Vulcan Complex Project Air Quality Assessment

Prepared for:

Vitrinite Pty Ltd

September 2020

Final

Prepared by:

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

www.katestone.global
admin@katestone.com.au
Ph +61 7 3369 3699

Document Control

Deliverable #:	D19001-6
Title:	Vulcan Complex Project Air Quality Assessment
Version:	1.1 (Final)
Client:	Vitrinite Pty Ltd
Document reference:	D19001-6 Vitrinite - Vulcan Complex Project Air Quality Assessment_v1.1_Final.docx
Prepared by:	Andrew Vernon and Paddy McDowell
Reviewed by:	Simon Welchman
Approved by:	 Natalie Shaw 18/09/2020

Disclaimer

https://katestone.global/report-disclaimer/

Copyright

This document, electronic files or software are the copyright property of Katestone Environmental Pty. Ltd. and the information contained therein is solely for the use of the authorised recipient and may not be used, copied or reproduced in whole or part for any purpose without the prior written authority of Katestone Environmental Pty. Ltd. Katestone Environmental Pty. Ltd. makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document, electronic files or software or the information contained therein.

© Copyright Katestone Environmental Pty. Ltd.

Contents

Executive Summary iv
1. Introduction 1
2. Overview of the Assessment Methodology 3
2.1 Assessment scenarios 3
2.2 Considerations for assessing air quality 5
2.3 Existing environment 5
2.4 Emissions 5
2.5 Impact assessment 5
3. Considerations for Assessing Air Quality 6
3.1 Pollutants 6
3.1.1 Particulate matter 6
3.1.2 Other pollutants 6
3.2 Legislative framework for air quality 6
4. Existing Environment 8
4.1 Local terrain and land-use 8
4.2 Sensitive receptors 8
4.3 Climate 10
4.3.1 Temperature and solar exposure 10
4.3.2 Rainfall 11
4.4 Local Meteorology 12
4.4.1 Wind speed and wind direction 12
4.4.2 Atmospheric stability and mixing height 15
4.5 Ambient Air Quality 16
4.5.1 Existing sources of air pollutants 16
4.5.2 Existing ambient air quality 17
4.5.3 Summary of background dust levels 19
5. Assessment Methodology 20
5.1 Emission Estimation 20
5.2 Site-specific Meteorology 20
5.3 Dispersion Modelling 21
5.4 Cumulative Impacts 21
5.5 Limitations of Dispersion Modelling 21
6. Emissions to the Atmosphere 22
6.1 Overview 22
6.2 Mitigation Measures 22
6.3 Emission Inventory 22
7. Impact Assessment 24
7.1 TSP 24
7.2 PM_{10} 25
7.3 $PM_{2.5}$ 26
7.4 Dust Deposition 27
8. Conclusions 28
9. References 29
Appendix A Detailed Dust Emissions Inventory Data 36
A1 Activity Data 36
A2 Calculation of Emission Factors 39
A2.1 Drilling 39
A2.2 Blasting 39
A2.3 Bulldozing on overburden 39
A2.4 Bulldozing on coal 39
A2.5 Material transfers and handling 40
A2.6 Grading 40
A2.7 Wind erosion from active stockpiles 40
A2.8 Wind erosion from exposed areas 41
A2.9 Wheel-generated dust 41

A2.10 Crushing 41
A2.11 Screening 42
Appendix B Meteorological and Dispersion Modelling Methodology 43
B1 Meteorology 43
B1.1 Selection of representative year 43
B1.2 TAPM meteorology 45
B1.3 CALMET meteorological modelling 46
B2 Dispersion Modelling 47
B2.1 Source configuration 47

Tables

Table 1 Project schedule for assessment year 3
Table 2 Air quality objectives (Air EPP) 7
Table 3 Nearest sensitive receptors to the VCP 8
Table 4 Dust emissions reported to NPI for 2017/2018 17
Table 5 Summary of 24-hour average PM_{10} concentrations measured at Moranbah 18
Table 6 Ambient background concentrations used to assess cumulative impacts 19
Table 7 Dust control measures and relative reduction in emissions 22
Table 8 Estimated TSP, PM_{10} and $PM_{2.5}$ emission rates for the VCP (kg/annum) 23
Table 9 VCP Year 2 – breakdown of TSP, PM_{10} and $PM_{2.5}$ emission rates (g/s) 23
Table 10 Predicted annual average ground-level concentrations of TSP (µg/m^3) 24
Table 11 Predicted ground-level concentrations of PM_{10} (µg/m^3) 25
Table 12 Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ (µg/m^3) 26
Table 13 Predicted maximum monthly dust deposition rates (mg/m^2/day) 27

Figures

Figure 1 Vulcan Complex Project – Location Plan 2
Figure 2 VCP Year 2 - Project General Arrangement 4
Figure 3 Location of sensitive receptors 9
Figure 4 Monthly mean temperature (°C) measured at Moranbah Water Treatment Plant (1986-2012) 10
Figure 5 Mean daily solar radiation (MJ/m^2) by month at Moranbah Water Treatment Plant (1986-2012) 11
Figure 6 Range of total monthly rainfall measured at Moranbah Water Treatment Plant (1986-2012) 12
Figure 7 Annual wind rose for the VCP site (extracted from CALMET) - 2018 13
Figure 8 Seasonal wind roses for the VCP site (extracted from CALMET) – 2018 14
Figure 9 Diurnal wind roses for the VCP site (extracted from CALMET) - 2018 14
Figure 10 Stability class frequency for the VCP site (extracted from CALMET) - 2018 15
Figure 11 Diurnal variation in mixing height at the VCP site (extracted from CALMET) - 2018 16

Contour Plates

Plate 1 Year 2 VCP - Predicted annual average ground-level concentrations of TSP for the cumulative assessment 30
Plate 2 Year 2 VCP - Predicted maximum 24-hour average ground-level concentrations of PM_{10} for the cumulative assessment 31
Plate 3 Year 2 VCP - Predicted annual average ground-level concentrations of PM_{10} for the cumulative assessment 32
Plate 4 Year 2 VCP - Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ for the cumulative assessment 33
Plate 5 Year 2 VCP - Predicted annual average ground-level concentrations of $PM_{2.5}$ for the cumulative assessment 34
Plate 6 Year 2 VCP - Predicted maximum monthly dust deposition rate for the cumulative assessment 35

Glossary

Term	Definition
µg/m^3	micrograms per cubic metre
µm	microns
°C	degrees Celsius
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
Nomenclature	**Definition**
PM_{10}	particulate matter with a diameter less than 10 micrometres
$PM_{2.5}$	particulate matter with a diameter less than 2.5 micrometres
TSP	total suspended particles
Abbreviations	**Definition**
Air EPP	*Environmental Protection (Air) Policy 2019*
BoM	Bureau of Meteorology
DES	Department of Environment and Science
EF	Emission Factor
EP Act	*Environmental Protection Act 1994*
ER	Emission Rate
ML	Mine Lease
NPI	National Pollutant Inventory database
ROM	Run of Mine
TAPM	The Air Pollution Model
US EPA	United States Environmental Protection Agency
VCP	Vulcan Complex Project

EXECUTIVE SUMMARY

Katestone Environmental Pty Ltd (Katestone) was commissioned by Mining and Energy Technical Services Pty Limited (METServe), on behalf of Vitrinite Pty Ltd, owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite), to complete an Air Quality Assessment of the Vulcan Complex Project (VCP), a proposed small scale open-cut coking coal mine located 30 km south of Moranbah.

The air quality assessment has investigated the potential for the VCP to affect air quality in the region. Year 2 of VCP operation was found to produce the highest emissions of air pollutants during the 4-year mine life. Year 2 was selected based on the proposed mining schedule and the proximity of sensitive receptors to critical emission generating activities. The assessment has used meteorological and dispersion models to assess the effect of particulate matter emissions on concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates in the surrounding region.

Concentrations of air pollutants due to proposed activities associated with the VCP in isolation, and with the inclusion of background levels of dust, were determined at sensitive residential receptors and on a cartesian grid covering the region. Predicted ground-level concentrations of air pollutants and dust deposition rates were compared with the relevant air quality objectives and guidelines.

The air quality assessment of the VCP found the following:

TSP

- Predicted ground-level concentrations of TSP comply with the relevant air quality objective at all residential receptors, when assessed in isolation and cumulatively.

PM_{10}

- Predicted 24-hour average ground-level concentrations of PM_{10} comply with the relevant air quality objective at all residential receptors, when assessed in isolation and cumulatively.
- Predicted annual average ground-level concentrations of PM_{10} comply with the relevant air quality objective at all residential receptors, when assessed in isolation. Cumulative concentrations exceed the objective because the background level of PM_{10}, taken from measurements at Moranbah, exceeds the objective.
- The contribution of the VCP to annual average ground-level concentrations of PM_{10} is 0.2 µg/m³ or less than 1% of the Air EPP objective.

$PM_{2.5}$

- Predicted 24-hour and annual average ground-level concentrations of $PM_{2.5}$ comply with the relevant air quality objectives at all residential receptors, when assessed in isolation and cumulatively.

Dust Deposition

- Predicted dust deposition rates comply with the guideline at all residential receptors, when assessed in isolation and cumulatively.

1. INTRODUCTION

Vitrinite Pty Ltd , owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite) proposes the Vulcan Complex Project (VCP), a small scale open cut coal mine located 35 km north of Dysart and 30 km south of Moranbah in Queensland's Bowen Basin (Figure 1). The VCP lies to the immediate west of several established mining operations including BMA's Peak Downs and Saraji mines.

The VCP will operate for approximately 4 years and will extract approximately 6 million tonnes (Mt) of Run of Mine (ROM) hard coking coal at a rate of up to 1.95 million tonnes per annum (Mtpa). Truck and shovel mining methods will be employed to develop a single pit. ROM coal will be screened and crushed on-site before being trucked off site for toll washing at a nearby facility between Moranbah and Coppabella on the Peak Downs Highway.

Katestone Environmental Pty Ltd (Katestone) was commissioned by Mining and Energy Technical Services Pty Limited (METServe), on behalf of Vitrinite, to complete an Air Quality Assessment of the VCP to support an environmental authority (EA) application.

This air quality assessment has been carried out in accordance with the Queensland Department of Environment and Science's (DES) requirements. The following scope of works has been completed:

- Describe the VCP with a focus on elements pertaining to impacts to air quality;
- Describe regulatory requirements relevant to the VCP, including air quality objectives and indicators in the *Environmental Protection (Air) Policy 2019*;
- Describe the environmental values in and surrounding the VCP areas including sensitive receptors, site topography and built environment, ambient air quality, and an assessment of meteorology;
- Describe onsite sources of air pollutants and develop an air pollutant emission inventory for a worst-case operational scenario of the mine;
- Conduct dispersion modelling to predict ground-level concentrations of dust associated with the mine, providing all model input data/parameters and assumptions;
- Analyse the incremental and cumulative concentrations of dust against the relevant air quality criteria and objectives for dust deposition and particulates;
- Propose management and mitigation measures for minimising effects on air quality, if required; and
- Prepare an air quality assessment report for inclusion in the EA application.



Figure 1 **Vulcan Complex Project – Location Plan**

2. OVERVIEW OF THE ASSESSMENT METHODOLOGY

The purpose of this air quality assessment is to address the potential impact to the air environment through consideration of the requirements in the DES's *Application requirements for activities with impacts to air* (DEHP, 2017a). The following sections outline the methodologies adopted in this assessment.

2.1 Assessment scenarios

The VCP is a small-scale mining operation, with coal extraction planned for approximately 3 years, followed by completion of rehabilitation activities in year 4. Construction of temporary infrastructure associated with the mining operation is expected to be completed with a month.

Accordingly, this air quality assessment has considered only Year 2 of the VCP, which represents worst-case emissions over the four-year mine life. Selection of Year 2 was based on the proposed mining schedule and the proximity of sensitive receptors to critical emission generating activities. Mining information is provided in Table 1 for the three extraction years. The Year 2 general arrangement is provided in Figure 2.

Table 1 Project schedule for assessment year

Project Year	Run of Mine (ROM) (approximate tonnes)	Product Coal (approximate tonnes)	Overburden (approximate tonnes)
Year 1	1,950,000	1,170,000	7,434,900
Year 2	1,950,000	1,170,000	7,441,500
Year 3	1,860,000	1,118,210	6,182,700

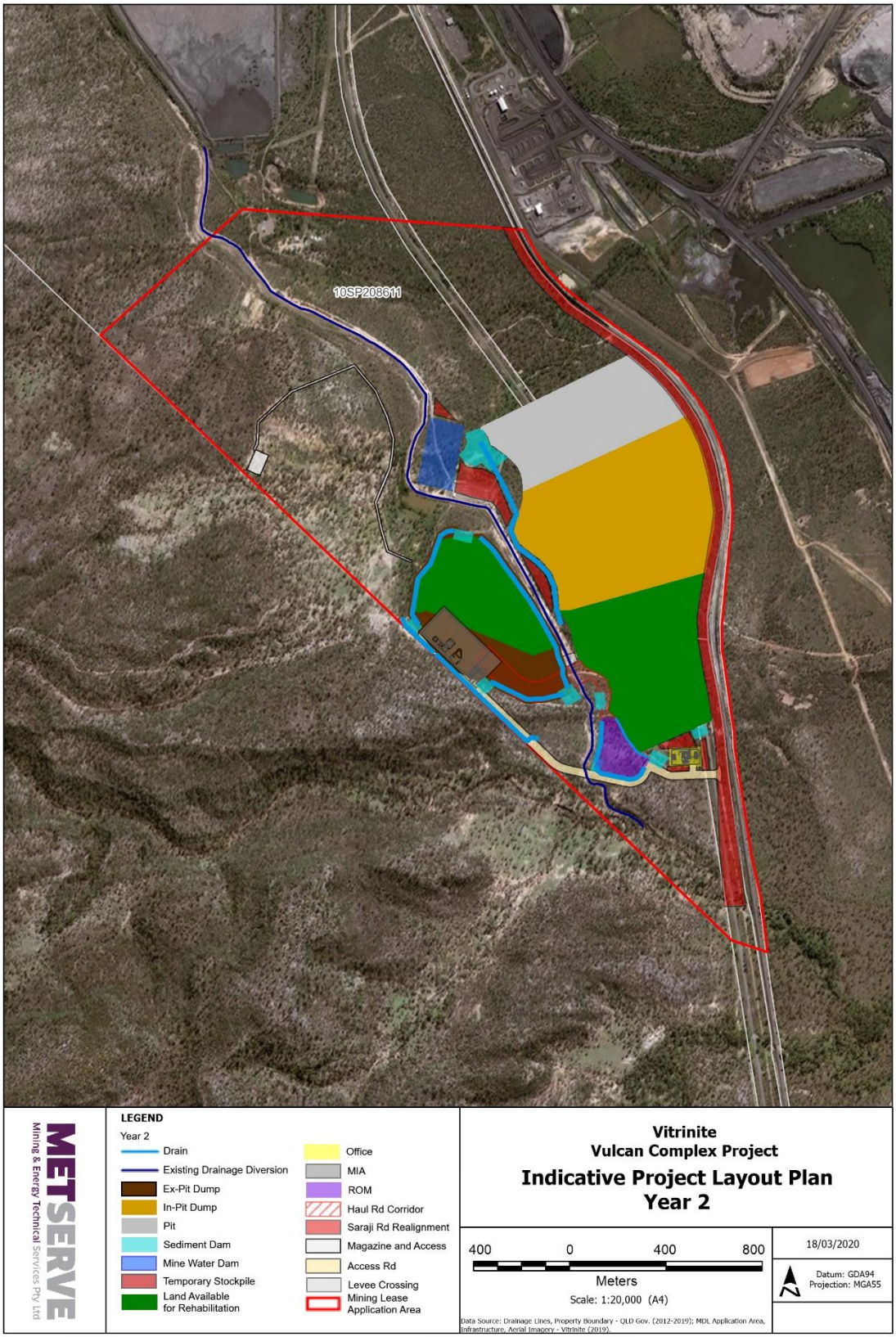


Figure 2 **VCP Year 2 - Project General Arrangement**

2.2 Considerations for assessing air quality

Air pollutants likely to be emitted from the VCP have been identified and the current Queensland regulatory requirements pertaining to these air pollutants have been reviewed and relevant objectives presented. Results of the dispersion modelling of air emissions from the VCP have been assessed against the applicable air quality objectives.

2.3 Existing environment

The assessment includes an analysis of the existing environment characteristics in the project area that are important for the dispersion of air pollutants from the site and that may influence the level of air pollutants in the surrounding area. Characteristics include the climate and local meteorology (temperature, wind, humidity and rainfall), any terrain features, the neighbouring land uses and the location of sensitive receptors. The existing air quality in the project area has been quantified through analysis of available ambient air quality monitoring data. Existing sources of similar air pollutants to the air pollutants released by the VCP have been identified.

2.4 Emissions

Emissions to the atmosphere associated with the proposed Year 2 VCP mining activities have been estimated. The primary air pollutant emitted from mining activities is particulate matter (PM) made up of various sized particles, including: TSP (total suspended particulates), PM_{10} (particulate matter with an aerodynamic diameter less than 10 microns) and $PM_{2.5}$ (particulate matter with an aerodynamic diameter less than 2.5 microns). Other air pollutants anticipated to be generated by the VCP, such as combustion emissions related to haul trucks, will be emitted in relatively small quantities and, have therefore, been addressed qualitatively.

2.5 Impact assessment

The potential of the VCP to impact air quality has been assessed through a dispersion modelling study and comparison with the air quality assessment criteria. Dispersion modelling has been carried out using the TAPM/CALMET/CALPUFF suite of meteorological and dispersion models.

A cumulative assessment has been undertaken to account for existing mines in the vicinity of VCP through addition of a representative ambient background. The impact assessment presents the results at identified sensitive receptor locations and across a cartesian grid centred on the VCP.

3. CONSIDERATIONS FOR ASSESSING AIR QUALITY

3.1 Pollutants

Particulate matter (i.e. dust) is the key air pollutant anticipated to be generated by activities on the VCP site.

3.1.1 Particulate matter

Mining activities can give rise to dust that, in elevated concentrations, has the potential to cause adverse impacts on the amenity and health of people living in the vicinity.

Dust can affect communities in various ways, depending upon the source and size of particles present. Dust typically emitted as a result of mining activities is assessed using the following metrics: TSP (total suspended particulates), dust deposition rate, PM_{10} and $PM_{2.5}$.

Dust from mining activities consists primarily of larger particles generated through the handling of rock and soil, as well as through wind erosion of stockpiles and exposed ground. Larger particles (measured as dust deposition and TSP) are mostly associated with dust nuisance or amenity impacts in residential areas, through settling or deposition of the particles. Elevated dust deposition rates can reduce public amenity, through soiling of clothes, buildings and other surfaces in the area.

Smaller particles such as PM_{10} and $PM_{2.5}$ can also be generated through mining activities. Elevated levels of PM_{10} and $PM_{2.5}$ have the potential to affect human health as these particles can be trapped in the nose, mouth or throat, or be drawn into the lungs. Fine particles (i.e. $PM_{2.5}$) are typically generated through combustion processes.

3.1.2 Other pollutants

Quantities of other air pollutants, such as oxides of nitrogen (NO_x), carbon monoxide (CO) and sulfur dioxide (SO_2), may also be emitted from vehicle traffic and blasting within the VCP site. The emission rates of these air pollutants are very low compared to the emission rates of particulate matter from mining activities. Further, the emissions are transient in nature, and therefore, are unlikely to have any negligible effect on air quality outside the of the pit and haul road corridor. Hence, particulate matter is considered the critical air pollutant for this assessment.

As will be shown in this report, the VCP project demonstrates compliance with air quality objectives for particulate matter at the nearest sensitive receptors, as a consequence, compliance with air quality objectives for NO_x, CO and SO_2 can be inferred. Therefore, these air pollutants do not require further assessment.

Odour is unlikely to be emitted from typical mining activities. Spontaneous combustion is a potential source of odour from mining activities but the potential for this is low and, therefore, odour has not been assessed further.

3.2 Legislative framework for air quality

The *Environmental Protection Act 1994* (EP Act) provides for the management of the air environment in Queensland. The EP Act gives DES the power to create Environmental Protection Policies that identify, and aim to protect, environmental values of the atmosphere that are conducive to the health and well-being of humans and biological integrity. *The Environmental Protection (Air) Policy* (Air EPP) was made under the EP Act and gazetted in 1997; the Air EPP was revised and reissued in 2019.

The purpose of the Air EPP is to identify the environmental values of the air environment to be enhanced or protected and to achieve the object of the Act, that is, ecologically sustainable development.

The environmental values to be enhanced or protected under the Air EPP are the qualities of the environment that are conducive to:

- protecting health and biodiversity of ecosystems;
- human health and wellbeing;
- protecting the aesthetics of the environment, including the appearance of building structures and other property; and
- protecting agricultural use of the environment.

The administering authority (DES) must consider the requirements of the Air EPP when it decides an application for an environmental authority, amendment of a licence or approval of a draft environmental management plan. Schedule 1 of the Air EPP specifies air quality indicators and objectives for pollutants that may be present in the air environment.

The air quality objectives that are relevant to the key air pollutants that may be generated from the VCP are presented in Table 2.

Also relevant is DES's *Application requirements for activities with impacts to air*, which outlines the information required to be provided to DES as part of the EA application process for environmentally relevant activities and how the information is used. It also outlines how the proposed activity will be assessed in the context of the requirements stipulated in the EP Act. In particular, this requires an application to include, if applicable:

- Description of the site and surrounding areas, including topography, prevailing winds and ambient air quality;
- Identification and appropriate assessment of any nearby sensitive places;
- Identification and evaluation of possible impacts on air quality; and
- Proposed management and mitigation measures, if required.

This air quality assessment has been conducted in accordance with these requirements.

Table 2 Air quality objectives (Air EPP)

Pollutant	Environmental value	Averaging period	Air quality objective/ guideline
TSP	Health and wellbeing	1-year	90 µg/m³
PM_{10}	Health and wellbeing	24-hour	50 µg/m³
		1-year	25 µg/m³
$PM_{2.5}$	Health and wellbeing	24-hour	25 µg/m³
		1-year	8 µg/m³
Dust deposition	Amenity	1-month	120 mg/m²/day[1]

Note:

[1] The dust deposition guideline is not defined in the Air EPP. DES's Model Mining Conditions (DEHP, 2017a) contains this guideline for dust deposition, which applies to total insoluble solids.

4. EXISTING ENVIRONMENT

4.1 Local terrain and land-use

The VCP is located approximately 35 km north of Dysart and 30 km south of Moranbah in central Queensland's Bowen Basin. The VCP is located on the lower eastern slopes of the Peak Downs Range.

The terrain rises steeply to the west of the VCP, due to the Peak Downs Range, with a maximum elevation of approximately 500 m above sea level. To the east the land is relatively flat and comprised of the plains adjacent to the Isaac River.

The land use within the region is predominantly rural, with the townships of Dysart and Moranbah located to the south and north. State forest, low intensity cattle grazing and coal mining are the dominant land uses in the VCP area.

4.2 Sensitive receptors

Sensitive receptors in proximity to the VCP have been identified by METServe, as shown in Table 3 and Figure 3. It should be noted that a number of receptors are either other operating coal mines or businesses that may service the VCP and have been classed as commercial receptors. There are only three residential receptors identified in the region.

The three residential receptors include two rural homesteads and the workers accommodation camp. These residential receptors are the focus of this assessment.

Table 3 Nearest sensitive receptors to the VCP

Receptor ID	Type	Description	Easting (km)	Northing (km)	Distance and direction from the VCP
1	Commercial	Kalari	622024.6	7535033	On Site
2		Dyno	622087.2	7534474	On Site
3		Dyno	622866.9	7534184	On Site
4		BMA Peak Downs	621288.7	7536144	100m NE
5		BMA Peak Downs	622256.2	7536261	244m NE
6		BMA Peak Downs	622156	7536420	1.6 km N
7		BMA Peak Downs	621438.8	7537872	On Site
8	Residential	Property Manager	630434	7523439	12.1 km SE
9		Workers Accommodation	630689	7522987	12.8 km SE
10	Commercial	BMA Saraji	631500	7520239	15.3 km SE
11	Residential	Saraji Station residence	629573	7519127	15.5 km SE



Figure 3 **Location of sensitive receptors**

4.3 Climate

Central Queensland has a sub-tropical continental climate characterised by high variability in rainfall, temperature and evaporation. The region can experience droughts, floods, heatwaves and frosts. In general, winter days are warm and nights are cool, while summer days are hot and nights are warm. Rainfall is summer dominant with almost half of the average annual rainfall occurring from December to February due to storms and tropical low-pressure systems associated with cyclones.

The Bureau of Meteorology (BoM) weather monitoring station nearest to the VCP is located at Moranbah Airport, approximately 30 km north-west. However, this weather station has only been in operation since 2012. Long-term climate data in the VCP region, from 1972 to 2012, has been collected from the (now decommissioned) BoM weather monitoring station located at Moranbah Water Treatment Plant. These data are described in the sections below.

4.3.1 Temperature and solar exposure

The mean daily maximum and minimum temperatures by month are presented in Figure 4. The analysis identifies a seasonal temperature profile typical of the sub-tropical Queensland climate, with cooler winter months of June to August and warmer summer months of December to February. The highest mean maximum daily temperature at the Moranbah monitoring station was 33.8 degrees Celsius (°C), recorded during the summer. The lowest mean minimum daily temperature at the monitoring station was 9.9°C, recorded during July.

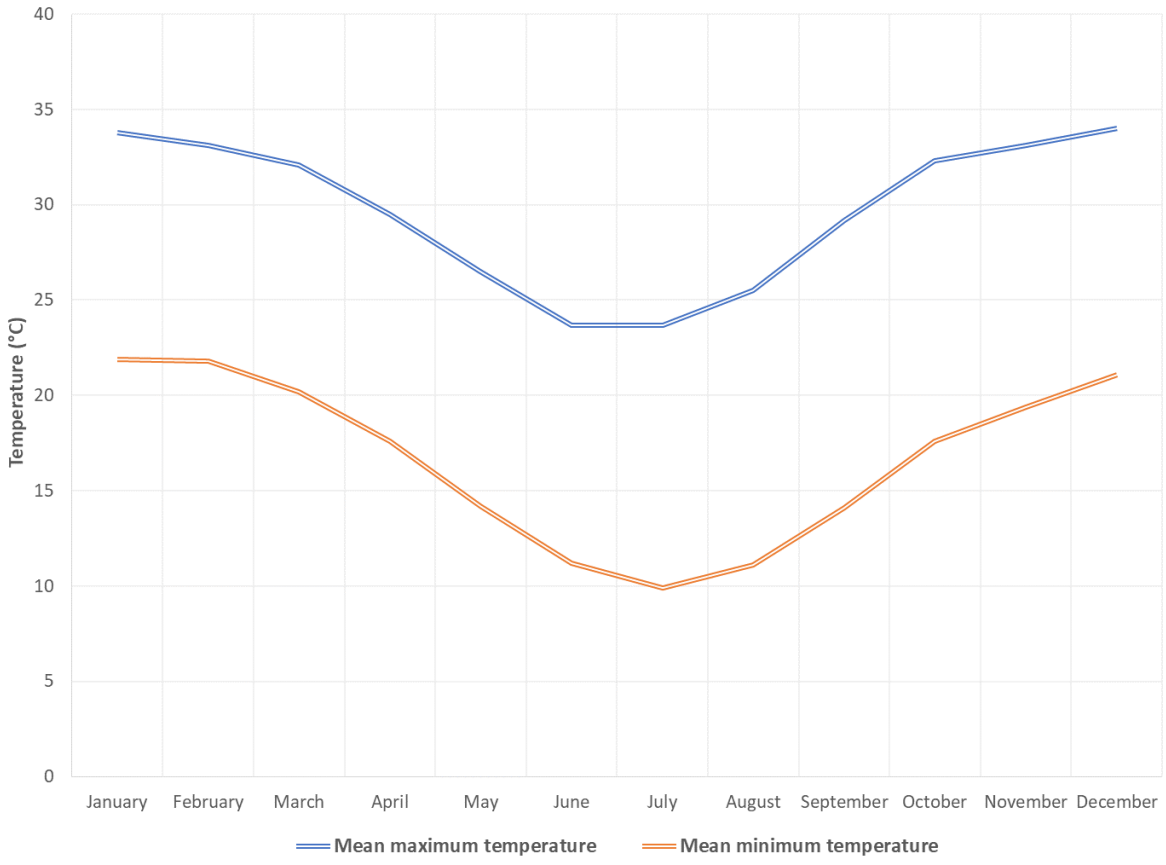


Figure 4 **Monthly mean temperature (°C) measured at Moranbah Water Treatment Plant (1986-2012)**

The amount of solar radiation received at ground-level is a primary driver for the weather patterns and climatic cycles that influence the Central Queensland region. The average daily solar radiation in megajoules per square metre (MJ/m²) by month is presented in Figure 5. This figure illustrates a clear seasonal pattern whereby summer solar radiation is much greater than during the winter months.

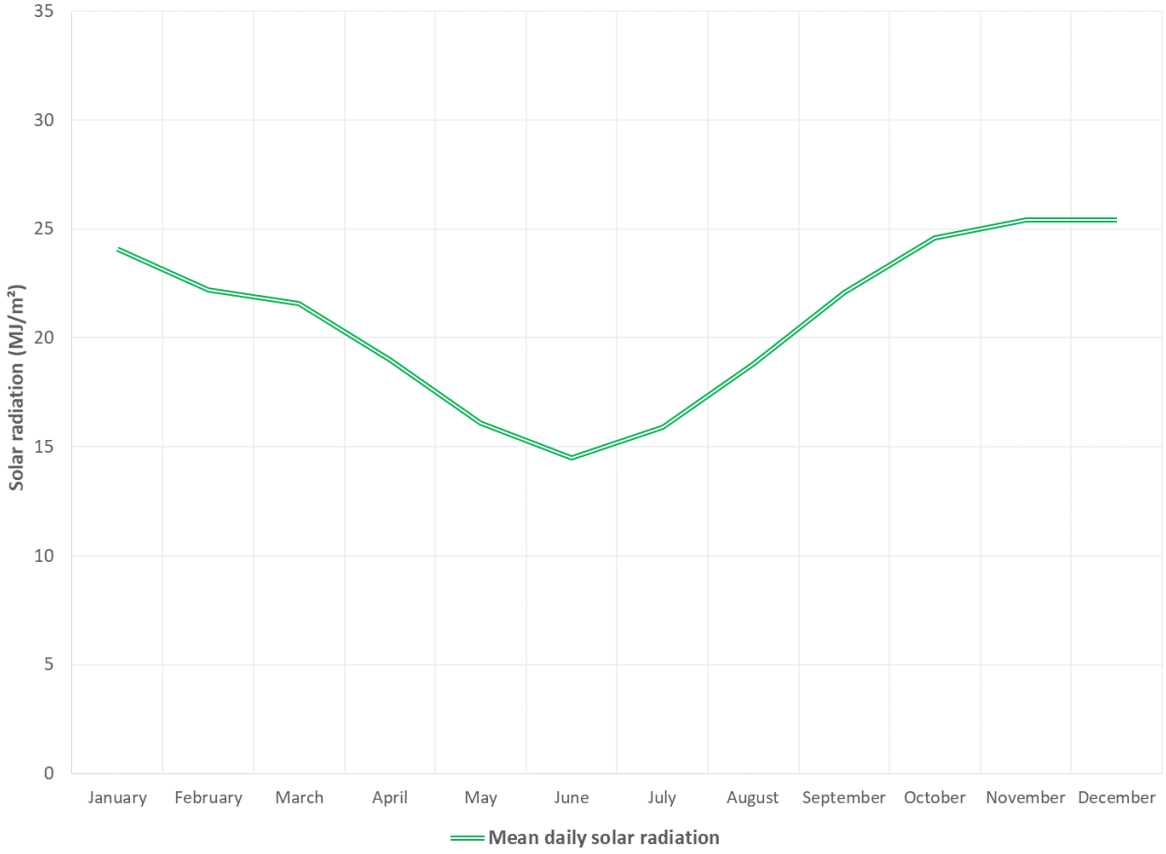


Figure 5 Mean daily solar radiation (MJ/m²) by month at Moranbah Water Treatment Plant (1986-2012)

4.3.2 Rainfall

The range of total monthly rainfall (mean and highest) at the Moranbah Water Treatment Plant for 1986-2012 is illustrated in Figure 6. The annual average rainfall is 614 millimetres (mm), with the wettest period occurring during the warmer months from December to February when, on average, 50% of the annual rainfall occurs.

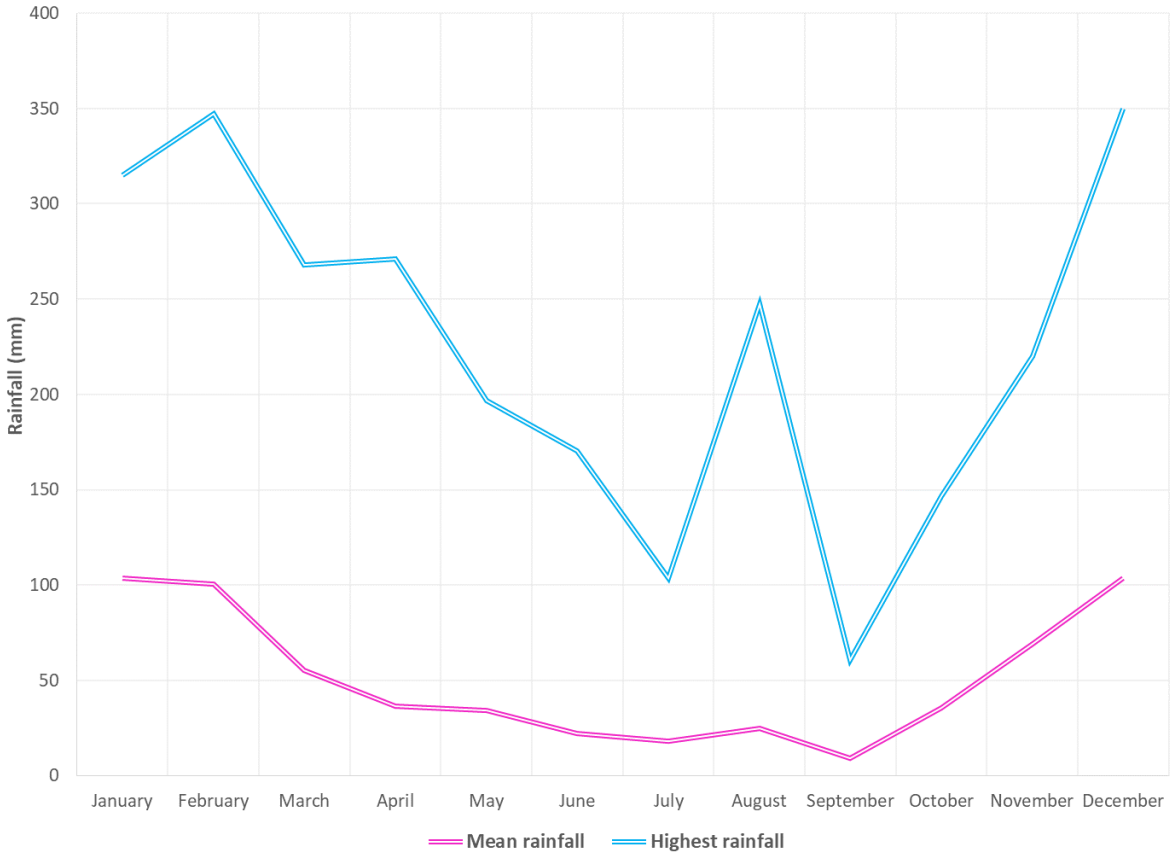


Figure 6 **Range of total monthly rainfall measured at Moranbah Water Treatment Plant (1986-2012)**

4.4 Local Meteorology

The following sections describe the local meteorology of the VCP area, focusing on parameters that are important for dispersion of air pollutants, namely wind speed, wind direction, atmospheric stability and boundary layer mixing height.

This local meteorological data has been generated for the year 2018 by the coupled The Air Pollution Model (TAPM) and CALMET meteorological models at the location of the VCP and used in the dispersion model assessment.

A description of the meteorological modelling methodology and process for selection of model year is described in Section 5.

4.4.1 Wind speed and wind direction

Wind speed and wind direction influence the rate of dispersion of dust emissions from sources such as wheel generated dust, material transfers, material processing and wind erosion. Wind speed also determines the amount of dust lifted into the air by wind erosion. The 2018 annual, seasonal and diurnal frequencies of winds at the VCP site are shown as wind roses in Figure 7, Figure 8 and Figure 9, respectively.

On average, 70% of winds at the site are from the northeast through to the southeast, with the south-easterlies being more prominent. During the year, winds vary with season, with south-easterlies most frequent during autumn and winter, and north-easterlies most frequent during spring.

The highest frequency of strongest winds (above 6 m/s) occurs during summer and autumn, from the east and east-southeast, which are also the most frequent wind directions.

There is a diurnal variation in the wind distribution, with a higher frequency of light winds occurring overnight (6 pm to 6 am) compared to the day. Winds from the east and east-southeast are most frequent during the afternoon (midday to 6 pm), whilst winds from the northeast are most frequent during the evening. Winds from midnight to midday are predominantly from the southeast.

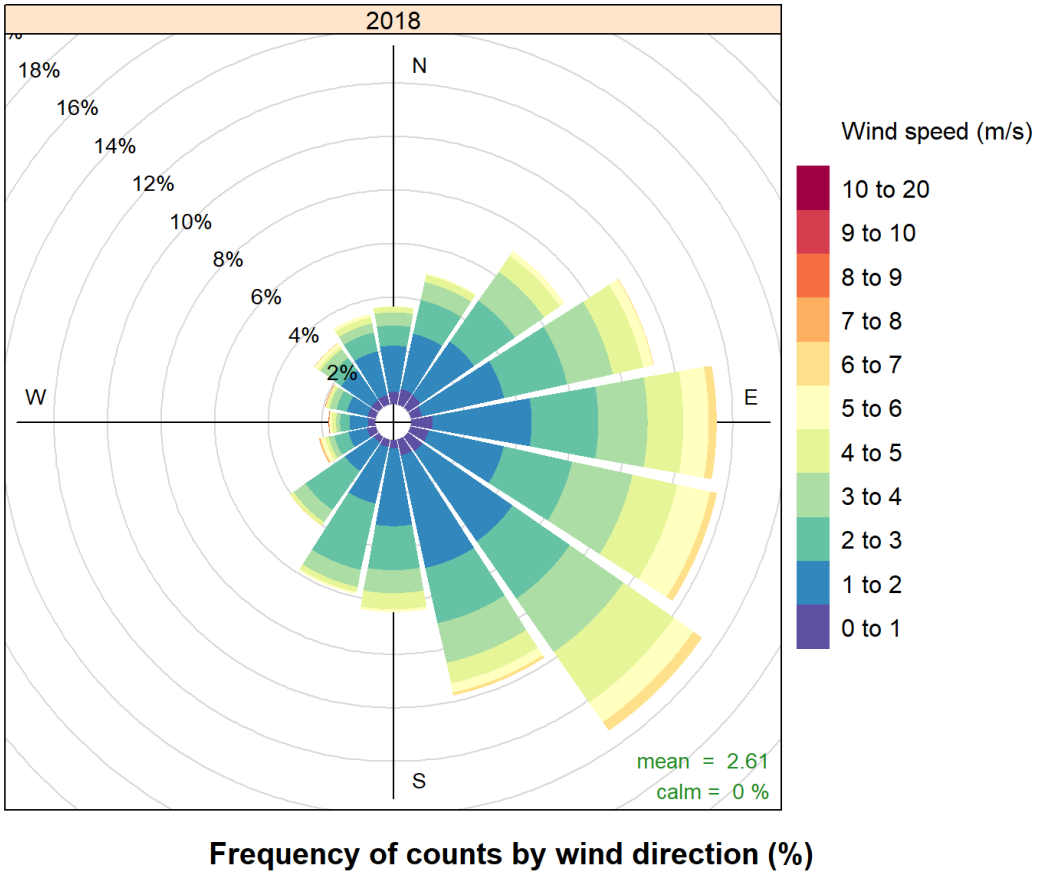


Figure 7 **Annual wind rose for the VCP site (extracted from CALMET) - 2018**

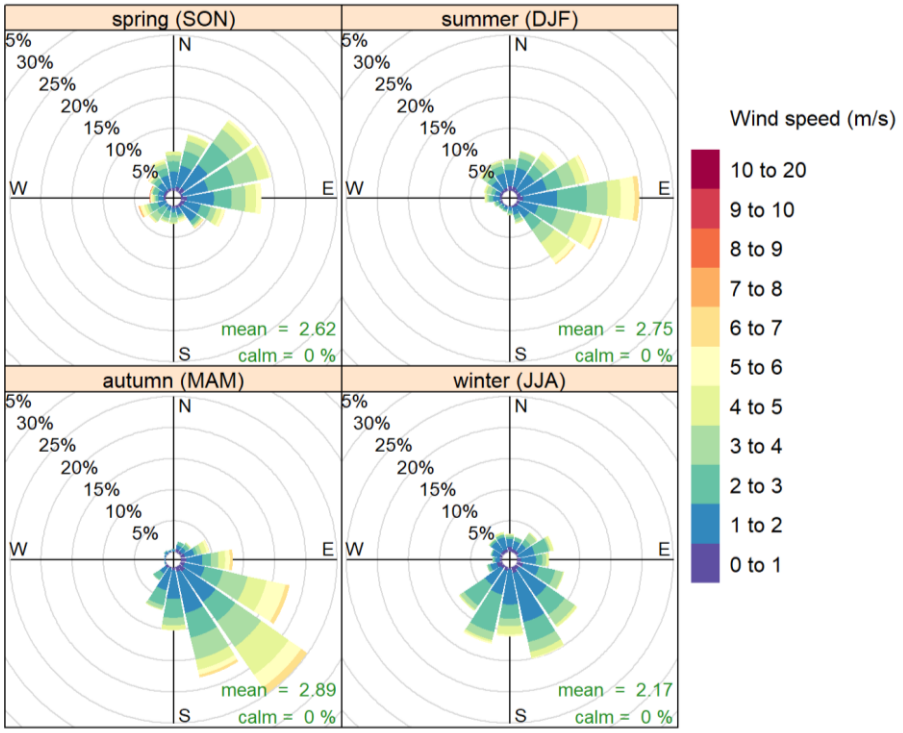


Figure 8 **Seasonal wind roses for the VCP site (extracted from CALMET) – 2018**

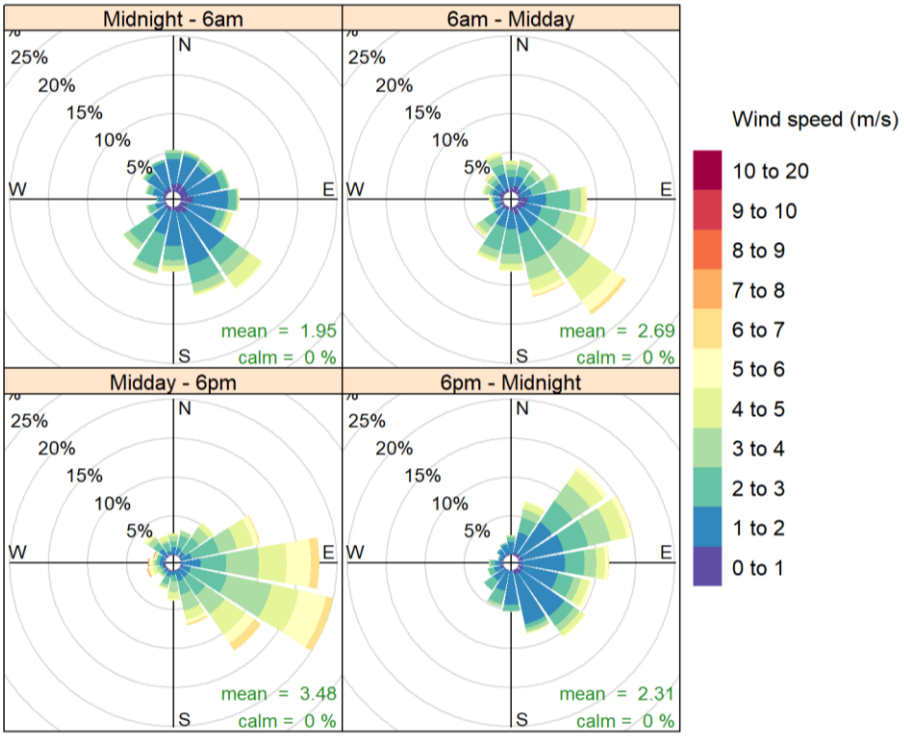


Figure 9 **Diurnal wind roses for the VCP site (extracted from CALMET) - 2018**

4.4.2 Atmospheric stability and mixing height

Atmospheric stability class is a measure of the stability of the atmosphere. Stability classes range from A class to F class. Figure 10 shows the predicted annual frequency of stability classes in the VCP area (taken from the meteorological dataset generated by the TAPM/CALMET models).

Class A represents the most unstable conditions and Class F the most stable conditions. Unstable conditions (Classes A to C) are characterised by strong to moderate solar heating of the ground. This 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 the most frequently occurring Class D conditions are dominated by mechanical turbulence, generated as the wind passes over irregularities in the local surface. During light wind and clear sky conditions at night, the atmosphere is generally stable (classes E and F). Strong winds and/or overcast conditions at night lead to Class D conditions.

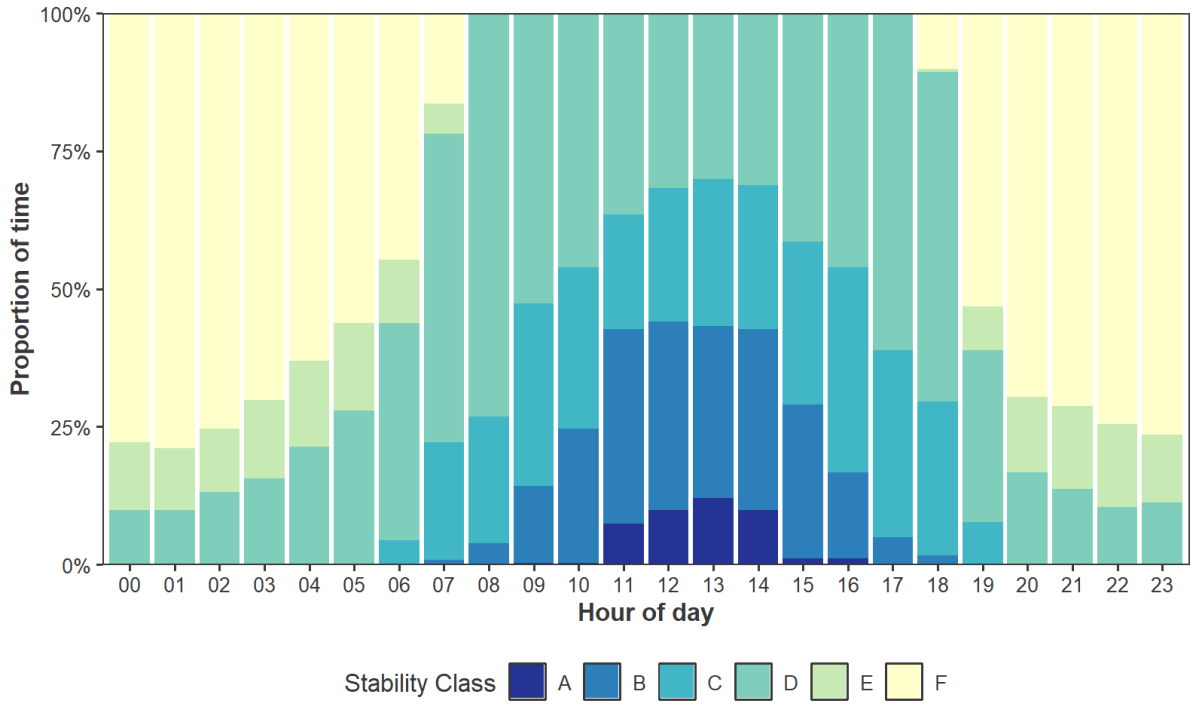


Figure 10 Stability class frequency for the VCP site (extracted from CALMET) - 2018

The mixing height defines the height of the mixed atmosphere above the ground (mixed layer), which varies diurnally. Particulate matter, or other pollutants released at or near the ground, will become dispersed within the mixed layer. 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 ground and causes the air above it to warm, resulting in convection and an increase to the mixing height. The growth of the mixing height is dependent on how well the warmer air from the ground 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 speeds, the air will be well mixed, resulting in a high mixing height.

Hourly mixing height information in 2018 has been extracted from the CALMET simulation over the VCP area and is presented in Figure 11 as a diurnal frequency plot. The data shows that, on average (blue dots), the mixing height develops at approximately 7 am, increases to a peak between 3 pm and 4 pm before descending rapidly until 6 pm.

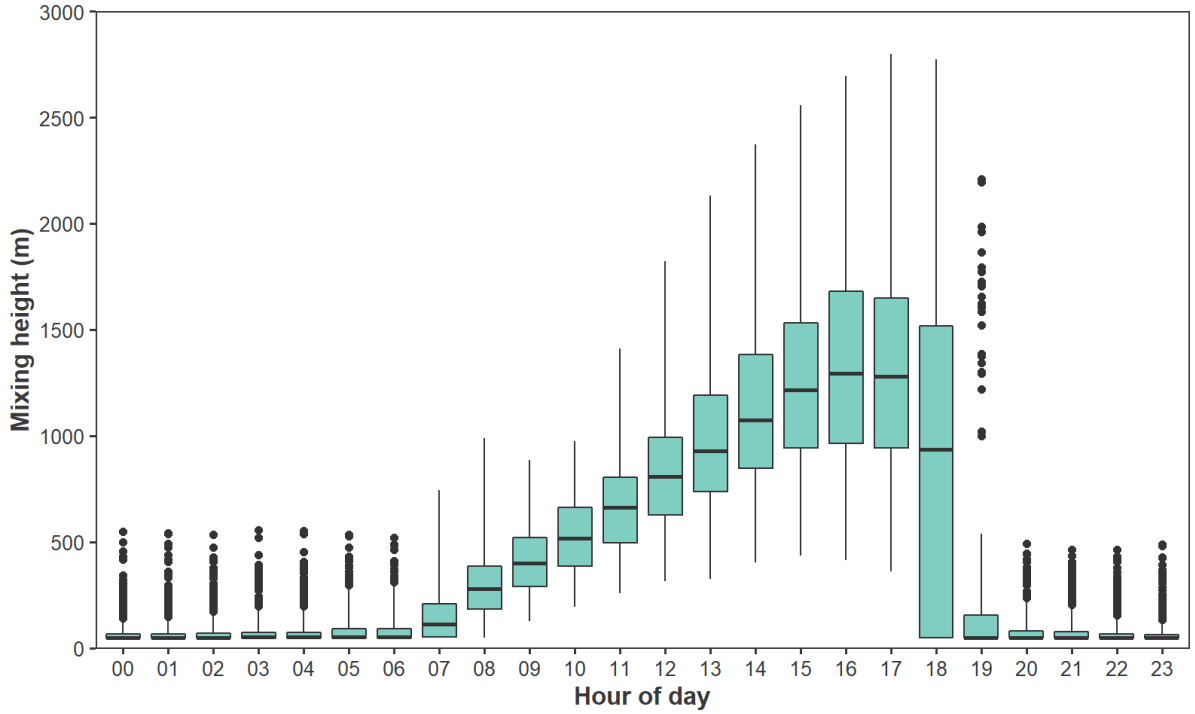


Figure 11 Diurnal variation in mixing height at the VCP site (extracted from CALMET) - 2018

4.5 Ambient Air Quality

There are several existing sources in the vicinity of the VCP that may generate dust, including a number of existing coal mines (BMA's Caval Ridge, Peak Downs and Saraji mines). Naturally generated dust in the environment may also be generated in the VCP region, sources include pollen and grass seeds; dust from the use of dirt roads; agricultural activities and wind erosion of non-vegetated areas.

Existing air quality has been determined from a review of available information on dust emissions and representative ambient air quality monitoring data in the region.

4.5.1 Existing sources of air pollutants

Industries within 35 km of the VCP that produce noteworthy dust emissions (PM_{10} and $PM_{2.5}$) have been identified through a review of the National Pollutant Inventory (NPI) database (NPI, 2017/18). The types of industries include:

- Mining; and
- Mining Support Services.

Table 4 details the dust emissions (PM_{10} and $PM_{2.5}$) reported to the NPI for 2017/18 (the most recent publicly available dataset) from identified industries in the VCP region.

Table 4 Dust emissions reported to NPI for 2017/2018

Facility Name	Main Activities	Distance and Direction from VCP Boundary	PM_{10} (tonnes/year)	$PM_{2.5}$ (tonnes/year)
Caval Ridge Mine	Coal Mining	18.4 km North West	6,996	97
Daunia Mine	Coal Mining	27.5 km North East	2,374	79
Lake Vermont	Coal Mining	34.9 km South East	9,743	658
Peak Downs Mine	Coal Mining	1.6 km North	14,295	163
Poitrel Coal Mine	Coal Mining	26 km North East	1,699	55
Red Mountain Infrastructure Joint Venture	Coal Mining Support	27.2 km North East	156	1.6
Saraji Mine	Coal Mining	17.3 km South	8,457	150
South Walker Creek Mine Operations	Coal Mining	4.8 km East	2,074	60

4.5.2 Existing ambient air quality

4.5.2.1 PM_{10}

DES operates a monitoring station on the eastern side of Moranbah. The monitoring station was established in March 2011. This monitoring station has been sited in accordance with the Australian Standards and is ideally located to monitor the impact of dust contributions from the surrounding mining operations on ambient air quality in the residential area at the eastern edge of Moranbah. The available dataset is considered to be reliable and suitable for use in determining representative ambient dust concentrations for the air quality assessment.

Data collected from the DES station from 2014 – 2019 is summarised in Table 5. Data in 2014 and 2016 complied with the DES criteria. During 2015, 24-hour average concentrations of PM_{10} were above 50 µg/m³ on 4 days. DES's monthly air quality bulletins noted that dust storms and bushfires were likely to have contributed to the elevated particulate levels on the days with concentrations of PM_{10} above 50 µg/m³.

During 2017, annual average concentrations of PM_{10} were above 50 µg/m³ on seven days, with six of these occurring in September and one in July. DES's July 2017 bulletin (DSITI, 2017a) for Central Queensland notes that vegetation fires are the most likely contributor to elevated concentrations of PM_{10} on 27 July 2017. DES's September 2017 bulletin (DSITI, 2017b) for Central Queensland notes that elevated particulate concentrations during September 2017 occurred during low wind speed conditions, also suggesting smoke rather than windblown dust from mining. The bulletin notes that extensive bushfires in the Shoalwater area and unreported vegetation fires in other locations appear to have contributed.

During 2018, 24-hour average concentrations of PM_{10} were above 50 µg/m³ on fifteen days. DES's monthly air quality bulletins note that smoke from bushfires or vegetation burning were likely to have contributed to the elevated particulate levels on the majority of days with concentrations of PM_{10} above 50 µg/m³.

During 2019, 24-hour average concentrations of PM_{10} were above 50 µg/m³ on thirty-two days. DES's monthly air quality bulletins noted that the combination of emission sources including dust storms, local dust sources, bushfires and planned hazard-reduction burns were likely to have contributed to the elevated particulate levels on the majority of days with concentrations of PM_{10} above 50 µg/m³.

Table 5 Summary of 24-hour average PM_{10} concentrations measured at Moranbah

Year	Max	No. of days > 50µg/m³	70th percentile	Average
2014	49.9	0	24.0	20.2
2015	91.9	4	25.7	21.8
2016	48.0	0	24.5	21.4
2017	66.0	7	29.5	25.8
2018	113.6	15	34.0	29.8
2019	217.8	32	35.0	30.1

4.5.2.2 TSP and $PM_{2.5}$

DES does not conduct monitoring of TSP at its Moranbah site. DES conducts monitoring of $PM_{2.5}$ at its Moranbah site; however, this only commenced in October 2019 so the available dataset is short and not suitable for determining ambient background concentrations of $PM_{2.5}$.

Publicly available information on ambient air quality monitoring in Moranbah is limited; however, a review of available data, including the Moranbah South EIS (2015) and Caval Ridge EIS (BHP Billiton Mitsubishi Alliance [BMA], 2010), provides information on available ambient air quality monitoring of TSP and $PM_{2.5}$ that can be used to represent background in this assessment.

BMA conducted monitoring of TSP and $PM_{2.5}$ at the corner of Jackson Avenue and Clements Street, Moranbah, using a Hi-volume air sampler in accordance with the Australian Standards for measurements of TSP and $PM_{2.5}$. Nine months of monitoring data is publicly available from this site from 1 January 2012 to 31 September 2012.

This data has been used to represent background levels of TSP and $PM_{2.5}$ in the VCP region, namely:

- TSP
  - 27.5 µg/m³ - Annual average
- $PM_{2.5}$
  - 4.3 µg/m³ - 24-hour average (70th percentile)
  - 3.6 µg/m³ - Annual average.

The historical BMA data results in a background value for TSP that is less than that for PM_{10}, which by definition cannot occur. This disparity is likely to be due to the different locations and times of monitoring. Accordingly, a TSP background concentration has been estimated based on the annual average PM_{10} background measured by DES in Moranbah and assuming that PM_{10} is approximately 50% of TSP.

4.5.2.3 Dust deposition rate

Dust deposition monitoring is not undertaken by DES in the VCP region. However, as detailed in the Moranbah South EIS (2015), Anglo undertook monthly dust deposition monitoring at the Moranbah Golf Course monitoring station every month from April 2009 to October 2012. The maximum rolling annual average from this site of 71 mg/m^2/day has been applied to represent the background dust deposition rate for the VCP.

4.5.3 Summary of background dust levels

Background levels of TSP, PM_{10}, $PM_{2.5}$ and dust deposition used in this assessment are summarised in Table 6. The background levels have been derived from the publicly available data presented in the previous sections.

Table 6 Ambient background concentrations used to assess cumulative impacts

Pollutant	Averaging Period	Concentration	Comment
TSP	Annual	60.2 µg/m^3	Used annual average PM_{10} of 30.1 and assumed PM_{10} is 50% of TSP
PM_{10}	24-hour	35 µg/m^3	Highest 70th percentile value at DES Moranbah, 2019
	Annual	30.1 µg/m^3	Highest average value at DES Moranbah, 2019
$PM_{2.5}$	Annual	4.3 µg/m^3	Historical monitoring reports
	24-hour	3.6 µg/m^3	
Dust deposition	Annual average	71 mg/m^2/day	

5. ASSESSMENT METHODOLOGY

The following section describes the modelling methodology that was adopted for the air quality assessment. The methodology uses standard industry dispersion models suitable for use in Australia and regulatory approved assessment techniques to predict ground-level concentrations of air pollutants in the areas surrounding the VCP.

5.1 Emission Estimation

To assess potential air quality impacts due to the VCP, potential dust emissions from individual mining activities in each scenario were accounted for and have been explicitly modelled. Specific activity information used to calculate dust emission rates associated with individual mining activities were provided or confirmed by METServe.

Dust emission rates were estimated using the base equation:

$$ER = A \times EF \times (1 - CF)$$

where:

ER	emission rate
A	activity / operations data
EF	emission factor
CF	reduction in emissions due to the implementation of control measures.

Emissions of TSP, PM_{10} and $PM_{2.5}$ from mining activities were estimated using recognised and accepted methods of dust emissions estimation. These include approximation of emission rates from NPI emissions estimation technique handbooks and the United States Environmental Protection Agency (US EPA) AP42 emission handbooks (US EPA, 1998; US EPA, 2006a; US EPA, 2006b; NPI, 2012).

The emissions estimation techniques applied in this assessment are based on standard methods that are applied throughout Australia and in the United States. These methods are consistent with those adopted for other air quality assessments conducted for other coal mines in Australia. The size distribution of dust particles was derived from the emission rates estimated for TSP, PM_{10}, and $PM_{2.5}$.

A dust emission inventory for the VCP is detailed in Section 6. The activity data and emission factor equations used to estimate dust emissions are detailed in Appendix A.

5.2 Site-specific Meteorology

The prognostic model TAPM (2008) (developed by the Commonwealth Scientific and Industrial Research Organisation [CSIRO]) and the diagnostic meteorological model CALMET (developed by Earth Tech, Inc.) were used to generate the three-dimensional meteorological dataset for the VCP area.

The year 2018 was selected as a representative year for meteorological modelling based on analysis of the last five complete years (2014 to 2018) of observations at the BoM Moranbah Airport monitoring station. The year 2018 was selected as representative, as observations of wind speed, wind direction and temperature in 2018 were closest to the average of the 2014 to 2018 period.

The three-dimensional wind field for 2018 produced by TAPM/CALMET was then used to create a meteorological file suitable for use with the CALPUFF dispersion model.

Details of the TAPM/CALMET model configuration and evaluation are discussed in Appendix B.

5.3 Dispersion Modelling

Source characteristics and dust emission rates from VCP activities were incorporated into a dispersion modelling study using the CALPUFF model.

CALPUFF is an advanced non-steady-state air quality modelling system. The meteorological data for 2018 generated by the TAPM/CALMET model was used as input for the dispersion model in order to include all weather conditions likely to be experienced in the region during a typical year. The modelling has been used to predict maximum ground-level concentrations and deposition rates of dust across a Cartesian grid of the VCP region and at the locations of the identified sensitive receptors.

Dust emissions have been modelled over a full year assuming 24 hours/day mining activities, except for blasting, which has been modelled between 6 am and 6 pm.

Technical details of the configuration of the CALPUFF model are discussed in Appendix B.

5.4 Cumulative Impacts

To determine the impact of the VCP upon the surrounding environment a representative background concentration for relevant air pollutants is required. Background levels of TSP, PM_{10}, $PM_{2.5}$ and dust deposition have been added to the dispersion modelling results of each scenario to provide a cumulative impact. The background levels that have been used in the assessment are summarised in Section 4.5.3.

5.5 Limitations of Dispersion Modelling

This study relies on the accuracy of several datasets including, but not limited to:

- Third party meteorological information
- Calculation of emission rates from mining activities; and
- DES ambient air quality monitoring data.

It is important to note that numerical models are based on an approximation of governing equations that represent complex natural processes. These will inherently incorporate some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included. Where uncertainty exists in characterising important properties of the environment or activities associated with the VCP, this study has erred on the side of caution and selected conservative inputs. The model outputs are therefore considered to be conservative.

6. EMISSIONS TO THE ATMOSPHERE

Dust will be emitted over the life of the VCP. Dust emissions can occur from the extraction, handling, transportation and processing of material (topsoil, overburden and coal), as well as from wind erosion of exposed areas and material stockpiles.

In addition to dust emissions, emissions of NO_X, SO_X and CO would occur due to blasting activities and the combustion of fuels on site. These emissions are transient, occur within the haul road corridor and open-cut pits and low in magnitude compared to dust emissions.

Dust mitigation measures proposed by Vitrinite and a dust emissions inventory for the VCP are provided in the following sections.

6.1 Overview

The key dust-generating activities over the life of the VCP would be:

- Topsoil stripping;
- Drilling and blasting;
- Haulage of overburden and ROM coal;
- Wind erosion of stockpiles, exposed and rehabilitated areas;
- On-site screening and crushing at mobile plant;
- Dozers;
- Material handling; and
- Road grading.

6.2 Mitigation Measures

Dust mitigation and operational controls have been included in the VCP design to limit dust emissions from mining activities, including:

- Water application on all major haul routes within the VCP domain;
- Progressive rehabilitation of areas that have been mined; and
- Covered loads on all trucks leaving the site.

These dust mitigation measures have been accounted for in the dust emissions inventory. The effectiveness of each control measure is presented in Table 7. An additional control factor of 50% for TSP and 5% for PM_{10} has been applied to all pit activities to account for pit retention (NPI, 2012 – Table 4).

Table 7 Dust control measures and relative reduction in emissions

Activity	Control measure	Reduction (%)
Wheel-generated dust and grading	Water application	85
Wind erosion	Rehabilitated areas (initial)	40

6.3 Emission Inventory

A summary of the total dust emission rates estimated for Year 2 of the VCP are presented in Table 8. A detailed breakdown of the dust inventory for each year is then provided in Table 9.

Emissions have been estimated as described in Appendix A. The inventory includes all VCP mining activities up to and including loading of product coal to trucks at the processing area for off-site haul.

Table 8 Estimated TSP, PM_{10} and $PM_{2.5}$ emission rates for the VCP (kg/annum)

Mine Year	Units	TSP	PM_{10}	$PM_{2.5}$
Year 2	kg/annum	1,365,863	547,745	138,846
	tonnes/annum	1,366	548	139

Table 9 VCP Year 2 – breakdown of TSP, PM_{10} and $PM_{2.5}$ emission rates (g/s)

Activity	TSP	PM_{10}	$PM_{2.5}$
Pit activities			
Bulldozing overburden	0.05	0.05	0.01
Drilling and blasting	0.33	0.32	0.02
Excavating overburden	3.00	2.74	0.43
Excavating ROM	1.13	0.33	1.13
Dumping activities			
Truck dumping overburden	2.88	1.96	0.41
Truck dumping ROM	2.26	0.35	0.12
Bulldozing overburden	0.12	0.05	0.02
Bulldozing ROM	2.55	0.88	0.06
Haulage			
ROM coal haulage	1.49	0.37	0.04
Overburden haulage	3.63	0.91	0.09
Grading haul roads	9.20	1.68	0.29
Processing			
Sizing and crushing	0.94	0.34	0.03
Truck loading and transfers	1.38	0.22	0.68
Wind erosion			
Stockpiles	10.94	5.47	0.82
Exposed areas	2.24	1.12	0.17
Rehabilitated areas	0.70	0.35	0.05
Total (g/s)	**42.85**	**17.14**	**4.37**

7. IMPACT ASSESSMENT

This section presents the results of the dispersion modelling assessment of the VCP. Modelling results associated with proposed Year 2 activities have been presented as ground-level concentrations or dust deposition rates at sensitive receptors as well as contours across the modelling domain.

Background dust levels have been added to the incremental model predictions in order to obtain an estimate of the potential cumulative impacts of the VCP. Results have been assessed by comparing the predicted concentrations and dust deposition rates with the relevant air quality objectives.

When considering the results, it is important to note the 24-hour average dispersion modelling results are based on the highest 24-hour average concentration of each pollutant predicted at a receptor over the one-year period and thus represent a peak-impact.

The contour plots are constructed such that the highest 24-hour average value is obtained and stored at each point in the modelled domain. As these values may occur at different times at different grid points, the contour plots do not represent a single snapshot of 24-hour average concentrations at any given time, rather a peak impact.

7.1 TSP

The predicted annual average ground-level concentrations of TSP for year 2 of the VCP assessed in isolation and with background levels applied (cumulative assessment) are presented in Table 10.

A contour plot of the predicted annual average ground-level TSP concentrations for year 2 of the VCP is presented in Plate 1 and provides the results for the cumulative assessment.

The results show that:

- Predicted ground-level concentrations of TSP ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively.

Table 10 Predicted annual average ground-level concentrations of TSP (µg/m³)

Receptor	Label	Year 2	
		VCP	Cumulative
1	Property Manager	0.3	60.5
2	Workers Accommodation	0.3	60.5
3	Saraji Station Residence	0.4	60.6
Background		-	*60.2*
Objective		**90 µg/m³**	

7.2 PM_{10}

The predicted maximum 24-hour average and annual average ground-level concentrations of PM_{10} for Year 2 of the VCP in isolation and with background levels applied (cumulative assessment) are presented in Table 11.

Contours of the predicted maximum 24-hour average and annual average ground-level concentrations of PM_{10} for Year 2 of the VCP are presented in Plate 2 and Plate 3.

The results show that:

- Predicted 24-hour average ground-level concentrations of PM_{10} ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively;
- Predicted annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all residential receptors, when assessed in isolation; and
- The background annual average concentration of PM_{10} is 30.1 µg/m³, which is above the Air EPP objective of 25 µg/m³. The contribution of the VCP to annual average $PM_{2.5}$ is 0.2 µg/m³ or less than 1% of the Air EPP objective, which is considered to be negligible.

Table 11 Predicted ground-level concentrations of PM_{10} (µg/m³)

Receptor	Label	Year 2			
		24-hour		Annual	
		VCP	Cumulative	VCP	Cumulative
1	Property Manager	3.1	38.1	0.1	30.2
2	Workers Accommodation	4.4	39.4	0.2	30.3
3	Saraji Station Residence	4.4	39.4	0.2	30.3
Background		-	*35*	-	*30.1*
Objective		**50 µg/m³**		**25 µg/m³**	

7.3 $PM_{2.5}$

The predicted maximum 24-hour average and annual average ground-level concentrations of $PM_{2.5}$ for year 2 of the VCP in isolation and with background levels applied (cumulative assessment) are presented in Table 12.

Contours of the predicted maximum 24-hour average and annual average ground-level concentrations of $PM_{2.5}$ for Year 2 of the VCP are presented in Plate 4 and Plate 5.

The results show that:

- Predicted 24-hour average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively; and
- Predicted annual average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively.

Table 12 Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ (µg/m³)

Receptor	Label	Year 2			
		24-hour		Annual	
		VCP	Cumulative	VCP	Cumulative
1	Property Manager	0.9	5.2	0.04	3.64
2	Workers Accommodation	1.1	5.4	0.05	3.65
3	Saraji Station Residence	1.4	5.7	0.08	3.68
	Background	-	*4.3*	-	*3.6*
Objective		**25 µg/m³**		**8 µg/m³**	

7.4 Dust Deposition

The predicted maximum monthly dust deposition rates for year 2 of the VCP in isolation and with background levels applied (cumulative assessment) are presented in Table 13.

A contour plot of the predicted maximum monthly dust deposition rates for Year 2 of the VCP are presented in Plate 6.

The results show that:

- Predicted dust deposition rates due to the VCP ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively.

Table 13 Predicted maximum monthly dust deposition rates (mg/m^2/day)

Receptor	Label	Year 2	
		VCP	Cumulative
1	Property Manager	0.9	71.9
2	Workers Accommodation	1.1	72.1
3	Saraji Station Residence	1.3	72.3
Background		-	*71*
Objective		**120 µg/m^3**	

8. CONCLUSIONS

This air quality assessment has investigated the potential for the VCP to affect air quality in the region. Year 2 of VCP operation was found to produce the highest emissions of air pollutants during the 4-year mine life. Year 2 was selected based on the proposed mining schedule and the proximity of sensitive receptors to critical emission generating activities. The assessment has used meteorological and dispersion models to assess the effect of particulate matter emissions on concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates in the surrounding region.

Concentrations of air pollutants due to the proposed operation of the VCP in isolation, and with the inclusion of background levels of dust, were determined at sensitive residential receptors and on a cartesian grid covering the region. Predicted ground-level concentrations of air pollutants and dust deposition rates were compared with the relevant air quality objectives and guidelines.

The air quality assessment of the VCP found the following:

TSP

- Predicted ground-level concentrations of TSP comply with the relevant air quality objective at all residential receptors, when assessed in isolation and cumulatively.

PM_{10}

- Predicted 24-hour average ground-level concentrations of PM_{10} comply with the relevant air quality objective at all residential receptors, when assessed in isolation and cumulatively.
- Predicted annual average ground-level concentrations of PM_{10} comply with the relevant air quality objective at all residential receptors, when assessed in isolation. Cumulative concentrations exceed the objective because the background level of PM_{10}, taken from measurements at Moranbah, also exceeds the objective.
- The contribution of the VCP to annual average ground-level concentrations of PM_{10} is 0.2 µg/m³ or less than 1% of the Air EPP objective, which is considered to be negligible.

$PM_{2.5}$

- Predicted 24-hour and annual average ground-level concentrations of $PM_{2.5}$ comply with the relevant air quality objectives at all residential receptors, when assessed in isolation and cumulatively.

Dust Deposition

- Predicted dust deposition rates comply with the guideline at all residential receptors, when assessed in isolation and cumulatively.

9. REFERENCES

Ambient air quality monitoring dataset from Moranbah Station 2012-2019, 2020, available for downland at Queensland Data (https://data.qld.gov.au/) (accessed February 2020).

BHP Billiton Mitsubishi Alliance, Caval Ridge Mine Project Environmental Impact Statement, 2010, available at: https://www.statedevelopment.qld.gov.au/assessments-and-approvals/caval-ridge-mine-eis-documents.html.

Department of Environment and Heritage Protection, 2017a. *Application requirements for activities with impacts to air.*

Department of Environment and Heritage Protection, 2017b. *Guideline – Model mining conditions.*

DSITI 2017a, *Air quality bulletin, Central Queensland, July 2017*.

DSITI 2017b, *Air quality bulletin, Central Queensland, September 2017*.

Katestone Environmental, 2015, Air Quality Impact Assessment for the Moranbah South Project EIS, report prepared for Hansen Bailey.

National Pollutant Inventory (NPI), 2012, Emission Estimation Technique Manual for Mining version 3.1. National Environment Protection Council.

National Pollutant Inventory (NPI), 2017/18 Database, Available online at: http://www.npi.gov.au/npi-data (accessed January 2020).

Queensland Government 1994, *Environmental Protection Act*.

Queensland Government 2019, *Environmental Protection (Air) Policy 2019.*

United States Environmental Protection Agency (USEPA), 1998, Western surface coal mining, AP42 Chapter 11.9, USEPA Office of Air Quality Planning and Standards.

United States Environmental Protection Agency (USEPA), 2006a, Industrial wind erosion, AP42 Chapter 13.2.5, USEPA Office of Air Quality Planning and Standards.

United States Environmental Protection Agency (USEPA), 2006b, Aggregate handling and storage piles, AP42 Chapter 13.2.4, USEPA Office of Air Quality Planning and Standards.

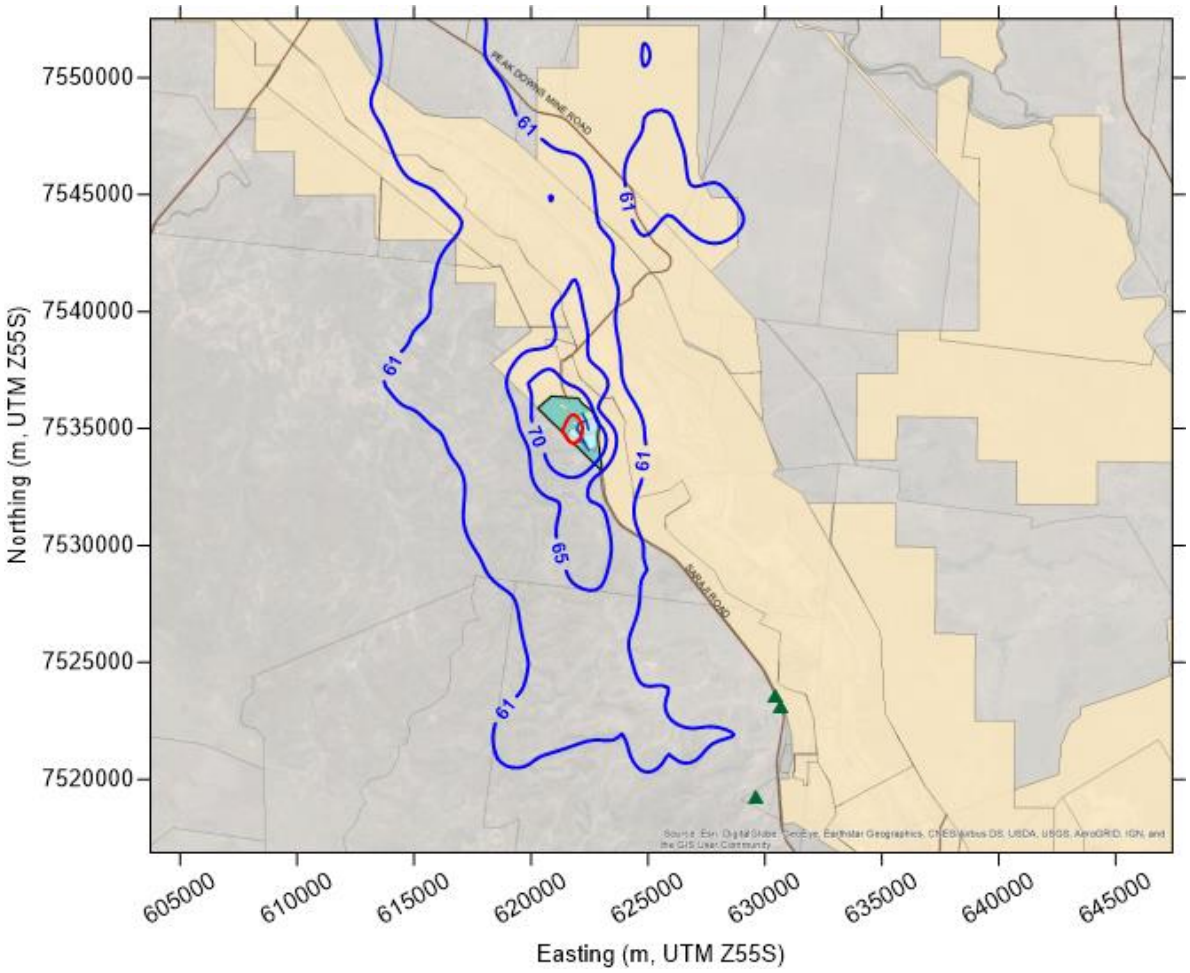


Plate 1 **Year 2 VCP - Predicted annual average ground-level concentrations of TSP for the cumulative assessment**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Complex Project, Moranbah, QLD	Annual	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	90 µg/m³ (red)	Paddy McDowell	March 2020

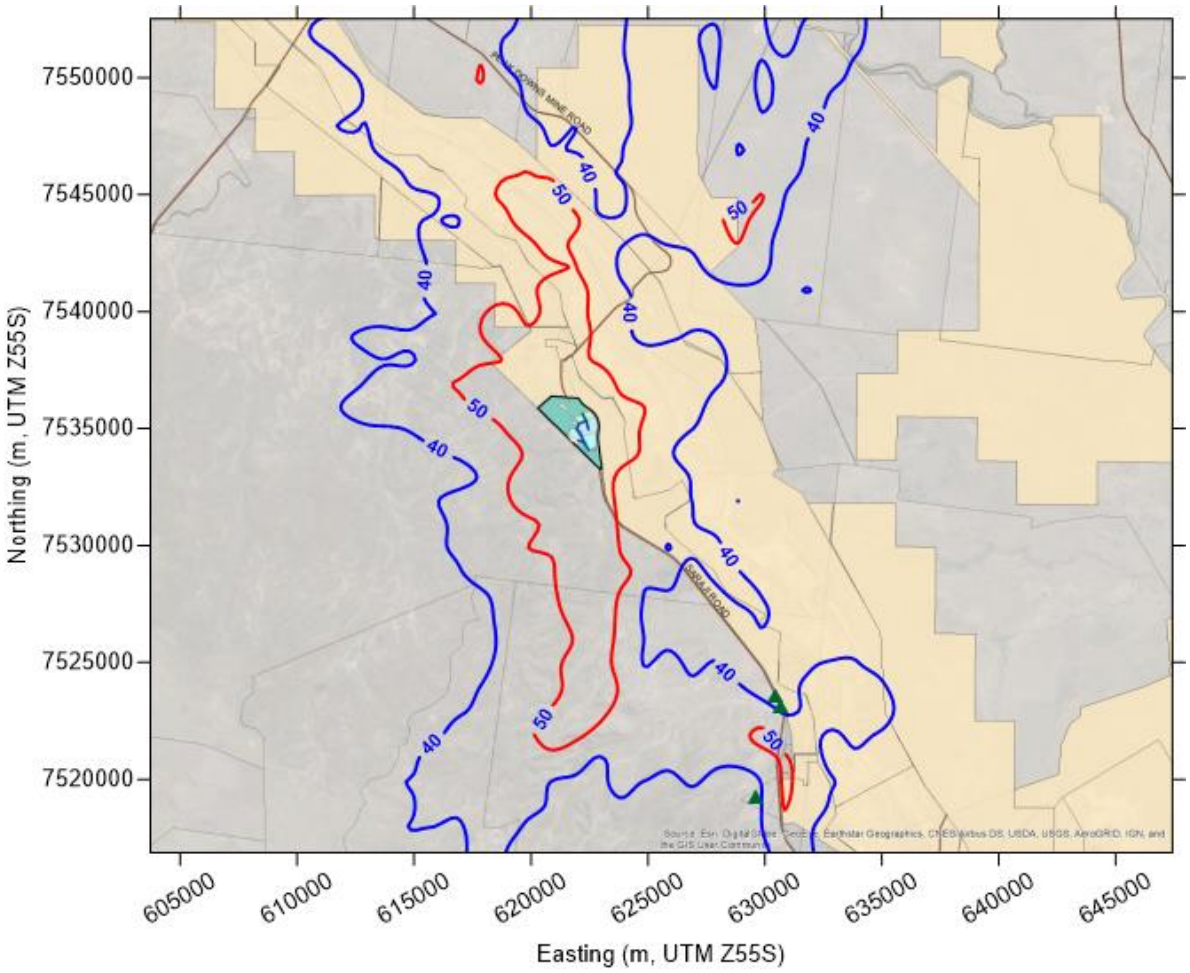


Plate 2 **Year 2 VCP - Predicted maximum 24-hour average ground-level concentrations of PM_{10} for the cumulative assessment**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Complex Project, Moranbah, QLD	24-hour maximum	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	50 µg/m³ (red)	Paddy McDowell	March 2020

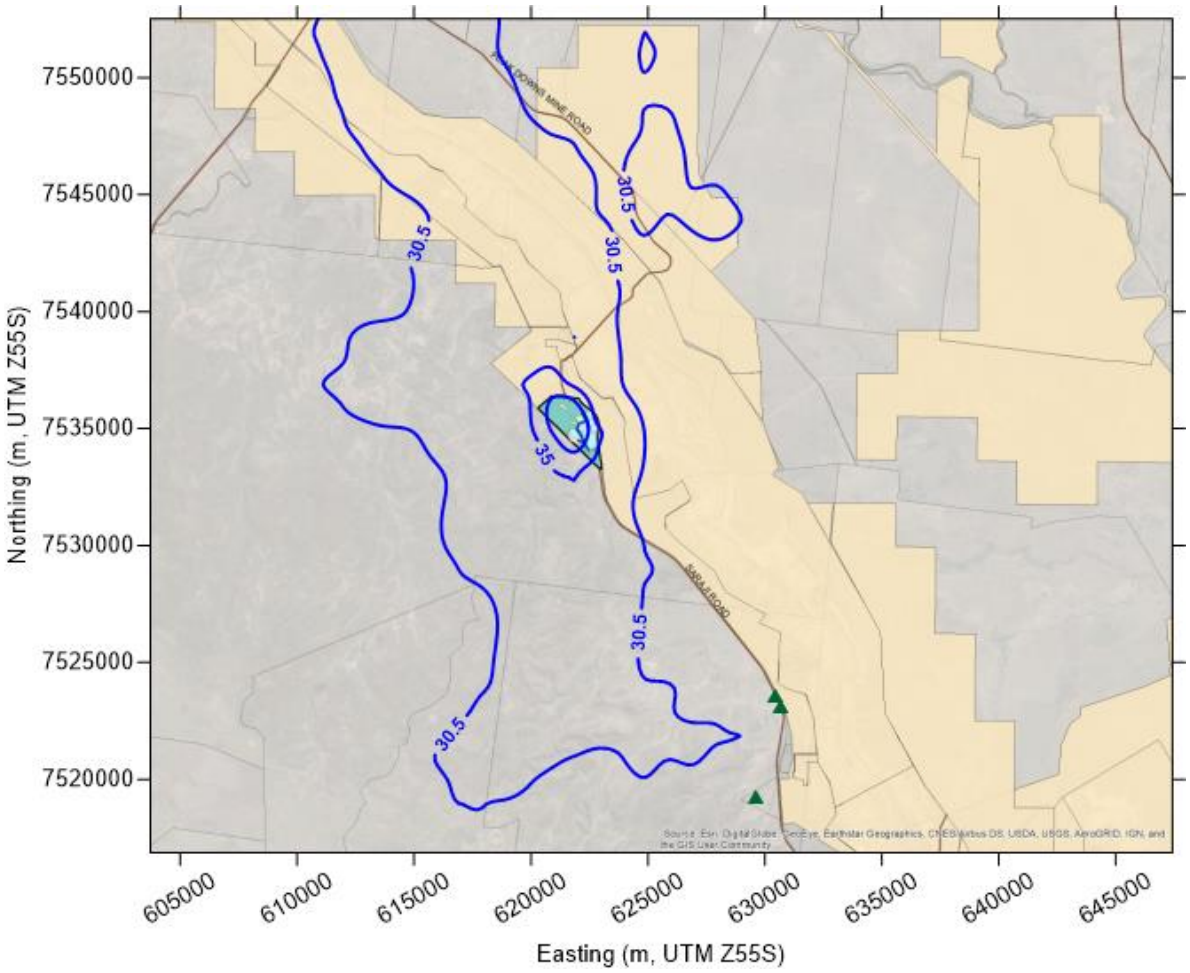


Plate 3 **Year 2 VCP - Predicted annual average ground-level concentrations of PM_{10} for the cumulative assessment**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Complex Project, Moranbah, QLD	Annual	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	25 µg/m³	Paddy McDowell	March 2020

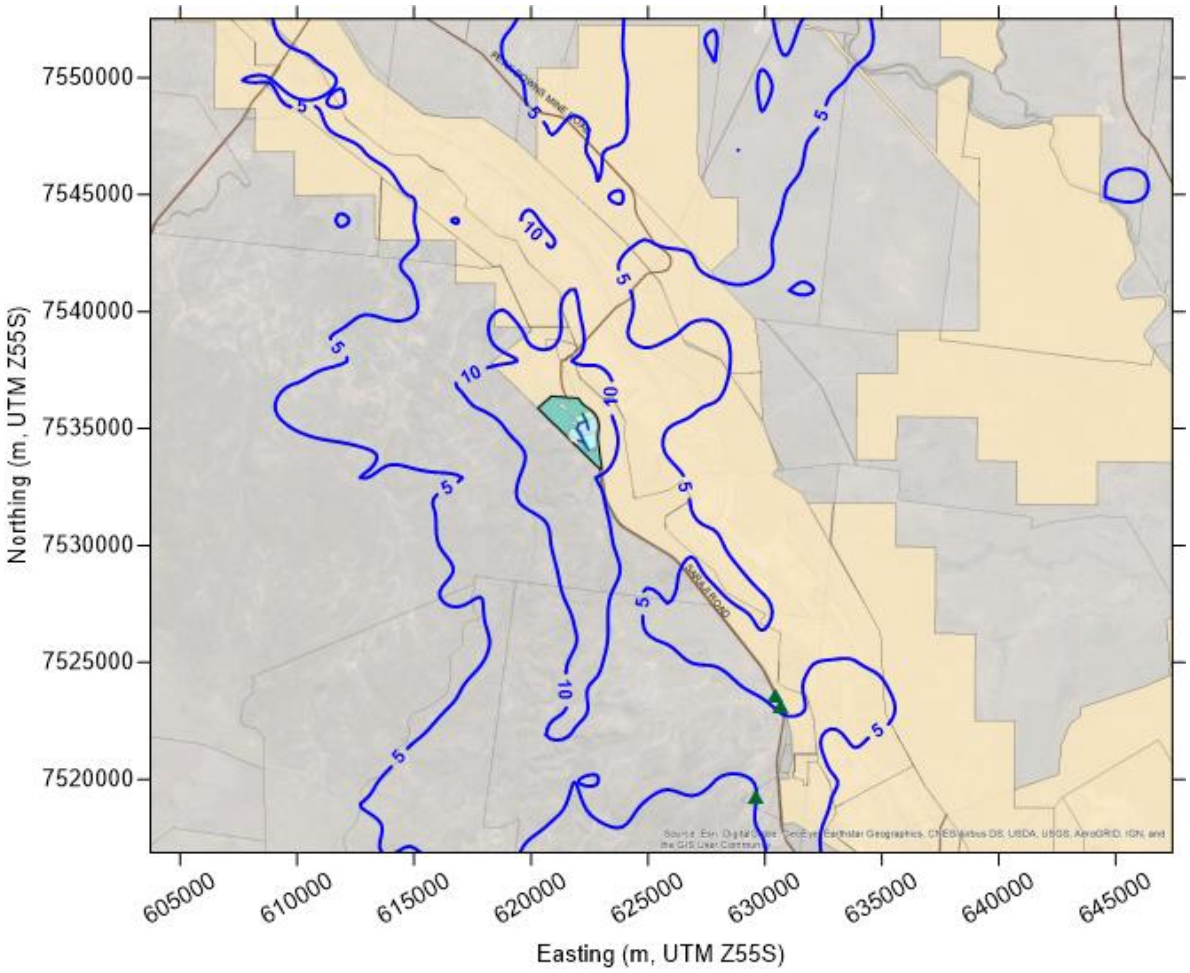


Plate 4 **Year 2 VCP - Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ for the cumulative assessment**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Complex Project, Moranbah, QLD	24-hour maximum	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	25 µg/m³ (red)	Paddy McDowell	March 2020

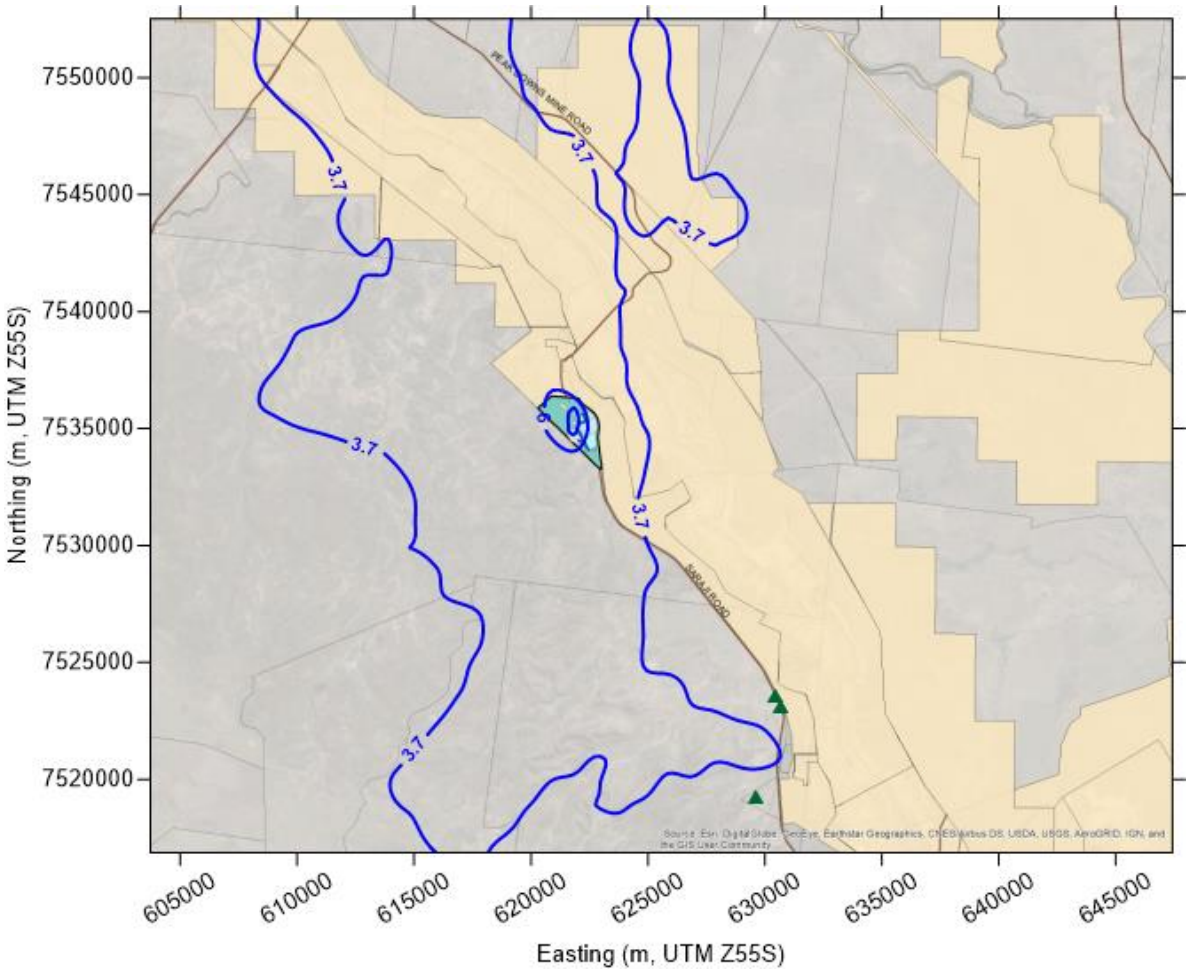


Plate 5 **Year 2 VCP - Predicted annual average ground-level concentrations of $PM_{2.5}$ for the cumulative assessment**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Complex Project, Moranbah, QLD	Annual	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	8 µg/m³ (red)	Paddy McDowell	March 2020

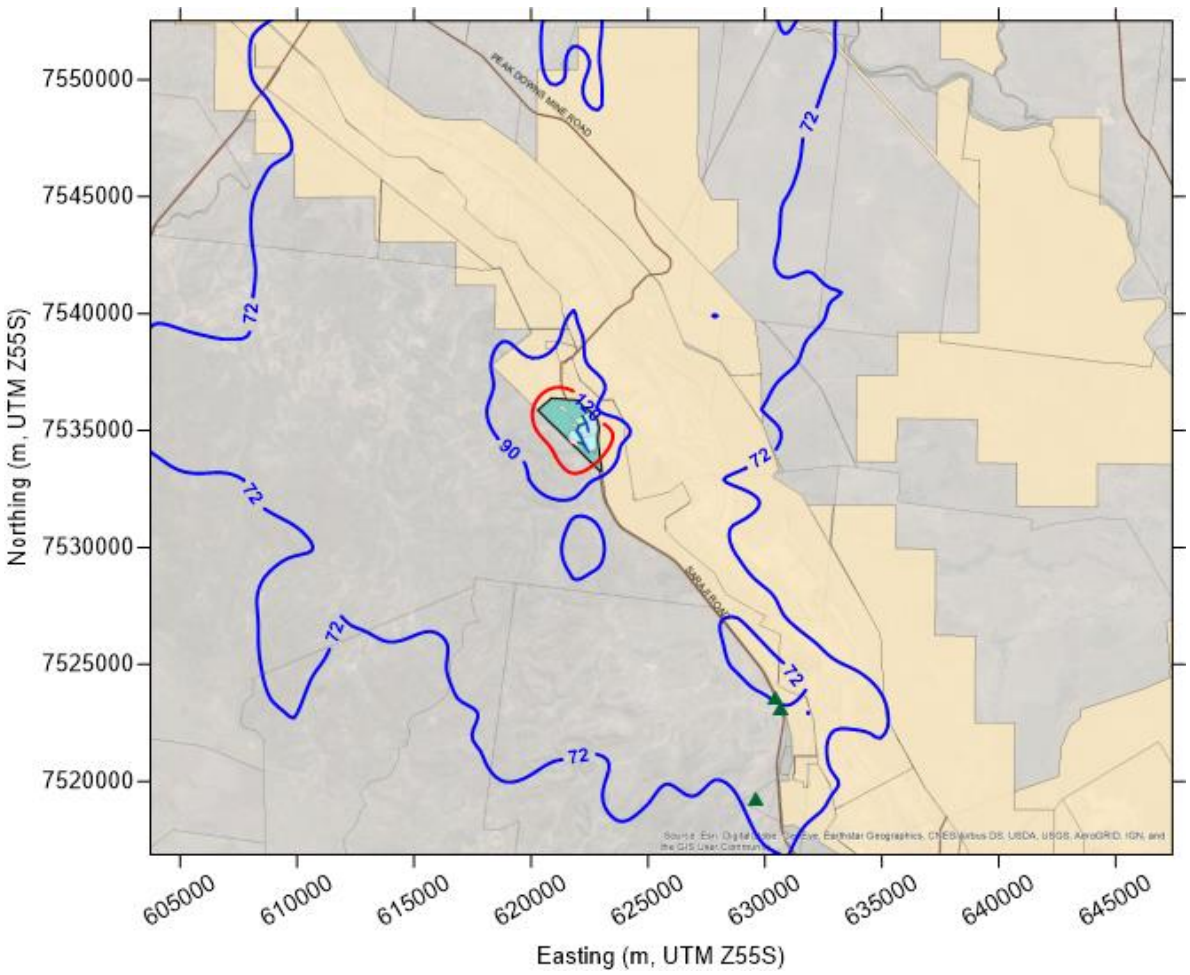


Plate 6 **Year 2 VCP - Predicted maximum monthly dust deposition rate for the cumulative assessment**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Complex Project, Moranbah, QLD	Monthly	CALPUFF	mg/m^2/day
Type:	**Guideline:**	**Prepared by:**	**Date:**
Maximum contours	120 mg/m^2/day (red)	Paddy McDowell	March 2020

APPENDIX A DETAILED DUST EMISSIONS INVENTORY DATA

A1 ACTIVITY DATA

The activity data presented in Table A1 are based on the following information:

- Information provided by METServe and Vitrinite, including site layouts, operational details, mining methods, throughput and fleet specifications; and
- Typical emissions characteristics documented in the National Pollutant Inventory (NPI) Handbooks and US EPA Compilation of Air Pollutant Emission Factors (AP-42).

Overburden and ROM extraction volumes, drilling activity, and dozer and grader utilisation have been determined based on the relative spatial extent of the active mining areas indicated in the supplied site plans. Where suitable values were not available, conservative assumptions have been used.

Table A1 Mine operations and activities data

Activity	Units	VCP Year 2	Information Source
Hours of operation (except blasting and Pits 7 and 8)	hours/day days/year	24 365	METServe
Blasting hours	hours/day	12	METServe
Overburden			
Moisture content	%	7.9	AP-42 Chapter 11.9-3, default value
Silt content	%	6.9	AP-42 Chapter 11.9-3, default value
Coal (ROM and product)			
Moisture content	%	10.4	AP-42 Chapter 11.9-3, default value
Silt content	%	8.6	AP-42 Chapter 11.9-3, default value
Road surface silt content	%	8.4	AP-42 Chapter 13.2.2, mean value for pit haul
Overburden			
Total overburden	tpa	7,441,500	METServe
Coal			
ROM coal total	Mtpa	1,950,000	METServe
Product coal total	Mtpa	1,170,000	METServe
Maximum number of blasts per day	blasts/day	1	METServe
Horizontal area of blast	m^2	20,000	METServe
Number of holes drilled per blast	holes/blast	400	METServe
Total holes drilled per year	holes/year	9,600	Calculated assuming maximum of 24 blasting days per year (METServe)
Total active pit area	ha	23	Measured from site layouts provided by METServe
Total overburden dump area (inpit)	ha	44	
Total overburden dump area (outpit)	ha	15	
Total rehabilitation area	ha	43	

Activity	Units	VCP Year 2	Information Source
Total ROM coal stockpile area	ha	4	
Temporary stockpile area	ha	5	
Haulage			
Total waste haulage	VKT/year	180,287	Calculated using site layouts provided by METServe
Total ROM coal haulage	VKT/year	84,805	
Total grader travel	VKT/year	115,396	
Waste trucks (Cat 798)			
Empty weight	tonnes	181	Manufacturer specification
Maximum payload	tonnes	143	Manufacturer specification
Average weight	tonnes	234	Calculated
ROM coal trucks (Cat 777)			
Empty weight	tonnes	75	Manufacturer specification
Maximum payload	tonnes	90	Manufacturer specification
Average weight	tonnes	120	Calculated
Bulldozers			
Utilisation rate	%	50	METServe
Number	-	2	METServe
Graders			
Number in operation	-	1	METServe
Average speed	km/h	30	METServe
Mean wind speed	m/s	2.53	CALMET modelling
Proportion of winds faster than 5.4m/s	%	2.8	CALMET modelling
Coal stockpile height	m	15	Assumed (typical value)

A2 CALCULATION OF EMISSION FACTORS

A2.1 Drilling

Emission factors for drilling were calculated according to AP-42 Chapter 11.9. The default TSP emission factor of 0.59 kg/hole was used, with PM10 and PM2.5 fractions of 52.5% (0.31 kg/hole) and 3% (0.02 kg/hole), respectively, according to AP-42 Chapter 11.9.

A2.2 Blasting

Emission factors for blasting were calculated according to AP-42 Chapter 11.9. The TSP emission factor is given by:

$$\mathrm{EF_{TSP}} = 0.00022\ A^{1.5}$$

where:

$\mathrm{EF_{TSP}}$	=	TSP emission factor (kg/blast)
A	=	horizontal blast area (m²)

PM_{10} and $PM_{2.5}$ emission factors were calculated using fractions of 52.5% and 3%, respectively, according to AP-42 Chapter 11.9.

A2.3 Bulldozing on overburden

Emission factors for dozers operating on overburden were calculated according to NPI Mining. The TSP and PM_{10} emission factors are given by:

$$\mathrm{EF_{TSP}} = \frac{2.6\ s^{1.2}}{M^{1.3}}$$

$$\mathrm{EF_{PM10}} = \frac{0.34\ s^{1.5}}{M^{1.4}}$$

where:

$\mathrm{EF_{TSP}}$	=	TSP emission factor (kg/ hr)
$\mathrm{EF_{PM10}}$	=	PM_{10} emission factor (kg//hr)
s	=	overburden silt content (%)
M	=	overburden moisture content (%)

The $PM_{2.5}$ emission factor was calculated from TSP using a fraction of 10.5% according to AP-42 Chapter 11.9.

A2.4 Bulldozing on coal

Emission factors for dozers operating on overburden were calculated according to NPI Mining. The TSP and PM_{10} emission factors are given by:

$$\mathrm{EF_{TSP}} = \frac{35.6\ s^{1.2}}{M^{1.4}}$$

$$\mathrm{EF_{PM10}} = \frac{6.33\ s^{1.5}}{M^{1.4}}$$

where:

$\mathrm{EF_{TSP}}$	=	TSP emission factor (kg/ hr)

$\mathrm{EF}_{\mathrm{PM10}}$	=	PM_{10} emission factor (kg//hr)
s	=	coal silt content (%)
M	=	coal moisture content (%)

The PM2.5 emission factor was calculated from TSP using a fraction of 2.2% according to AP-42 Chapter 11.9.

A2.5 Material transfers and handling

Materials handling and transfers include truck loading, dumping, conveyor transfers and train load-out. These emission factors were calculated according to AP-42 Chapter 13.2.4 using the following equation:

$$\mathrm{EF} = k(0.0016)\left(\frac{U}{2.2}\right)^{1.3}\left(\frac{M}{2}\right)^{-1.4}$$

where:

EF	=	emission factor (kg/Mg)
k	=	particle size multiplier
U	=	mean wind speed (m/s)
M	=	material moisture content (%)

The particle size multiplier k varies with aerodynamic particle size range as follows:

$k = 0.74$	Particle size < 30 µm (TSP)
$k = 0.35$	Particle size < 10 µm (PM_{10})
$k = 0.053$	Particle size < 2.5 µm ($PM_{2.5}$)

A2.6 Grading

Emission factors for grading were calculated according to AP-42 Chapter 11.9. The TSP and PM_{10} emission factors are given by:

$$\mathrm{EF}_{\mathrm{TSP}} = 0.0034\,S^{2.5}$$

$$\mathrm{EF}_{\mathrm{PM10}} = 0.0034\,S^{2}$$

where:

$\mathrm{EF}_{\mathrm{TSP}}$	=	TSP emission factor (kg/VKT)
$\mathrm{EF}_{\mathrm{PM10}}$	=	PM_{10} emission factor (kg/VKT)
S	=	grader average speed (km/h)

The PM2.5 emission factor was calculated from TSP using a fraction of 3.1% according to AP-42 Chapter 11.9.

A2.7 Wind erosion from active stockpiles

Emission factors for wind erosion of active stockpiles were calculated on an hourly basis using the emission factor for active storage piles from AP-42 Chapter 11.9. The TSP emission factor is given by:

$$\mathrm{EF}_{\mathrm{TSP}} = 1.8u$$

Where:

$\mathrm{EF}_{\mathrm{TSP}}$	=	TSP emission factor (kg/ha/hr)
u	=	hourly-average wind speed (m/s)

PM_{10} and $PM_{2.5}$ emission factors were calculated using fractions of 50% and 7.5%, respectively, according to AP-42 Chapter 11.9.

A2.8 Wind erosion from exposed areas

Emission factors for wind erosion of exposed areas were calculated on an hourly basis using the emission factor for exposed areas from AP-42 Chapter 11.9 and adapted to include a threshold for dust lift-off.

The default TSP emission factor of 0.85 Mg/ha/yr was used, with the annual emissions apportioned into hourly emissions according to the square of the hourly wind speed compared with the threshold of $(5.4\ \mathrm{m/s})^2$. This reflects the tendency for stronger winds to generate more dust lift-off (if above the threshold for lift-off) and yields worse emissions during hours of strong winds.

PM_{10} and $PM_{2.5}$ emission factors were calculated using fractions of 50% and 7.5%, respectively, according to AP-42 Chapter 11.9.

A2.9 Wheel-generated dust

Emission factors for wheel-generated dust on unpaved roads were calculated according to AP-42 Chapter 13.2.2 via the following equation:

$$\mathrm{EF} = k(281.9)\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}$$

where

EF	=	emission factor (g/VKT)
k	=	particle size multiplier
s	=	surface material silt content (%)
W	=	mean vehicle weight (tons)
a, b	=	empirical constants

A factor of 1.10231 was used to convert the vehicle weights in Table A1 to imperial tons. The particle size multiplier and empirical constants vary with aerodynamic particle size range as defined in Table A2.

Table A2 Constants used in calculating emissions from wheel-generated dust

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

A2.10 Crushing

Emission factors for the crushing of coal were calculated according to AP-42 Chapter 11.19.2. The default TSP and PM_{10} emission factors were used, equal to 0.0027 kg/tonne and 0.0012 kg/tonne of coal crushed, respectively. The $PM_{2.5}$ emission factor was calculated from TSP using a ratio of 8.33% according to AP-42 Chapter 11.19.2.

A2.11 Screening

Emission factors for the screening of coal were calculated according to AP-42 Chapter 11.19.2. The default TSP and PM_{10} emission factors were used, equal to 0.0125 kg/tonne and 0.0043 kg/tonne of coal screened, respectively. The $PM_{2.5}$ emission factor was calculated from TSP using a ratio of 2.27% according to AP-42 Chapter 11.19.2.

APPENDIX B METEOROLOGICAL AND DISPERSION MODELLING METHODOLOGY

B1 METEOROLOGY

The meteorological modelling methodology for the VCP included the following steps:

- Selection of a representative year;
- TAPM modelling; and
- CALMET modelling.

The following sections describe each step of the meteorological modelling conducted for the VCP.

B1.1 Selection of representative year

A representative year is required to be selected at the beginning of the meteorological modelling process. Using a representative year in the air quality assessment ensures that the conditions experienced at the VCP site are reflected in the model.

Selection of a representative year has been done through statistical analysis of historical meteorological observations at BoM Moranbah Airport weather station. Meteorological observations from the past five years at Moranbah Airport were analysed in order to assess the inter-annual variability.

The annual frequency distributions of wind direction, wind speed and temperature for the period 2014 to 2018 were analysed and compared to the average distribution for the same five-year period. The analysis indicated that there was not a significant amount of variation in the distributions of wind direction, wind speed or temperature as illustrated graphically in Figure B1 to Figure B3, with the exception of Year 2016. Based on the analysis, the year 2018 was selected as the year for modelling as this year presented as the most recent year and also close to the 5-year average.

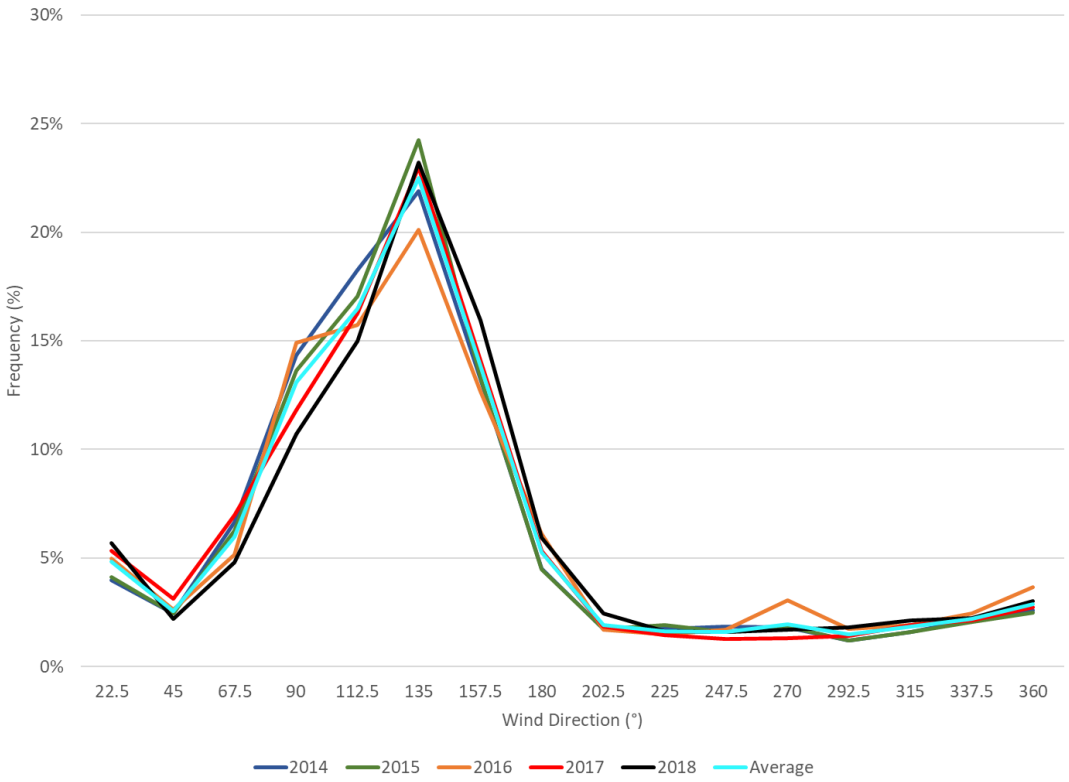


Figure B1 **Annual Wind Direction Frequency Distribution at Moranbah Airport**

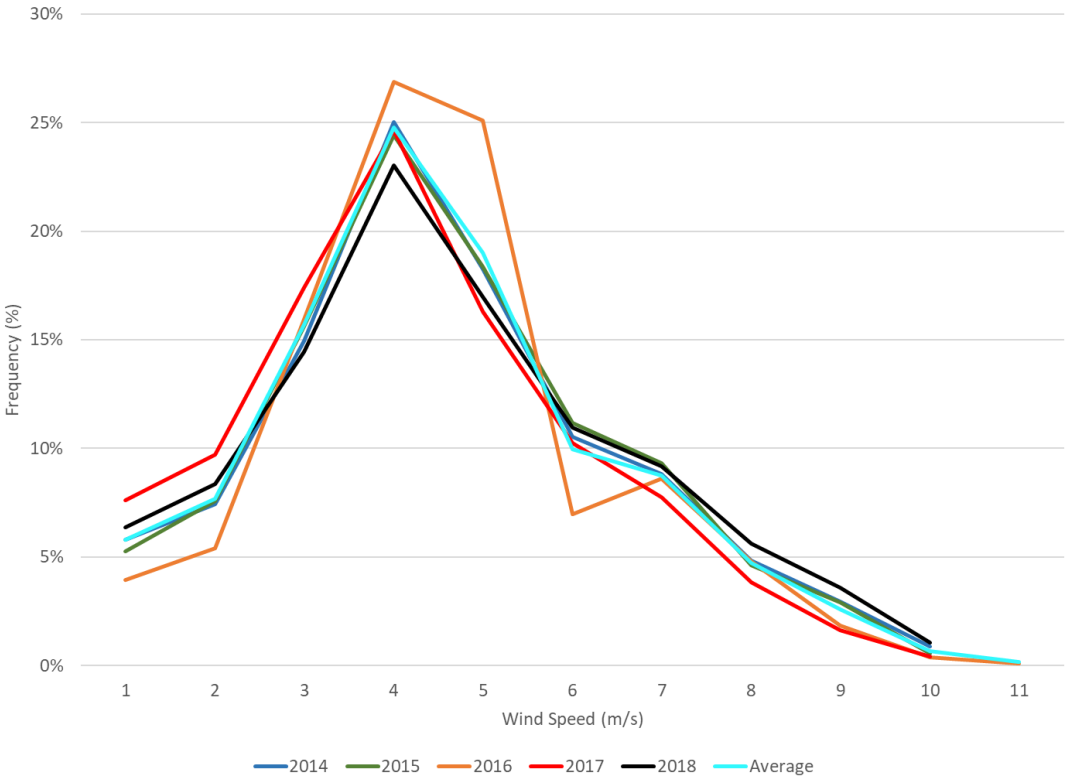


Figure B2 **Annual Wind Speed Frequency Distribution at Moranbah Airport**

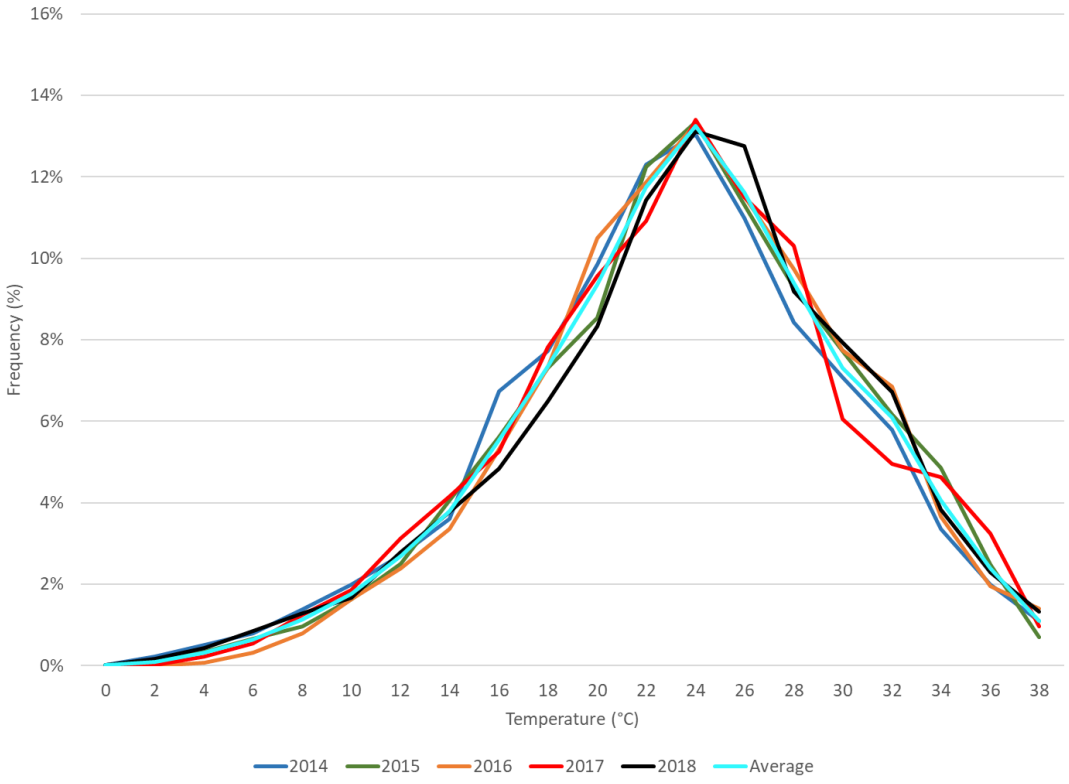


Figure B3 Annual Temperature Frequency Distribution at Moranbah Airport

B1.2 TAPM meteorology

The meteorological model, TAPM has been validated by the CSIRO, Katestone and others for many locations in Australia, in south-east Asia and in North America (CSIRO, 2008). Katestone has used the TAPM model throughout Australia as well as in parts of America, Bangladesh, New Caledonia and Vietnam. This model has performed well for simulating regional winds patterns. TAPM has proven to be a useful model for simulating meteorology in locations where monitoring data is unavailable.

TAPM is a prognostic meteorological model which 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 (m)). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the region. This information is generated by a global model similar to the large-scale models used to forecast the weather. The data were supplied on a grid resolution of approximately 75km, and at elevations of 100m to 5km 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.

Landcover data for TAPM are sourced from the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC) at 30-second (approximately 1 km) grid spacing.

TAPM was configured as follows:

- Modelling period for one year from 1 January to 31 December 2018;
- 30 x 30 grid point domain with an outer grid of 30 km and nesting grids of 10 km, 3 km and 1km;
- 25 vertical levels;
- Grid centred near the VCP (latitude –22° 21.0', longitude 148° 14.5');
- Geoscience Australia 9 second DEM terrain data;
- Land cover data based on TAPM's default land-use database and edited to match recent land-use imagery;
- Default options selected for advanced meteorological inputs; and
- No data assimilation.

B1.3 CALMET meteorological modelling

CALMET is an advanced non-steady-state diagnostic 3D 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 can read hourly meteorological data as data assimilation from multiple sites within the modelling domain; it can also be initialised with the gridded three-dimensional prognostic output from other meteorological models such as TAPM. This can improve dispersion model output, particularly over complex terrain as the near surface meteorological conditions are calculated for each grid point.

CALMET (version 6.5) was used to simulate meteorological conditions in the region. The CALMET simulation was initialised with the gridded TAPM 3D wind field data from the 3km grid. CALMET treats the prognostic model output as the initial guess field for the CALMET diagnostic model wind fields. The initial guess field is then adjusted for the kinematic effects of terrain, slope flows, blocking effects and 3D divergence minimisation.

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

- Domain area of 81 by 81 grid points at 1 km spacing;
- Twelve vertical levels set at 20 m, 60 m, 100 m, 150 m, 200 m, 250 m, 350 m, 500 m, 800 m, 1600 m, 2600 m and 4600 m;
- 365 days (1 January to 31 December 2018);
- No observations mode, with prognostic wind fields generated by TAPM input as MM5/3D.dat at surface and upper air for "initial guess" field;
- Gridded cloud cover from prognostic relative humidity at all levels;
- No extrapolation of surface winds observations;
- All other wind field options set as default;
- Terrain radius of influence set at 20 kilometres;
- Mixing height parameters all set as default;
- 3D Relative humidity and temperature from prognostic data; and
- No data assimilation.

All other options and factors were set to default.

B2 DISPERSION MODELLING

CALPUFF simulates the dispersion of air pollutants to predict ground-level concentration and deposition rates across a network of receptors spaced at regular intervals, and at identified discrete locations. CALPUFF is a non-steady-state Lagrangian Gaussian puff model. CALPUFF employs the 3D 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 takes into account the geophysical features of the study area that affects dispersion of pollutants and ground-level concentrations of those pollutants in identified regions of interest. 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.

Key features of CALPUFF v7.2.1 used to simulate dispersion in the VCP assessment include:

- Domain area of 81 km by 81 km equivalent to the domain defined in CALMET;
- 365 days modelled (1 January to 31 December 2018);
- Gridded 3D hourly-varying meteorological conditions generated by CALMET;
- Partial plume path adjustment and transitional plume rise modelled;
- No chemical transformation or wet removal modelled;
- PDF used for dispersion under convective conditions; and
- Dispersion coefficients calculated internally from sigma v and sigma w using micrometeorological variables.

All other options set to default.

B2.1 Source configuration

Characteristics for modelled sources are summarised in Table B1.

Emissions from all source types (haul roads, extraction and material handling, wind erosion and processing area) were modelled as area sources. Wind erosion was modelled as an hourly-varying emission source. Emissions from blasting were modelled to reflect daytime operations only from 6am to 6pm.

An additional control factor of 50% for TSP and 5% for PM_{10} has been applied to in-pit activities (drilling and blasting and material extraction/handling) to account for pit retention.

Table B1 Characteristics of modelled area sources

Source Type	Effective height	Initial vertical dispersion coefficient (σ_z)
	m	m
Haul roads	10	2.5
Pit activities (drilling and blasting)	8	2
All extraction and material handling activities	10	2.5
Wind erosion of ROM, product and rejects stockpiles	5	1.25
Wind erosion of exposed and rehabilitated areas	1	0.25
Processing area	10	2.5