the processing plant. A breakdown of the processed ore into the various grades is presented in Table 13.

Table 13 Estimated ore throughput at the Metallurgical Plant during Year 3

Material	Tonnes [1]
UHG ore	1,023,257
VHG ore	276743
Total ore	**1,300,000**

Table note:

1 Total tonnes of material transferred from storage stockpiles to RoM stockpile and subsequently processed at Metallurgical Plant during modelled period

Key parameters used to estimate emissions of dust from quarry operations are presented in Table 14.

Table 14 Details used to estimate quarry emissions during Year 3 (provided by Cameco)

Parameter	Units	Value
Surface area	m^2	100,000
Material extracted from quarry	tonnes/day	457
Haul distance from quarry to Metallurgical Plant	km	8

5.3 Operational controls

A suite of best practice operational controls have been applied to the emissions estimate. These controls are listed in Table 15.

Table 15 Operational controls employed as best practice and included in the dispersion modelling

Source	Control measure	Level of control
Active stockpiles [1]	Continuous watering using water cart and local ground water sources	50%
Topsoil stockpiles	Sealant product (e.g. Rainstorm Gluon 240) applied via water cart	84% (after 3 months of inactivity)
Inactive stockpiles [2]	Sealant product (e.g. Rainstorm Gluon 240) applied via water cart	84% (after 3 months of inactivity)
Working pit areas (active [3])	Continuous watering using water cart and local ground water sources	50%
Inactive pit areas [4]	Rehabilitated with original surface cover material appropriately stockpiled, followed by ripping and seeding with appropriate native vegetation	99%
Onsite haul Roads	Continuous watering using water cart and local ground water sources and road stabilisation product applied (Level 2 watering of > 2.0 litres/m²/hr)	75%
Metallurgical Plant (leaching, CCD and uranium recovery)	Enclosed	100%[5]
Packaging area	Wet scrubber will be installed and area will be at negative pressure	100%[5]

Table note:

1 Active stockpiles refers to those where loading and/or dumping activities are carried out during the operational period

2 Inactive stockpiles refers to those used previously, with no loading and/or dumping activities carried out during the operational period

3 Active/working pit refers to the pit where excavation, loading, etc. activities are carried out during the operational period

4 Inactive pit areas refers to those used previously, with no excavation, loading, etc. activities are carried out during the operational period

5 100% control has been assumed for the assessment. In reality emissions may occur, however, these will be negligible due to the proposed control measures

5.4 Emissions inventory

Dust emission rates have been calculated using the detailed information on mining activities, standard metalliferous mining emission factors, published literature values for some material characteristics and meteorological data. These emission factors, activity data and literature values are provided in Appendix B. The estimated emissions are summarised in Table 16 and Table 17.

Table 16 **Estimated dust emission rates from mining, metallurgical plant and quarry during Year 3**

Emission source	Total dust emission rate (kg/annum)		
	TSP	PM_{10}	$PM_{2.5}$
Mining activities	1,215,900	482,017	64,002
Metallurgical Plant	146,909	46,309	5,166
Quarry	14,887	7,444	1,117
Generators	-	541	541
Total	1,377,696	536,310	70,825

Table 17 **Stack characteristics and estimated emission rates from on-site power generation during Year 3**

Parameter	Units	Value
Number of units	number	12
Stack height	m	6
Stack diameter	m	0.3
Exit velocity	m/s	62.9
Exhaust temperature	°C	420
Emission rate of NO_x (per unit)	g/s	9.36
Emission rate of CO (per unit)	g/s	0.37
Emission rate of SO_2 (per unit)	g/s	0.09
Emission rate of PM_{10} (per unit)	g/s	0.009
Emission rate of $PM_{2.5}$ (per unit)[1]	g/s	0.009

Table note:

1 Assumed to be the same as PM_{10}

6. DISPERSION METEOROLOGY FOR THE SITE

This section presents a summary of the CALMET predicted wind speed, wind direction, stability class and mixing height for the Yeelirrie Uranium Project for the model simulation period of February 2010 to January 2011.

6.1 Wind speed and wind direction

Wind speed and wind direction are important aspects that can influence the emission rate of dust from the Yeelirrie Uranium Project. Exposed surfaces such as stockpiles and active pits will have higher dust emissions during strong winds than during light winds. The dust emissions will also be transported over greater distances during periods of higher wind speeds due to the dust particles remaining suspended and getting carried further distances. However, stronger winds will also cause greater atmospheric turbulence, resulting in lower ground-level concentrations of dust.

The annual, diurnal and seasonal distributions of CALMET predicted winds at the Yeelirrie Uranium Project are presented as wind roses in Figure 9, Figure 10 and Figure 11. The predominant winds from the east will transport dust to regions west of the Yeelirrie Uranium Project.

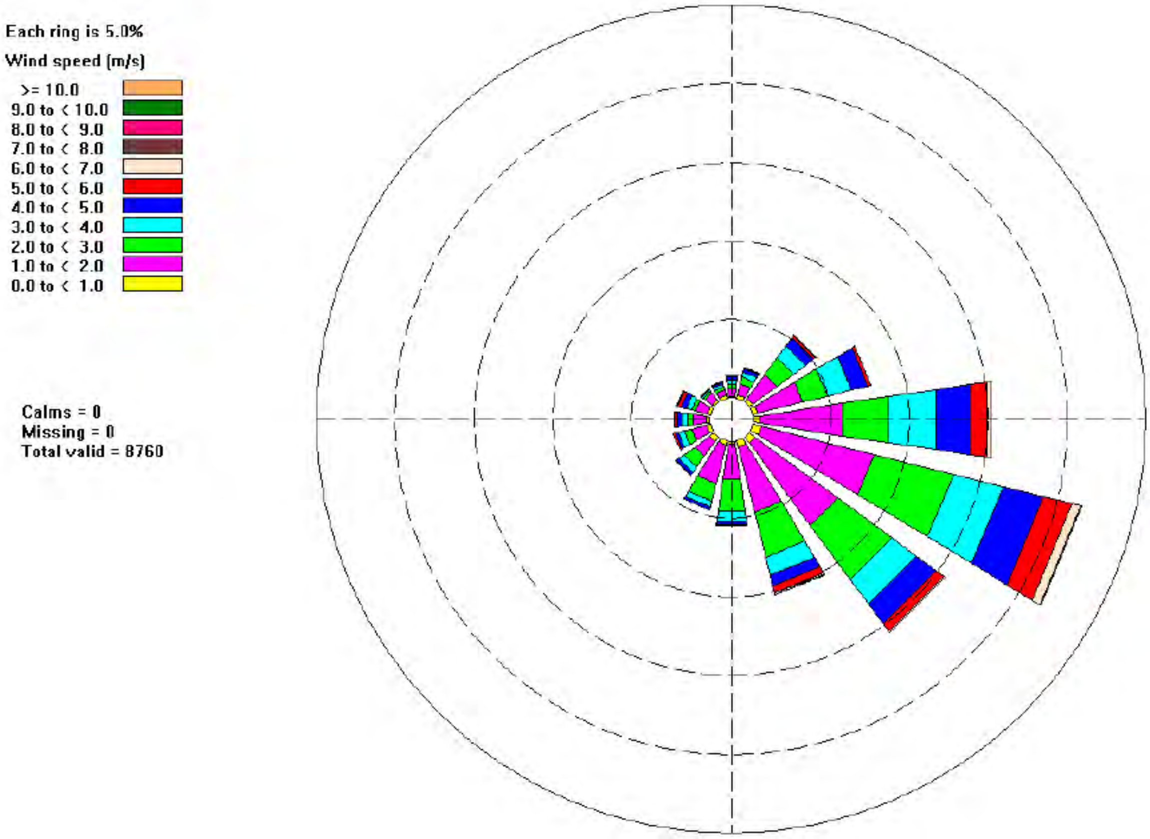


Figure 9 **Predicted annual distribution of winds at the Yeelirrie Uranium Project**

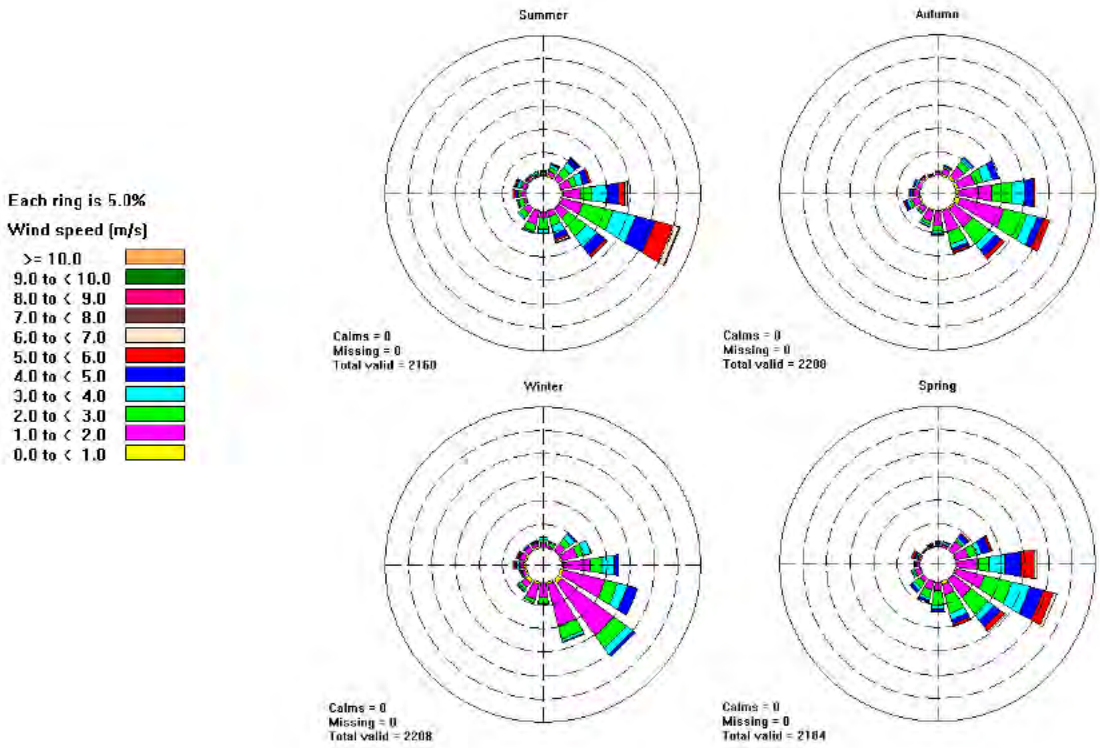


Figure 10 Predicted seasonal distribution of winds at the Yeelirrie Uranium Project

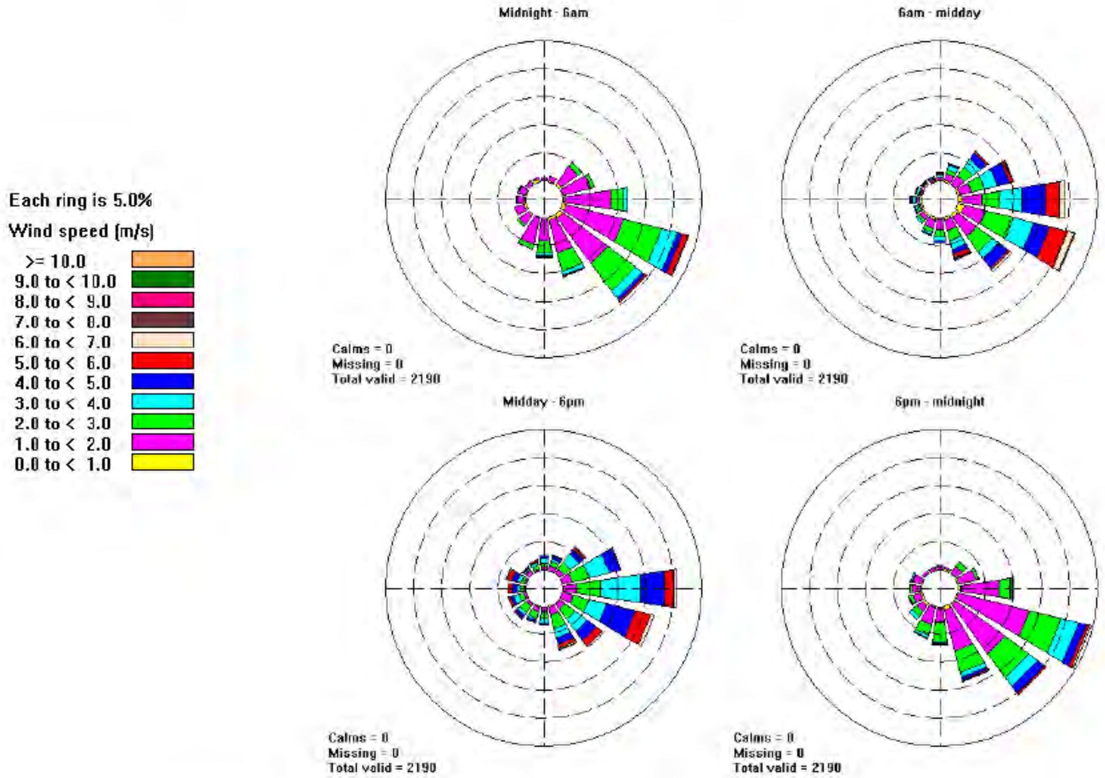


Figure 11 Predicted diurnal distribution of winds at the Yeelirrie Uranium Project

A summary of the annual, diurnal and seasonal frequency of wind speeds predicted by CALMET at the site of the Yeelirrie Uranium Project is shown in Table 18. The data show the winds are predominantly light to moderate, with approximately 43% of winds less than 2 m/s, and a further 39% of winds between 2 and 4 m/s. Dust emissions associated with wind erosion of erodible surfaces, such as exposed ground, spoil dumps and stockpiles, are essentially zero at low wind speeds and will remain so until the wind speed exceeds a threshold that is specific to the particular material surface, but is generally found to be above 5 – 6 m/s. CALMET predicts around 16% of the annual winds to be greater than 4 m/s. During the afternoon period (midday to 6pm), 31% of winds are predicted to be greater than 4 m/s, and during spring 23% of winds greater than 4 m/s.

During light wind conditions, dust levels in close proximity to dust producing activities may be relatively elevated due to the lower rate of dispersion that occurs under such conditions. Light winds (i.e. with speed less than 2 m/s) are predicted to account for 43% of the annual winds at the project site, with these winds occurring predominantly during the early morning (midnight to 6am) and night (6pm to midnight). Seasonally, these light wind conditions are significantly more likely to occur during autumn and winter.

Table 18 Summary of wind speeds at Yeelirrie Uranium Project as generated by CALMET

Period	**Wind speed**			
	< 2 m/s	**2 – 4 m/s**	**4 – 6 m/s**	**> 6 m/s**
Annual	43 %	39 %	16 %	1 %
Diurnal distribution				
Midnight to 6am	65 %	31 %	4 %	< 1 %
6am to midday	32 %	41 %	24 %	3 %
Midday to 6pm	17 %	50 %	31 %	2 %
6pm to midnight	60 %	35 %	5 %	< 1 %
Seasonal distribution				
Spring	33 %	42 %	23 %	2 %
Summer	28 %	48 %	21 %	3 %
Autumn	51 %	36 %	13 %	< 1 %
Winter	62 %	31 %	7 %	0 %

6.2 Atmospheric stability and mixing height

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 Class A, which represents very unstable atmospheric conditions that may typically occur on a sunny day to Class F, 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 19 shows the percentage of stability classes at the project site for the February 2010 to January 2011 meteorological data used in the dispersion modelling, where Class A represents the most unstable conditions and Class F representing the most stable conditions.

Table 19 **Frequency of occurrence (%) of surface atmospheric stability at the project site under Pasquil-Gifford stability classification scheme**

Pasquil-Gifford stability class	Classification	Frequency (%)
A	Extremely unstable	1.3
B	Unstable	13.1
C	Slightly unstable	20.8
D	Neutral	18.9
E	Slightly stable	6.9
F	Stable	38.9

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 project site and is presented in Figure 12. The data shows that the mixing height develops around 7am, increases to a peak around 3pm before descending rapidly.

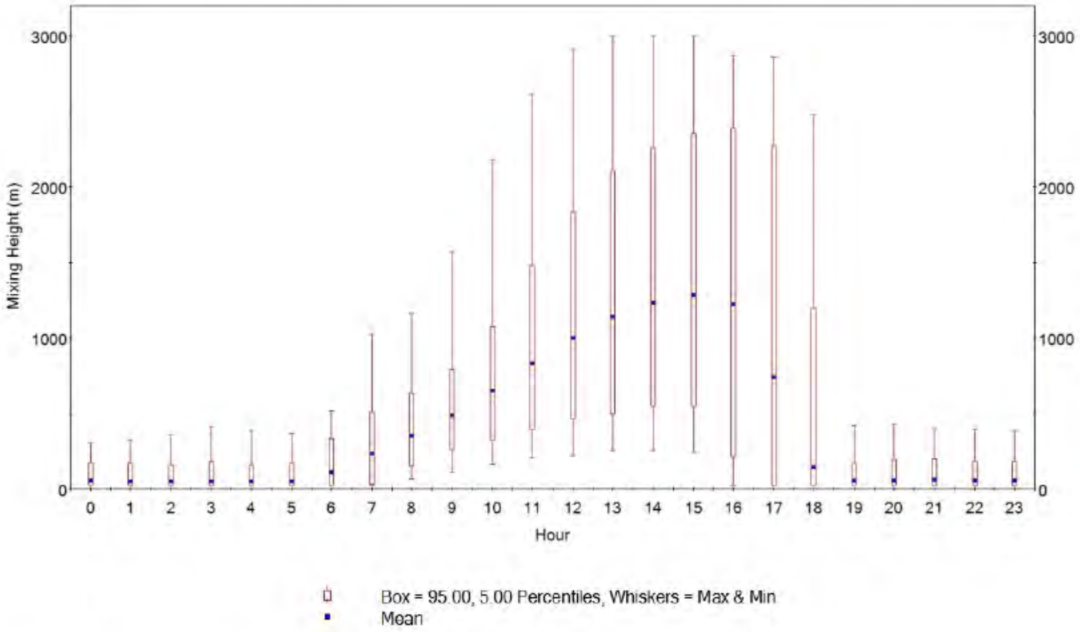


Figure 12 **Diurnal profile of mixing height at the project site**

7. RESULTS OF DISPERSION MODELLING

7.1 Mining, metallurgical plant and quarry

Plate 1 to Plate 12 show the maximum predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates due to the Yeelirrie Uranium Project.

The predicted maximum 24-hour average and annual average ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ to the Yeelirrie Uranium Project at the nearest sensitive receptor locations are presented in Table 20. Annual average dust deposition rates are also shown in Table 20. Results have been presented for the Yeelirrie Pool, Accommodation Village, Yeelirrie Homestead, Ululla Homestead and Palm Springs. As the Accommodation Village and Yeelirrie Homestead are in close proximity, the maximum predicted ground-level concentration of each pollutant has been presented. All other sensitive receptors listed in Section 4.2, Table 4 are outside of the model domain. Predicted ground-level concentrations of air pollutants at these receptors that are likely to occur due to the Yeelirrie Uranium Project were predicted to be well below the relevant air quality criteria for all pollutants.

The ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ are presented with and without a background concentration. The dust deposition rates are presented for the project in isolation and compared to the criterion of 2.0 g/m²/month in accordance with the NSW EPA's Approved Methods.

The results of dispersion modelling of particulates from the Yeelirrie Uranium Project show:

- The predicted maximum 24-hour average ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ at the nearest sensitive receptors due to mine operations (with background) ***comply*** with the relevant air quality criteria.
- The predicted annual average ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ at the nearest sensitive receptors due to mine operations (with background) ***comply*** with the relevant air quality criteria.
- Incremental dust deposition rates outside the MLA boundary due to mine operations are predicted to ***comply*** with the air quality criterion of 2 g/m²/month.

Table 20 **Predicted ground-level concentrations (µg/m³) of TSP, PM_{10} and $PM_{2.5}$ and dust deposition rate (g/m²/month) due to the Yeelirrie Uranium Project**

Pollutant	Averaging Period	Air quality criteria	Accommodation village/ Yeelirrie Homestead		Yeelirrie Pool		Ululla Homestead		Palm Springs	
			Operationally contributed	With back-ground	Operationally contributed	With back-ground	Operationally contributed	With back-ground	Operationally contributed	With back-ground
TSP	24-hour maximum	90	4.7	54.7	14.4	64.4	5.6	55.6	0.4	50.4
	Annual	90	0.1	25.1	1.1	26.1	0.2	25.2	0.01	25.0
PM_{10}	24-hour 6th highest [1]	50	1.3	26.3	10.9	35.9	1.7	26.7	0.1	25.1
	Annual	25	0.1	12.6	1.0	13.5	0.2	12.7	0.01	12.5
$PM_{2\ 5}$	24-hour maximum	25	1.1	11.9	3.5	14.3	0.9	11.7	0.1	10.9
	Annual	8	0.01	7.7	0.2	7.9	0.04	7.7	0.002	7.7
Dust dep.	Annual	2 [2]	0.002	n/a	0.013	n/a	0.006	n/a	0.0004	n/a

Table note:

1 6th Highest 24-hour concentration presented for PM_{10} in accordance with the Air NEPM
2 Dust deposition criterion of 2 g/m²/month is maximum increase in deposited dust level above background

7.2 On-site power generation

Plate 13 to Plate 19 show the predicted maximum ground-level concentrations of NO_2, CO and SO_2 due to emissions from the on-site diesel generators. As discussed in Section 5.1.5, the exhaust emissions from the diesel generators will be captured and conveyed for use at the Metallurgical Plant to convert sodium hydroxide to sodium carbonate and bicarbonate; however, this assessment has assumed that NOx, CO, SO_2, hydrocarbons and particulate emissions are unchanged as a result of this to provide a worst-case assessment of potential impacts due to the Yeelirrie Uranium Project.

The predicted maximum and annual average ground-level concentrations at the nearest sensitive receptor locations are presented in Table 21. Results have been presented for the Yeelirrie Pool, Accommodation Village, Yeelirrie Homestead, Ululla Homestead and Palm Springs. As the Accommodation Village and Yeelirrie Homestead are in close proximity, the maximum predicted ground-level concentration of each pollutant has been presented. All other sensitive receptors listed in Section 4.2, Table 4 are outside of the model domain. Ground-level concentrations at these receptors that are likely to occur due to the Yeelirrie Uranium Project are predicted to be well below the relevant air quality criteria for all air pollutants.

The results of dispersion modelling of pollutants show:

- The maximum 1-hour average NO_2 concentration at Yeelirrie Pool is predicted to be greater than the Air NEPM criterion of 250 $\mu g/m^3$; however, one exceedance day is allowed for by the Air NEPM. As the maximum 1-hour average concentration on the 2nd highest day is 157.5 $\mu g/m^3$, concentrations at this receptor ***comply*** with the Air NEPM criterion
- The ground-level concentrations of 1-hour average NO_2 at all other nearest receptors ***comply*** with the air quality criterion;
- The ground-level concentrations of CO, SO_2, PM_{10}, and annual average NO_2 at all nearest sensitive receptors due to on-site power generation are predicted to ***comply*** with the relevant air quality criteria.

Emission rates of NOx have been based on rich-burn engines with no emission controls. Rich burn engines can employ catalytic controls that will reduce NOx, CO and hydrocarbon emissions significantly. Alternatively, lean-burn engines can also produce lower emissions of NOx compared with uncontrolled rich burn engines. It is expected that available contemporary NOx control technology can employed to significantly reduce NOx impacts in practice.

Table 21 **Predicted operationally contributed ground-level concentrations (µg/m^3) due to diesel generators (Assume zero capture of generator emissions)**

Pollutant	Averaging Period	Air quality criteria	Accommodation village/ Yeelirrie Homestead	Yeelirrie Pool	Ululla Homestead	Palm Springs
Nitrogen dioxide	1-hour maximum	250	42.2	157.5[1]	82.6	10.6
	Annual	62	0.02	0.6	0.2	0.03
Carbon monoxide	8-hour maximum	11,000	0.7	10.1	4.2	0.6
Sulfur dioxide	1-hour maximum	570	1.9	17.0	3.6	0.5
	24-hour maximum	230	0.1	1.6	0.7	0.1
	Annual	57	0.001	0.024	0.01	0.001
PM$_{10}$	24-hour 6th highest [1]	50	<0.01	0.07	0.02	<0.01
	Annual	25	<0.01	<0.01	<0.01	<0.01
PM$_{2.5}$	24-hour maximum	25	0.02	0.3	0.1	0.02
	Annual	8	<0.01	<0.01	<0.01	<0.01

Table note:

1 Maximum 1-hour concentration on 2nd highest day in accordance with the Air NEPM
2 6th Highest 24-hour concentration presented for PM$_{10}$ in accordance with the Air NEPM

8. CONCLUSIONS

Cameco Australia Pty Ltd (Cameco) proposes to develop an open pit uranium mine and associated processing facility at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie and 60 km west of Mt Keith. The Yeelirrie Uranium Project would provide approximately 7,500 tpa of uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), through the development and operation of an open pit mine and on-site Metallurgical Plant.

Katestone Environmental Pty Ltd has been commissioned by Cameco to prepare the air quality assessment of the proposed Yeelirrie Uranium Project, as part of a Public Environmental Review for the project. This assessment investigates the potential for air quality impacts to occur due to mining operations for a scenario representing a stage in the development that is likely to result in the highest ground-level concentrations at the closest sensitive receptors.

The assessment used meteorological and dispersion models to assess the potential impact associated with dust emissions (TSP, PM_{10}, $PM_{2.5}$ and dust deposition) from the proposed Yeelirrie Uranium Project in isolation (operationally contributed) and with the inclusion of ambient background levels of dust representative of the region.

The air quality assessment demonstrates that ground-level concentrations of the key mining related air pollutants: $PM_{2.5}$, PM_{10}, TSP and dust deposition would be below the relevant criteria at all sensitive receptors.

The Yeelirrie Uranium Project also includes onsite power generation using diesel generators. The potential air quality impact associated with the diesel generators was also assessed. The key air pollutants associated with diesel power generators include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and particulates (as PM_{10}).

Emission rates of NOx have been based on rich-burn engines with no emission controls. Rich burn engines can employ catalytic controls that will reduce NOx, CO and hydrocarbon emissions significantly. Alternatively, lean-burn engines can also produce lower emissions of NOx compared with uncontrolled rich burn engines.

The air quality assessment of the power generation plant demonstrates that NO_2, SO_2 and CO concentrations are predicted to comply with the air quality criteria at all sensitive receptors. One exceedance day of the 1-hour average NO_2 criterion of 250 $\mu g/m^3$ was predicted at the nearest receptor (Yeelirrie Pool, which is located 16.4 km southeast of the ore body); however, one exceedance day is allowed for by the Air NEPM.

It is expected that available contemporary NOx control technology can be employed to significantly reduce the NO_2 impacts in practice.

9. REFERENCES

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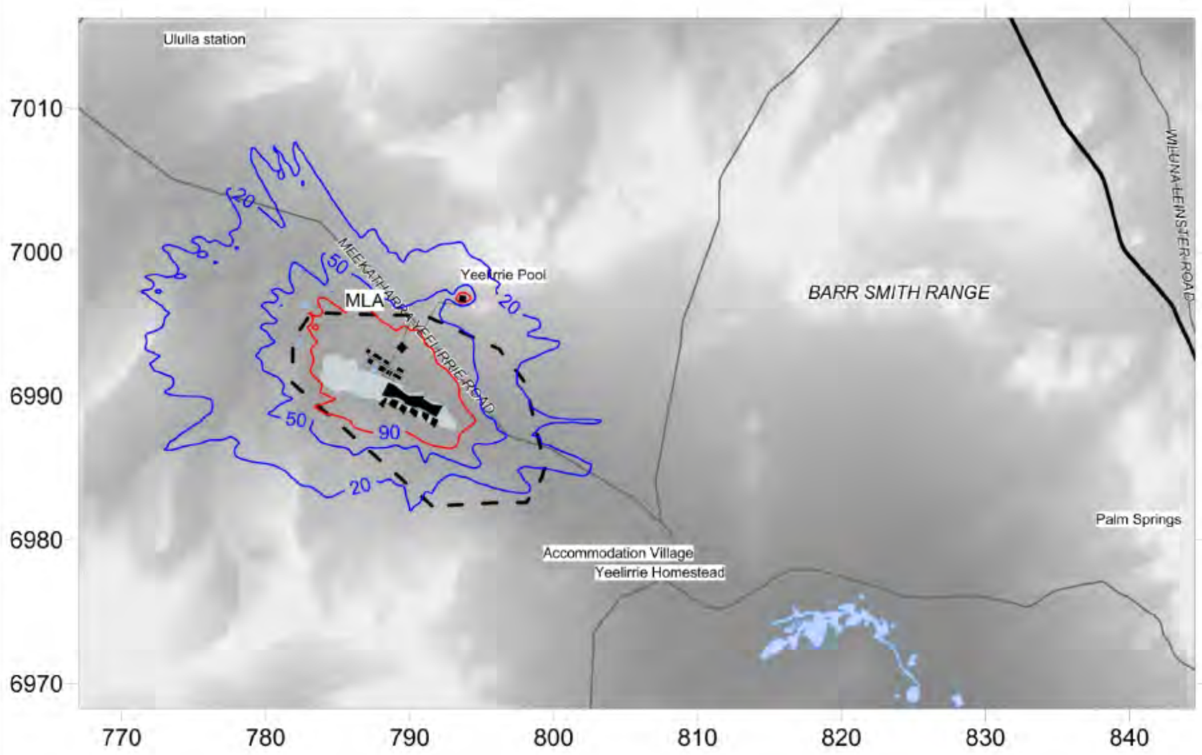


Plate 1 **Predicted operationally contributed maximum 24-hour average ground-level concentration of TSP**

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 90 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

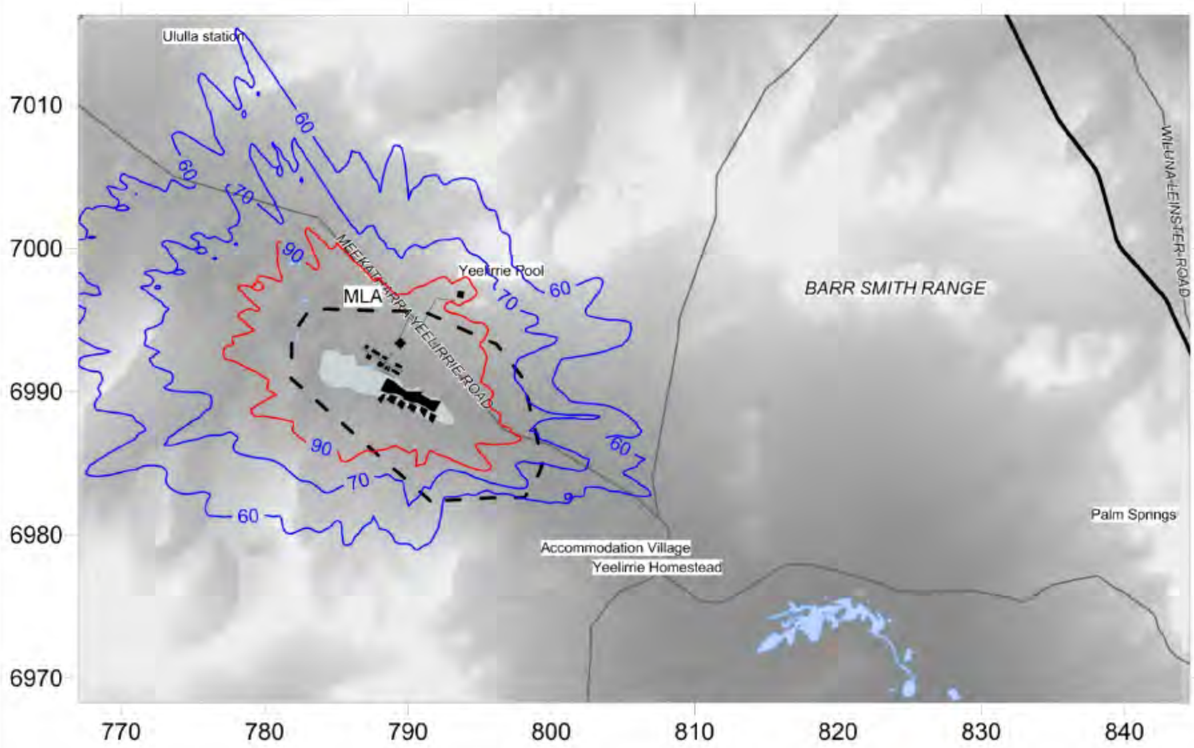


Plate 2 **Predicted maximum 24-hour average ground-level concentration of TSP with ambient background**

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 90 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

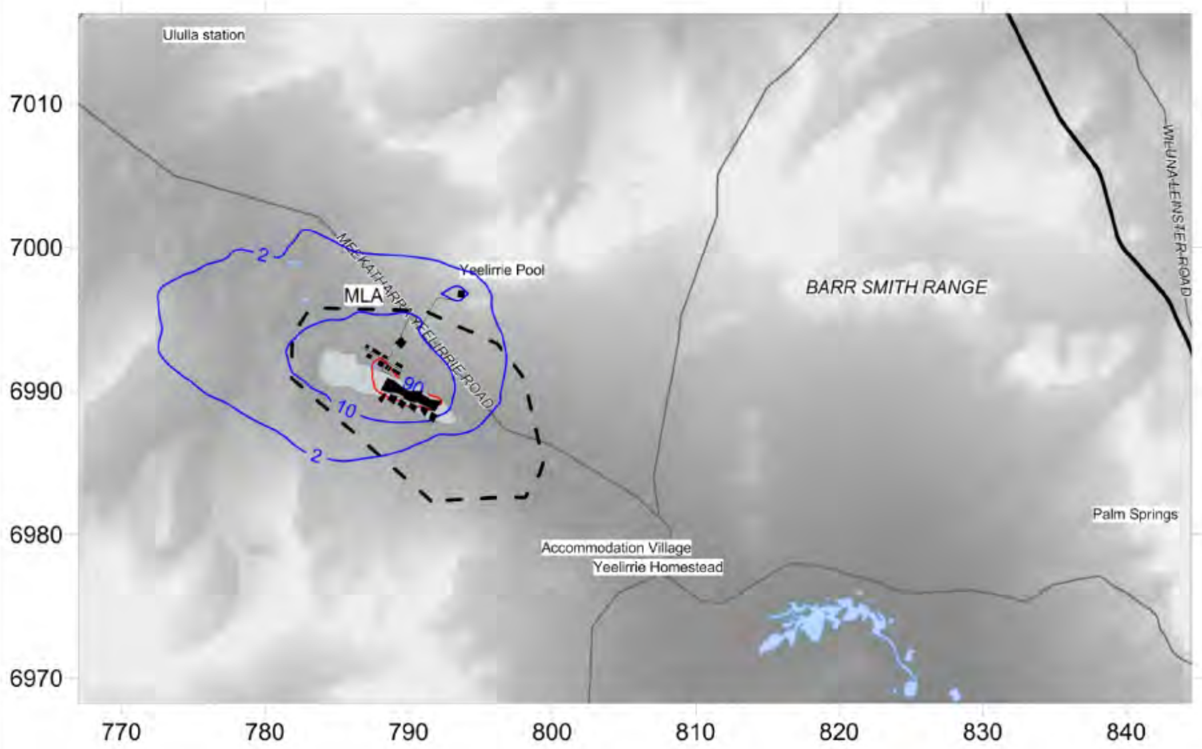


Plate 3 Predicted operationally contributed annual average ground-level concentration of TSP

Location: Yeelirrie, WA	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual contours, no background	**Standard:** 90 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

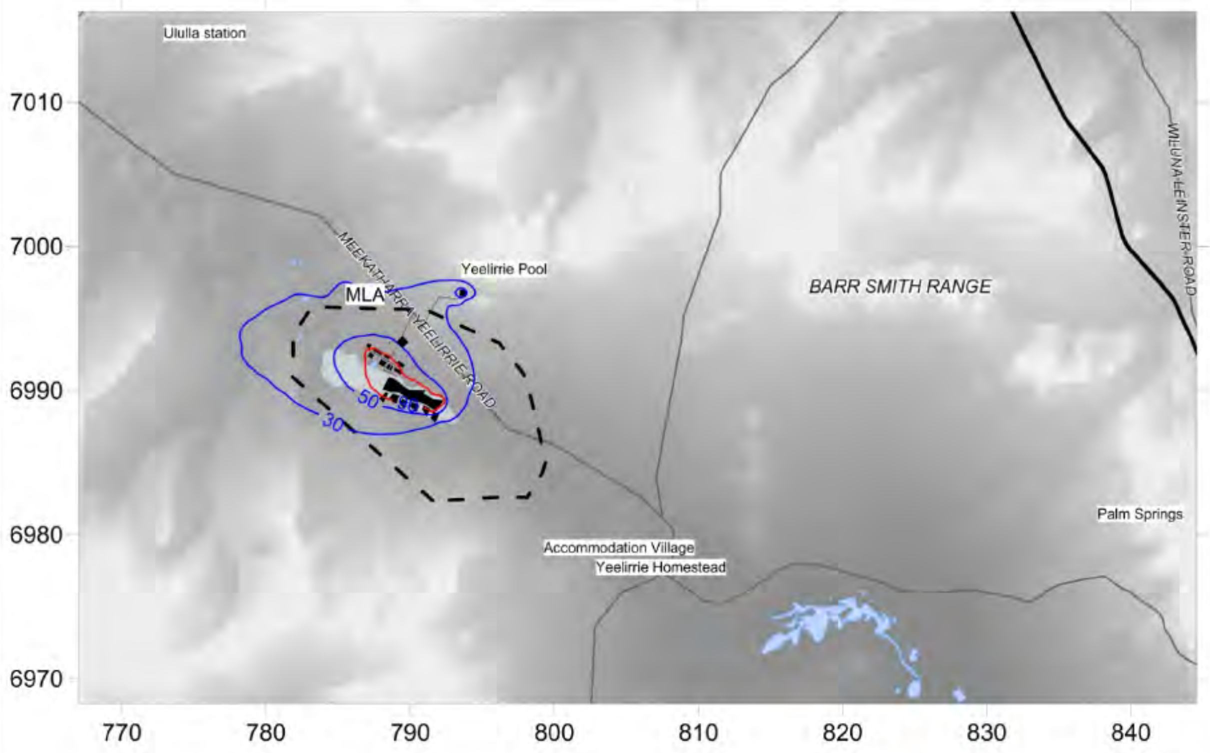


Plate 4	**Predicted annual average ground-level concentration of TSP with ambient background**		
Location: Yeelirrie, WA	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual contours, no background	**Standard:** 90 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

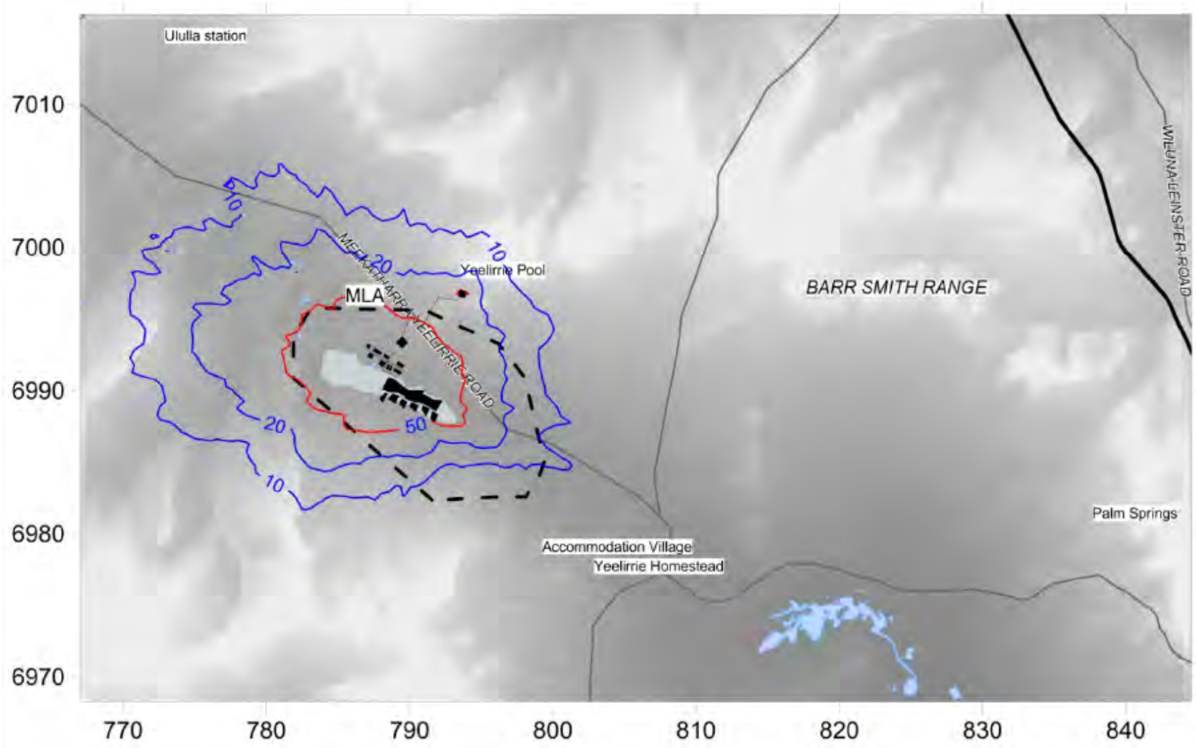


Plate 5 Predicted operationally contributed 6th highest 24-hour average ground-level concentration of PM_{10}

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA	24-hour	CALPUFF	µg/m³
Type:	**Standard:**	**Prepared by:**	**Date:**
6th highest contours, no background	50 µg/m³	Tania Haigh	2014

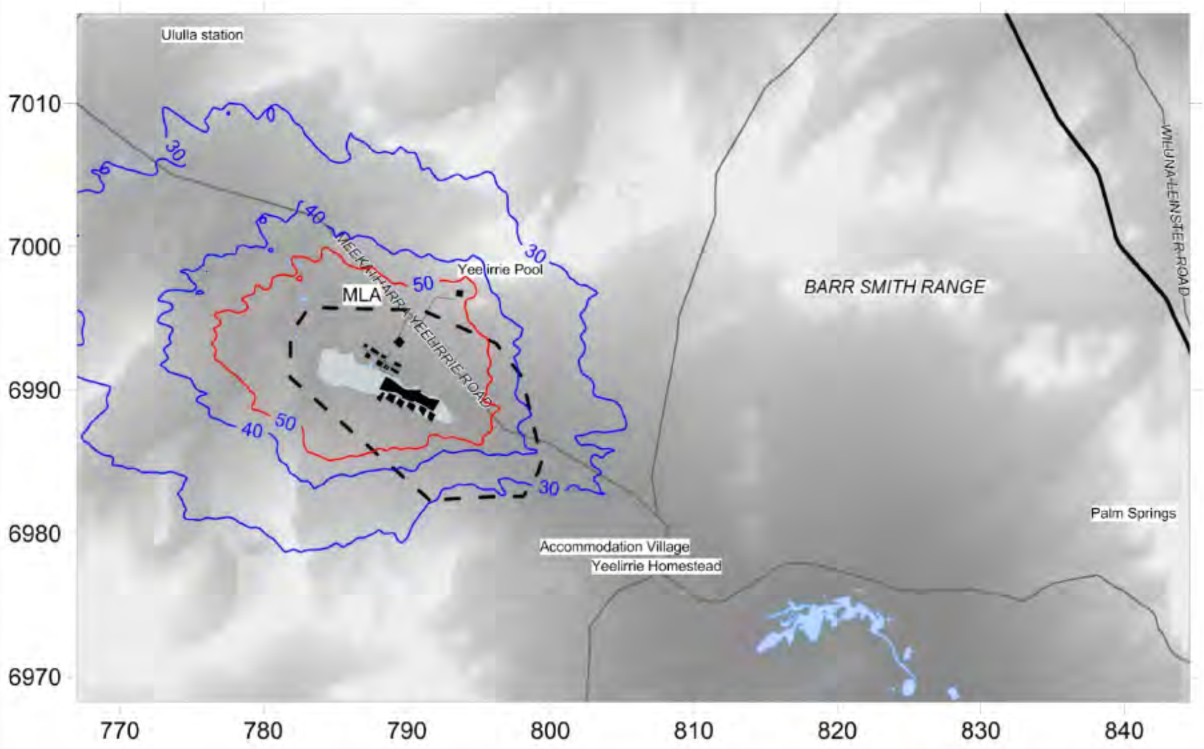


Plate 6 Predicted 6th highest 24-hour average ground-level concentration of PM_{10} with ambient background

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: 6th highest contours, no background	**Standard:** 50 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

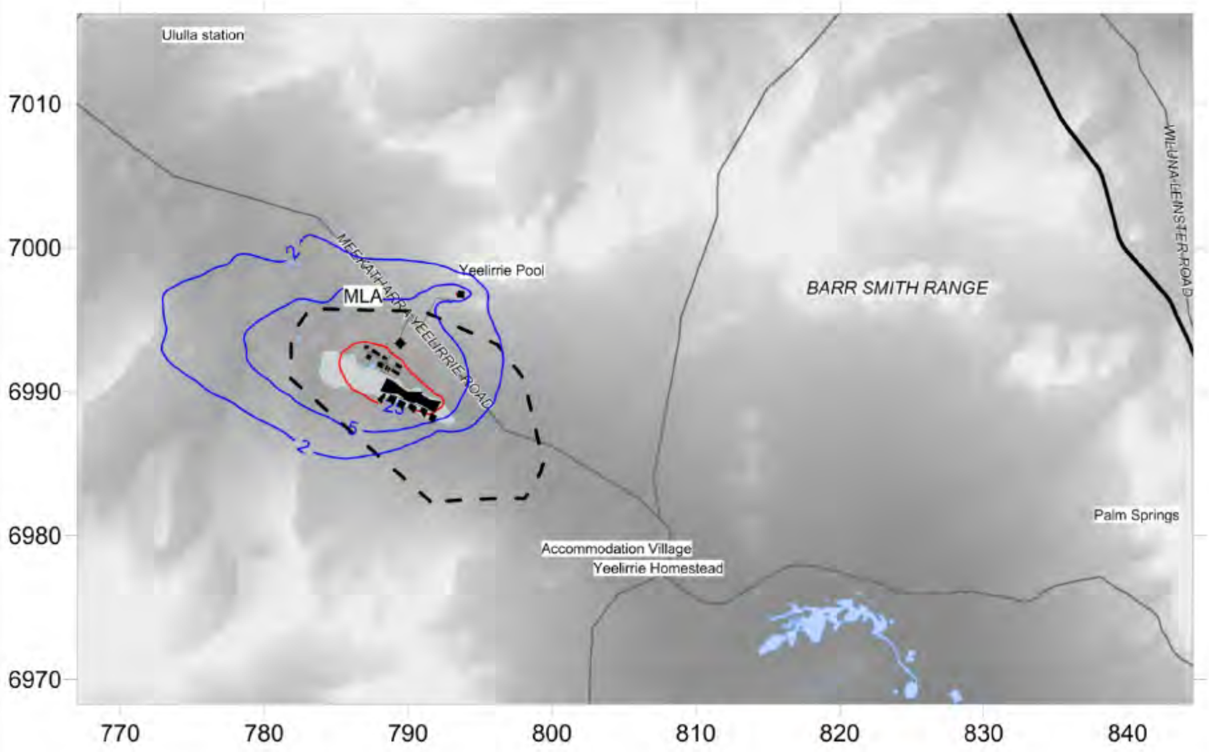


Plate 7 **Predicted operationally contributed annual average ground-level concentration of PM_{10}**

Location: Yeelirrie, WA	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual contours, no background	**Standard:** 25 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

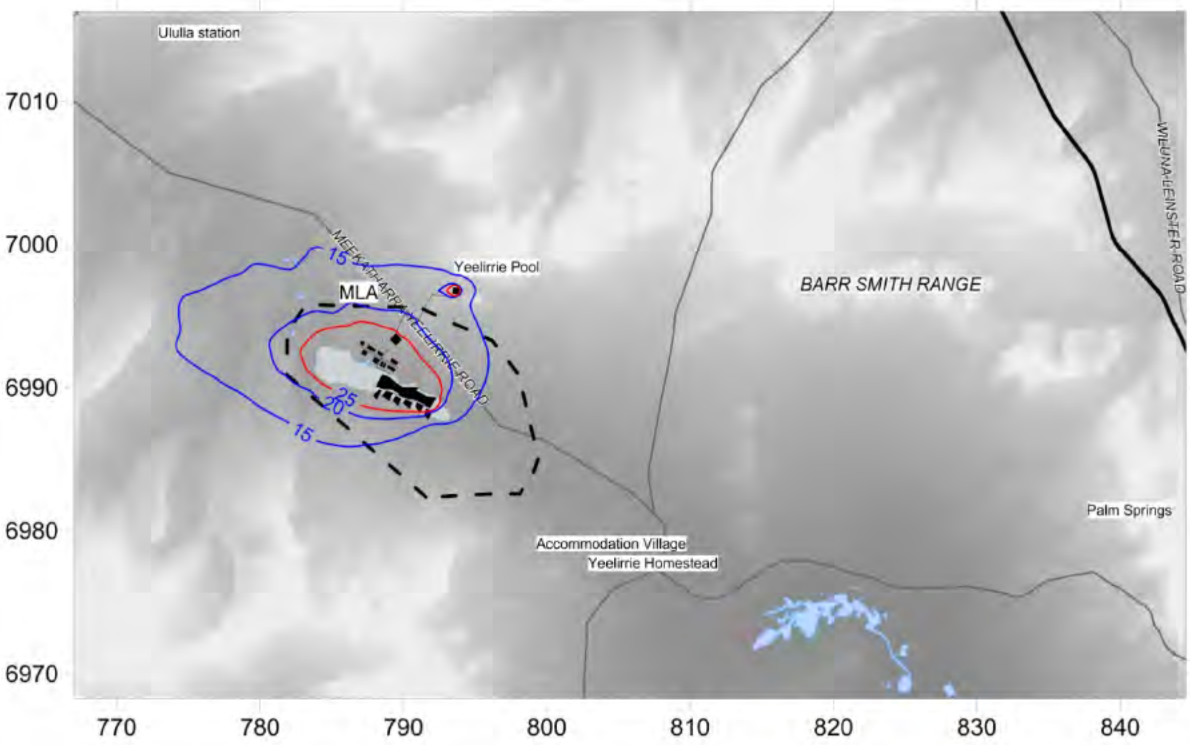


Plate 8 Predicted annual average ground-level concentration of PM_{10} with ambient background

Location: Yeelirrie, WA	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual contours, no background	**Standard:** 25 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

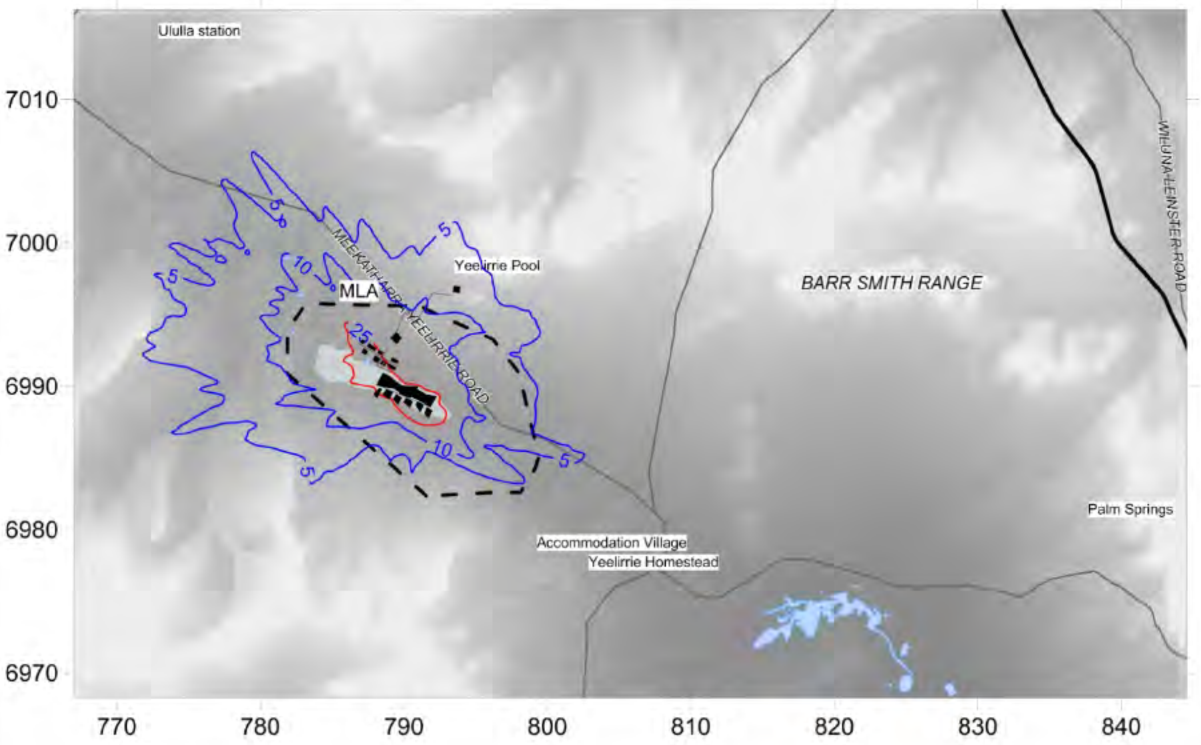


Plate 9 Predicted operationally contributed maximum 24-hour average ground-level concentration of $PM_{2.5}$

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 25 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

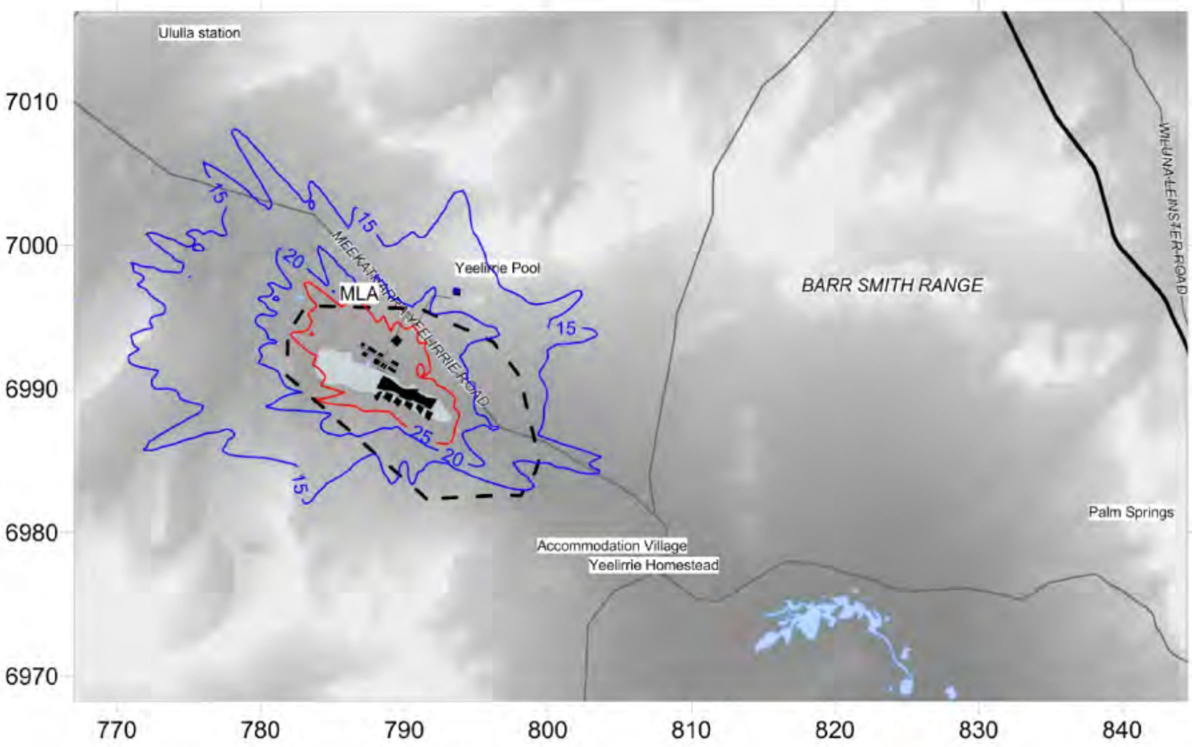


Plate 10 Predicted maximum 24-hour average ground-level concentration of $PM_{2.5}$ with ambient background

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 25 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

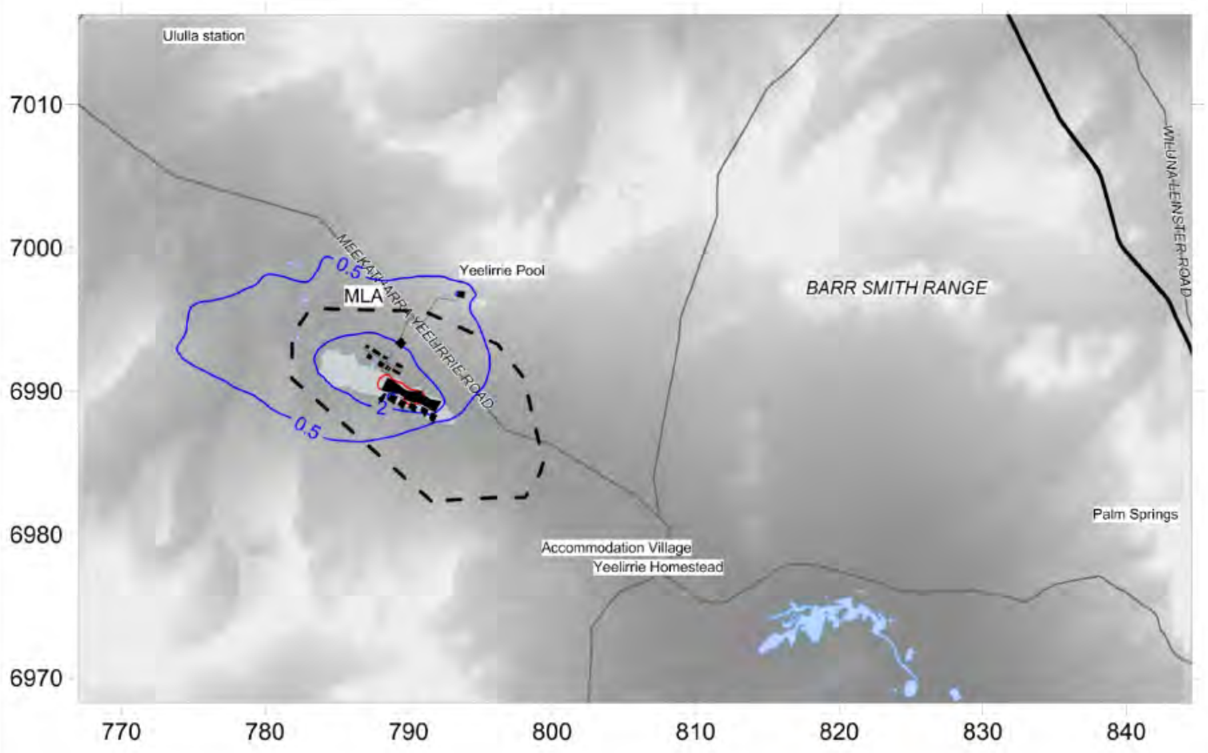


Plate 11 Predicted operationally contributed annual average ground-level concentration of $PM_{2.5}$

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA	Annual	CALPUFF	µg/m³
Type:	**Standard:**	**Prepared by:**	**Date:**
Annual contours, no background	8 µg/m³	Tania Haigh	2014

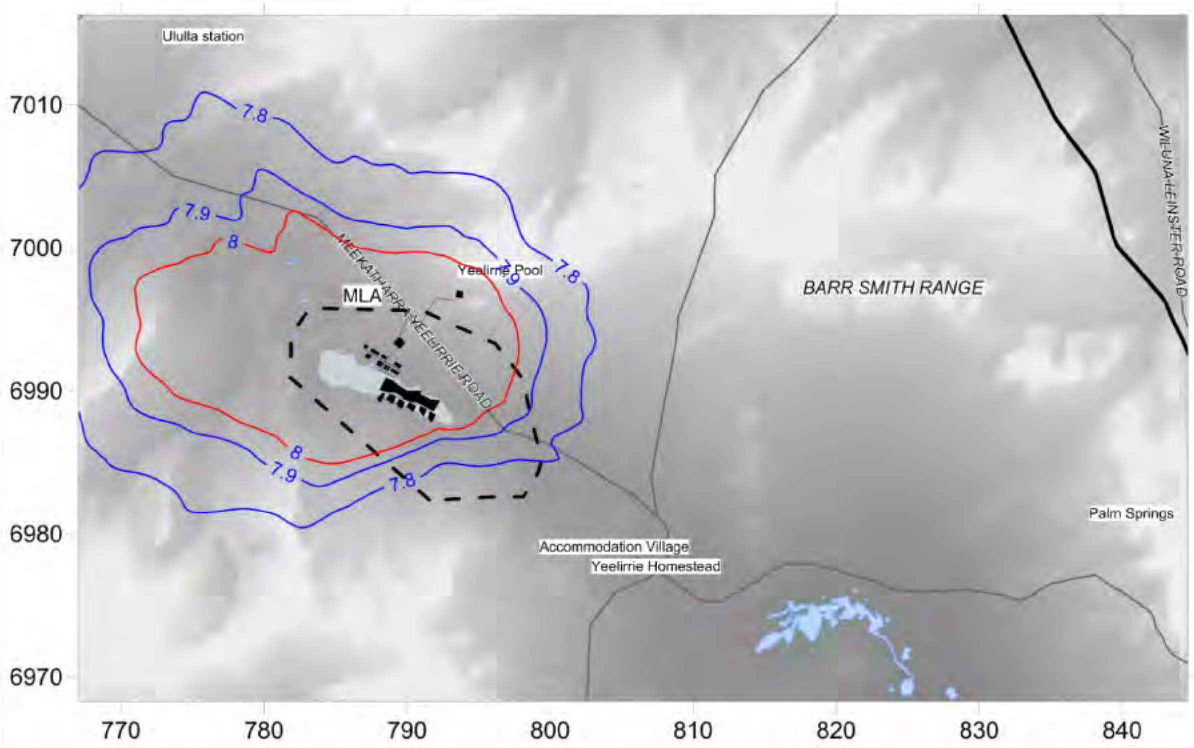


Plate 12 **Predicted annual average ground-level concentration of $PM_{2.5}$ with ambient background**

Location: Yeelirrie, WA	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual contours, no background	**Standard:** 8 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

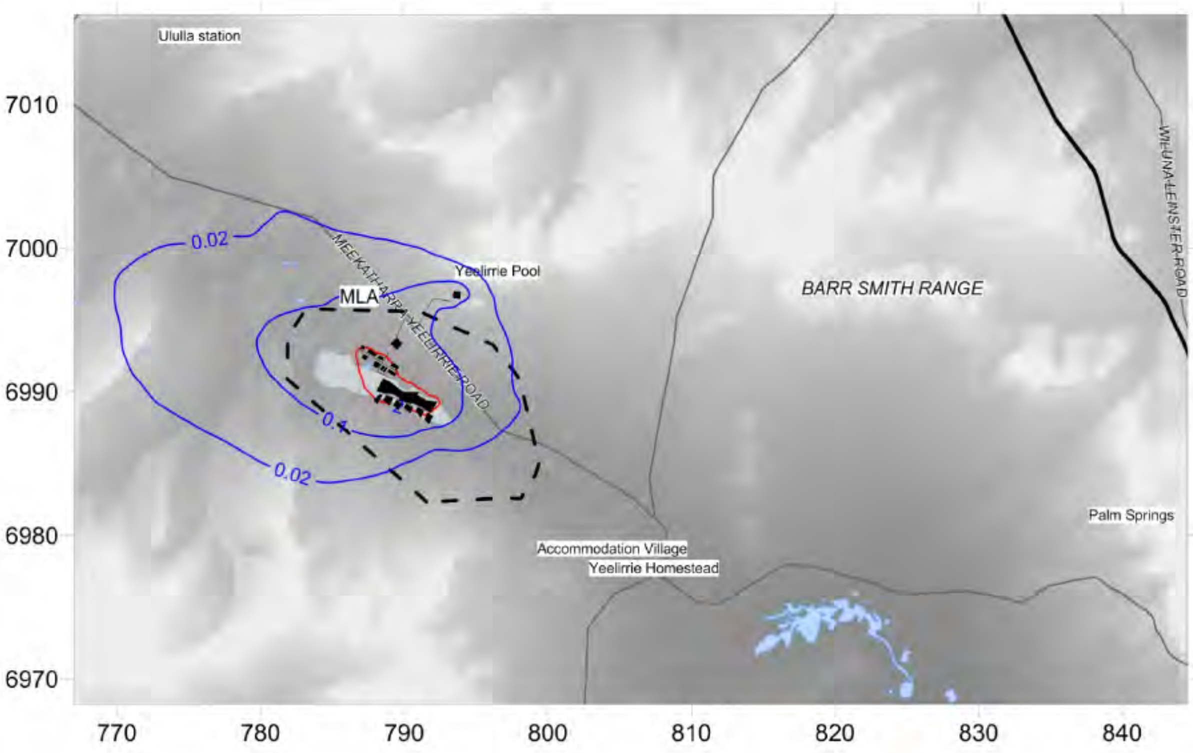


Plate 13 Predicted operationally contributed annual average dust deposition rate

Location: Yeelirrie, WA	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Annual contours, no background	**Standard:** 2g/m²/month (incremental)	**Prepared by:** Tania Haigh	**Date:** 2014

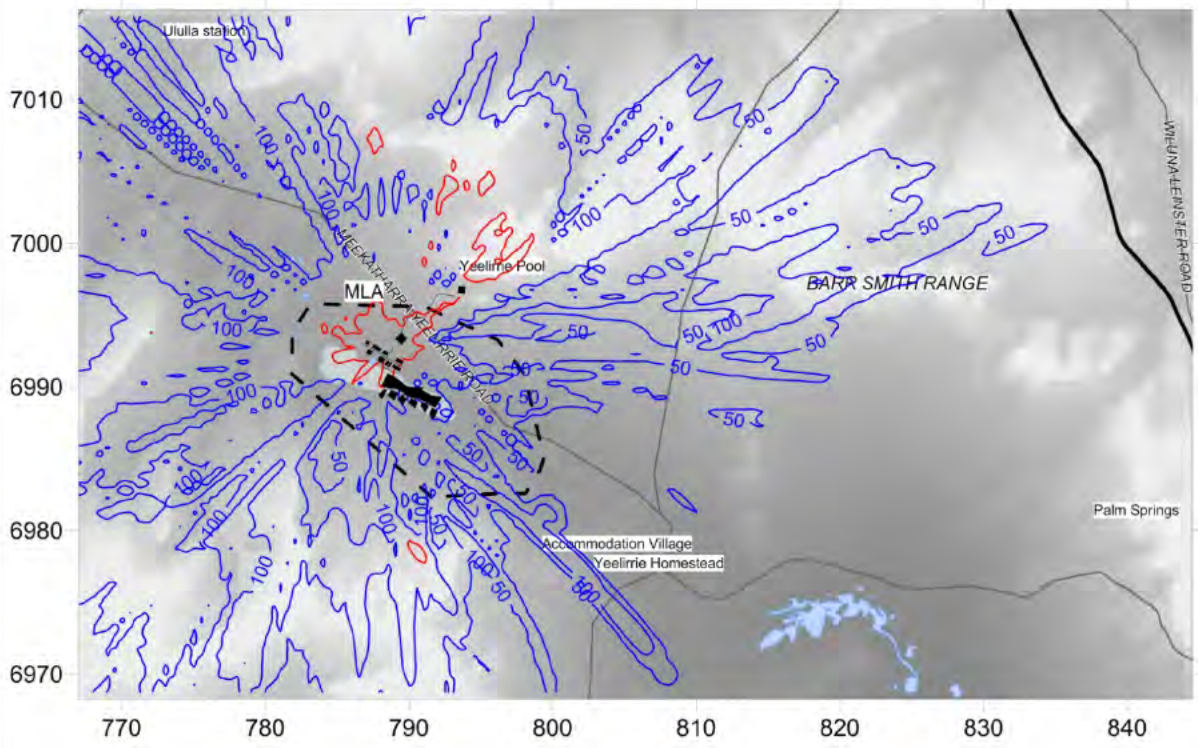


Plate 14 Predicted operationally contributed maximum 1-hour average ground-level concentration of nitrogen dioxide (assume no capture of generator emissions)

Location: Yeelirrie, WA	**Averaging period:** 1-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 246 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

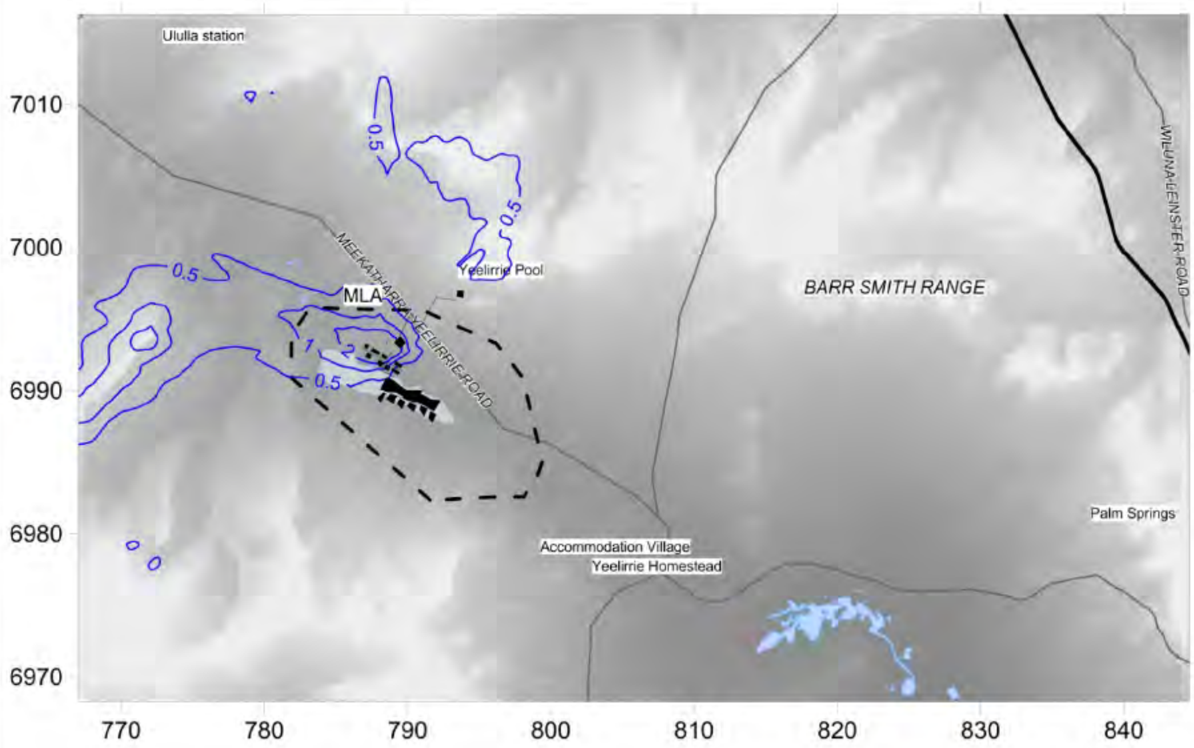


Plate 15 **Predicted operationally contributed annual average ground-level concentration of nitrogen dioxide (assume no capture of generator emissions)**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA	Annual	CALPUFF	µg/m³
Type:	**Standard:**	**Prepared by:**	**Date:**
Annual contours, no background	62 µg/m³	Tania Haigh	2014

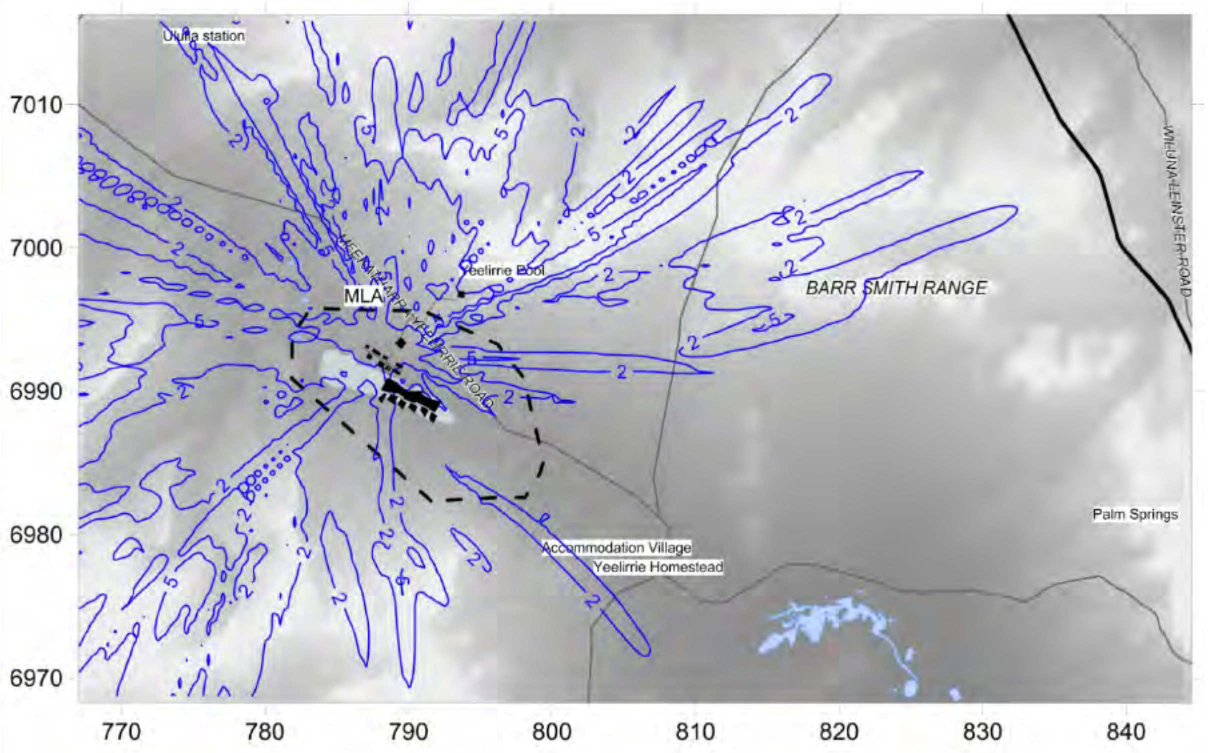


Plate 16 Predicted operationally contributed maximum 8-hour average ground-level concentration of carbon monoxide (assume no capture of generator emissions)

Location: Yeelirrie, WA	**Averaging period:** 8-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 11,000 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

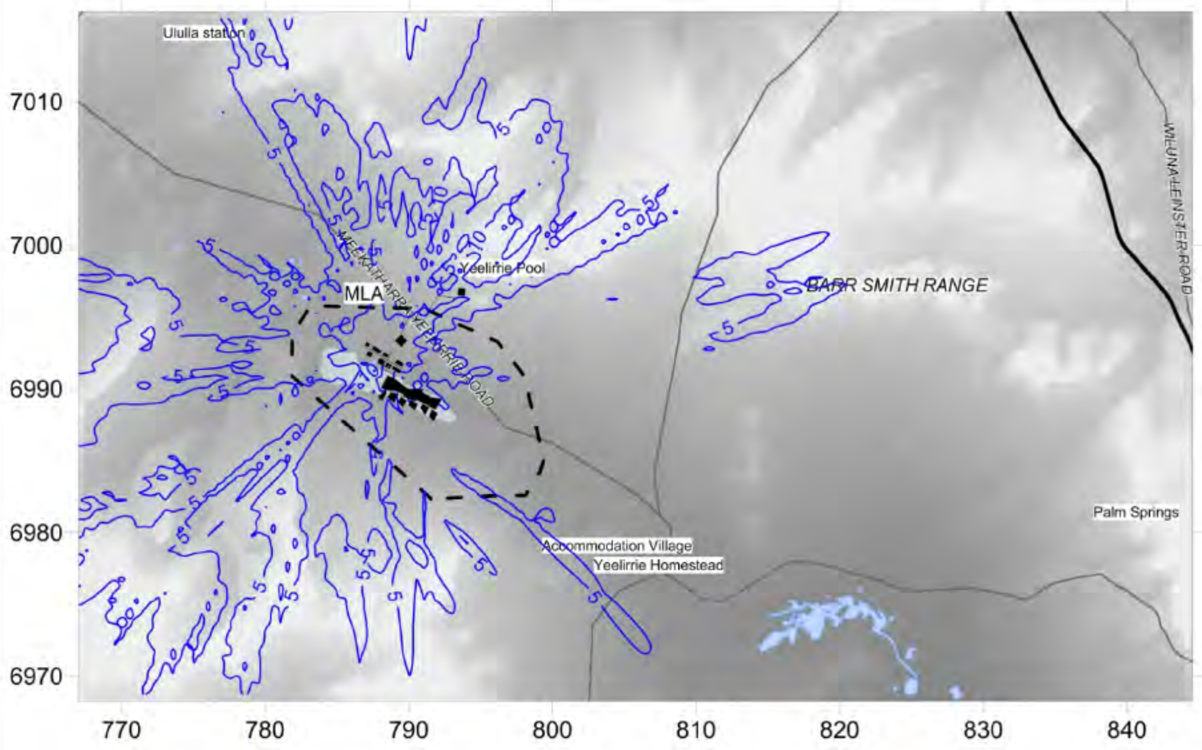


Plate 17 Predicted operationally contributed maximum 1-hour average ground-level concentration of sulfur dioxide (assume no capture of generator emissions)

Location: Yeelirrie, WA	**Averaging period:** 1-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 570 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

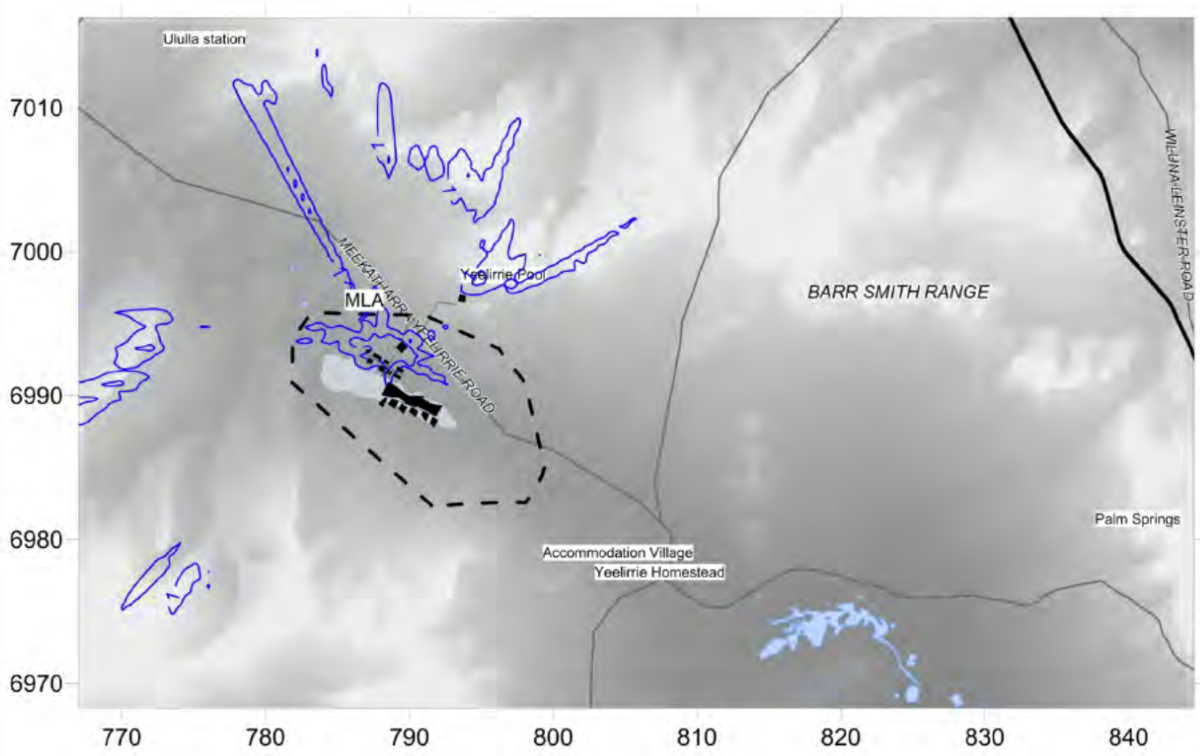


Plate 18 Predicted operationally contributed maximum 24-hour average ground-level concentration of sulfur dioxide (assume no capture of generator emissions)

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours, no background	**Standard:** 228 µg/m³	**Prepared by:** Tania Haigh	**Date:** 2014

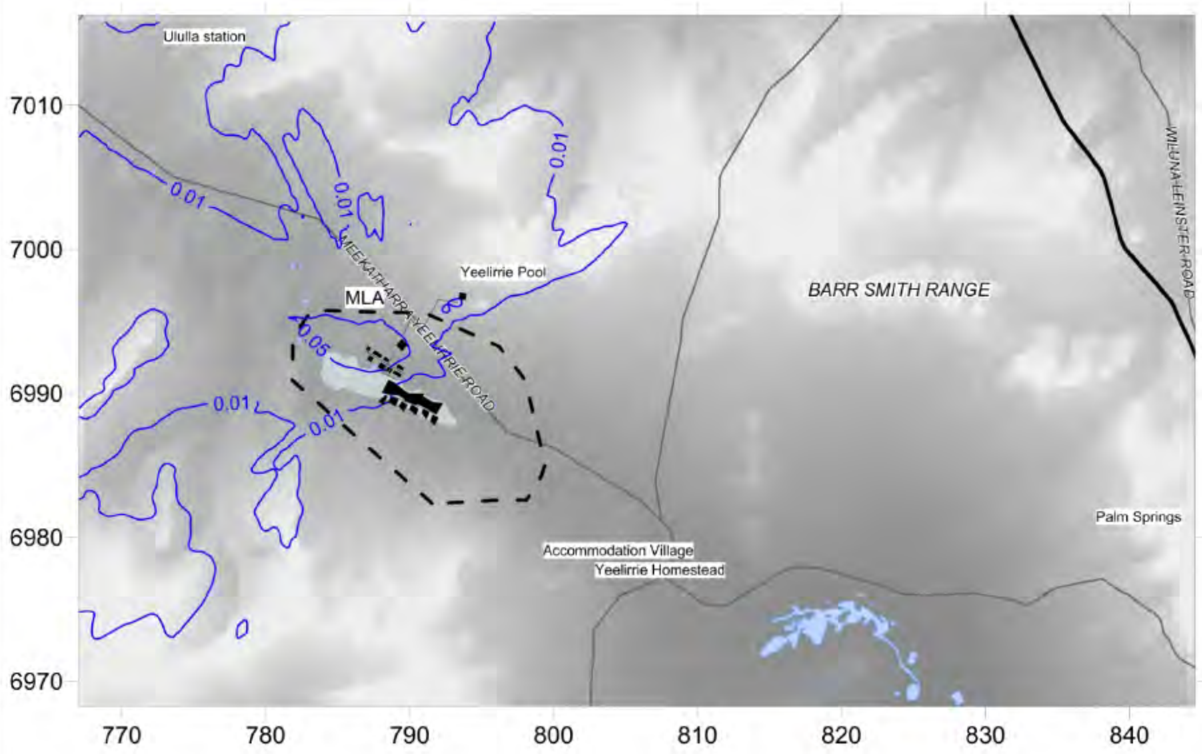


Plate 19 Predicted operationally contributed annual average ground-level concentration of sulfur dioxide (assume no capture of generator emissions)

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA	Annual	CALPUFF	µg/m³
Type:	**Standard:**	**Prepared by:**	**Date:**
Annual contours, no background	60 µg/m³	Tania Haigh	2014

APPENDIX A DISPERSION MODELLING

A1 METEOROLOGICAL MODELLING

The meteorological data for this study was generated by coupling TAPM, a prognostic mesoscale model to CALMET, a diagnostic meteorological model. The coupled TAPM/CALMET modelling system was developed by Katestone to enable high resolution modelling capabilities for regulatory and environmental assessments. The modelling system incorporates 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.

A1.1 TAPM

The meteorological model, TAPM (The Air Pollution Model) Version 4.0.1, was developed by the 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). Katestone has used TAPM throughout Australia as well as in parts of New Caledonia, Bangladesh, America and Vietnam. This model has performed well for simulating regional meteorological conditions. 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 km to 200 km) and at a local scale (down to a few hundred metres). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the study 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.

TAPM was initialised with the following parameters:

- 80 by 50 mother domain at a horizontal resolution of 18 km
- 3 nested domains at a horizontal resolution of 8 km, 3 km and 1 km (Figure A 1)
- 25 vertical levels from 10 m to 8000 m
- Land use and terrain generated from AUSLIG 9 arc second database (TAPM default) and crosschecked against data from previous assessments
- Modelled period for evaluation against automatic weather stations (2004 to 2009)
- Final modelled period February 2010 to January 2011
- Data assimilation using available data from AWS monitoring site at Yeelirrie, with a 5 km radius of influence up to 150 m above ground-level

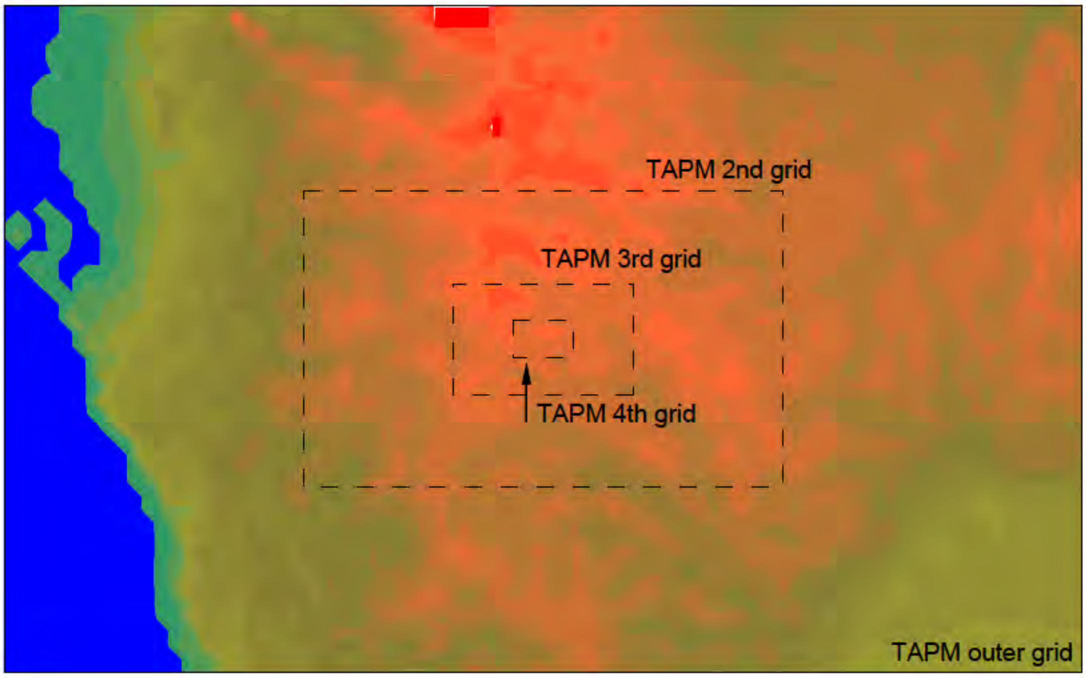


Figure A1 **TAPM nested grids**

A1.2 CALMET

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 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 6.4) was used to simulate meteorological conditions in the study region. The CALMET simulation was initialised with the gridded TAPM three dimensional wind field data from the 1 km grid.

The geophysical data (land use and terrain heights) were generated from the Shuttle Radar Topography Model v.3 (SRTM3) dataset (Figure A2). Land use characteristics were generated from the Australia/Pacific Land Cover Characteristics Data Base Version 2.0 and refined based on Katestone's knowledge of the site.

Key features of CALMET used to stimulate dispersion are as follows:

- Domain area of 78 by 48 grid points at 1km spacing
- 365 days (1 February 2010 to 31 January 2011)
- Twelve vertical levels at 0m, 20m, 60m, 100m, 150m 200m, 250m, 350m, 500m, 800, 1600m, 2600m and 4600m
- No observation mode, NOOBS = 2, use prognostic data from TAPM (3D.dat) for surface, overwater and upper air data
- Gridded cloud data from prognostic relative humidity at all levels (MM5toGrads algorithm)

- No kinematic effects calculated
- No slope flows calculated

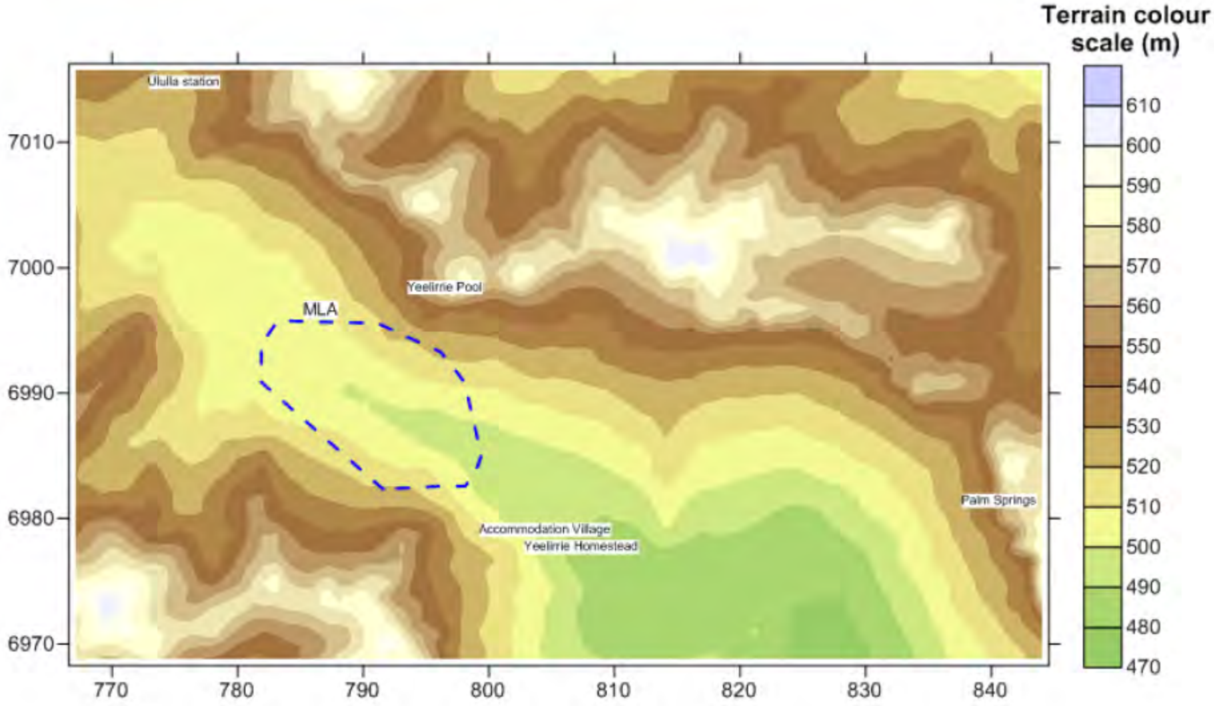


Figure A2 Terrain information as included in CALMET

A2 METEOROLOGICAL EVALUATION

To allow an evaluation of the performance of TAPM an initial run was undertaken without data assimilation. A comparison of the model predictions against the Yeelirrie AWS can then be made to determine the models ability to simulate the range of meteorological conditions present at the proposed Yeelirrie development site as shown in the AWS monitoring data. Wind speed, wind direction, temperature and relative humidity were extracted from TAPM and compared to the AWS monitoring data. Model evaluation was limited to the period of available monitoring data at the Yeelirrie AWS (7 February 2010 to 19 January 2011). As wind direction has a cross point at north between 0° and 360° it has been decomposed into its U component (east-west) and V component (north-south) for statistical analysis.

A2.1 Statistical measures

Root Mean Square Error (RMSE)

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2}$$

The RSME can be described as the standard deviation of the difference for hourly predicted and observed pairings at a specific point. The RMSE is a quadratic scoring rule which measures the average magnitude of the error. The difference between predicted and corresponding observed values are each squared and then averaged over the sample. Finally, the square root of the average is taken. Since the errors are squared before they are averaged, the RMSE gives a relatively high weight to large errors. This means the RMSE is most useful when large errors are particularly undesirable. Overall, the RSME is a good overall measure of model performance, but since large errors are weighted heavily (due to squaring), its value can be distorted. RMSE is equal to the unit of the values being analysed i.e. an RMSE of 1.2 for wind speed = 1.2 m/s^{-1}.

Systematic Root Mean Square Error (RMSE$_S$)

$$\mathrm{RMSE_S} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{P}_i - O_i)^2}$$

The RMSE$_S$ is calculated as the square root of the mean square difference of hourly predictions from the regression formula and observation pairings, at a specific point. The regressed predictions are taken from the least squares formula. The RMSE$_S$ estimates the model's linear (or systematic) error. The systematic error is a measure of the bias in the model due to user input or model deficiency, i.e. data input errors, assimilation variables, choice of model options etc.

Unsystematic Root Mean Square Error (RMSE_u)

$$\text{RMSE}_{\text{U}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{P}_i - P_i)^2}$$

The RMSE_u is calculated as the square root of the mean square difference of hourly predictions from the regression formula and model prediction value pairings, at a specific point. The RMSE_u is a measure of how much of the difference between predictions and observations resulting from random processes or influences outside the legitimate range of the model. This error may require model refinement, such as new algorithms or higher resolution grids, or that the phenomena being simulated cannot be fully resolved by the model.

Ultimately for 'good' model performance, the RMSE should be a low value, with most of the variation explained in the observations. Here, the systematic error RMSE_s should approach zero and the unsystematic error, $\text{RMSE}_{u,}$ should approach the RMSE since:

$$\text{RMSE}^2 = \text{RMSE}_{\text{S}}^2 + \text{RMSE}_{\text{u}}^2$$

Mean Error (ME) and Mean Absolute Error (MAE)

The ME is simply the average of the hourly modelled values minus the hourly observed values. It contains both systematic and unsystematic errors and is heavily influence by high and low errors.)

The MAE measures the average magnitude of the errors in a set of predictions, without considering their direction. It measures accuracy for continuous variables. Expressed in words, the MAE is the average over the verification sample of the absolute values of the differences between predictions and the corresponding observation. The MAE is a linear score which means that all the individual differences are weighted equally in the average. The MAE and the RMSE can be used together to diagnose the variation in the errors in a set of predictions. The RMSE will always be larger or equal to the MAE; the greater difference between them, the greater the variance in the individual errors in the sample. If the RMSE=MAE, then all the errors are of the same magnitude Both the MAE and RMSE can range from 0 to ∞. They are negatively-oriented scores: Lower values are better.

Skill measure statistics are given in terms of a score, rather than in absolute terms.

Index of Agreement (IOA)

$$\text{IOA} = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i=1}^{N}(|P_i - O_{mean}| + |O_i - O_{mean}|)^2}$$

The IOA is calculated using a method described in Willmott (1982). The IOA can take a value between 0 and 1, with 1 indicating perfect agreement. The IOA is the ratio of the total RMSE to the sum of two differences: the difference between each prediction and the observed mean, and the difference between each observation and observed mean. From another perspective, the IOA is a measure of the match between the departure of each prediction from the observed mean and the departure of each observation from the observed mean.

(Note: N is the number of observations, P_i are the hourly model predictions, O_i are the hourly observations, O_{mean} is the observed observation mean, and $\hat{P}_i = a + bO_i$ is the linear regression fitted with intercepts *a* and slope *b*.)

A models skill can be measured by the difference in the standard deviation of the modelled and observed values.

SE is indicative of the of how much of the standard deviation in the observations is predicted to be due to random/natural processes (unsystematic) in the atmospheric boundary layer. (i.e., turbulence).

SV shows how closely the modelled standard deviation matches the observed standard deviation

SR takes into account systematic and unsystematic errors in relation to the observed standard deviation.

Skill is determined by the following benchmarks:

- SKILL_E (se) = (RMSE_U/StdvOBS) < 1 shows skill
- SKILL_V (sv) = (Stdv_MOD/Stdv_OBS) close to 1 shows skill
- SKILL_R (sr) = (RMSE/Stdv_OBS) < 1 shows skill

A2.2 Model evaluation

The model evaluation (Table A1) shows that there is a good degree of correlation between the modelled and observed wind speed, temperature, relative humidity and the U and V components, with an index of agreement (IOA) of 0.7 or greater for all parameters. Wind speed and wind direction (shown as vector components) display small values for RMSE, below 2 and low MAE. Temperature and relative humidity show larger values for RMSE and MAE; however, the high IOA indicates that the frequency of conditions is accurate while the magnitude is either under estimated and/or over estimated.

Table A1 Evaluation of model performance for annual data

Statistical measure	Wind speed (m/s)	Temperature (°C)	Relative Humidity (%)	U vector (m/s)	V vector (m/s)
intercept	1.17	0.29	25.08	-0.76	0.43
slope	0.61	0.88	0.74	0.74	0.56
rmse	1.19	3.22	19.20	1.30	1.47
rmse_s	0.59	20.36	101.90	0.74	0.69
rmse_u	1.03	18.08	90.08	1.07	1.30
ioa	0.81	0.96	0.83	0.90	0.74
se	0.70	2.09	3.82	0.47	0.85
sv	0.93	0.91	0.89	0.88	1.01
sr	0.80	0.37	0.81	0.57	0.96
MAE	0.91	2.69	16.28	0.96	1.03
ME	0.12	-2.18	14.12	-0.44	0.15

Annual, seasonal and daily wind roses for the modelled and observed winds are presented in Figure A3, Figure A4 and Figure A5. The wind roses indicate that the model simulates the winds at the AWS site in a realistic and consistent manner across the three time scales.

Probability density function (PDF) plots of the modelled and observed wind speed (Figure A6), wind direction (Figure A7), relative humidity (Figure A8), temperature (Figure A9) and the U (Figure A10) and V (Figure A11) components are also presented. The model is shown to follow the distribution of wind speed and wind direction of the AWS very closely. The model tends to under predict the frequency of periods with a relative humidity below 40% and over predict the frequency periods with relative humidity above 60%. The model also tends to over predict the frequency of temperatures lower than 22 °C and under predict the frequency of temperatures greater than 22 °C. This may be due to the default deep soil volumetric moisture content values used by TAPM not being specifically adjusted to the particular region and time period of the simulation. However, without a large scale research program to determine these values they cannot be adjusted with any confidence and the default values must remain unchanged.

TAPM is shown to simulate the frequency and magnitude of atmospheric conditions at the Yeelirrie development site very closely to the conditions recorded at the AWS. To ensure that the best meteorological data is ingested into the dispersion model TAPM was rerun to include the AWS data. Due the fact that TAPM already produced very similar wind fields to the AWS in both time and space no erroneous or spurious artefacts of the assimilation process are expected. The assimilated three dimensional meteorological file produced by TAPM was then processed through CALMET for inclusion in CALPUFF, the air dispersion model.

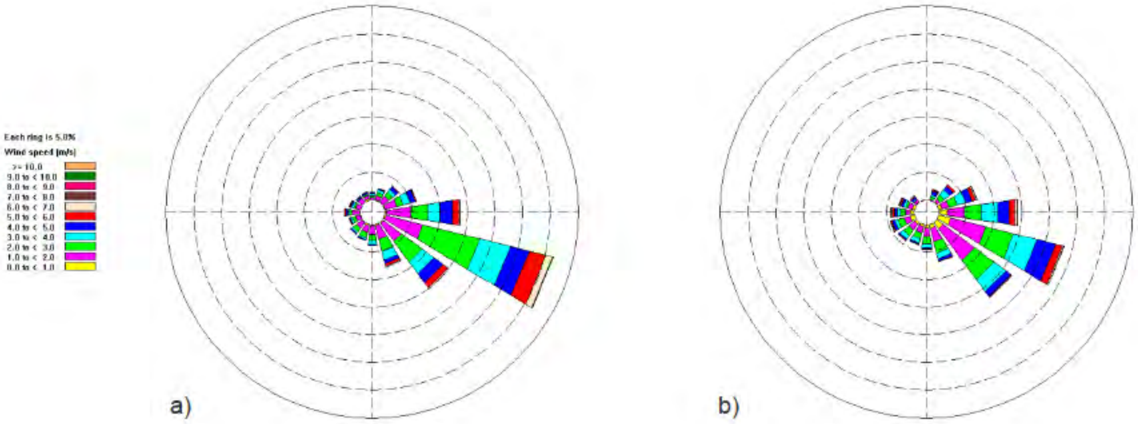
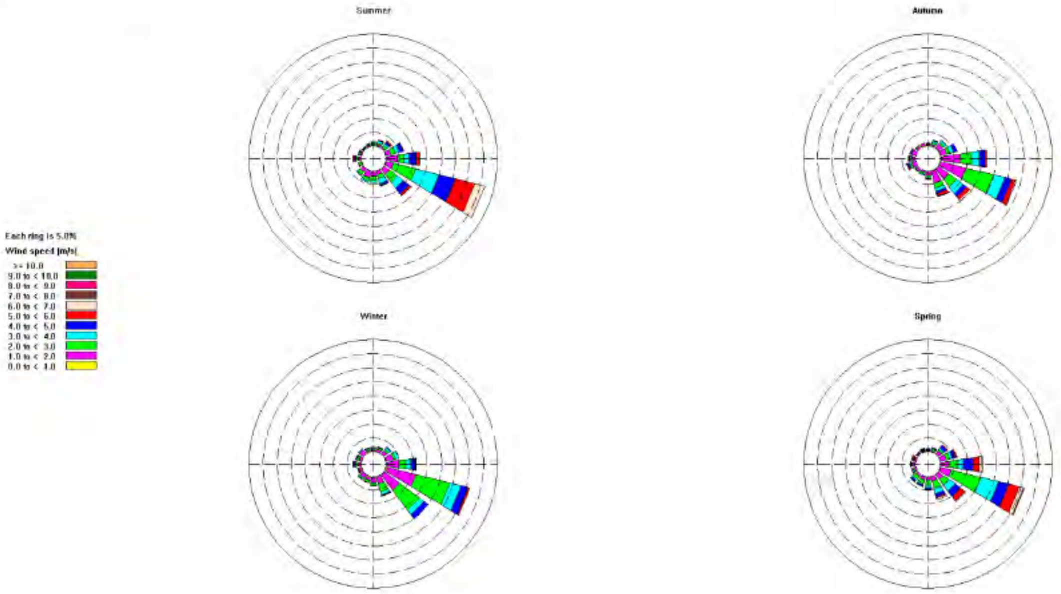


Figure A3 Annual wind rose for (a) modelled (TAPM unassimilated) and (b) observed winds at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

a) Modelled



b) Observed

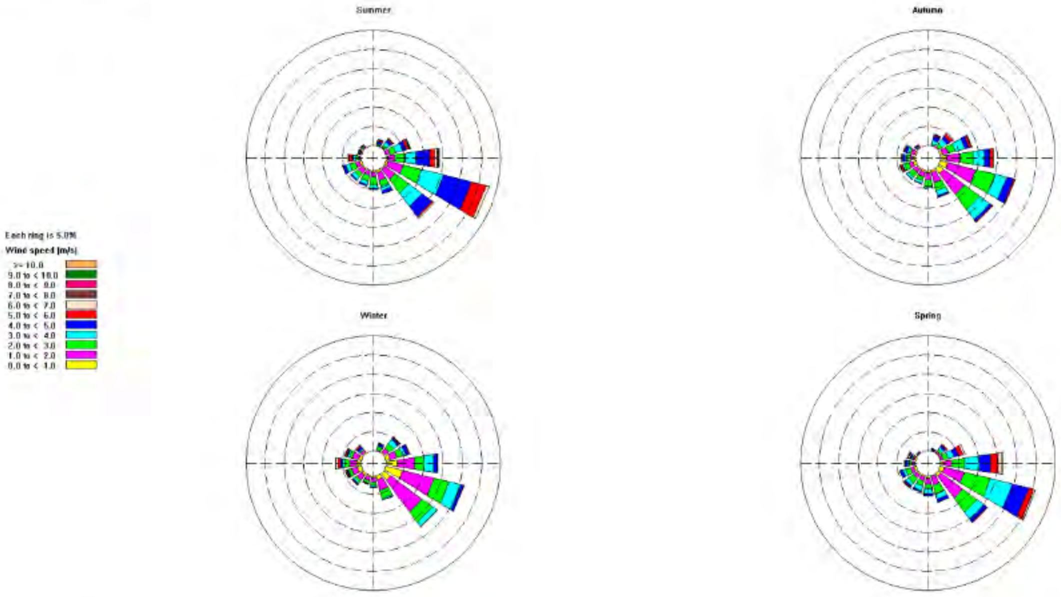
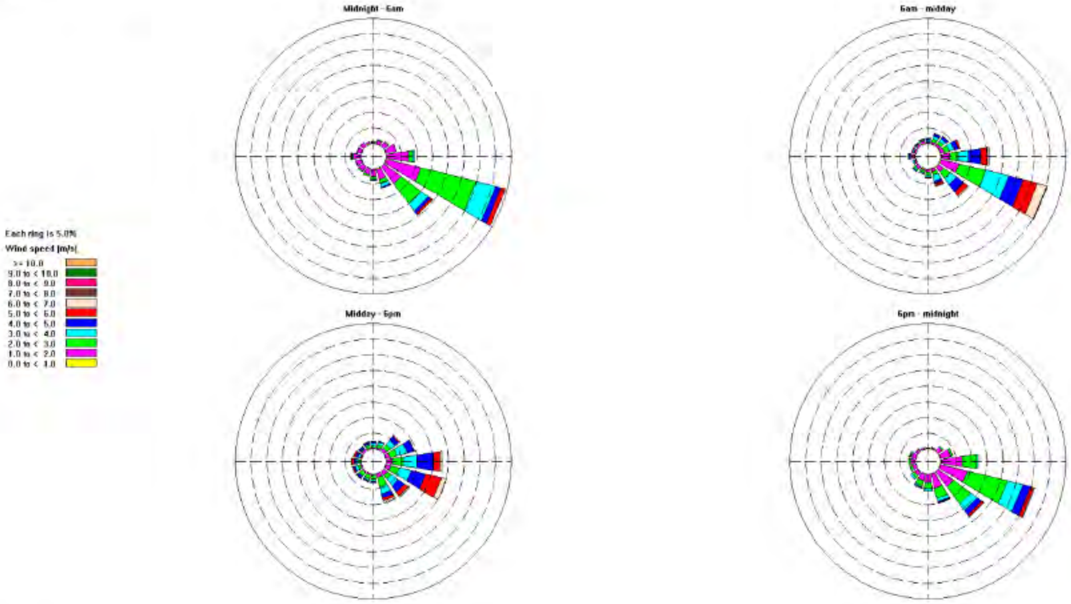


Figure A4 **Seasonal windrose for a) modelled (TAPM unassimilated) and b) observed winds at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)**

a) Modelled



b) Observed

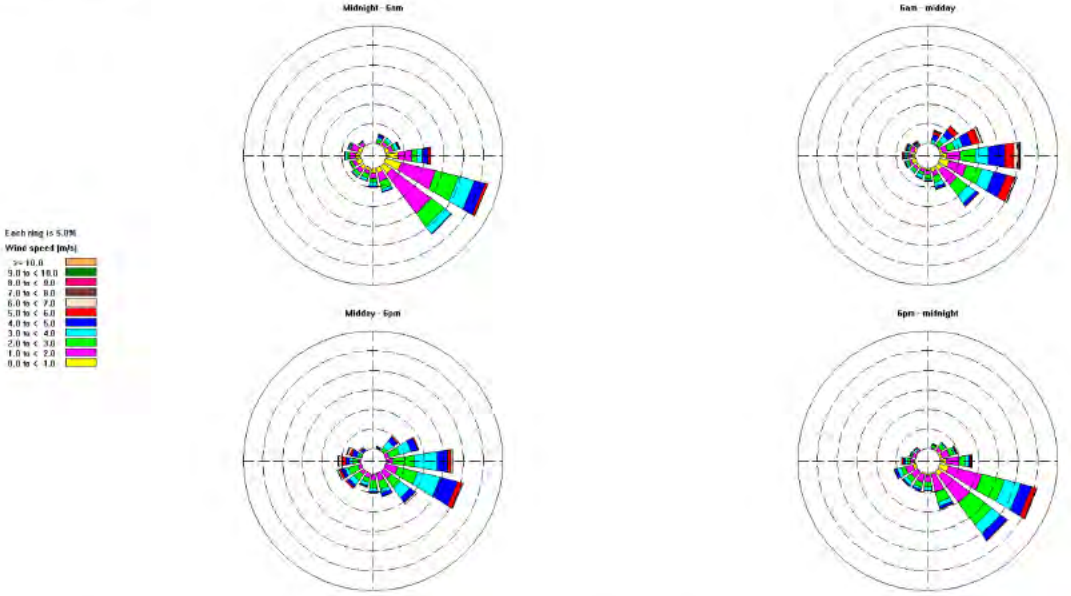


Figure A5 **Diurnal windrose for a) modelled (TAPM unassimilated) and b) observed winds at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)**

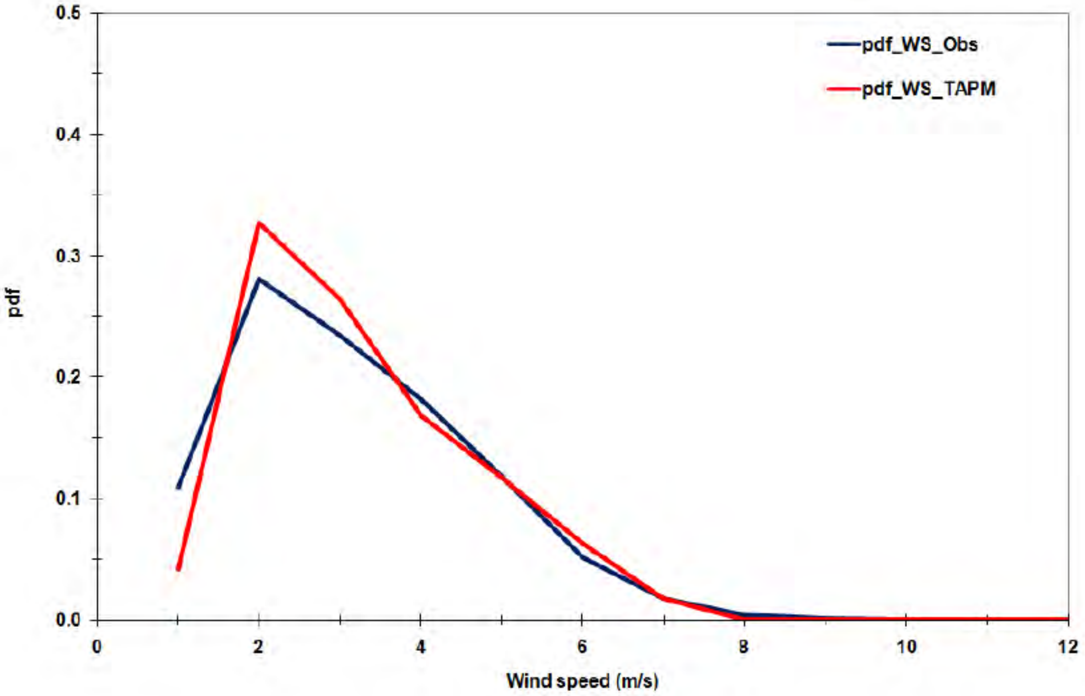


Figure A6 Frequency distribution of modelled (TAPM unassimilated) and observed wind speeds at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

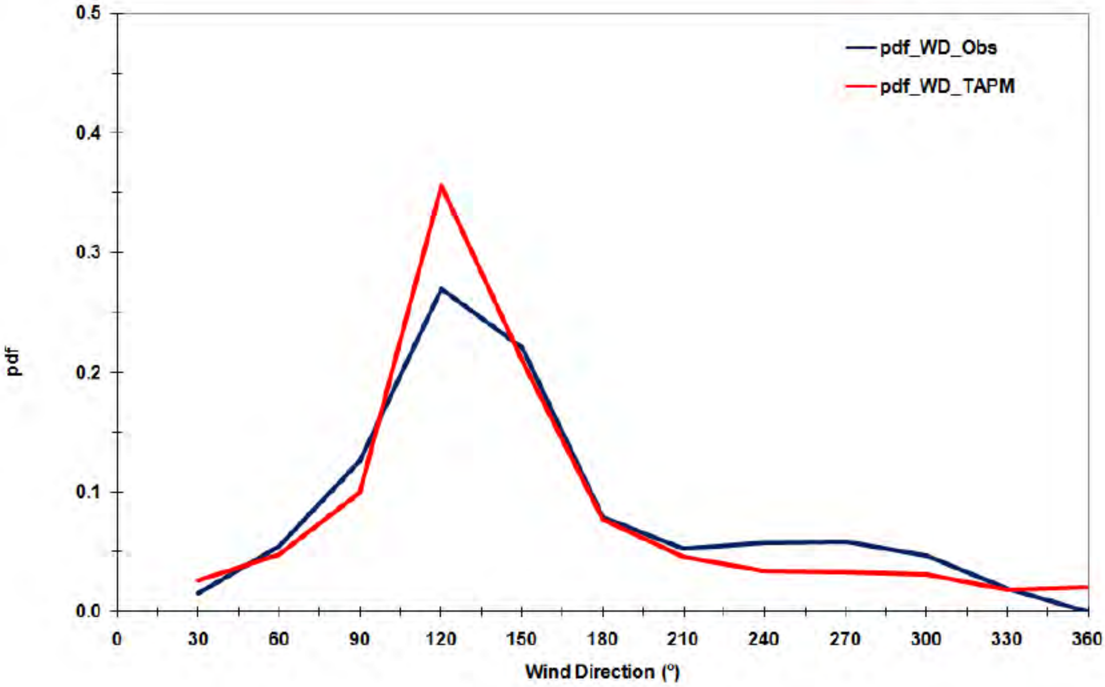


Figure A7 Frequency distribution of modelled (TAPM unassimilated) and observed wind direction at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

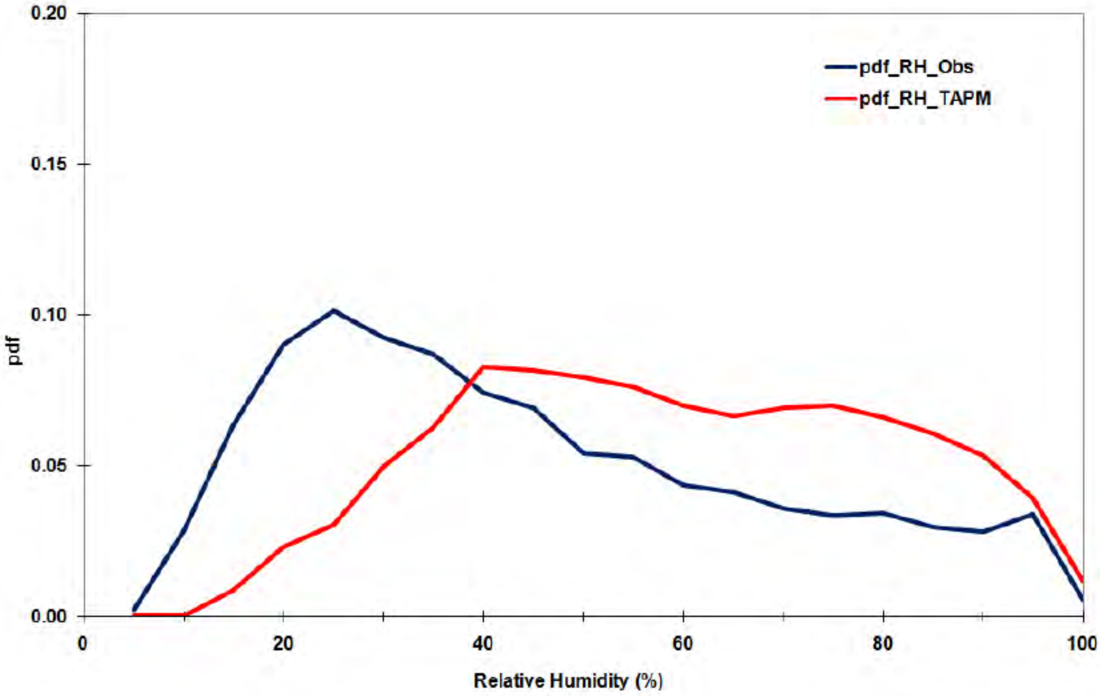


Figure A8 Frequency distribution of modelled (TAPM unassimilated) and observed relative humidity at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

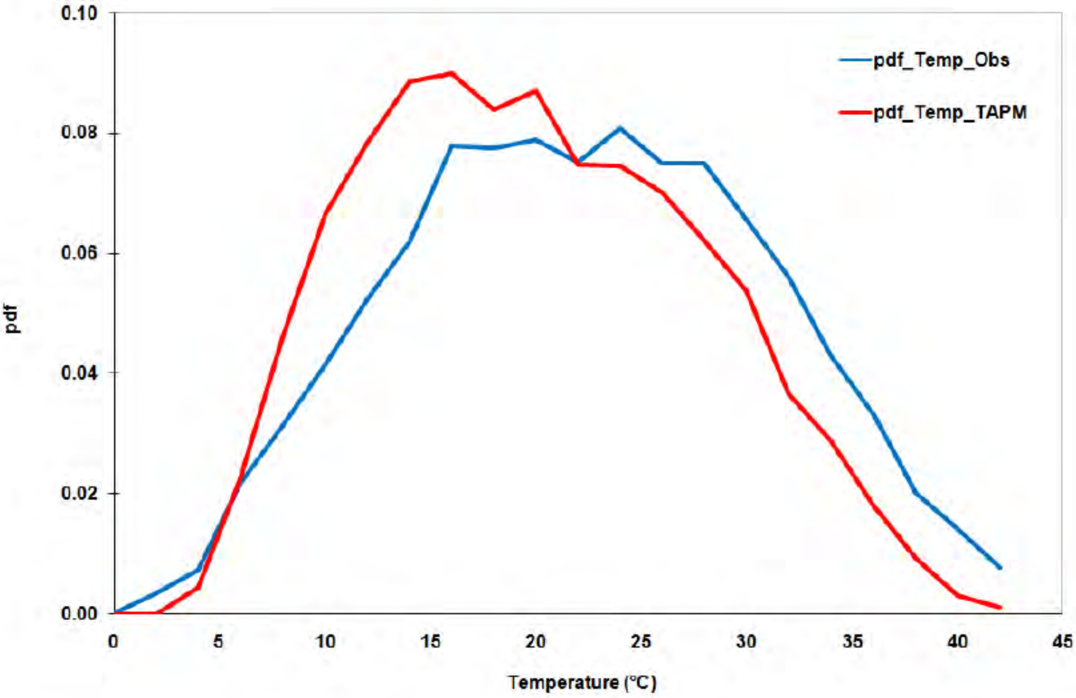


Figure A9 Frequency distribution of modelled (TAPM unassimilated) and observed temperature at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

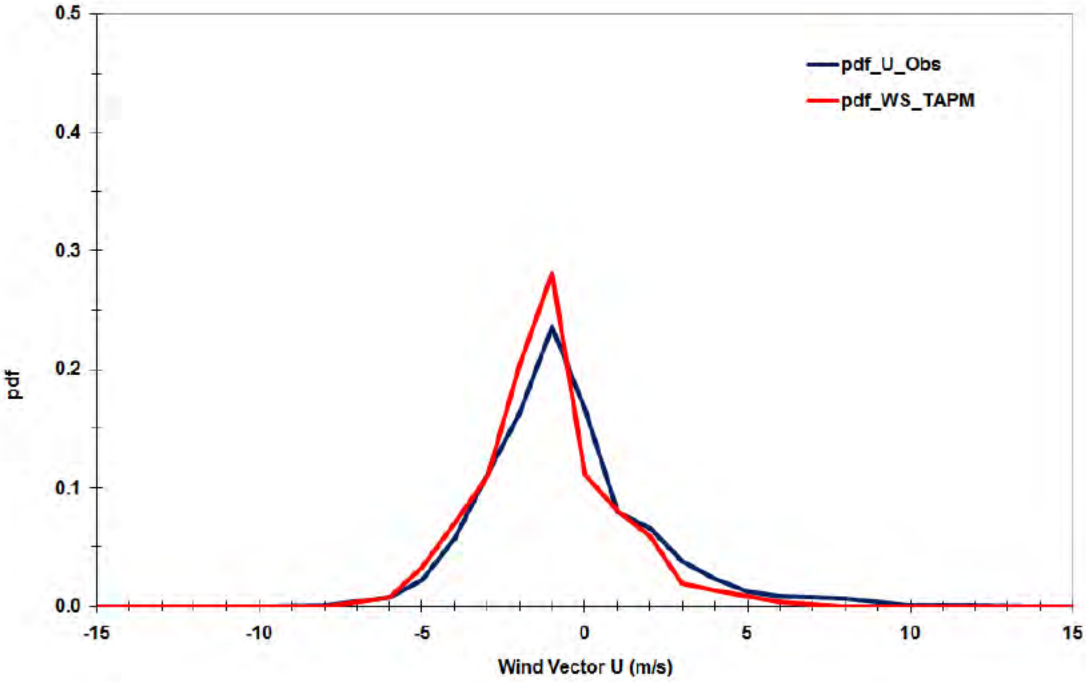


Figure A10 Frequency distribution of modelled (TAPM unassimilated) and observed wind U component at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

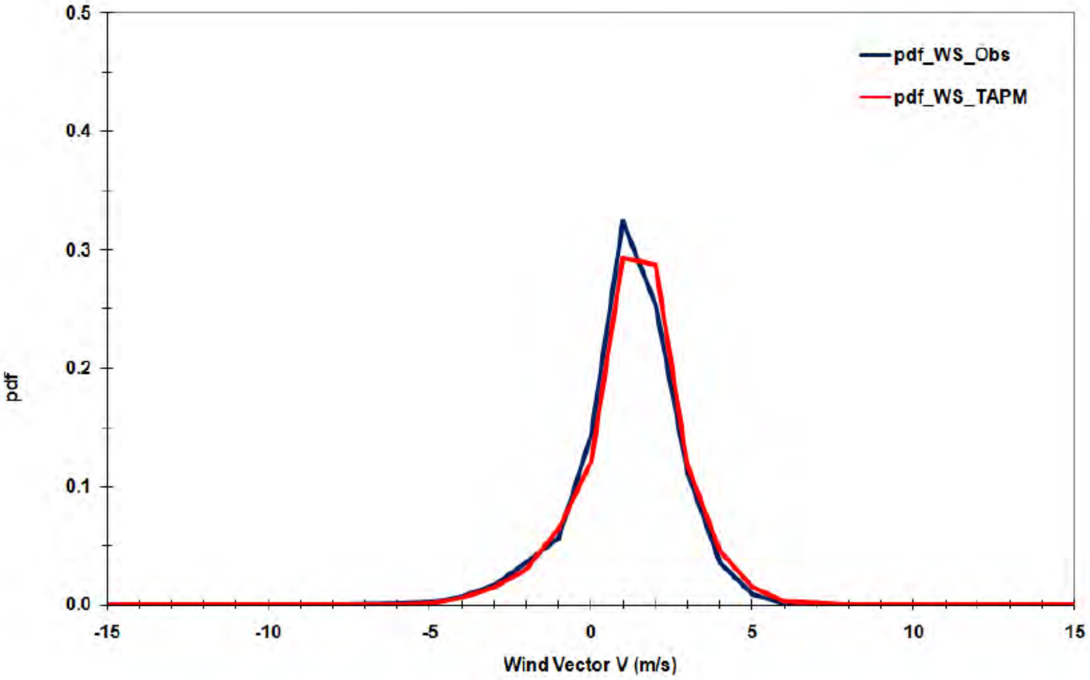


Figure A11 Frequency distribution of modelled (TAPM unassimilated) and observed wind V component at the site of the Yeelirrie AWS (8/02/2010 to 19/01/2011)

A2.3 Nocturnal inversions

One of the most important aspects of the local meteorology around the Yeelirrie region for air dispersion is the frequency and intensity of nocturnal inversions. The model has been shown to adequately simulate the majority of atmospheric conditions and weather types in the Yeelirrie region, while also showing its limitations in simulating the frequency of north-westerly winds in winter and spring. However, it is the atmospheric conditions that are associated with these wind patterns that are essential to dispersion not necessarily the wind direction by itself.

The air environment around Yeelirrie is quite complex, as previous studies identified a high percentage of nocturnal inversions and an associated low-level jet, which predominantly forms during winter and early spring when the variation in daytime and night-time temperatures are at their highest (Steedman 1978 and Lyons and Steedman 1981)

Low level jets occur due to surface friction and a decoupling of the air flow at the surface from the air flow at elevation. Two atmospheric layers are produced as a result of: a stable near surface layer (or stable boundary layer (SBL)); and, a free atmosphere above.

After decoupling, the free atmosphere layer is no longer acted upon by the surface and therefore the friction velocity is reduced to near zero and a local acceleration of the air mass is observed. This is evidenced by a maximum wind speed in the vertical profile of the horizontal wind speed above the decoupling point (Banta et al. 2002).

These low level jets are a typical feature of relatively flat desert terrain where strong surface cooling is experienced overnight, as is the case in the Yeelirrie region. The SBL is a nocturnal inversion layer in which vertical movement of the air is suppressed. The point at which the SBL is decoupled from the free atmosphere above is located near the top of the inversion layer and demarcates the zone of local acceleration of the horizontal wind speed.

The meteorological modelling found that stable boundary layer conditions (Pasquill-Gifford F class) were likely to occur frequently (39% of hours in the period from February 2010 to January 2011). These conditions occur at night and are more prominent during the winter months when surface cooling is at a maximum.

The Pasquill-Gifford scale is an approximation of turbulence. Mathematically, turbulence is described by the fundamental equations of fluid dynamics, known as the Navier-Stokes equations. These equations form the basis of the TAPM model and all modern numerical weather prediction systems. TAPM solves the Navier-Stokes equations and accounts for terrain, vegetation characteristics and soil characteristics dynamically at each model time step, which feeds back into the modelling system for subsequent model time steps. Consequently, the TAPM model has the capability to simulate the types of conditions described by Lyons and Steedman (1981).

To determine the model's reliability in simulating this complex behaviour the vertical profile of wind speed and virtual potential temperature was extracted from TAPM for the winter months of the simulation period. Figure A12 and Figure A13 show the night-time vertical profiles of wind speed and virtual potential temperature of the atmosphere during winter. The formation of a low-level jet is apparent and coincides with the inversion layer designated by the virtual potential temperature profile.

These conditions are the dominant weather type during the winter months. It is these conditions that also lead to worst case dispersion conditions for pollutants suspended in the atmosphere.

Steedman *et al.* 1978 found that stable night-time conditions occurred on 39% of all nights in the Yeelirrie region. The frequency of modelled stable night-time conditions was 37%. This modelled outcome provides another indication of the models' representativeness of the area and its conservativeness.

The frequency of a stable atmosphere coupled with the formation of a low level jet (Figure A12 and Figure A13), shows that the model is capable of simulating the extreme conditions experienced at the project site.

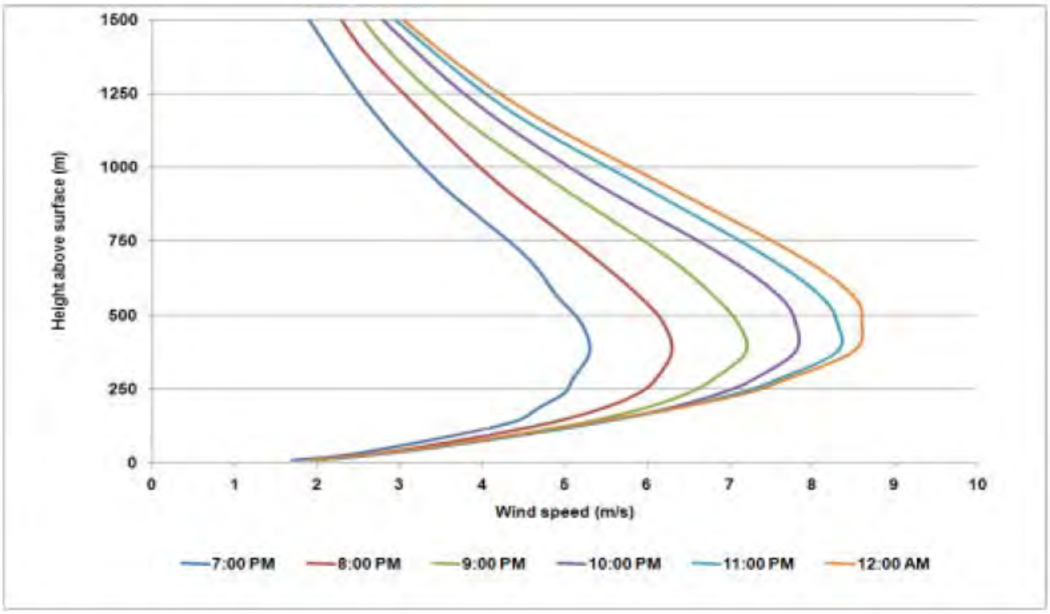


Figure A12 Winter vertical profile of wind speed from 7 pm to 12 am showing the development of a low level jet

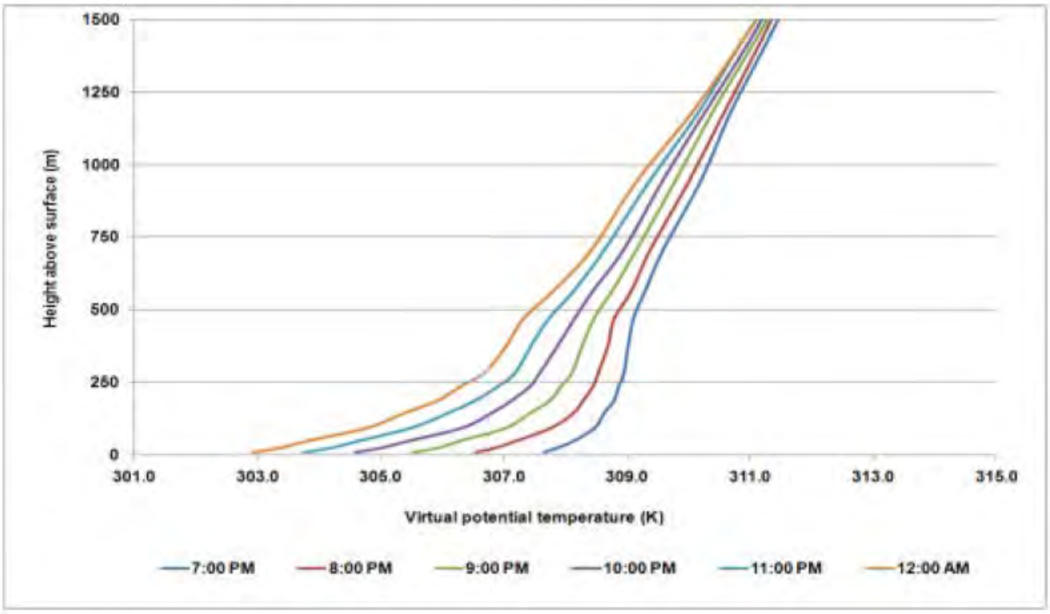


Figure A13 Winter vertical profile of vertical potential temperature from 7 pm to 12 am showing the development of a low level jet

A3 CALPUFF

The CALPUFF dispersion model utilises the three-dimensional wind fields from CALMET to simulate the dispersion of air pollutants to predict ground-level concentrations across a gridded domain. 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 6.42) was used to simulate the dispersion characteristics and concentrations of particulate matter generated by the project. Hourly varying meteorological conditions were obtained from CALMET at 1km.

- Domain area of 156 by 96 grid points at 500 m spacing
- 365 days (1 February 2010 to 31 January 2011)
- Dispersion coefficients calculated internally from sigma v and sigma w using micrometeorological variables
- Minimum turbulence velocity of sigma-v over land set to 0.2 m/s
- Minimum wind speed allowed for non-calm conditions 0.2 m/s
- Maximum mixing height 4600 m
- Minimum mixing height 20 m
- Dry deposition modelled as computed particle

The default values for gravitational settling and dust deposition in the CALPUFF model for the species "PM_{10}" are limited to values for a gas, not particles from extractive industries. However, this limitation can be avoided by defining new species in the CALPUFF model rather than to rely on the default "PM_{10}" species. The new species can be defined to represent any number of particle fractions (e.g. TSP, PM_{10} and $PM_{2.5}$ components of dust) and the user can define geometric mass mean diameters and geometric standard deviations for each particle fraction.

Dry dust deposition rates were modelled using three geometric mass mean diameters of 30 microns, 10 microns and 2.5 microns, representing TSP, PM_{10} and $PM_{2.5}$ components of dust. The geometric standard deviation was set to zero and the various components were added to determine overall TSP, PM_{10} and $PM_{2.5}$ concentrations.

A4 REFERENCES

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APPENDIX B EMISSION FACTORS AND EMISSION RATES

B1 ACTIVITY DATA

Operational activity data, including proposed dust control measures, has been provided by Cameco and this is presented in the following sections. Where assumptions have been made by Katestone, these have been noted in the tables.

Table B1 Activity data

Parameter	Units	Year 3
Operating Hours (all activities except dozers)	days/year	365
	hours/day	24
Dozer ripping operation	days/yr	365
	hours/day	5.33
Dozer on topsoil stockpiles	hours/yr	199.8
Dozer on overburden stockpiles	hours/yr	2,383.2
Dozer on Ultra High Grade (UHG) Ore stockpiles	hours/yr	4,229.33
Dozer on Very High Grade (VHF) Ore stockpiles	hours/yr	3,162.70
Dozer on High Grade (HG) Ore stockpiles	hours/yr	5,448.39
Dozer on Medium Grade (MG) Ore stockpiles	hours/yr	5,380.17
Extraction and processing		
Tonnes extracted from pit	Topsoil	330,317
	Overburden	7,441,137
	UHG Ore	1,018,850.3
	VHG Ore	943,889.4
	HG Ore	1,489,466.2
	MG Ore	1,120,011.1
Tonnes removed from stockpiles	UHG Ore	1,019,775.2
	VHG Ore	276,743.4
	HG Ore	0
	MG Ore	0
Total quantity of ore processed (all grades)	tonnes	1,300,000
Total surface area of all UHG stockpiles	m^2	258,050
Total surface area of all VHG stockpiles	m^2	169,900
Total surface area of all HG stockpiles	m^2	295,875
Total surface area of all MG stockpiles	m^2	303,900
Total surface area of all LG stockpiles	m^2	183,200

Parameter	Units	Year 3
Total surface area of ROM stockpile	m^2	8,769
Length of conveyor from crusher to miller	m	300
Tonnes returned to pit	Topsoil	0
	Overburden	0
Pit and overburden areas		
Active pit area	m^2	2,513,864
Exposed pit area (unrehabilitated)	m^2	401,398
Exposed pit area (rehabilitated)	m^2	0
Total surface area of topsoil stockpiles	m^2	152,750[2]
Total surface area of overburden stockpiles	m^2	1,496,925[2]
Haulage		
Overburden haul truck capacity	tonnes	61
Overburden haul truck empty weight	tonnes	46.2[4]
Distance between pit and topsoil stockpile (return)	m	1,858
Distance between pit and overburden stockpile (return)	m	1,858
Overburden haul truck capacity	tonnes	61
Overburden haul truck empty weight	tonnes	46.2[4]
Distance between pit and ore stockpile (return)	m	6,726
Distance - stockpile to processing plant (return)	m	3,392
Material characteristics		
Overburden silt content	%	7.5[3]
Overburden moisture content	%	15
Ore silt content	%	7.5[3]
Ore moisture content	%	15
Road surface silt content	%	10[5]
Meteorological parameters		
Mean wind speed	m/s	2.7

Table notes:

[1] Assumption - area coloured green on Year 15 production schedule has been assumed to be rehabilitated, all other areas unrehabilitated.

[2] Calculated using stockpile dimensions from GIS data provided by Cameco, an assumed rectangular stockpile 20m high

[3] Assumption - Mean value for overburden from AP42 Chapter 13.2.4, Western Surface Coal Mining

[4] Taken from manufacturer specifications sheet

[5] Default value in the NPI Emission Estimation Technique Manual for Mining V3.1

B2 EMISSION FACTORS

The emission factors are based on the factors developed by the US EPA (AP42) and National Pollutant Inventory Handbooks:

- National Pollutant Inventory (NPI) (2012), "Emission Estimation Technique Manual for Mining".
- US EPA (2004), "Crushed Stone Processing and Pulverized Mineral Processing", AP-42 Chapter 11.19.2
- US EPA (2006a), "Unpaved Roads", AP-42 Chapter 13.2.2,
- US EPA (2006b), "Aggregate handling and storage piles", AP-42 Chapter 13.2.4,

Table B2 Emission factors: Removal of overburden and topsoil

Activity	Units	Emission factors		
		TSP	PM_{10}	$PM_{2.5}$
Dozer activity	kg/hr	0.86	0.16	0.09
Excavator	kg/tonne	0.00009	0.00004	0.000003
Loading	kg/tonne	0.00009	0.00004	0.000003
Transport	g/VKT	5,462	1,612	161
Dumping	kg/tonne	0.00009	0.00004	0.000003

Table B3 Emission factors: Removal of ore (all grades)

Activity	Units	Emission factors		
		TSP	PM_{10}	$PM_{2.5}$
Excavator	kg/tonne	0.00009	0.00004	0.000003
Loading	kg/tonne	0.00009	0.00004	0.000003
Transport	g/VKT	5,462	1,612	161
Dumping	kg/tonne	0.00009	0.00004	0.000003
Dozer operation	kg/hr	0.86	0.16	0.09

Table B4 Emission factors: Metallurgical processing plant

Activity	Units	Emission factors		
		TSP	PM_{10}	$PM_{2.5}$
FEL pick up from ROM	kg/tonne	0.00009	0.00004	0.000003
FEL drop into crusher	kg/tonne	0.00009	0.00004	0.000003
Single stage crushing unit	kg/tonne	0.0027	0.0012	0.0002
Transfer points	kg/tonne	0.00009	0.00004	0.000003
Conveyor	g/m/s	0.00006	0.00003	0.000005
Semi-autogenous-grinding (SAG) mill	kg/tonne	No emissions	No emissions	No emissions

Table B5 Emission factors: Fugitive dust emissions

Activity	Units	Emission factors		
		TSP	PM_{10}	$PM_{2.5}$
Wind erosion	kg/ha/hr	0.4	0.2	0.002

B3 EMISSION RATES

Table B6 presents the emission rates calculated due to the proposed mine during Year 3 operations. These emission rates are based on the activity data and emission factors presented in Section B1 and B2, respectively.

Table B6 Dust emission rates for Year 3

Dust emission source	Year 3		
	TSP	**PM_{10}**	**$PM_{2.5}$**
Removal of overburden and topsoil and filling in previously used pit areas			
Dozer ripping	0.05	0.01	0.01
Excavator	0.02	0.01	0.001
Loading	0.02	0.01	0.001
Transport	10.25	3.03	0.30
Dumping	0.02	0.01	0.001
Dozer operation	0.07	0.01	0.01
Subtotal	*10.44*	*3.08*	*0.32*
Removal of ore (all grades)			
Excavator	0.01	0.01	0.0005
Loading	0.01	0.01	0.0005
Transport	21.83	6.44	0.64
Dumping	0.01	0.01	0.0005
Dozer operation	0.50	0.09	0.05
Subtotal	*22.37*	*6.55*	*0.70*
Processing plant			
Pick from stockpile	0.004	0.002	0.0001
Transport to ROM	3.12	0.92	0.09
Dumping to ROM	0.004	0.002	0.0001
FEL pick up from ROM	0.004	0.002	0.0001
FEL drop into crusher	0.004	0.002	0.0001
Single stage crushing unit	0.11	0.05	0.01
Transfer points	0.01	0.00	0.0003
Conveyor	0.02	0.01	0.001
Semi-autogenous-grinding (SAG) mill	0.00	0.00	0.00
Subtotal	*3.27*	*0.99*	*0.10*
Fugitive dust emissions			
Active stockpiles	9.66	4.83	0.36
Working pit area (active)	13.97	6.98	0.52
Previous pit used for dumping	2.23	1.11	0.08
Rehabilitated previous pits	0.00	0.00	0.00

Dust emission source	**Year 3**		
	TSP	**PM_{10}**	**$PM_{2.5}$**
RoM stockpile	0.10	0.05	0.004
Quarry	3.01	1.11	0.10
Subtotal	*28.96*	*14.09*	*1.07*
Total Emissions	***65.04***	***24.71***	***2.19***