Evolution
MINING

APPENDIX E

Air Quality and Greenhouse Gas Assessment

COWAL GOLD OPERATIONS MINE LIFE MODIFICATION

Environmental Assessment
2016

Resource Strategies

Final Report

Cowal Gold Operations Modification 13 – Air Quality & Greenhouse Gas Assessment

Document Control Number: AQU-NW-009-21396
Date: 8 November 2016

Pacific Environment Limited

Technologies Consulting Monitoring

Project Name:	Cowal Gold Operations Modification 13 – Air Quality & Greenhouse Gas Assessment
Document Control Number:	AQU-NW-009-21396
Prepared For:	Evolution Mining (Cowal) Pty Limited
Approved For Release By:	Jane Barnett
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Version	Date	Comment	Prepared by	Reviewed by
Draft 01	30/09/2016	Draft 1	Jane Barnett	Judith Cox
Draft 02	17/10/2016	Draft 2	Jane Barnett	Judith Cox
Final Draft	25/10/2016	Final draft	Jane Barnett	Judith Cox
Final	03/11/2016	Final report	Jane Barnett	Judith Cox
Final V2	08/11/2016	Final report	Jane Barnett	Judith Cox

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Executive summary

Pacific Environment Limited has been engaged by Evolution Mining (Cowal) Pty Limited (Evolution), to complete an Air Quality and Greenhouse Gas Assessment for the Cowal Gold Operations (CGO) Modification 13 (the Modification). The Modification involves increasing the pit depth, modifying the design of the two tailings storage facilities and increasing the total life of mine by eight years, to the end of 2032.

Existing Environment

The CGO currently operates an air quality network consisting of 19 deposition gauges and a high volume air sampler (HVAS) measuring total suspended particulates (TSP). These data were analysed to determine existing air quality in the immediate vicinity of the mine. There are currently no direct measurements made for either particulate matter with an aerodynamic diameter of 10 micrometres (μm) or less (PM_{10}) or particulate matter with an aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$), so assumptions were made from the TSP data to estimate these concentrations. The following background values were established and applied to the annual average cumulative assessment:

• Annual average $PM_{2.5}$ concentration	5.3 micrograms per cubic metre ($\mu g/m^3$)
• Annual average PM_{10} concentration	17 $\mu g/m^3$
• Annual average TSP concentration	42 $\mu g/m^3$
• Annual average dust deposition level	2.5 grams per square metre per month (g/m^2/month)

Meteorological data and models used

The assessment is based on the use of a three-dimensional computer-based dispersion model to predict ground-level dust concentrations at the nearest sensitive receptors (residences). To assess the effect that emissions would have on existing air quality, the dispersion model predictions have been compared against the relevant air quality criteria.

Modelling of local meteorology was undertaken using a combination of the TAPM and CALMET models. CALMET is a meteorological pre-processor endorsed by the United States Environmental Protection Agency (US EPA) and recommended by the New South Wales (NSW) Environment Protection Authority (EPA) for use in complex terrain and was used to compile a representative meteorological dataset suitable for use in the plume dispersion model CALPUFF.

Emissions

Two operating scenarios over the life of the Modification, Year 14 (2018) and Year 18 (2022), have been assessed to represent the potential worst case air quality impacts that the Modification would have on private residences surrounding the mine. Detailed emission inventories were prepared for the two operating scenarios for TSP, PM_{10} and $PM_{2.5}$, using emission factors developed by the US EPA, and consistent with the NSW EPA's guidance document titled *"Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales"* (Department of Environment and Conservation, 2005) (the Approved Methods), to estimate the amount of particulate matter produced by each activity. The emission estimates were based on the type of equipment to be used, volumes of material handled and locations of potential wind erosion areas, and take into account information on the material properties such as the silt and moisture contents of various materials and active haul roads between the extraction area, stockpiles and the processing plant.

Assessment criteria

Predicted pollutant concentrations and dust deposition levels as a result of the Modification have been determined following the Approved Methods, which also specifies the impact assessment criteria against which these have been compared.

The assessment criteria are based on considerations of possible nuisance and health effects and provide benchmarks, which are intended to protect the community against the adverse effects of air pollutants.

Impact assessment

Predictions were made for all private and mine-owned sensitive receptors within the modelling domain. No exceedances of the incremental or annual cumulative assessment criteria were predicted at any of these receptors.

No additional exceedances of the short-term cumulative PM_{10} criterion are likely to occur due to the Modification.

Greenhouse gas assessment

A greenhouse gas assessment indicates that average annual Scope 1 and 2 emissions from the Modification (0.24 million tonnes carbon dioxide equivalent [Mt CO_2-e]) would represent approximately 0.041 percent of Australia's commitment under the Kyoto Protocol (591.5 Mt CO_2-e) and a very small proportion of global greenhouse emissions.

Table of contents

List of Figures

List of Tables

1. Introduction

Pacific Environment Limited has been commissioned by Evolution Mining (Cowal) Pty Limited (Evolution), to complete an Air Quality and Greenhouse Gas Assessment for the Cowal Gold Operations (CGO) Modification 13. The purpose of this assessment is to assess potential air quality impacts and greenhouse gas (GHG) emissions associated with Modification 13 for inclusion in the Environmental Assessment.

2. Modification description

The CGO is located approximately 38 kilometres (km) north-east of West Wyalong in central New South Wales (NSW). Figure 2.1 shows the location of the CGO and nearest receptors and the list of landholders is shown in Figure 2.2. The area is sparsely populated with the closest residence located approximately 2 km south-west of the Mining Lease (ML) 1535 boundary. Figure 2.3 shows the local topography, which is generally flat with some low isolated hills.

Mining operations at the CGO are approved to 31 December 2024 and are carried out in accordance with Development Consent DA 14/98 (as modified).

Evolution proposes to modify Development Consent DA 14/98 under section 75W of the *NSW Environmental Planning and Assessment Act, 1979* (EP&A Act) to facilitate the continuation of open pit mining and processing operations at the CGO for an additional 8 years (i.e. to the end of 2032). This is referred to hereafter as the Modification.

2.1 Approved CGO

The CGO is an existing open pit gold mine that commenced in 2004 in accordance with Development Consent 14/98. The major components of the CGO include an open pit, a process plant to extract gold from ore, mine waste rock emplacement areas and two tailings storage facilities (TSFs). Gold is extracted from the ore using a conventional carbon-in-leach cyanide leaching circuit. The CGO is currently approved to produce up to approximately 3.1 million ounces of gold. Up to 7.5 million tonnes (Mt) of ore is processed per year.

The CGO adopts conventional open pit mining methods using excavators, off road haul trucks and wheel and track dozers. Blasting is generally approved for a maximum of one blast per day, although only required approximately once every second day. Mining activities are approved to occur 24 hours per day, seven days per week.

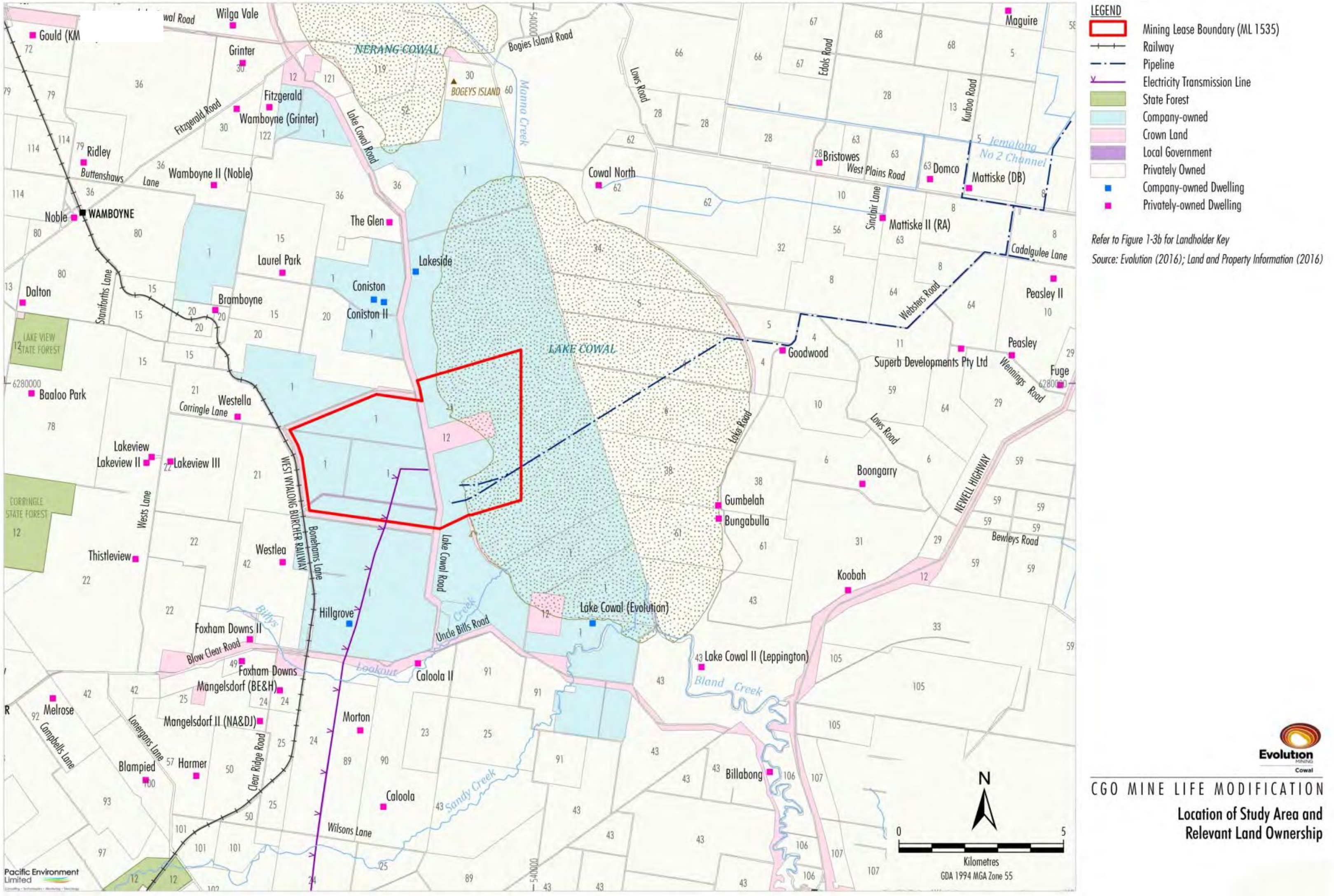


Figure 2.1: Location of study area and relevant land ownership

Reference No	Landholder
1	Evolution Mining (Cowal) Pty Limited
2	Bland Shire Council
3	Graincorp Operations Limited
4	BE Mattiske
5	DB Mattiske
6	IW Low
8	PG Hammond
10	SL Peasley
11	RG Hammond
12	The State of New South Wales
13	West Plains (Forbes) Pty Limited
15	HJ & WJ Buttenshaw
20	WJ Buttenshaw
21	AJ McClintock
22	The West Pastoral Company Pty Limited
23	EA & M Mangelsdorf
24	BE & H Mangelsdorf
25	NA & DJ Mangelsdorf
27	State Rail Authority of New South Wales
28	Bristowes Pastoral Pty Ltd
29	NJ Fuge
30	SK & RC Grinter
31	JA Duff
32	HE & AJ Duff
33	AJ Duff
34	HE Duff
36	MW & G Noble
38	BR Dent
42	GJ Davies
43	Leppington Pastoral Co Pty Limited
44	MH Duff
49	CL Lee
50	GF Carnegie
51	HC & GK West
52	HJ Buttenshaw
56	RA Mattiske
57	RF Harmer
58	Twynam Pastoral Co Pty Limited
59	Wyalong Rural Investments Pty Limited
60	SJ & EP Mickan
61	ML Dent
62	WR Low
63	Domco Trading Pty Limited
64	Superb Developments Pty Ltd
66	BV Tooth
67	HWR McDonald
68	AJR McDonald
69	GLR McDonald
70	KA Maguire
71	LR & TJ Mackay and LJ & RP Grayson
72	KM & LR Goold
73	CJ Ridley
74	HM Corliss and JA & FG Ridley
75	The Grain Handling Authority Of New South Wales
77	Country Rail Infrastructure Authority
78	CF Fuller
79	IO Ridley
80	TG & JM Dalton
81	West Wyalong Local Aboriginal Land Council
82	LJ Doecke
83	RJ Moore
85	JM Ridley
89	GM & BM Morton
90	RJ Granleese and PJ & DK Donohue
91	GR Spackman
92	KA Lindner & GP Lindner
93	EJ McCarthy
95	JD & VH Boneham
96	BY & IG Boyd
97	Clevedon Properties Pty Ltd
98	MW Rees
100	AJ & LF Blompied
101	MW & MD Carnegie
102	W Goodwin
103	LR Martin
104	MW & MD Carnegie
105	MK & RT Coles
106	FR Maslin
107	Marsden Minoru Pty Limited
109	EH & JW Maslin
113	BC & DW Rogers
114	WJ Warner
116	IJ Ridley
118	AB & KM Maslin
119	ML & CJ Ridley
120	Forbes Shire Council
121	BJ & RK Goold
122	DG Fitzgerald
123	Telstra Corporation Limited
124	AGL Pipelines (NSW) Pty Limited
126	D Williams
130	N.S.W. Grain Corporation Limited
131	IH Shephard
132	CR & RD McManus
133	MA Squier
134	JT Gray
135	NA Wilson

Source: Evolution (2016) and Land and Property Information (2016)

CGO MINE LIFE MODIFICATION

Landholder Key

Figure 2.2: Landholder key

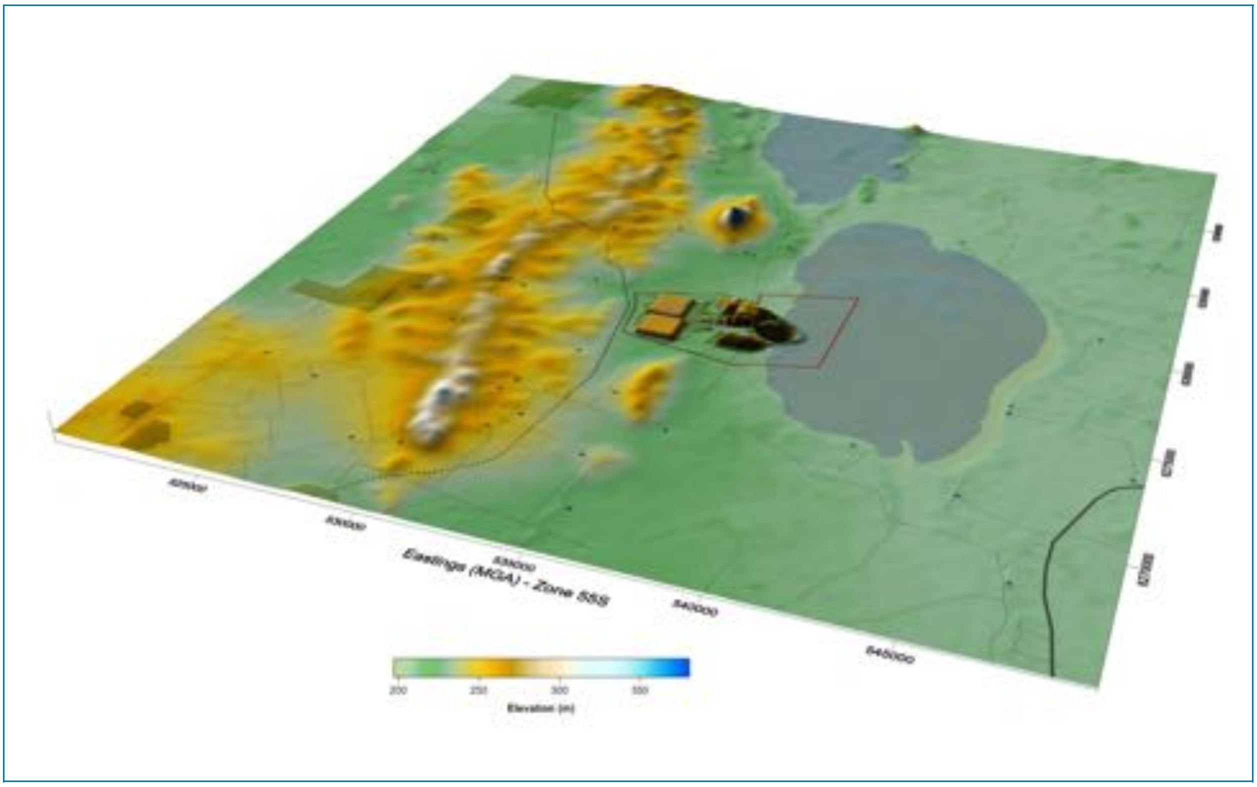


Figure 2.3: Pseudo three dimensional representation of local terrain

2.2 The proposed Modification

The main activities associated with the development of the Modification (and relative to air quality) include:

- increasing the final depth of the open pit by 70 metres (m) to enable mining of additional ore and an increase in total gold production;
- extending the life of the approved CGO by up to 8 years, to 31 December 2032;
- upgrades to the existing leach circuit within the processing plant to improve gold recovery;
- increasing the total life of mine ore production/volume of tailings and mined waste rock;
- maximising tailings storage capacity of the existing TSFs via additional lifts and converting the area between the existing TSFs into a new storage area;
- incorporation of a rock fill buttress cover on the outer slopes of the TSF embankments to provide long-term stability; and
- an increase to the TSF embankment lift fleet.

The Modification would involve no change to the following key components of the existing operations (in relation to dust):

- mining tenement;
- surface development extent;
- mining methods;

- ore processing rate;
- waste rock emplacement footprints or maximum design heights;
- exploration activities;
- hours of operation; or
- TSF embankment construction hours of 7 am to 6 pm.

2.3 Mine schedule and modelling scenarios

A mining and processing schedule for the Modification is provided in Table 2.1. Based on this schedule, two modelling scenarios have been developed. Year 14 (2018) was chosen as it is the year with the largest total volume of material extracted. Year 18 (2022) was chosen as this is the last year that the full mining fleet is in operation. To be conservative, the higher material extraction rates for Year 17 (2021) have been used to estimate the emissions, using the mine layout of Year 18 (2022). The variations in waste rock and ore extraction rates can be seen from year to year in Figure 2.4. Figure 2.5 and Figure 2.6 show the Year 14 (2018) and Year 18 (2022) general arrangements for the Modification, respectively.

Table 2.1: Mine schedule for the Modification

Year	CGO year	Waste rock mined (Mt)	Ore mined (Mt)	Total mined (Mt)	Ore Processed (Mt)
2017	13	15.57	10.48	26.05	7.50
2018	**14**	**22.14**	**10.32**	**32.46**	**7.36**
2019	15	23.48	6.71	30.19	7.30
2020	16	21.49	3.83	25.32	7.50
2021	**17**	**10.76**	**14.99**	**25.75**	**7.46**
2022	18	4.11	14.50	18.61	7.36
2023	19	2.08	10.01	12.09	7.33
2024	20	0.80	2.04	2.84	7.47
2025	21	-	-	-	7.50
2026	22	-	-	-	7.50
2027	23	-	-	-	7.50
2028	24	-	-	-	7.50
2029	25	-	-	-	7.50
2030	26	-	-	-	7.50
2031	27	-	-	-	7.50
2032	28	-	-	-	2.29

Note: Year selected for modelling (mine layout) indicated with a blue border and the year selected for material extraction rates is indicated with blue fill.

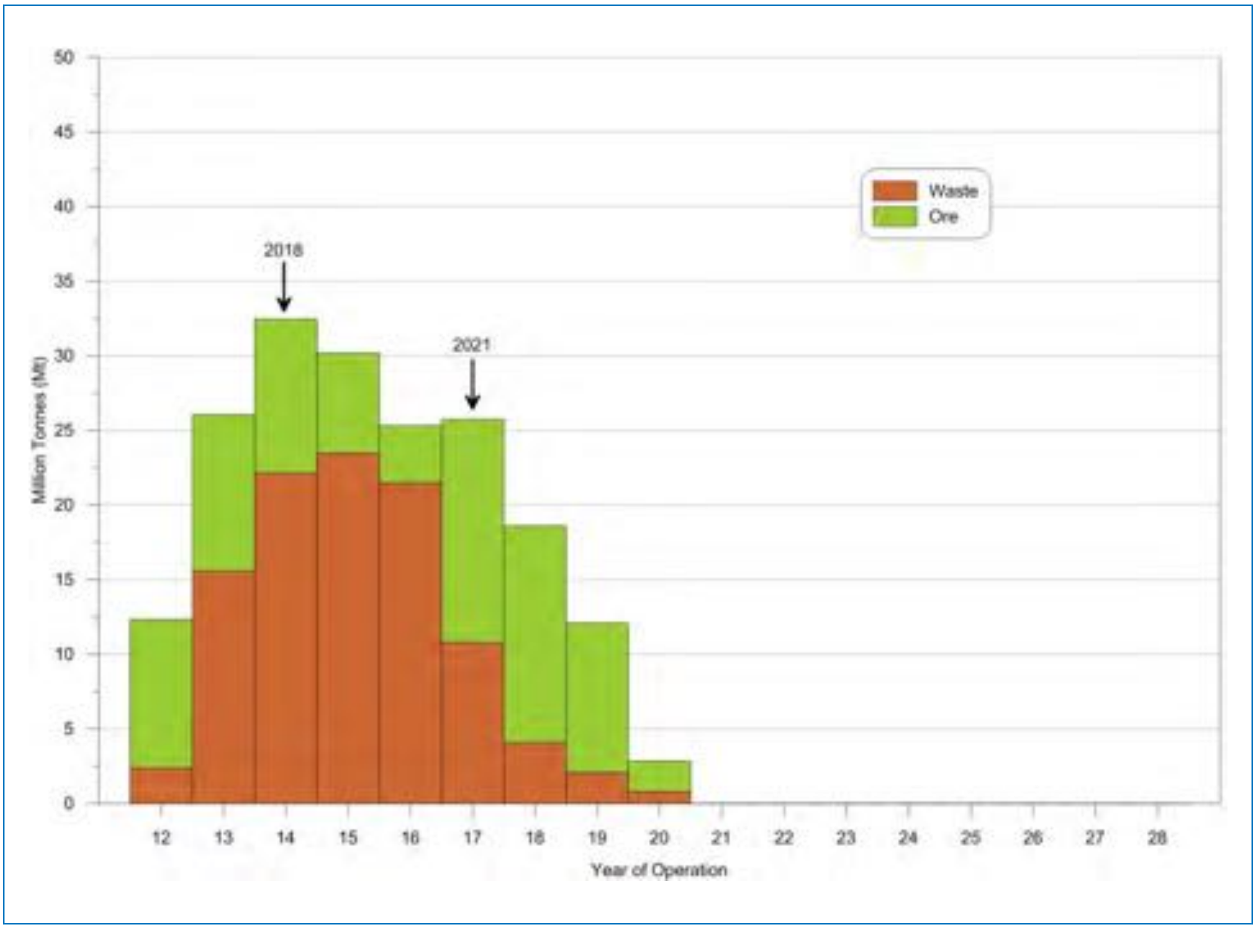


Figure 2.4: Variations in extraction rates for the life of the proposed Modification

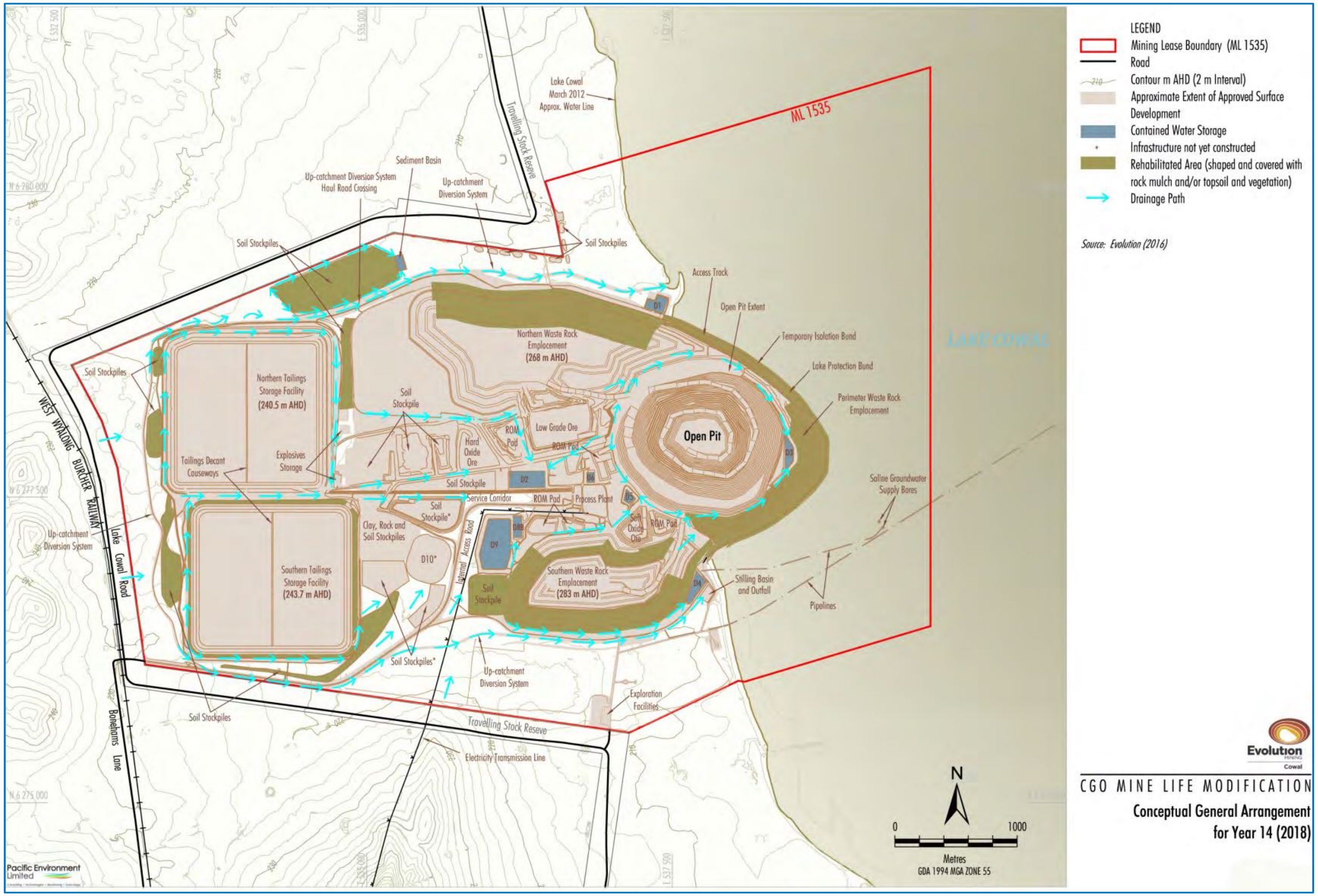


Figure 2.5: General arrangement for Year 14 (2018)

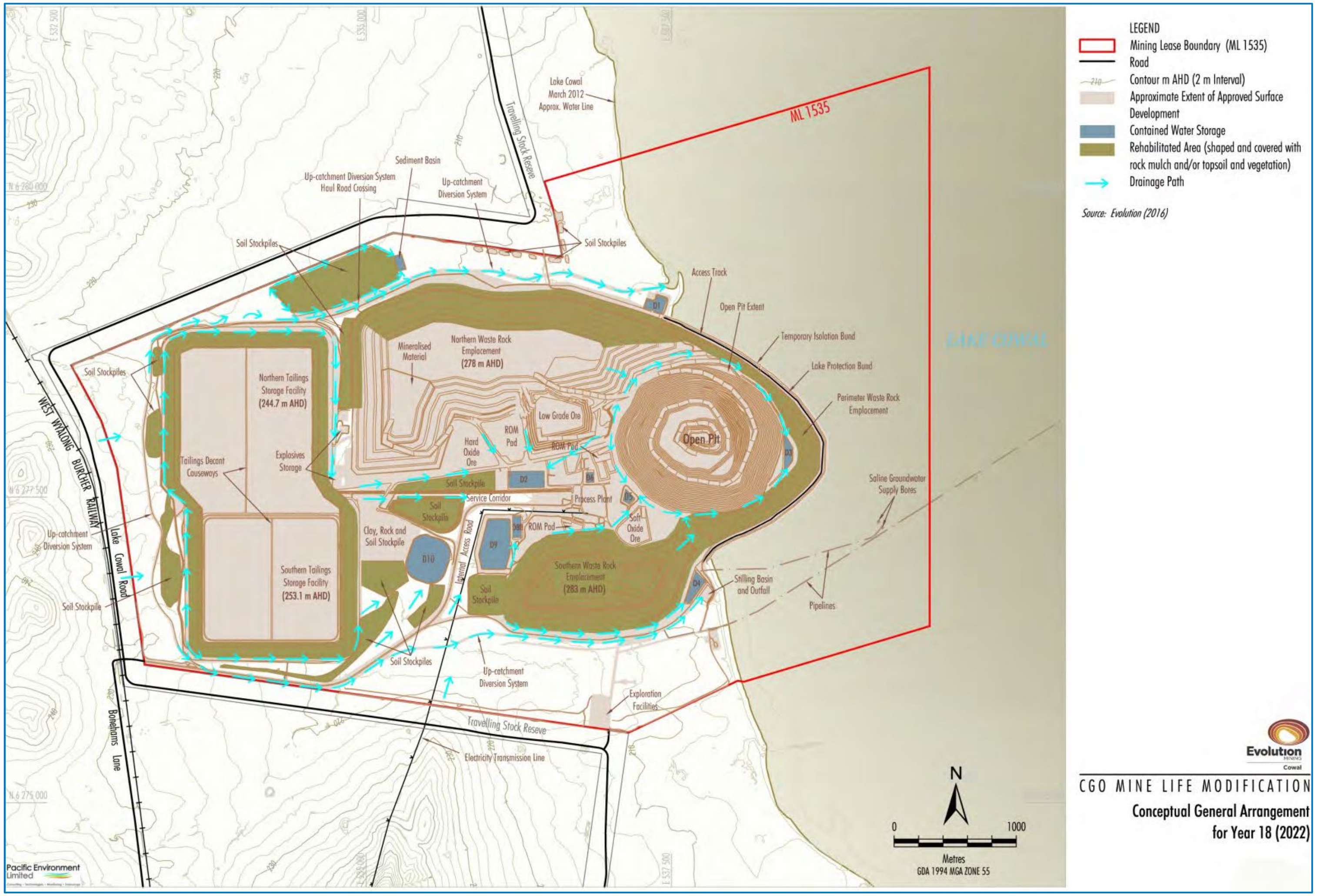


Figure 2.6: General arrangement for Year 18 (2022)

3. Air quality issues and effects

From an air quality perspective, it is important to consider the potential emissions that would occur during the operation of the Modification. The key pollutants will be those associated with the extractive activities and will include particulate matter.

Particulate matter has the capacity to affect health and to cause nuisance effects, and is categorised by size and/or by chemical composition. The potential for harmful effects depends on both. The particulate size ranges are commonly described as:

- TSP – refers to all suspended particles in the air. The upper size range is typically 30 micrometres (μm).
- PM_{10} – refers to all particles with equivalent aerodynamic diameters of less than 10 μm, that is, all particles that behave aerodynamically in the same way as spherical particles with diameters less than 10 μm and with a unit density. PM_{10} are a sub-component of TSP.
- $PM_{2.5}$ – refers to all particles with equivalent aerodynamic diameters of less than 2.5 μm. These are often referred to as the fine particles and are a sub-component of PM_{10}.
- $PM_{2.5-10}$ – defined as the difference between PM_{10} and $PM_{2.5}$ mass concentrations. These are often referred to as coarse particles.

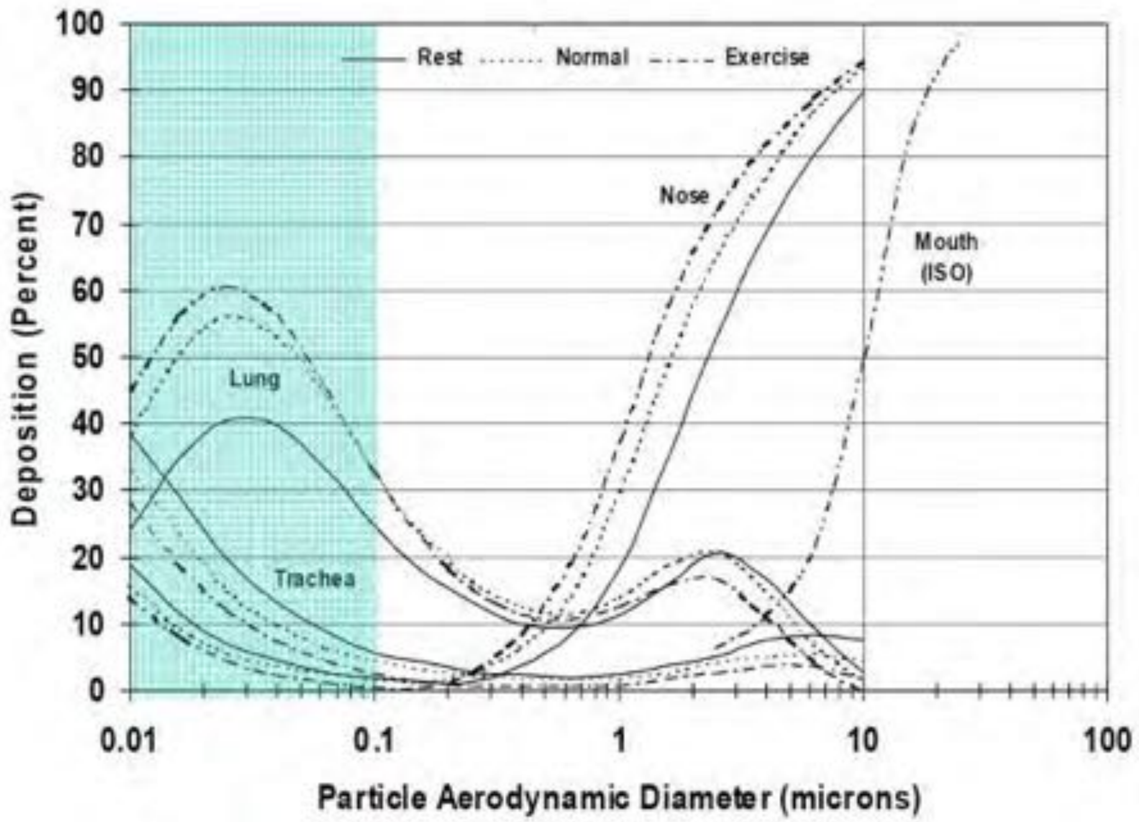
Evidence suggests that health effects from exposure to airborne particulate matter are predominantly related to the respiratory and cardiovascular systems (World Health Organization, 2011). The human respiratory system has in-built defensive systems that prevent larger particles from reaching the more sensitive parts of the respiratory system. Particles larger than 10 μm, while not able to affect health, can soil materials and generally degrade aesthetic elements of the environment. For this reason, air quality goals make reference to measures of the total mass of all particles suspended in the air, referred to as TSP. In practice particles larger than 30 to 50 μm settle out of the atmosphere too quickly to be regarded as air pollutants.

Both natural and anthropogenic processes contribute to the atmospheric load of particulate matter. Coarse particles ($PM_{2.5-10}$) are derived primarily from mechanical processes resulting in the suspension of dust, soil, or other crustal materials from roads, farming, mining and dust storms. Coarse particles also include sea salts, pollen, mould, spores, and other plant parts. Mining dust is likely to be composed of predominantly coarse particulate matter (and larger).

Fine particles, or $PM_{2.5}$, are derived primarily from combustion processes, such as vehicle emissions, wood burning, coal burning for power generation and natural processes such as bush fires. Fine particles also consist of transformation products, including sulphate and nitrate particles, and secondary organic aerosol from volatile organic compound emissions. $PM_{2.5}$ may penetrate beyond the larynx and into the thoracic respiratory tract and evidence suggests that particles in this size range are more harmful than the coarser component of PM_{10}.

The size of particles determine their behaviour in the respiratory system, including how far the particles are able to penetrate, where they deposit, and how effective the body's clearance mechanisms are in removing them. This is demonstrated in Figure 3.1, which shows the relative deposition by particle size within various regions of the respiratory tract. Additionally, particle size is an important parameter in determining the residence time and spatial distribution of particles in ambient air and is a key consideration in assessing exposure.

The health-based assessment criteria used by the NSW Environment Protection Authority (NSW EPA) have, to a large extent, been developed by reference to epidemiological studies undertaken in urban areas with large populations where the primary pollutants are the products of combustion (National Environment Protection Council [NEPC], 1998a; NEPC, 1998b). This means that, in contrast to dust of crustal origin, the particulate matter from urban areas would be composed of smaller particles and would generally contain substances that are associated with combustion.



Source: Chow, 1995

Figure 3.1: Particle deposition within the respiratory tract

4. Air quality criteria

4.1 Impact assessment criteria

The NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (Department of Environment and Conservation [DEC], 2005) (hereafter referred to as the 'Approved Methods') specify air quality assessment criteria relevant for assessing impacts from air pollution. The air quality criteria relate to the total dust burden in the air and not just the dust from proposed activities such as mining. In other words, consideration of background dust levels needs to be made when using these criteria to assess potential impacts. Table 4.1 summarises the air quality criteria for concentrations of particulate matter that are relevant to this study.

These criteria are consistent with the now superseded National Environment Protection (Ambient Air Quality) Measure (referred to as the Ambient Air-NEPM) (NEPC, 1998a). However, the NSW EPA's criteria include averaging periods which are not included in the Ambient Air-NEPM, and also reference other measures of air quality, namely dust deposition and TSP.

In January 2016, the NEPC released an amended Ambient Air-NEPM (NEPC, 2016) to take into account the latest scientific evidence about the health impacts of particles. The amendment changed the 'advisory reporting standards' status for annual average and 24-hour average $PM_{2.5}$ to 'standards', but in absence of any other relevant assessment criteria, the 2016 Ambient Air-NEPM standards for $PM_{2.5}$ have been used in this report for comparison against dispersion modelling results only.

Table 4.1: NSW air quality criteria/standards for particulate matter concentrations

Pollutant	Standard	Averaging Period	Source
PM_{10}	50 $\mu g/m^3$ 30 $\mu g/m^3$	24-Hour Annual	DEC (2005)
$PM_{2.5}$	25 $\mu g/m^3$ 8 $\mu g/m^3$	24-Hour Annual	NEPC (2016)
TSP	90 $\mu g/m^3$	Annual	DEC (2005)

$\mu g/m^3$ = micrograms per cubic metre

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including native vegetation and crops. Larger particles do not tend to remain suspended in the atmosphere for long periods of time and will fall out relatively close to source. Dust fallout can soil materials and generally degrade aesthetic elements of the environment, and are assessed for nuisance or amenity impacts.

Table 4.2 shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective, as well as the maximum total overall dust deposition. These criteria for dust fallout levels are set to protect against nuisance impacts (DEC, 2005).

Table 4.2: NSW criteria for dust deposition (insoluble solids)

Pollutant	Averaging period	Maximum increase	Maximum total
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

g/m^2/month = grams per square metre per month

4.2 Voluntary land acquisition and mitigation policy

In December 2014, NSW Department of Planning and Environment (DP&E) released a policy relating to voluntary mitigation and land acquisition criteria for air quality and noise (NSW Government, 2014). The policy sets out voluntary mitigation and land acquisition rights where it is not possible to comply with the EPA impact assessment criteria, even with the implementation of all reasonable and feasible avoidance and/or mitigation measures.

The DP&E voluntary mitigation and acquisition criteria are summarised in Table 4.3 and Table 4.4, respectively. The Modification has been assessed against these criteria, in addition to the EPA impact assessment criteria discussed in Section 4.1.

Total impact includes the impact of the amended Project and all other sources, whilst incremental impact refers to the impact of the amended Project considered in isolation.

Table 4.3: DP&E particulate matter mitigation criteria

Pollutant	Standard	Averaging Period	Application
PM_{10}	50 $\mu g/m^3$ 30 $\mu g/m^3$	24-Hour Annual	Incremental impact(a) Total impact
TSP	90 $\mu g/m^3$	Annual	Total impact
Deposited dust	2 g/m^2/month 4 g/m^2/month	Annual	Incremental impact(a) Total impact

(a) Zero allowable exceedances of the criterion over the life of the development.

Table 4.4: DP&E particulate matter acquisition criteria

Pollutant	Standard	Averaging Period	Application(a)
PM_{10}	50 $\mu g/m^3$ 30 $\mu g/m^3$	24-Hour Annual	Incremental impact(b) Total impact
TSP	90 $\mu g/m^3$	Annual	Total impact
Deposited dust	2 g/m^2/month 4 g/m^2/month	Annual	Incremental impact(b) Total impact

(a) Voluntary acquisition rights apply where the project contributes to exceedances of the acquisition criteria at any residence or workplace on privately-owned land or, on more than 25% of any privately-owned land, and a dwelling could be built on that land under exiting planning controls.

(b) Up to five allowable exceedances of the criterion over the life of the development.

5. Existing Environment

The CGO air quality monitoring network currently consists of an array of dust deposition gauges, a TSP high volume air sampler (HVAS) and a meteorological station. The locations of these are shown in Figure 5.1, and data collected from each site are described in the following sections.

Dust monitoring forms part of the Air Quality Management Plan (AQMP), required under Development Consent Condition (DCC) 6.1(c), and results are published every 12 months in the Annual Review required under DCC 9.1(b). The Annual Review also notes any dust-related complaints that have been received in that period. In Section 6.1.1 of the latest Annual Review (Evolution, 2015a), it is noted that there were no complaints received relating to dust at the CGO, nor any exceedances of the Development Consent air quality impact assessment criteria during the reporting period. A review of the all Annual Reviews since 2011 indicates that there have been no dust related complaints for a period of at least five years.

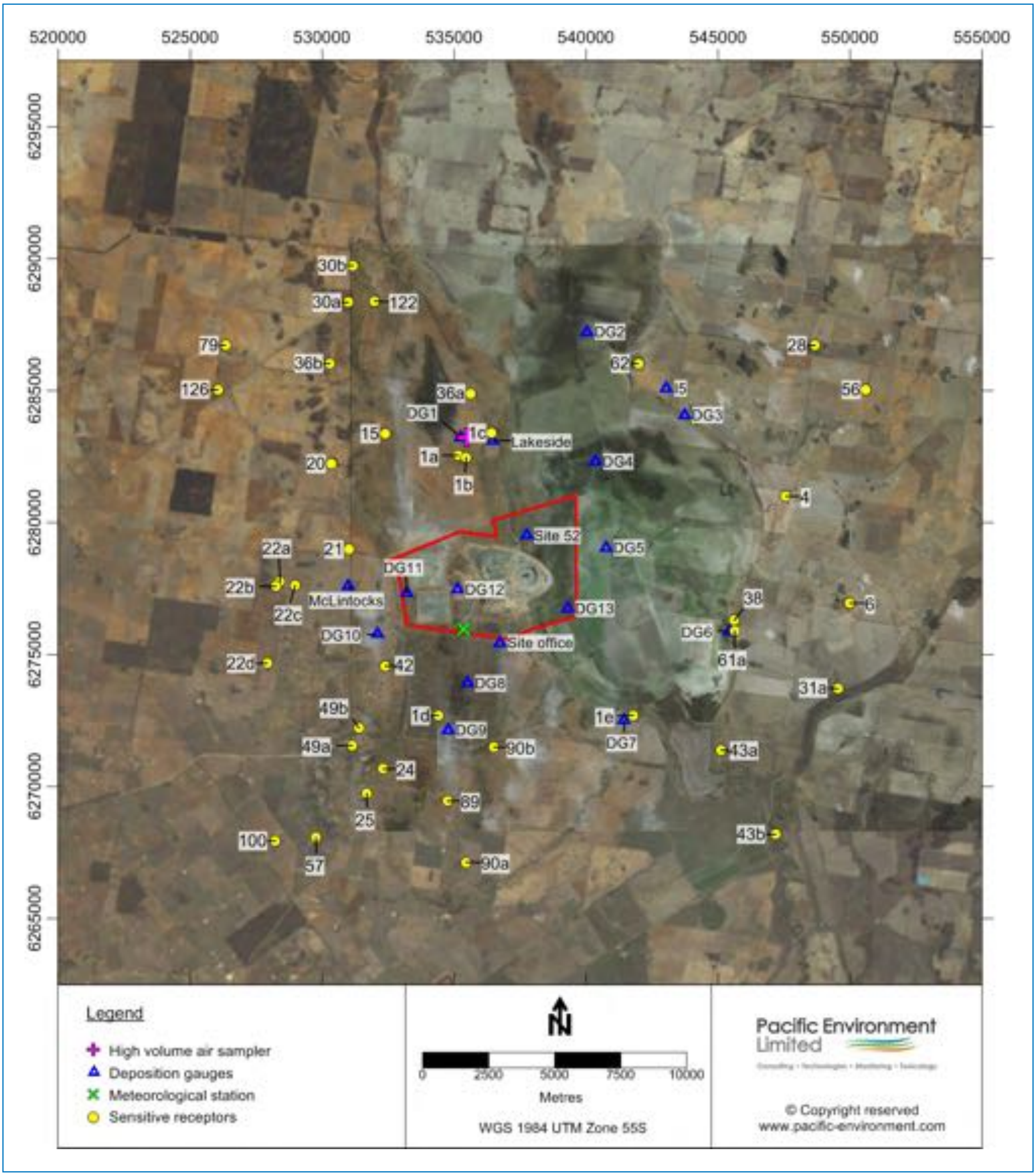


Figure 5.1: Locations of the CGO dust and meteorological monitoring sites

5.1 Meteorology

5.1.1 Representative meteorological data

An analysis of the meteorological data collected between January 2011 and December 2015 was completed to determine a representative 1-year period suitable for air dispersion modelling. The period chosen for modelling was the 12 month period from 1 January to 31 December 2015. The paragraphs below present the data available and some of the analysis carried out to determine the most appropriate year for modelling.

The annual wind patterns for 2011 to 2015 are shown in Figure 5.2. It can be seen from these windroses that there are winds from most directions, with slightly more from the south western quadrant (with the exception of 2011). The plots for each year are very similar and suggest that wind patterns do not vary significantly from year to year. A frequency distribution of wind speeds for each year is presented in Figure 5.3 and also suggests that these are reasonably consistent from year to year.

Further analysis on other meteorological parameters such as humidity, temperature and rainfall is presented in Figure 5.4. It shows that temperature and humidity, in particular, vary throughout the year, with cooler conditions corresponding with higher humidity. All five years show similar seasonal patterns, with an exception for humidity in 2011 which remained higher for longer than in other years. This is not unreasonable given that 2011 was significantly wetter than the other four years.

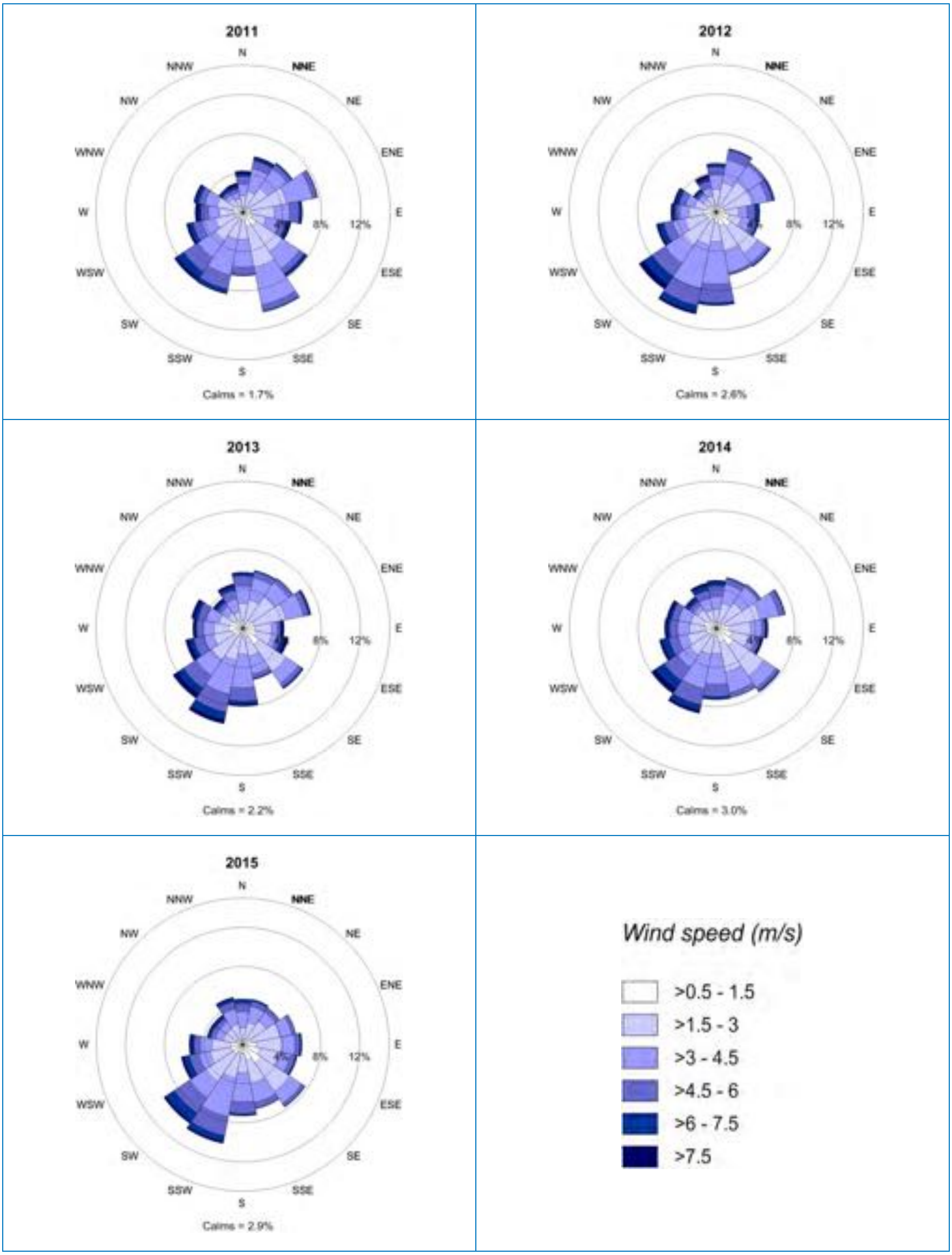


Figure 5.2: Annual windroses for CGO from 2011 – 2015

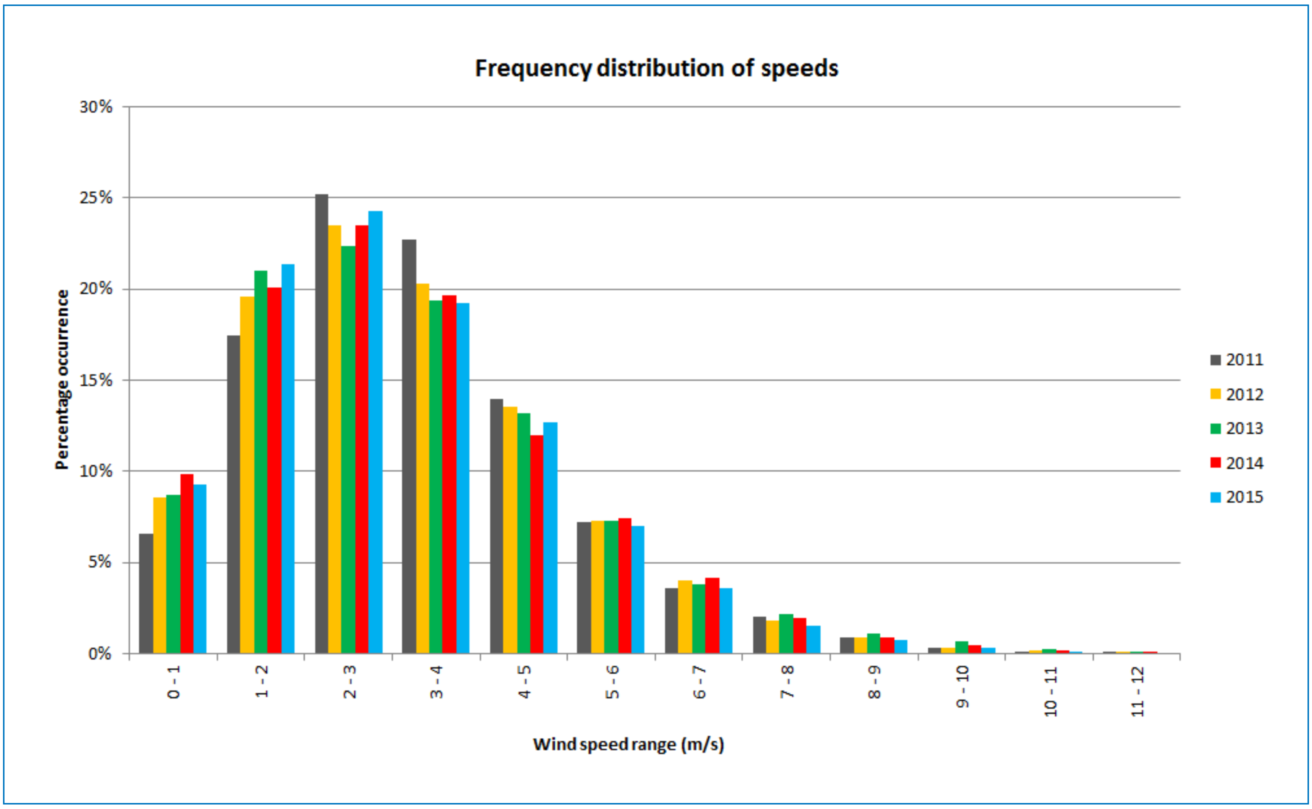


Figure 5.3: Distribution of wind speeds for each calendar year at CGO

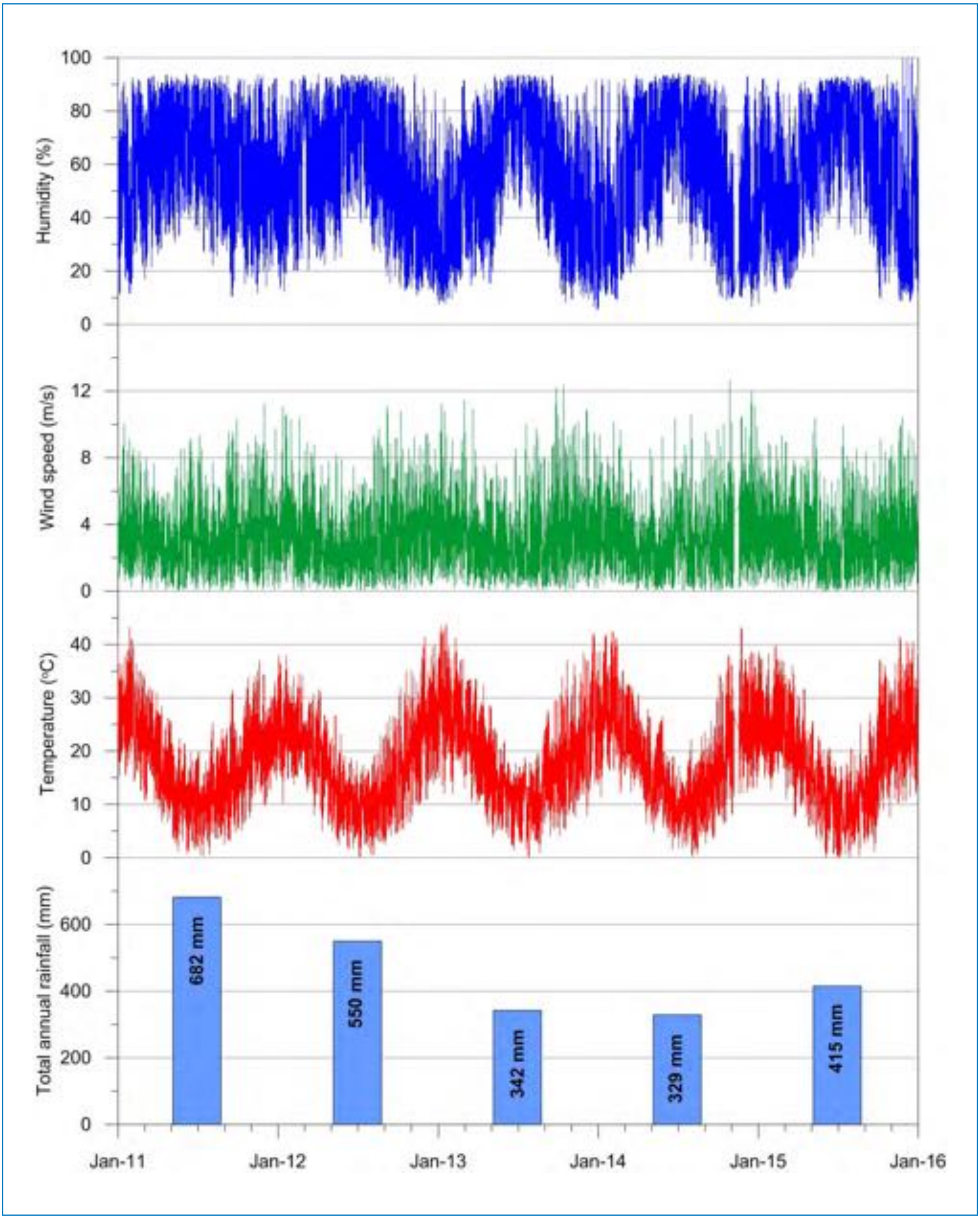


Figure 5.4: Humidity, wind speed, temperature and rainfall at CGO from 2011 – 2015

The identification of a representative meteorological year has been investigated by examining the statistics for the five years from 2011 to 2015, shown in Table 5.1.

Table 5.1: Annual statistics from data collected at the CGO meteorological station

Statistic	2011	2012	2013	2014	2015
Mean wind speed (metres per second [m/s])	3.2	3.2	3.2	3.1	3.0
Percentage of calms (%)	1.7	2.6	2.2	3.0	2.9
Total rainfall (millimetres [mm])	682	550	342	329	415
Percentage data capture (%)	100	100	100	92	100

With the exception of the notably higher rainfall in 2011 (and to a lesser extent, 2012), none of these years appear to be significantly different to the other years. For this assessment the 2015 calendar year has been selected as the meteorological modelling year, based on:

- Similar wind patterns to other years.
- Rainfall was neither the highest nor the lowest, but slightly lower than the long term average for the area of 479 mm (Bureau of Meteorology, 2016).
- Air quality conditions showed similarities to other recent years and were not adversely influenced by significant regional dust events (shown in Section 5.2.1).

Methods for incorporating the 2015 data into the meteorological model (CALMET) and dispersion model (CALPUFF) are discussed in Section 6.

5.1.2 Wind speed and direction

Having determined that 2015 is a representative year for the area, further analysis of the wind patterns in this year was carried out. Figure 5.5 presents the annual and seasonal windroses for 2015. The annual pattern is similar to that seen in spring. In autumn and winter winds are predominantly from the south western quadrant while in summer they are generally from the north east.

There are calm conditions for approximately 2.9% of the time, and most of these occur in winter.

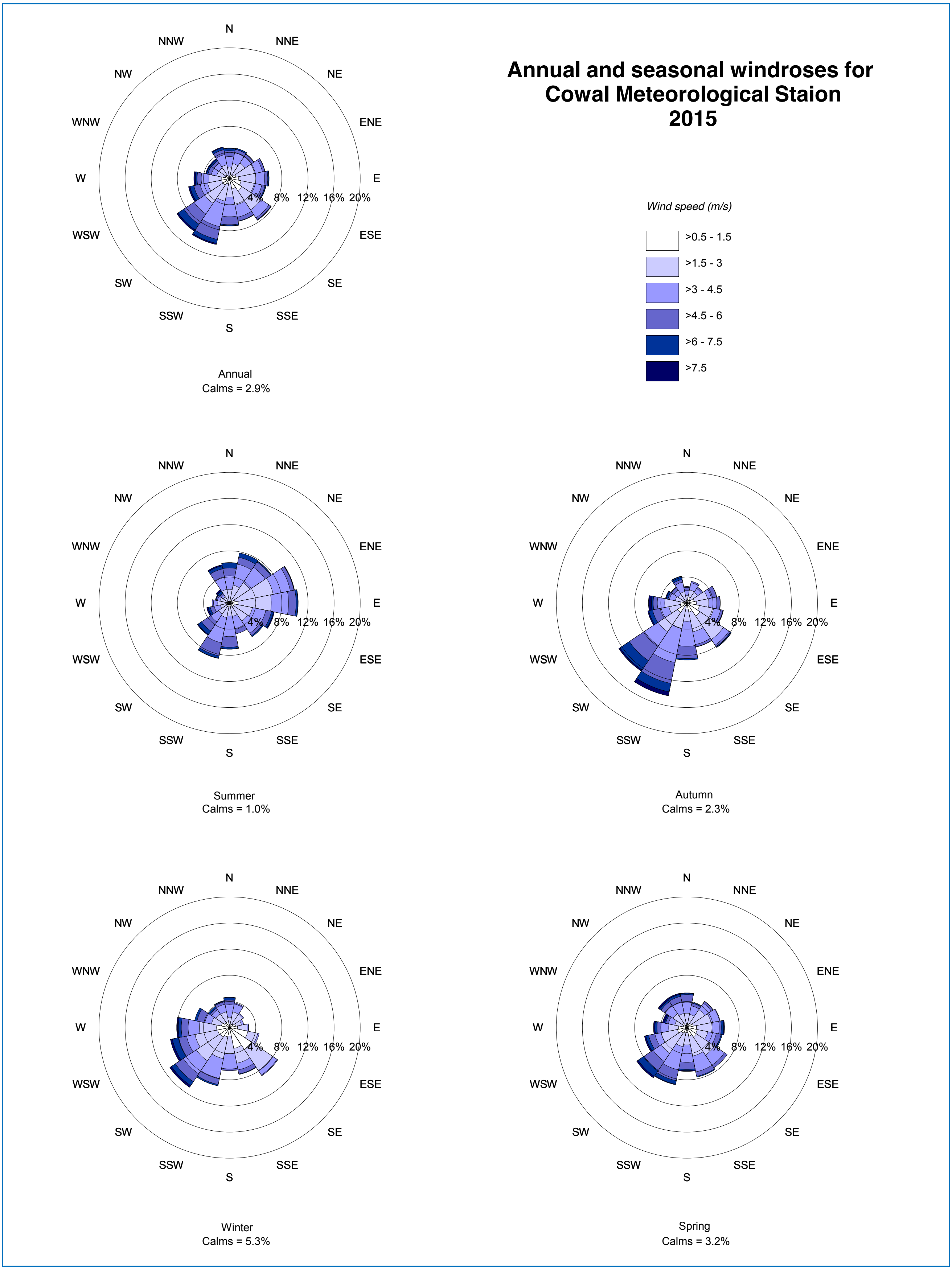


Figure 5.5: Annual and seasonal windroses for CGO 2015

5.2 Existing air quality

Air quality standards and criteria refer to pollutant levels that include the contribution from specific projects and existing sources. To fully assess impacts against the relevant standards and criteria listed in Section 4, it is necessary to have information or estimates on existing dust concentrations and deposition levels in the area in which the Modification is likely to contribute to these levels. It is also important to note that the existing air quality conditions are influenced to some degree by the existing CGO and so there will be an element of double counting.

Dust concentration (TSP) and dust deposition data are collected in the vicinity of the CGO. The locations of the monitoring sites are shown in Figure 5.1. There is currently one HVAS (HV1) measuring TSP, and 19 dust deposition gauges. There are no PM_{10} data collected at this time.

5.2.1 Dust concentration

Figure 5.6 shows a time series of the TSP monitoring data from January 2005 to June 2016, collected by HV1. HV1 is located approximately 3 km to the north of the CGO (near the Coniston homestead) and measures the contribution from a range of particulate matter sources, including traffic on unsealed roads, agricultural activities and dust sources associated with the existing CGO.

Figure 5.6 also presents ‘inferred’ PM_{10} data over the same monitoring period. These data have been inferred from the daily TSP data by assuming that 40% of the TSP is PM_{10}. This relationship was obtained from data collected by co-located TSP and PM_{10} monitors operated in the Hunter Valley (NSW Minerals Council, 2000). While the location of the CGO is obviously significantly removed from the Hunter Valley, the crustal nature of the dust is similar and therefore the relationship between the two particle sizes is likely to also be reasonably similar. This approach has been used for previous air quality assessments for the CGO (Pacific Environment, 2013), and is considered appropriate for this assessment.

Typically, the TSP and inferred PM_{10} concentrations in the area are lowest in the winter months and highest in the warmer, summer months. This seasonal cycle is evident in all available years of monitoring data. The summer months are drier than the winter months and the occurrence of bushfires and dust storms would be more common, potentially leading to higher airborne dust concentrations. Agricultural activities, such as harvesting that usually begins in November, will also contribute to airborne dust concentrations.

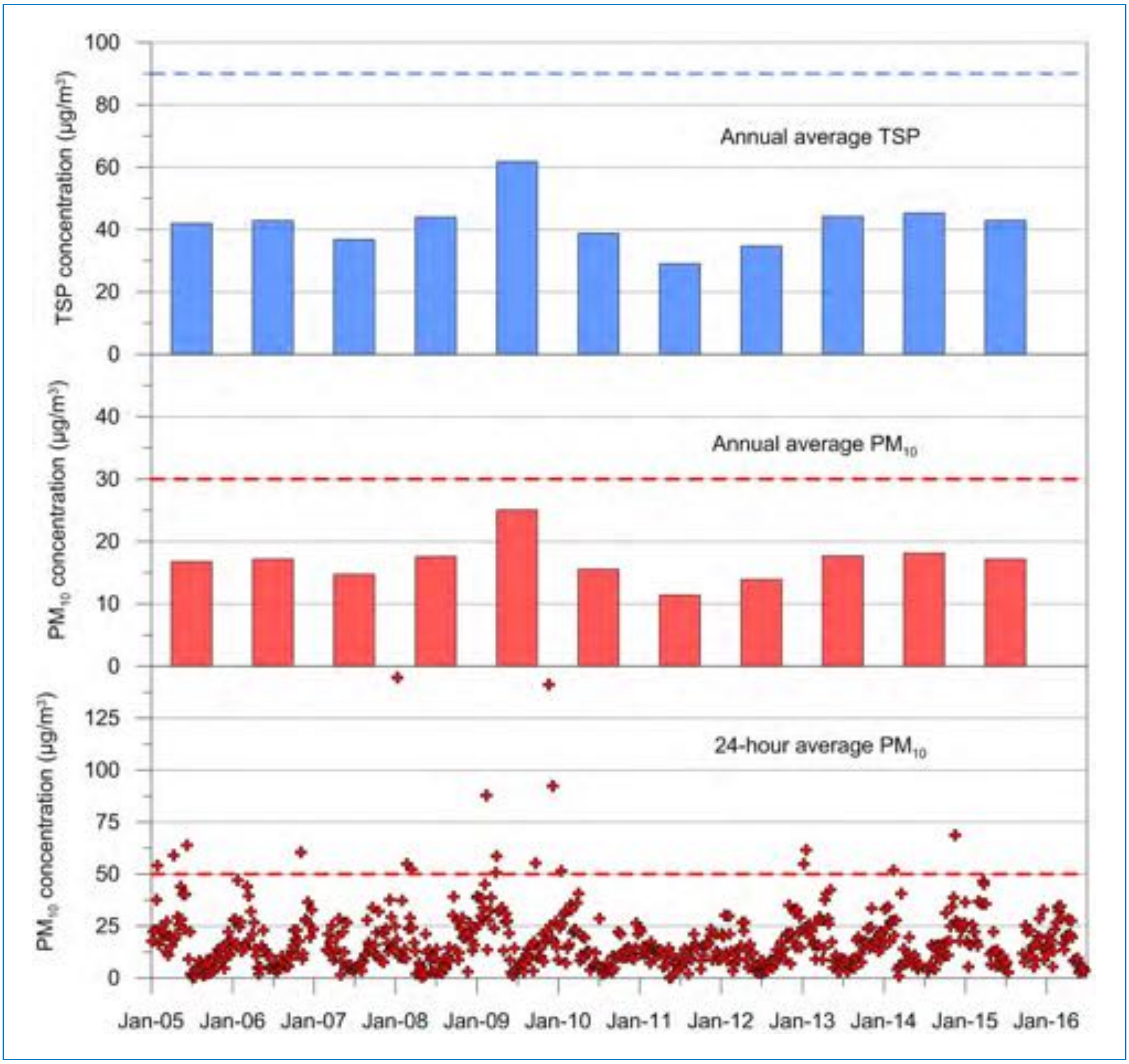


Figure 5.6: Measured TSP and inferred PM_{10} data from 2005 – 2016

The monitoring shows that the inferred 24-hour average PM_{10} concentrations (inferred from the TSP concentrations) have been above the NSW EPA's assessment criterion of 50 $\mu g/m^3$ on approximately 18 days since 2005. The two highest inferred PM_{10} concentrations to date were on 12 January 2008 and 20 November 2009. An analysis of meteorological monitoring data from the CGO automatic weather station (AWS) showed the prevailing winds on 12 January 2008 were from the north-west. Based on the CGO location relative to the monitor, the CGO is unlikely to have contributed to the exceedance on that day. The winds on 20 November 2009 were also predominantly from the north and therefore not likely to be a result of emissions from the CGO. It should also be noted that there were significant dust storms and high winds across NSW during much of November 2009 which are likely to have contributed to elevated TSP and PM_{10} levels in the CGO area. As mentioned above, November is also the main month for harvesting to begin.

In NSW, it is quite common to measure 24-hour average PM_{10} concentrations above the NSW EPA 50 μg/m^3 criterion on occasions. Events such as bushfires or dust storms are often the cause of elevated PM_{10} concentrations, which can be observed over large geographical areas.

Figure 5.7 shows the inferred PM_{10} data from the measured TSP data, ranked from highest to lowest for all data collected for the last 11 years. The 95th and 90th percentile values are also plotted showing that for 95% of the time the 24-hour average is less than 39 μg/m^3 and for 90% of the time it is less than 32 μg/m^3.

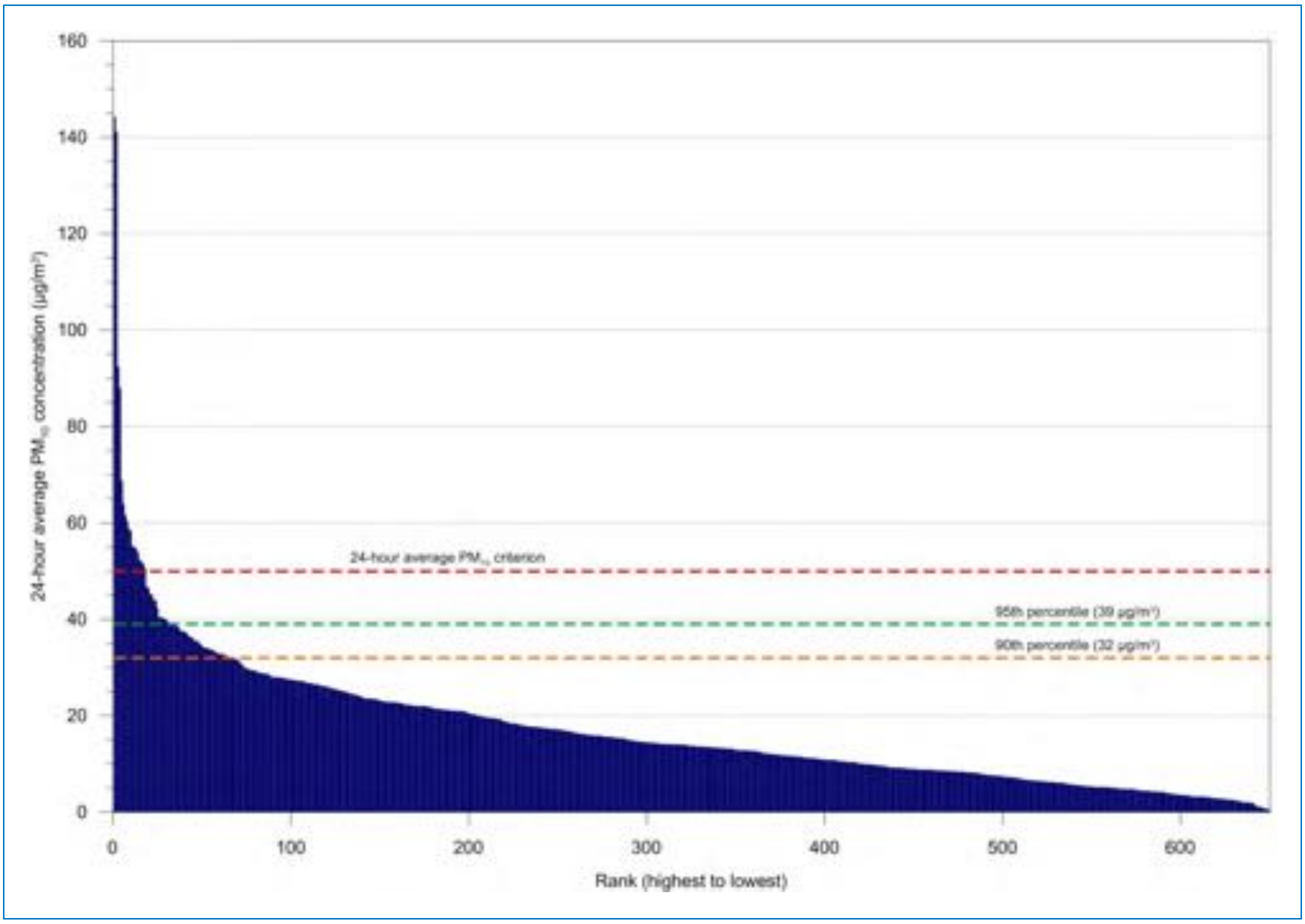


Figure 5.7: Ranked inferred 24-hour average PM_{10} concentrations from 2005 onwards

The annual average TSP and inferred PM_{10} concentrations are shown in Figure 5.6 and are also summarised in Table 5.2. The inferred annual average PM_{10} concentrations have ranged between 11 μg/m^3, in 2011, and 25 μg/m^3 in 2009, when there was significant bushfire and dust storm activity across NSW. These levels are below the NSW EPA's annual average criterion of 30 μg/m^3. Measured TSP concentrations have remained below the NSW EPA annual average criterion of 90 μg/m^3.

The inferred annual average PM_{10} concentration of 17 μg/m^3 in 2015 was equal to the average over the previous 10 years, further confirming this as a representative year.

Table 5.2: Annual average TSP and inferred PM_{10} concentrations from 2005 – 2015

Year	Annual average TSP ($\mu g/m^3$)	Annual average PM_{10} ($\mu g/m^3$)
2005	42	17
2006	43	17
2007	37	15
2008	44	18
2009	62	25
2010	38	16
2011	29	11
2012	35	14
2013	44	18
2014	45	18
2015	43	17
Average	**42**	**17**

An estimate of the annual average background value for PM2.5 has also been inferred, as there are no direct measurements in the area. Annual average data from a number of NSW Office of Environment and Heritage (OEH) sites with co-located PM_{10} and $PM_{2.5}$ measurements were analysed. These data are plotted in Figure 5.8, showing a relationship between the two particle size groups. Applying the same regression function to the inferred annual average PM_{10} concentration of 17 $\mu g/m^3$, presented in Table 5.2, gives an estimated annual average $PM_{2.5}$ concentration of approximately 5.3 $\mu g/m^3$. This value has been used to represent the annual average $PM_{2.5}$ background for this assessment.

It should be noted that the locations of NSW OEH monitoring sites with co-located PM_{10} and $PM_{2.5}$ monitors are generally close to regional centres (towns), rather than less populated rural areas. As such, $PM_{2.5}$ concentrations could be expected to be lower at the CGO than the inferred values (i.e. the NSW EPA monitoring sites would likely be closer to significant anthropogenic combustion emissions than the CGO).

The background level adopted is therefore considered to be a reasonable (yet conservative) representation of background $PM_{2.5}$ levels based on analysis of similar areas and comparison with Pacific Environment Limited (2013).

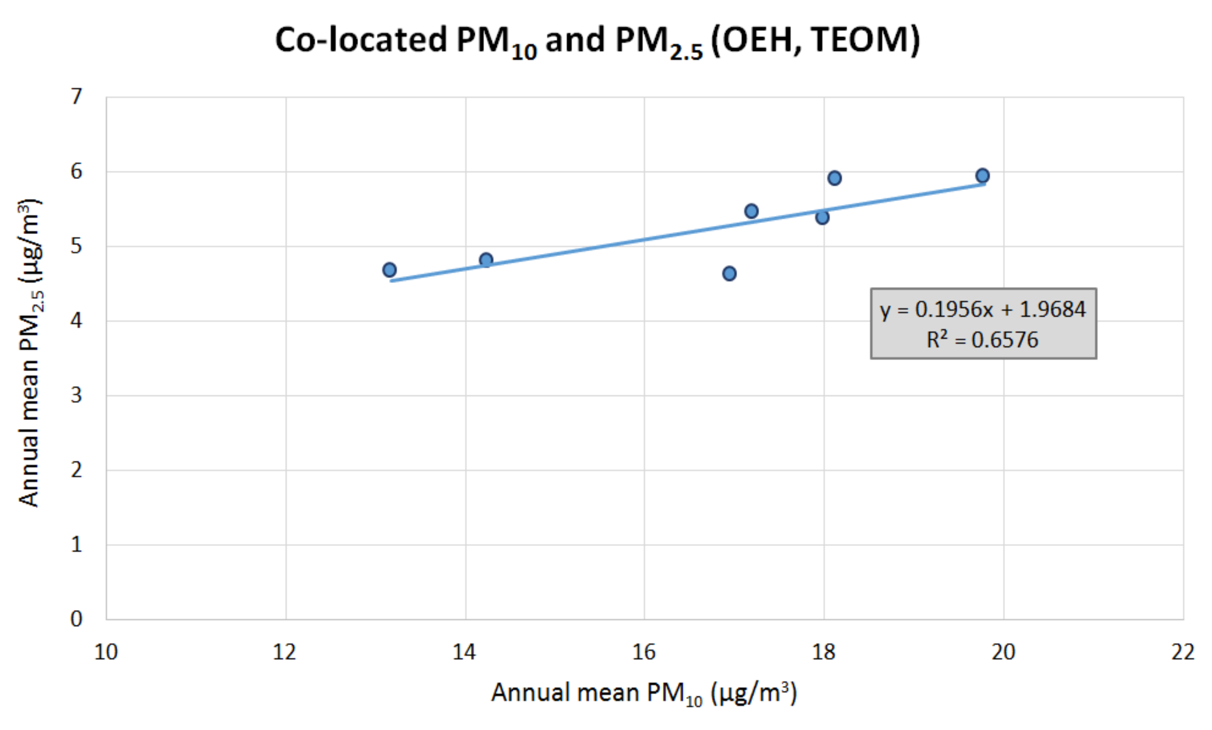


Figure 5.8: Annual average $PM_{2.5}$ and PM_{10} data from co-located OEH TEOMs in NSW

5.2.2 Dust deposition

Prior to the development of the CGO, monthly dust deposition was measured at three locations for a one year period (1993 to 1994). All three sites were located within ML 1535 and annual average dust deposition ranged between 1.0 and 1.6 g/m^2/month (Barrick, 2003), well below the 4 g/m^2/month NSW EPA annual average criterion.

The current dust deposition monitoring includes gauges at various locations in the vicinity of the CGO (refer Figure 5.1). Annual averages from data collected over the eight year period from 2008 to 2015 (inclusive) are presented in Table 5.3.

Table 5.3: Annual average dust deposition results from 2008 – 2015 (g/m^2/month)

Site	2008	2009	2010	2011	2012	2013	2014	2015	Average
McLintocks	4.3	4.0	7.7	3.2	18.6	3.1	3.9	4.0	**6.1**
Lakeside	6.0	6.4	2.2	2.0	7.3	2.5	1.7	5.2	**4.2**
I5	3.4	4.8	5.7	4.4	3.8	-	-	-	**4.4**
DG1	2.5	2.7	1.2	1.2	1.6	1.7	1.0	1.0	1.6
DG2	2.6	3.2	3.1	1.3	1.1	0.7	1.7	0.9	1.8
DG3	4.0	2.7	4.7	1.2	2.0	2.0	1.6	1.5	2.5
DG4	3.6	3.1	4.3	0.9	2.1	0.9	3.8	1.9	2.6
DG5	-	-	-	-	-	1.7	0.7	4.5	2.3
DG6	8.4	4.8	5.7	1.9	6.5	2.2	3.4	1.3	**4.3**
DG7	6.7	5.4	7.4	3.2	4.7	4.0	6.4	2.0	**5.0**
DG8	4.7	3.6	1.4	0.8	2.3	2.7	-	-	2.6
DG9	3.2	3.9	1.6	1.2	1.5	1.1	4.0	2.7	2.4
DG10	3.9	3.8	1.2	3.4	1.9	2.2	1.0	0.8	2.3
DG11*	-	-	-	-	-	2.3	4.1	4.3	3.6
DG12*	-	-	-	-	-	4.1	5.4	4.9	**4.8**
DG13*	-	-	-	-	-	1.2	2.2	4.6	2.7
DG14	-	-	-	-	-	1.1	0.8	1.9	1.3
Site Office	-	-	-	-	-	2.9	3.3	3.2	3.1
Site 52*	-	-	-	-	-	2.9	2.7	2.2	2.6

* These sites are inside the ML1535 boundary

The monitoring results presented in Table 5.3 show that dust deposition levels above 4 g/m^2/month were measured at several locations. In the case of the McLintocks gauge, which measured an average of 6.1 g/m^2/month, the on-site DG11, which is in the same direction as McLintocks, yet much closer to mining activities, measured an average of 3.6 g/m^2/month over the same period. Hence, the dust deposition at McLintocks is most likely due to localised sources to that gauge. Likewise, the Lakeside gauge measured an average of 4.2 g/m^2/month, compared with the closely located DG1, which measured an average of only 1.6 g/m^2/month. Gauge I5 measured an average of 4.4 g/m^2/month, compared with DG4, in the same direction as I5, yet much closer to mining activities, which measured an average of 2.6 g/m^2/month over the same period. Also, DG3, which is closely located to I5, measured an average dust deposition of 2.5 g/m^2/month. This would indicate that the exceedance of the 4 g/m^2/month criterion at these gauges is due to localised activities (very close to the gauge) and unlikely to be due to the mining activity at the CGO. Similarly, gauges DG6 and DG7 returned averages above 4 g/m^2/month. These gauges are distant from mining activities (some 7 km and 6 km away, respectively) and are most likely influenced by other more localised dust sources.

For the remaining gauges, the annual values average approximately 2.5 g/m^2/month.

5.2.3 Background values

In summary, the following values have been used as representative background levels for the annual average cumulative assessment:

Annual average $PM_{2.5}$ concentration	5.3 μg/m^3
Annual average PM_{10} concentration	17 μg/m^3
Annual average TSP concentration	42 μg/m^3
Annual average dust deposition level	2.5 g/m^2/month

These background levels are considered to be conservative for the purposes of impact assessment for the Modification. They include any existing contributions of the CGO, therefore resulting in double counting when these adopted background levels are considered cumulatively with modelled impacts from the CGO incorporating the Modification.

6. Methodology

6.1 Approach to assessment

The overall approach to the assessment follows the Approved Methods using the Level 2 assessment methodology. The Approved Methods specify how assessments based on the use of air dispersion models should be completed. They include guidelines for the preparation of meteorological data to be used in dispersion models and the relevant air quality criteria for assessing the significance of predicted concentration and deposition rates from the Modification.

The air dispersion modelling conducted for this assessment is based on an advanced modelling system using the models TAPM and CALMET/CALPUFF.

The modelling system works as follows:

- TAPM is a prognostic meteorological model that generates gridded three-dimensional meteorological data for each hour of the model run period.
- CALMET, the meteorological pre-processor for the dispersion model CALPUFF, calculates fine resolution three-dimensional meteorological data based upon observed ground and upper level meteorological data, as well as observed or modelled upper air data generated, for example, by TAPM.
- CALPUFF then calculates the dispersion of plumes within this three-dimensional meteorological field.

Output from TAPM, plus local observational weather station data, were entered into CALMET, a meteorological pre-processor endorsed by the United States Environmental Protection Agency (US EPA) and recommended by the NSW EPA for use in complex terrain and non-steady state conditions (that is, conditions that change in time and space). From this, a 1-year representative meteorological dataset suitable for use in the 3-dimensional plume dispersion model, CALPUFF, was compiled. Figure 6.1 presents an overview of the modelling system and the details on the model configuration and data inputs are provided in the following sections.

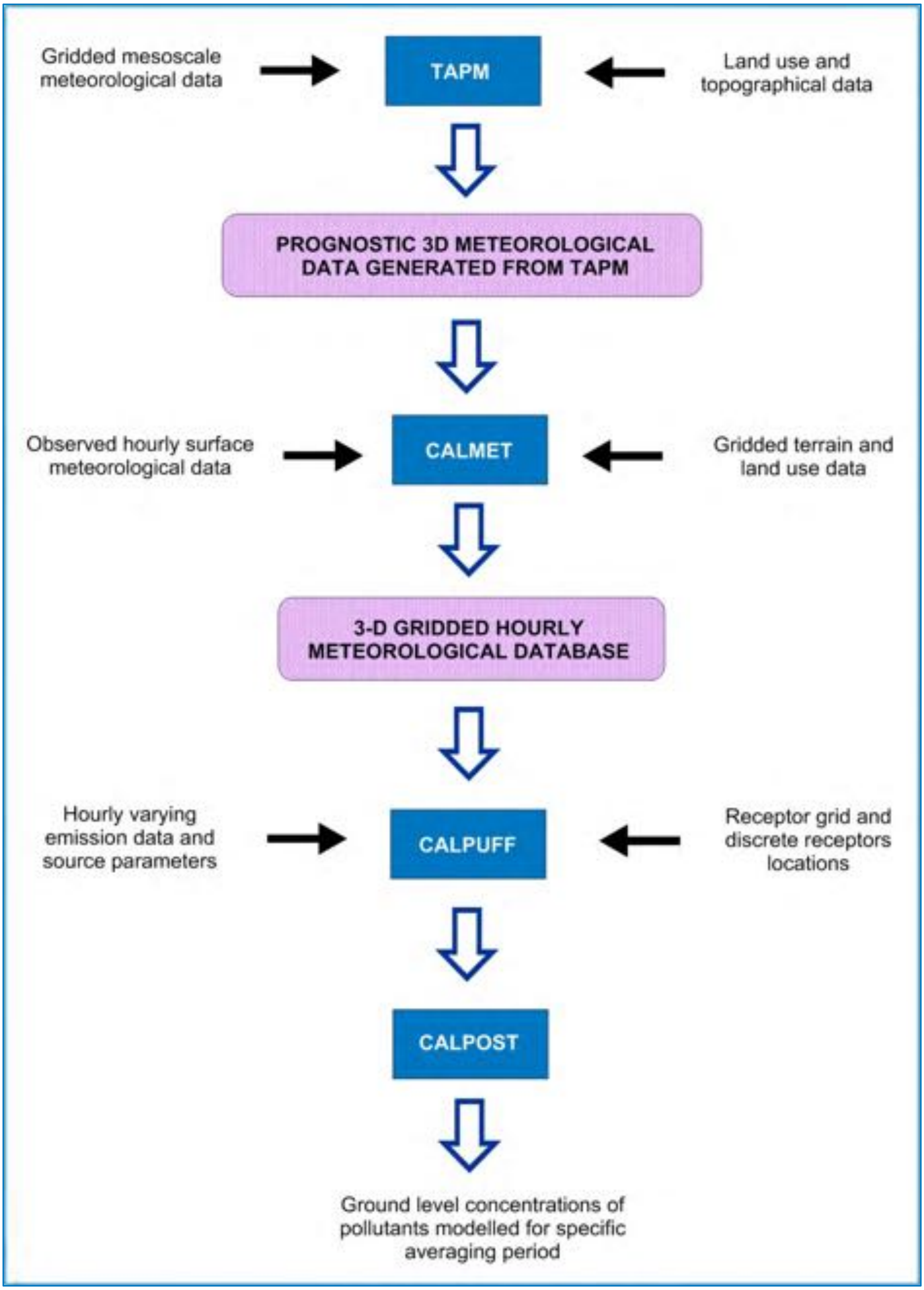


Figure 6.1: Overview of modelling methodology

6.2 TAPM

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model developed by the Commonwealth Scientific and Industrial Research Organisation Division of Atmospheric Research. Detailed description of the TAPM model and its performance is provided in Hurley (2008) and Hurley et al. (2009).

TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

For this project, TAPM was set up with 3 domains, composed of 25 grid points along both the x and the y axes, centred on -33˚38' Latitude and 147˚24' Longitude. Each nested domain had a grid resolution of 30 km, 10 km and 3 km respectively.

6.3 CALMET

CALMET is a meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the three-dimensional meteorological fields that are utilised in the CALPUFF dispersion model (i.e. the CALPUFF dispersion model requires meteorological data in three dimensions). CALMET uses the meteorological inputs in combination with land use and geophysical information for the modelling domain to predict gridded meteorological fields for the region.

Terrain for this area was principally derived from 90 m NASA SRTM (Shuttle Radar Topography Mission) data. Finer resolution terrain data from Light Detection and Ranging (LiDAR) was used to represent the Modification, and combined with the NASA SRTM data to represent the entire modelling domain. Land use for the domain was determined from Google Earth aerial photography.

There are four main land uses represented across the modelling domain. The dominant land use is agricultural land, with the barren land category used to represent the active mining areas. Figure 6.2 presents this information across the domain.

Meteorological parameters such as wind speed, wind direction, temperature and relative humidity were sourced from the on-site station. Upper air information was incorporated through the use of prognostic three-dimensional data extracted from TAPM. The CALMET model generated meteorological parameters across the grid domain of 40 km x 40 km with a 250 m resolution, centred on the CGO.

6.4 CALPUFF

CALPUFF is the dispersion module of the CALMET/CALPUFF suite of models. It is a multi-layer, multi species, non-steady-state puff dispersion model that can simulate the effects of time-varying and space-varying meteorological conditions on pollutant transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. The model employs dispersion equations based on a Gaussian distribution of pollutants across released puffs and takes into account the complex arrangement of emissions from point, area, volume and line sources (Scire et al., 2000).

Each dust generating activity was represented by a series of volume sources situated according to their location, as shown in Section 7. The plume dimensions were determined using an initial lateral spread (sigma [σ] y) of 10 m and initial vertical spread (sigma [σ] z) of 2 m. All sources were given a release height of 2 m. Model predictions were made across the domain at gridded receptors at a spacing of 1 km x 1 km, as well as at 54 discrete receptors representing private and mine-owned residences.

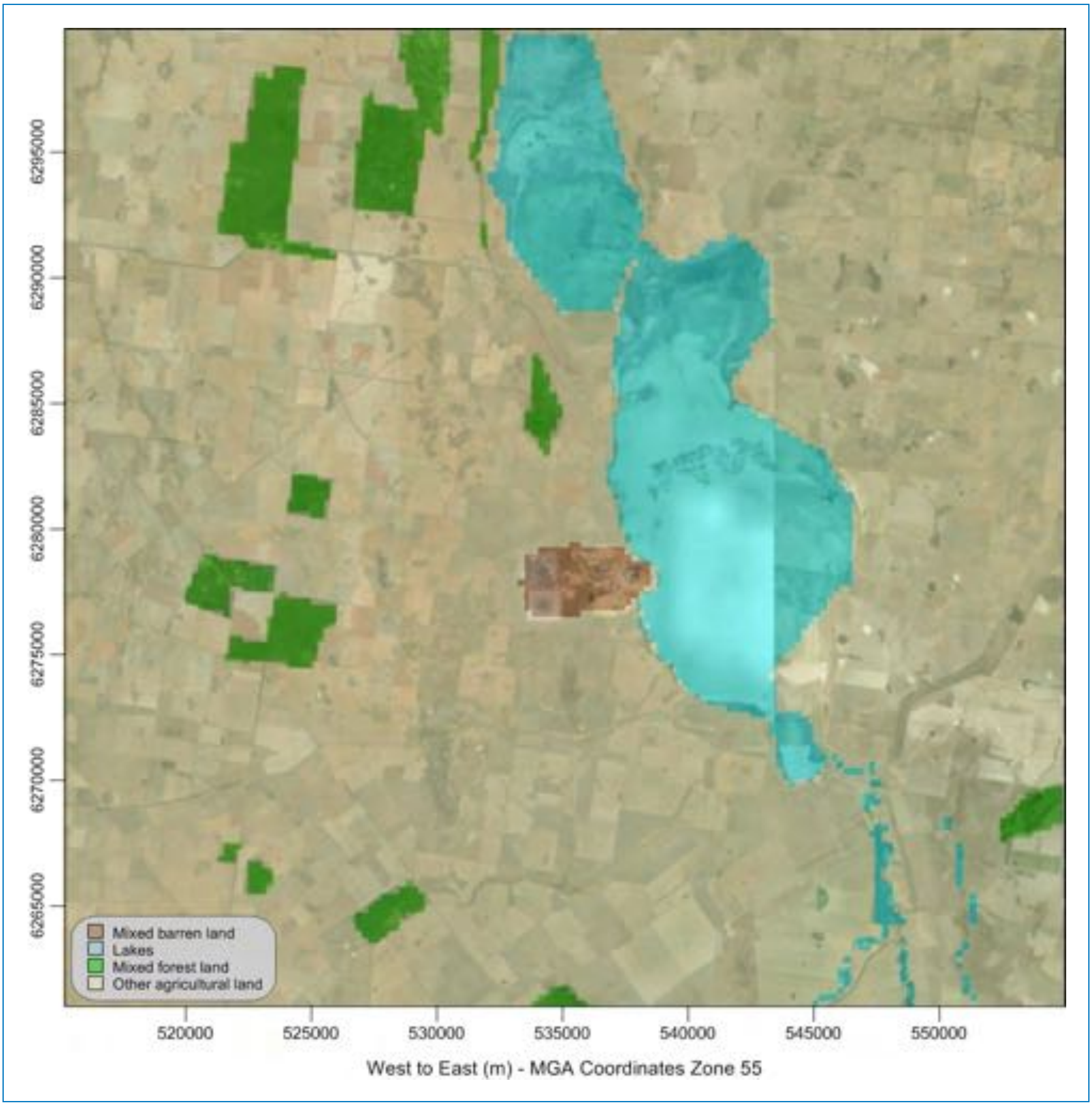


Figure 6.2: Landuse categories used for meteorological modelling

7. Emissions to air

Estimates of emissions for each source were developed on an hourly time step taking into account the activities that would take place at that location. Thus, for each source, for each hour, an emission rate was determined which depended on the level of activity and the wind speed. Dust generating activities were represented by a series of volume sources situated according to the location of activities for the modelled scenarios.

Not every activity will occur at each source location and some source locations would see significantly more activities than others. For example, in the active pit area a variety of activities will be taking place simultaneously, such as drilling, blasting, loading to trucks, haulage and wind erosion. The source locations in the pit would therefore include a proportion of emissions from some, or all, of these activities.

The operations were analysed and estimates of dust emissions for the key dust generating activities were made. Emission factors developed by the US EPA were applied to estimate the amount of dust produced by each activity. The emission factors applied are considered to be the most reliable, contemporary methods for determining dust generation rates.

Detailed emissions inventories were prepared for the two key operating scenarios determined in Section 2.3. Table 7.1 and Table 7.2 list all activities that have been modelled for these scenarios and their corresponding estimated annual emissions for TSP, PM_{10} and $PM_{2.5}$.

Further detail on the emission factors and calculations is provided in Appendix A.

To model the effect of pit retention for emissions for the Modification, detailed mine plan terrain data has been incorporated into the modelling. All activities except blasting and TSF lift activities (which are restricted to daytime hours) have been modelled as potentially occurring 24 hours per day.

Table 7.1: Estimated emissions for Year 14 (2018)

Activity	TSP (kg)	PM_{10} (kg)	$PM_{2.5}$ (kg)
Drilling	8,098	4,211	243
Blasting	28,808	14,980	864
Waste - Excavators loading haul trucks	5,084	2,404	364
Waste - Hauling to northern waste dump	1,184,098	304,257	30,426
Waste - Hauling to southern waste dump	-	-	-
Waste - Hauling to northern TSF stockpile	93,044	23,908	2,391
Waste - Hauling to southern TSF stockpile	50,612	13,005	1,300
Waste - Unloading at northern waste dump	4,678	2,213	335
Waste - Unloading at southern waste dump	-	-	-
Waste - Unloading at northern TSF stockpile	257	122	18
Waste - Unloading at southern TSF stockpile	148	70	11
Waste - Loading trucks at northern TSF stockpile	257	122	18
Waste - Loading trucks at southern TSF stockpile	148	70	11
Waste - Hauling from northern TSF stockpile to TSF embankment	80,054	20,570	2,057
Waste - Hauling from southern TSF stockpile to TSF embankment	44,564	11,451	1,145
Waste - Unloading at northern TSF embankment	257	122	18
Waste - Unloading at southern TSF embankment	148	70	11
Waste - Dozer on northern TSF embankment	1,564	264	164
Waste - Dozer on southern TSF embankment	1,564	264	164
Waste - Dozers in pit	2,864	483	301
Waste - Dozers on northern waste dump/mineral waste stockpiles	2,864	483	301
Waste - Dozers on southern waste dump	-	-	-
Ore - Loading mineral waste ore to haul trucks	2,069	979	148
Ore - Hauling mineral waste ore to northern dump	77,527	19,921	1,992
Ore - Unloading mineral waste ore to northern dump	2,069	979	148
Ore - Loading ore to haul trucks	17,169	8,120	1,230
Ore - Hauling ore to run-of-mine (ROM) pad	562,859	144,628	14,463
Ore - Unloading ore to ROM pad	5,151	2,436	369
Ore - Rehandling ore	3,090	1,462	221
Ore - Crushing and screening	15,657	5,894	691
Ore - Loading to coarse ore stockpile	4,116	1,947	295
Grading roads	10,783	377	334
Wind erosion - Open pit	93,500	46,750	7,013
Wind erosion - Northern dump	124,950	62,475	9,371
Wind erosion - Southern dump	29,750	14,875	2,231
Wind erosion - Stockpiles and exposed areas	127,500	63,750	9,563
Wind erosion - Northern TSF lift construction area	51,000	25,500	3,825
Wind erosion - Southern TSF (half of total area)	25,500	12,750	1,913
Northern TSF Lift - Hauling to northern TSF	54,556	14,018	1,402
Northern TSF Lift - Unloading soil/clay at northern TSF	116	55	8
Northern TSF Lift - Dozer shaping soil/clay	1,564	264	164
Total	**2,718,041**	**826,246**	**95,523**

Note: kg = kilograms.

Table 7.2: Estimated emissions for Year 18 (2022)

Activity	TSP (kg)	PM_{10} (kg)	$PM_{2.5}$ (kg)
Drilling	8,098	4,211	243
Blasting	28,808	14,980	864
Waste - Excavators loading haul trucks	20,917	9,893	1,498
Waste - Hauling to northern waste dump	356,469	91,596	9,160
Waste - Hauling to southern waste dump	-	-	-
Waste - Hauling to northern TSF stockpile	241,220	61,982	6,198
Waste - Hauling to southern TSF stockpile	134,777	34,631	3,463
Waste - Unloading at northern waste dump	11,923	5,639	854
Waste - Unloading at southern waste dump	-	-	-
Waste - Unloading at northern TSF stockpile	5,648	2,671	404
Waste - Unloading at southern TSF stockpile	3,347	1,583	240
Waste - Loading trucks at northern TSF stockpile	5,648	2,671	404
Waste - Loading trucks at southern TSF stockpile	3,347	1,583	240
Waste - Hauling from northern TSF stockpile to TSF embankment	207,543	53,329	5,333
Waste - Hauling from southern TSF stockpile to TSF embankment	118,673	30,493	3,049
Waste - Unloading at northern TSF embankment	5,648	2,671	404
Waste - Unloading at southern TSF embankment	3,347	1,583	240
Waste - Dozer on northern TSF embankment	11,367	2,231	1,193
Waste - Dozer on southern TSF embankment	11,367	2,231	1,193
Waste - Dozers in pit	20,819	4,086	2,186
Waste - Dozers on northern waste dump/mineral waste stockpiles	10,409	2,043	1,093
Waste - Dozers on southern waste dump	-	-	-
Ore - Loading mineral waste ore to haul trucks	8,767	4,147	628
Ore - Hauling mineral waste ore to northern dump	314,999	80,940	8,094
Ore - Unloading mineral waste ore to northern dump	8,767	4,147	628
Ore - Loading ore to haul trucks	20,373	9,636	1,459
Ore - Hauling ore to ROM pad	640,474	164,571	16,457
Ore - Unloading ore to ROM pad	6,112	2,891	438
Ore - Rehandling ore	3,667	1,734	263
Ore - Crushing and screening	17,816	6,707	786
Ore - Loading to coarse ore stockpile	4,351	2,058	312
Grading roads	10,783	377	334
Wind erosion - Open pit	93,500	46,750	7,013
Wind erosion - Northern dump	102,850	51,425	7,714
Wind erosion - Southern dump	-	-	-
Wind erosion - Stockpiles and exposed areas	65,450	32,725	4,909
Wind erosion - Northern TSF (half total area)	25,500	12,750	1,913
Wind erosion - Southern TSF (lift construction area)	51,000	25,500	3,825
Southern TSF Lift - Hauling to southern TSF	123,799	31,810	3,181
Southern TSF Lift - Unloading soil/clay at southern TSF	2,233	1,056	160
Southern TSF Lift - Dozer shaping soil/clay	11,367	2,231	1,193
Total	**2,721,180**	**811,564**	**97,566**

8. Modelling results

8.1 Introduction

The NSW EPA air quality assessment criteria used for identifying which properties are likely to experience air quality impacts are summarised in Section 4 and have been applied in this assessment. It is important to note that there are currently no impact assessment criteria for $PM_{2.5}$. The predicted concentrations have been compared with the Ambient Air-NEPM standards for $PM_{2.5}$. The predictions are focussed on inhabited residential properties.

Dispersion model predictions have been made for Years 14 (2018) and 18 (2022). These modelled years were selected as representative, worst case years for the life of the mine.

Contour plots of particulate concentrations and deposition levels show the areas that are predicted to be affected by dust at different levels. These contour figures are presented to provide a visual representation of the predicted impacts. To produce the contours it is necessary to make interpolations, and as a result the contours will not always match exactly with predicted impacts at any specific location. The actual predicted particulate concentrations/levels at nearby residences are presented in tabular form.

Section 8.2 presents results for the Modification alone and Section 8.3 presents an annual average cumulative assessment. A separate cumulative assessment of 24-hour average PM_{10} and $PM_{2.5}$ is provided in Section 8.4.

8.2 Modification only

8.2.1 Year 14 (2018)

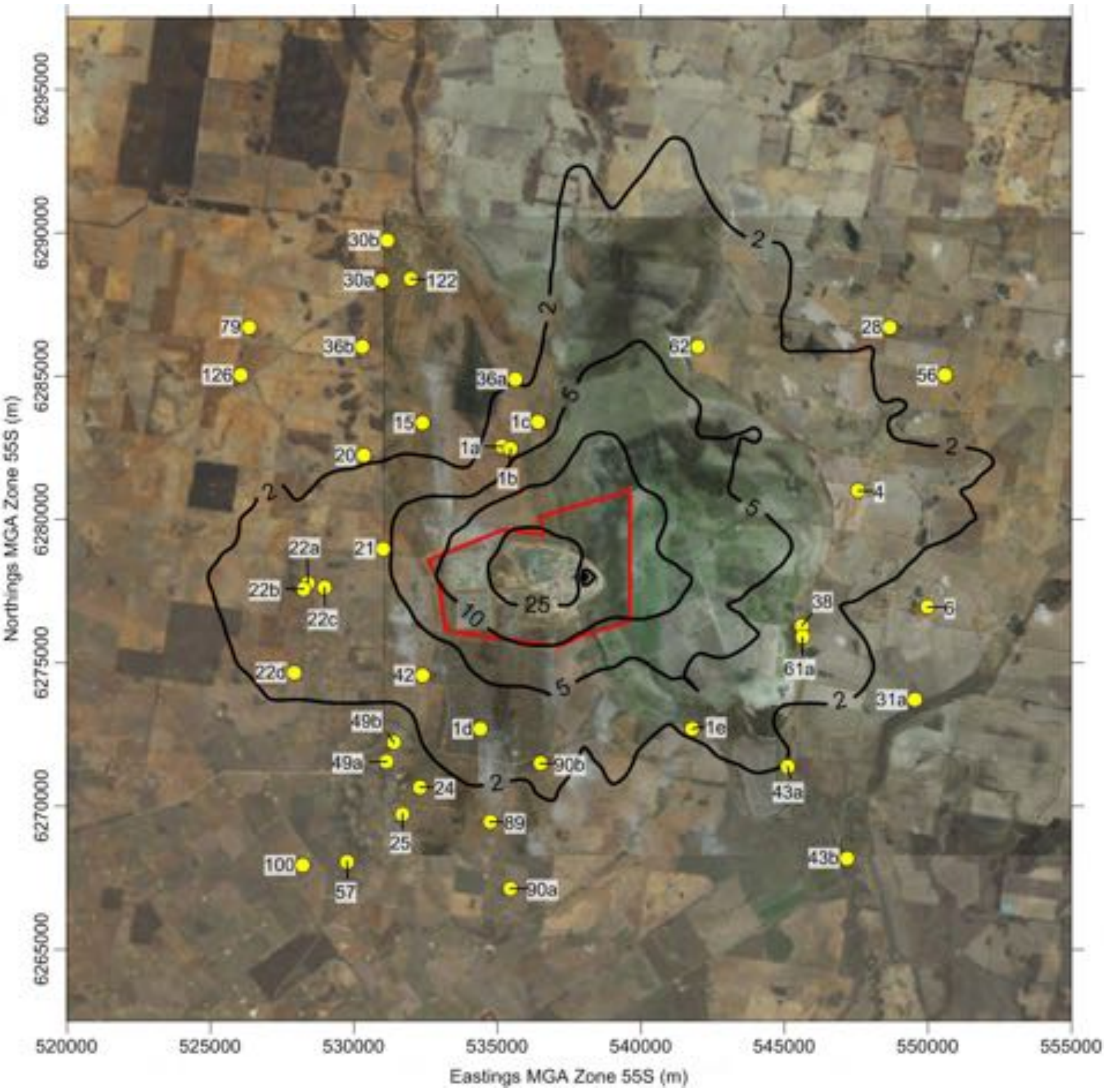
A summary of the predicted concentration and deposition levels at all sensitive receptors (that is residences both private and mine-owned) due to the operations of the Modification alone in Year 14 is presented in Table 8.1. Figure 8.1 to Figure 8.6 show these predictions across the modelling domain.

With the exception of dust deposition, predictions are not compared to EPA impact assessment criteria, as these criteria are cumulative. However, for individual residences the maximum 24-hour average PM_{10} predictions can be compared to the NSW DP&E voluntary acquisition incremental criterion of 50 $\mu g/m^3$.

Figure 8.2 shows that there are no predicted exceedances of the incremental maximum 24-hour average PM_{10} criterion of 50 $\mu g/m^3$ as a result of the Modification in Year 14. The predicted dust deposition levels are also well below the incremental criterion of 2 g/m^2/month at all residential receptors (Figure 8.6). These results include consideration of the extent of the 50 $\mu g/m^3$ PM_{10} and 2 g/m^2/month dust deposition contours in relation to privately-owned land (i.e. assessment against the voluntary acquisition criteria described in Table 4.4 applicable to 25% of land).

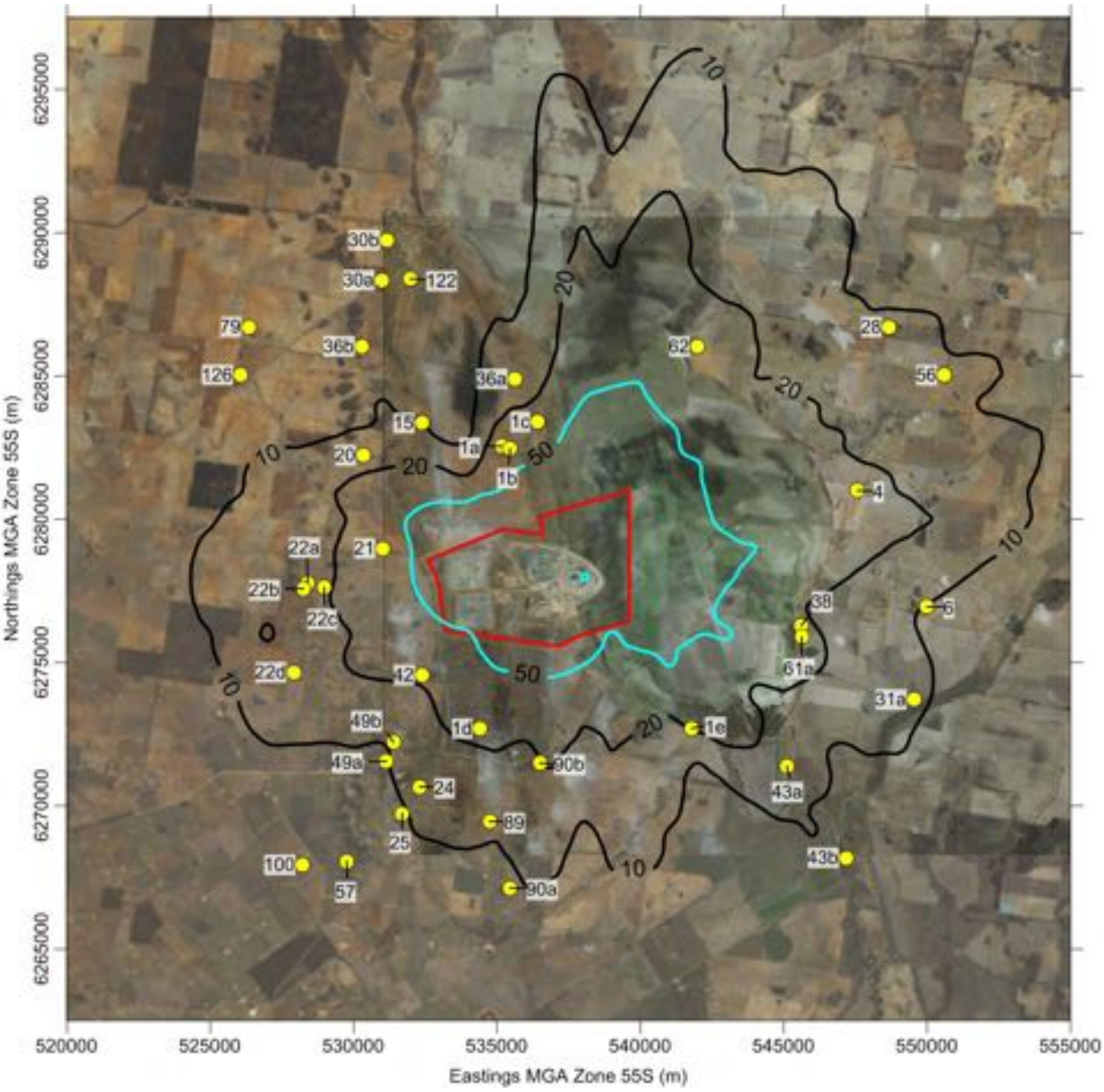
Table 8.1: Predicted concentrations and dust deposition levels at individual residences for Year 14 (2018) – Modification only

Receptor ID	24-hour average		Annual average			
	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	TSP (µg/m³)	Dust deposition (g/m²/month)
Criteria/Standard	**25**	**50**	**N/A**	**N/A**	**N/A**	**2**
1a	3.5	29.3	0.3	2.0	4.7	0.09
1b	4.4	36.2	0.3	2.4	5.8	0.11
1c	3.1	25.1	0.3	2.4	5.9	0.10
1d	3.0	23.1	0.2	1.6	4.1	0.09
1e	2.5	19.7	0.1	0.8	2.0	0.03
4	3.3	25.4	0.2	1.2	2.7	0.06
6	1.4	9.6	0.1	0.6	1.3	0.02
15	1.2	10.0	0.1	0.6	1.5	0.03
20	1.7	13.2	0.1	0.7	1.6	0.03
21	4.5	34.5	0.3	2.2	5.1	0.08
22a	2.7	18.0	0.2	1.3	2.8	0.04
22b	2.7	18.2	0.2	1.3	2.7	0.04
22c	2.8	19.3	0.2	1.4	3.1	0.05
22d	2.2	16.1	0.2	1.2	2.6	0.05
24	1.6	12.0	0.1	0.9	2.1	0.05
25	1.3	9.6	0.1	0.7	1.7	0.04
28	1.8	11.4	0.1	0.8	1.6	0.03
30a	0.4	3.2	0.0	0.3	0.6	0.01
30b	0.5	3.7	0.0	0.3	0.6	0.01
31a	1.5	10.9	0.1	0.4	0.9	0.01
36a	2.0	16.3	0.2	1.3	3.0	0.07
36b	0.5	4.4	0.0	0.3	0.7	0.01
38	3.0	22.9	0.2	1.2	2.7	0.05
42	2.8	22.2	0.3	2.4	5.8	0.11
43a	1.9	15.8	0.1	0.5	1.2	0.01
43b	1.3	9.4	0.0	0.3	0.6	0.01
49a	1.3	9.7	0.1	1.0	2.3	0.04
49b	1.5	10.8	0.1	1.1	2.7	0.05
56	1.6	12.3	0.1	0.7	1.4	0.02
57	1.0	7.4	0.1	0.5	1.2	0.03
61a	3.2	24.6	0.1	1.1	2.4	0.05
62	3.6	26.8	0.4	2.8	6.5	0.10
79	0.5	3.6	0.0	0.2	0.5	0.01
89	1.5	11.7	0.1	0.8	2.0	0.05
90a	1.2	9.2	0.1	0.6	1.4	0.03
90b	2.5	20.2	0.2	1.2	3.1	0.07
100	0.8	5.7	0.1	0.5	1.0	0.02
122	0.5	4.1	0.0	0.3	0.7	0.01
126	0.6	5.0	0.0	0.3	0.5	0.01



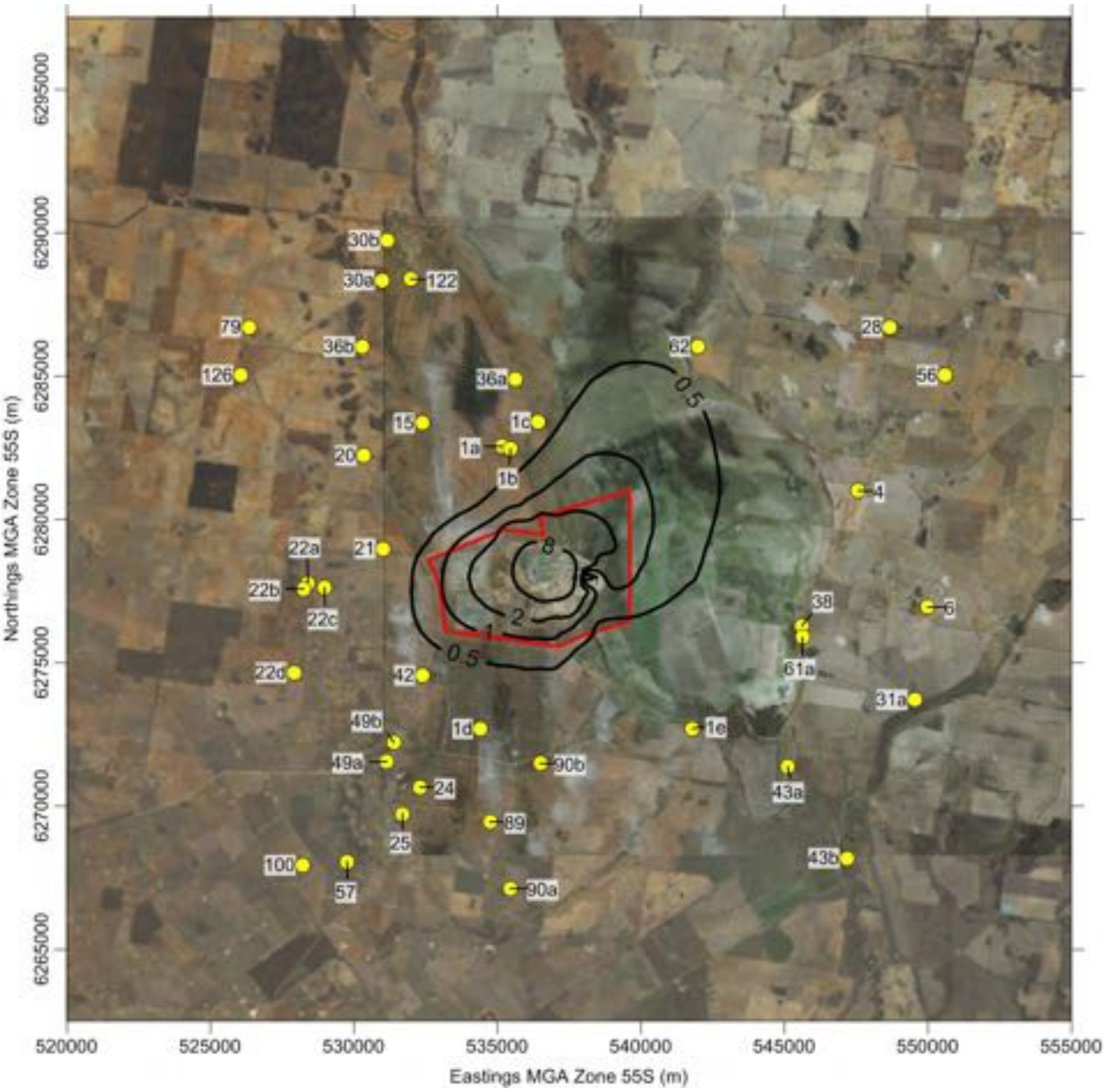
Pollutant: $PM_{2.5}$	**Location:** Cowal	**Scenario:** Year 14 – Modification	**Percentile:** 100th	**Averaging Time:** 24-hour
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.1: Predicted maximum 24-hour average $PM_{2.5}$ concentrations in Year 14 (2018) – Modification Only



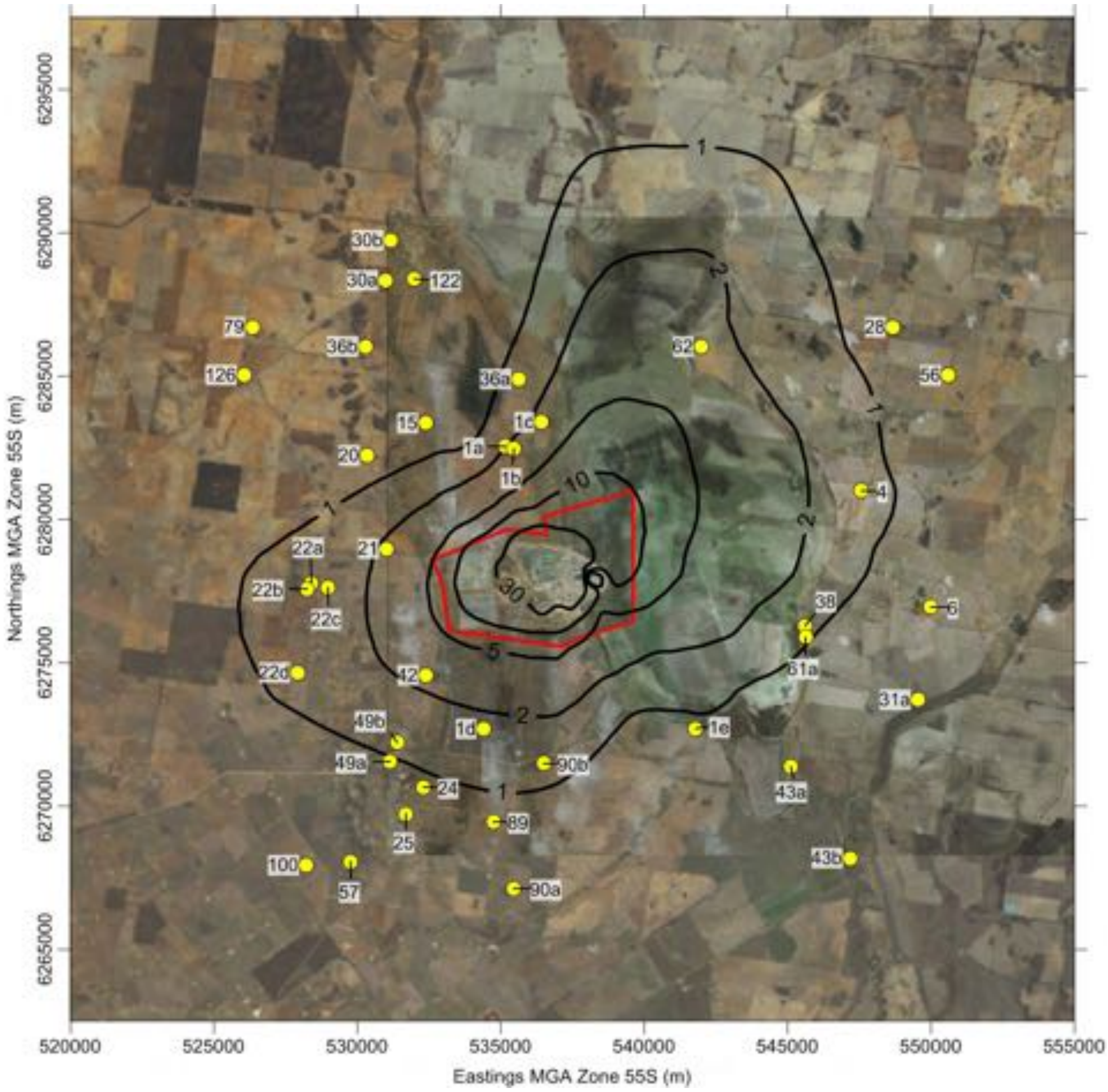
Pollutant: PM$_{10}$	**Location:** Cowal	**Scenario:** Year 14 – Modification	**Percentile:** 100th	**Averaging Time:** 24-hour
Model: CALPUFF	**Units:** µg/m^3	**Criterion:** 50	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.2: Predicted maximum 24-hour average PM$_{10}$ concentrations in Year 14 (2018) – Modification Only



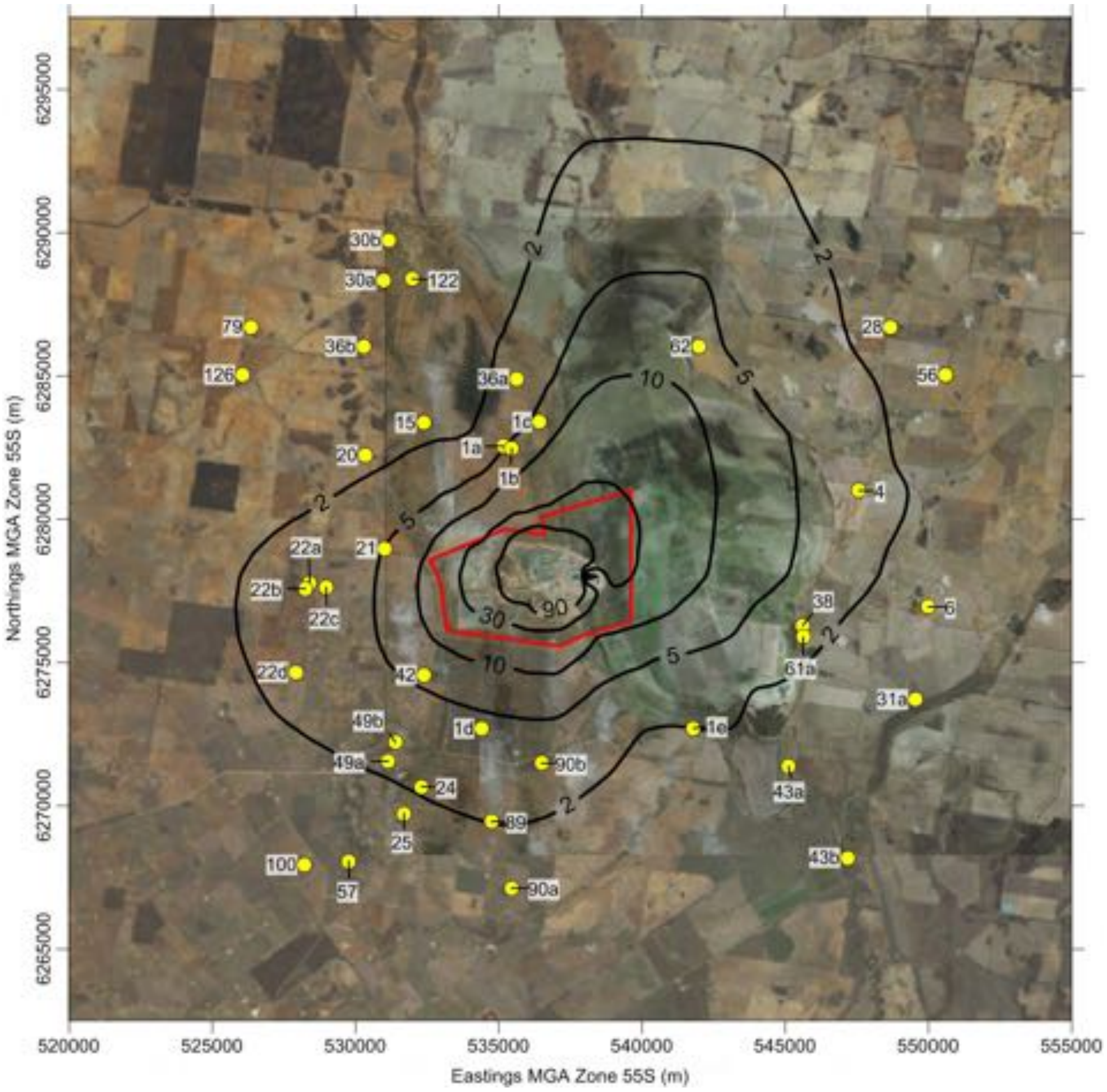
Pollutant: PM$_{2.5}$	**Location:** Cowal	**Scenario:** Year 14 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.3: Predicted annual average PM$_{2.5}$ concentrations in Year 14 (2018) – Modification Only



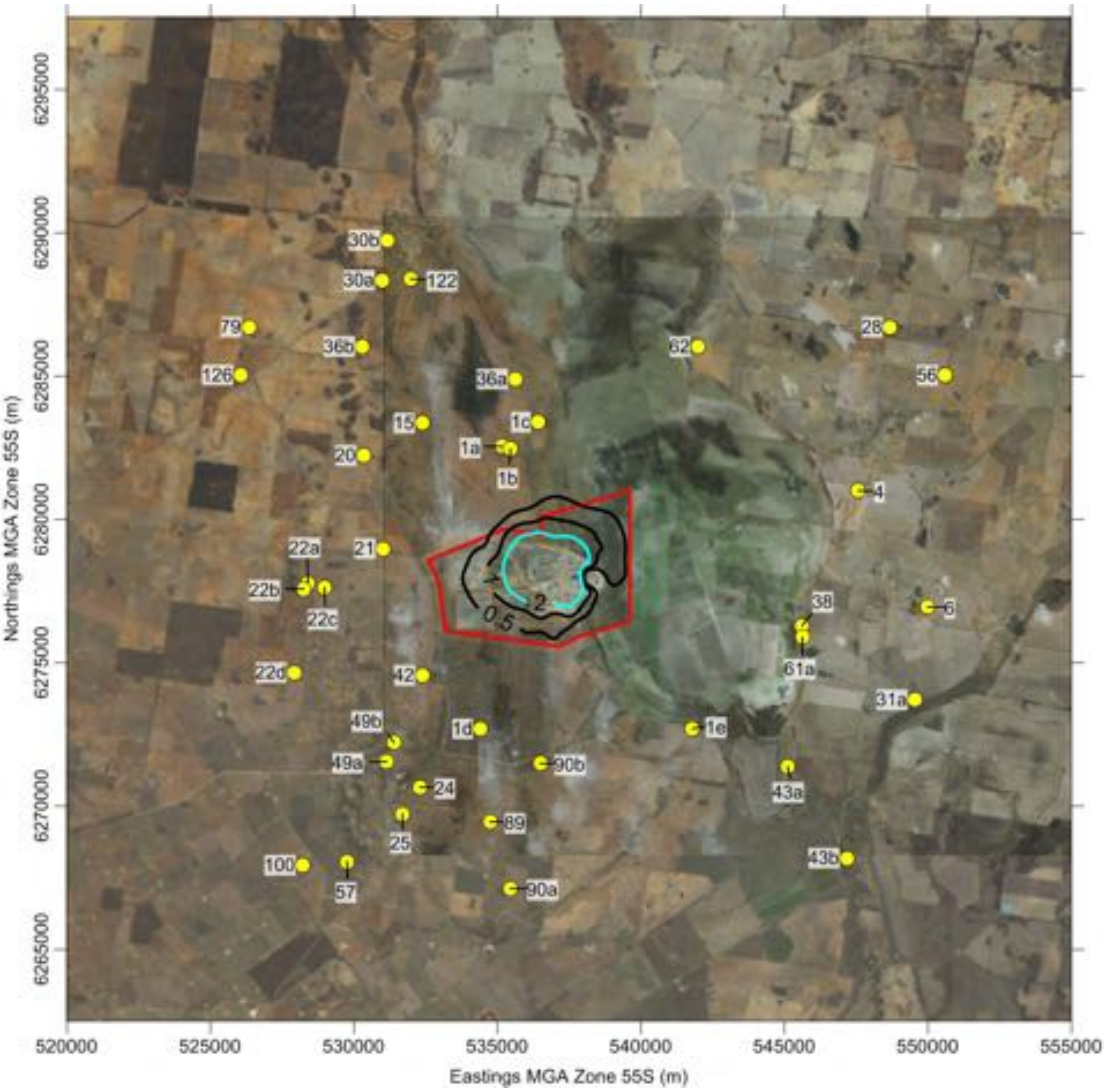
Pollutant: PM$_{10}$	**Location:** Cowal	**Scenario:** Year 14 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.4: Predicted annual average PM$_{10}$ concentrations in Year 14 (2018) – Modification Only



Pollutant: TSP	**Location:** Cowal	**Scenario:** Year 14 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.5: Predicted annual average TSP concentrations in Year 14 (2018) – Modification Only



Pollutant: Deposition	**Location:** Cowal	**Scenario:** Year 14 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** g/m^2/month	**Criterion:** 2	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.6: Predicted annual average dust deposition in Year 14 (2018) – Modification Only

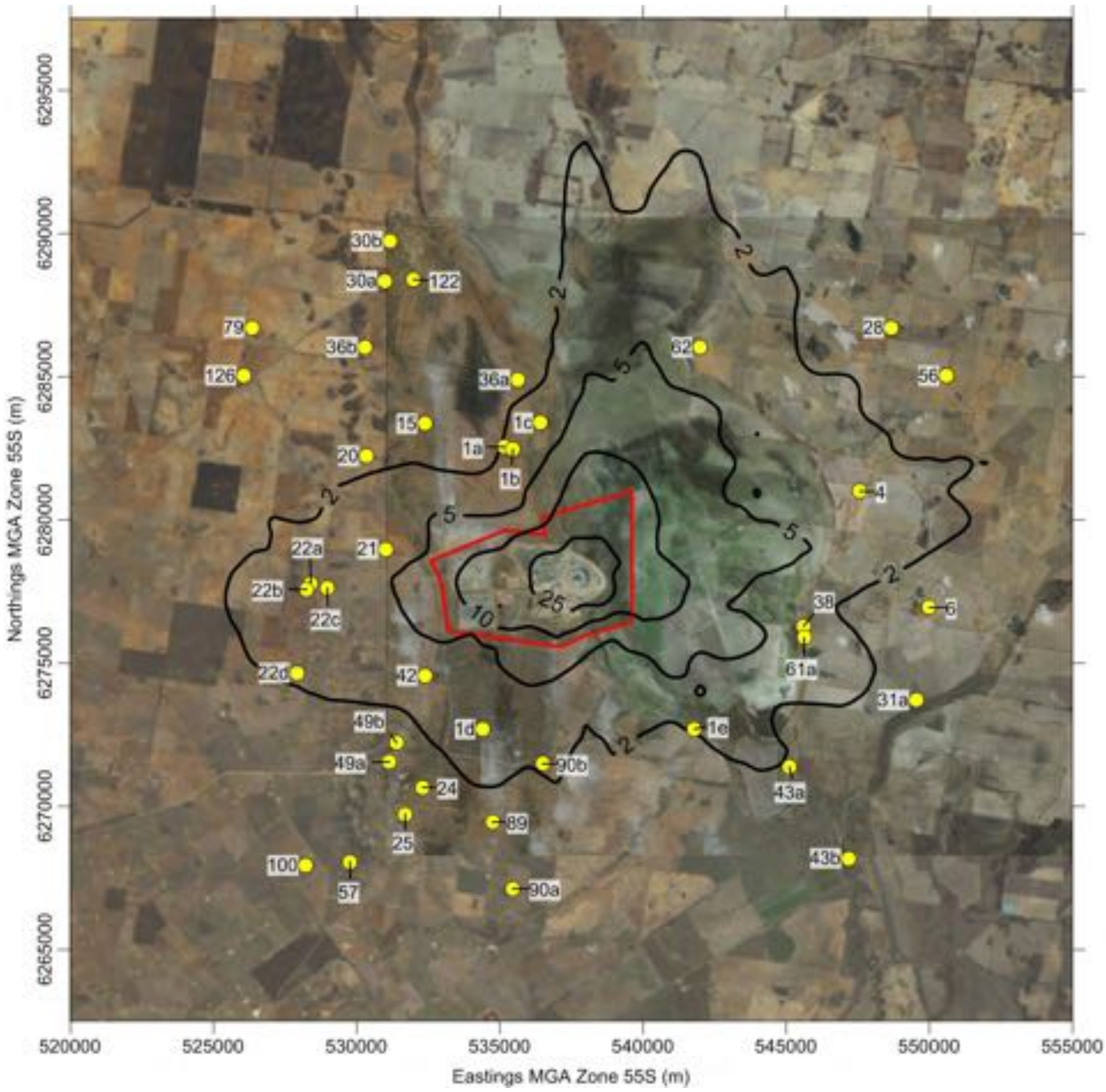
8.2.2 Year 18 (2022)

A summary of the predicted concentration and deposition levels at all sensitive receptors (that is residences both private and mine-owned) due to the operations of the Modification alone in Year 18 is presented in Table 8.2. Figure 8.7 to Figure 8.12 show these predictions across the modelling domain.

Figure 8.8 shows that there are no predicted exceedances of the incremental maximum 24-hour average PM_{10} criterion of 50 $\mu g/m^3$ as a result of the Modification in Year 18. The predicted dust deposition levels are also well below the incremental criterion of 2 g/m^2/month at all residential receptors (Figure 8.12). These results include consideration of the extent of the 50 $\mu g/m^3$ PM_{10} and 2 g/m^2/month dust deposition contours in relation to privately-owned land (i.e. assessment against the voluntary acquisition criteria described in Table 4.4 applicable to 25% of land).

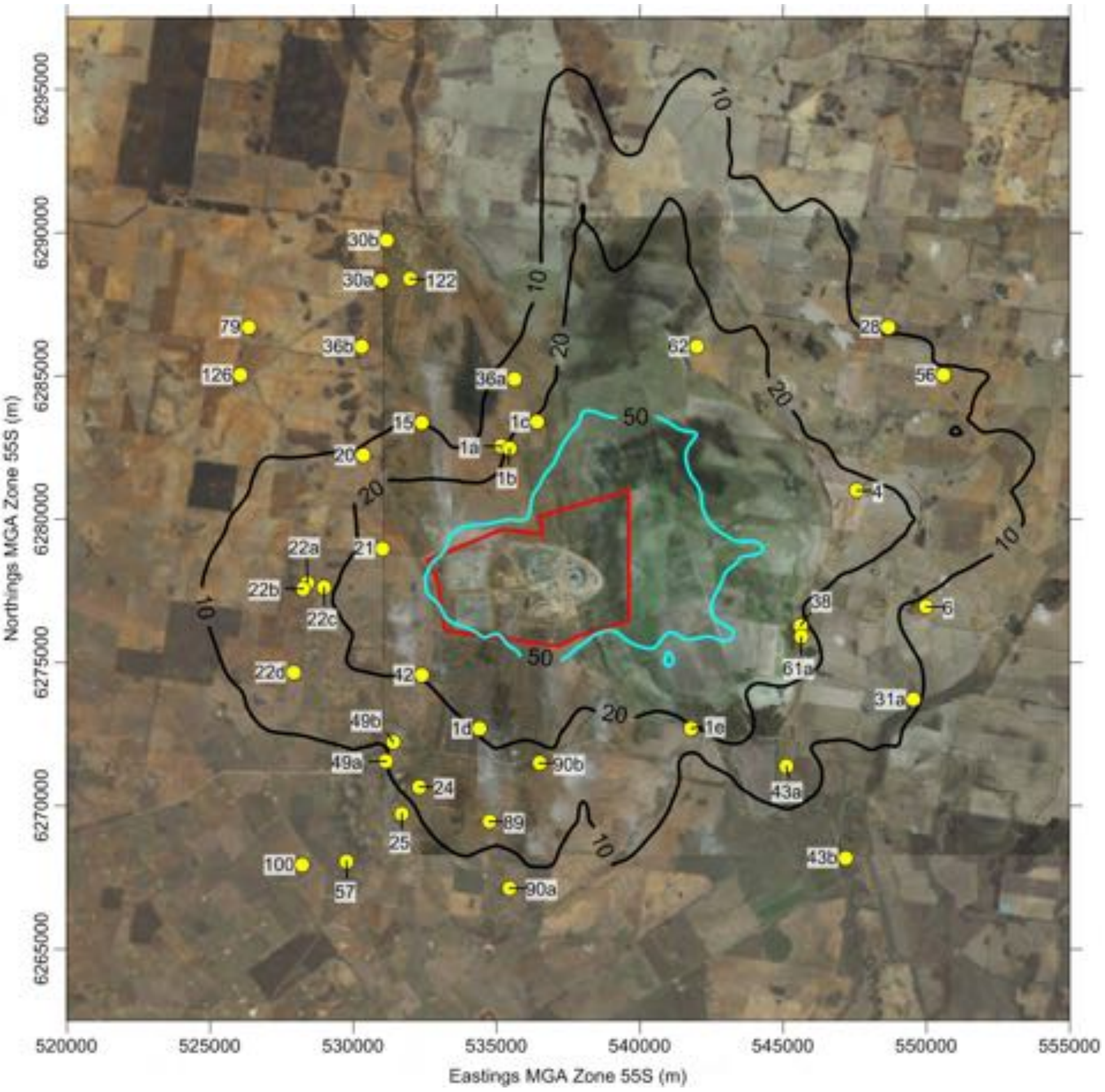
Table 8.2: Predicted concentrations and dust deposition levels at individual residences for Year 18 (2022) – Modification only

Receptor ID	24-hour average		Annual average			
	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	TSP (µg/m³)	Dust deposition (g/m²/month)
Criteria/Standard	25	50	N/A	N/A	N/A	2
1a	2.2	17.6	0.2	1.6	3.8	0.08
1b	2.7	21.3	0.2	1.8	4.5	0.09
1c	2.8	21.2	0.3	2.0	5.0	0.09
1d	2.7	20.8	0.2	1.5	3.8	0.09
1e	2.0	15.4	0.1	0.7	1.8	0.03
4	3.2	24.0	0.1	1.1	2.3	0.05
6	1.3	9.0	0.1	0.6	1.2	0.02
15	1.3	10.6	0.1	0.6	1.5	0.03
20	1.4	10.8	0.1	0.7	1.5	0.03
21	3.6	24.3	0.3	1.9	4.4	0.07
22a	2.6	17.8	0.2	1.2	2.6	0.04
22b	2.6	18.1	0.2	1.2	2.6	0.04
22c	2.7	18.8	0.2	1.3	2.9	0.04
22d	2.1	14.9	0.2	1.1	2.4	0.04
24	1.5	11.0	0.1	0.8	2.0	0.04
25	1.3	9.3	0.1	0.7	1.6	0.04
28	1.5	9.5	0.1	0.7	1.4	0.03
30a	0.4	3.0	0.0	0.3	0.6	0.01
30b	0.5	3.3	0.0	0.3	0.6	0.01
31a	1.5	10.4	0.1	0.4	0.9	0.01
36a	1.7	12.7	0.2	1.1	2.6	0.06
36b	0.6	4.6	0.0	0.3	0.7	0.01
38	2.9	21.3	0.1	1.1	2.4	0.04
42	2.7	20.8	0.3	2.2	5.4	0.11
43a	1.9	14.9	0.1	0.5	1.1	0.01
43b	1.2	8.5	0.0	0.3	0.6	0.01
49a	1.4	9.9	0.1	0.9	2.1	0.04
49b	1.5	10.8	0.1	1.1	2.5	0.05
56	1.4	10.4	0.1	0.6	1.2	0.02
57	1.0	7.2	0.1	0.5	1.1	0.03
61a	3.2	23.5	0.1	1.0	2.2	0.04
62	3.4	24.0	0.3	2.5	5.7	0.09
79	0.4	3.3	0.0	0.2	0.5	0.01
89	1.6	12.1	0.1	0.8	2.0	0.05
90a	1.1	8.5	0.1	0.6	1.3	0.03
90b	2.2	17.0	0.1	1.1	2.9	0.07
100	0.7	5.1	0.1	0.4	0.9	0.02
122	0.5	3.5	0.0	0.3	0.7	0.01
126	0.6	4.5	0.0	0.3	0.5	0.01



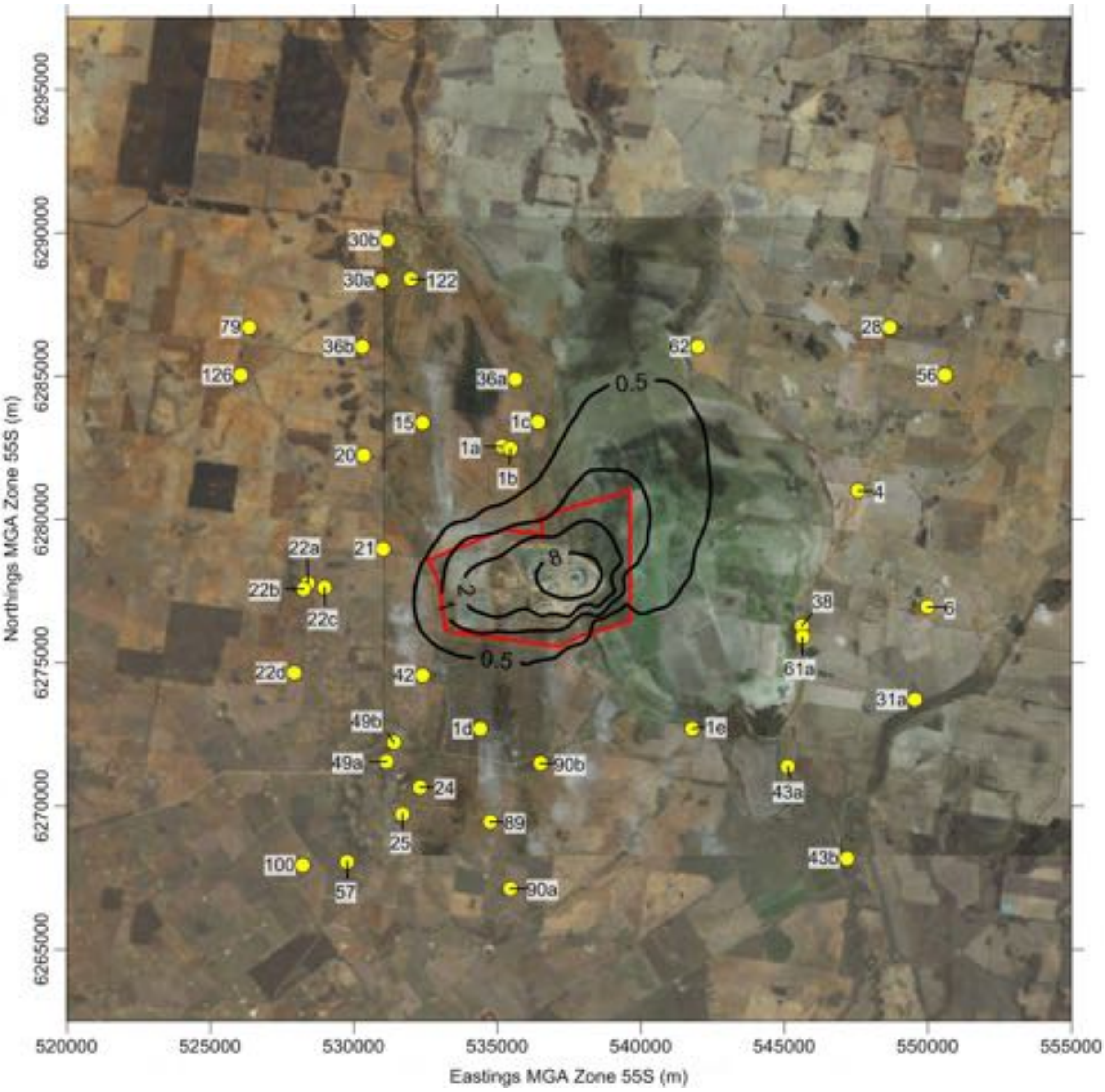
Pollutant: $PM_{2.5}$	**Location:** Cowal	**Scenario:** Year 18 – Modification	**Percentile:** 100th	**Averaging Time:** 24-hour
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.7: Predicted maximum 24-hour average $PM_{2.5}$ concentrations in Year 18 (2022) – Modification Only



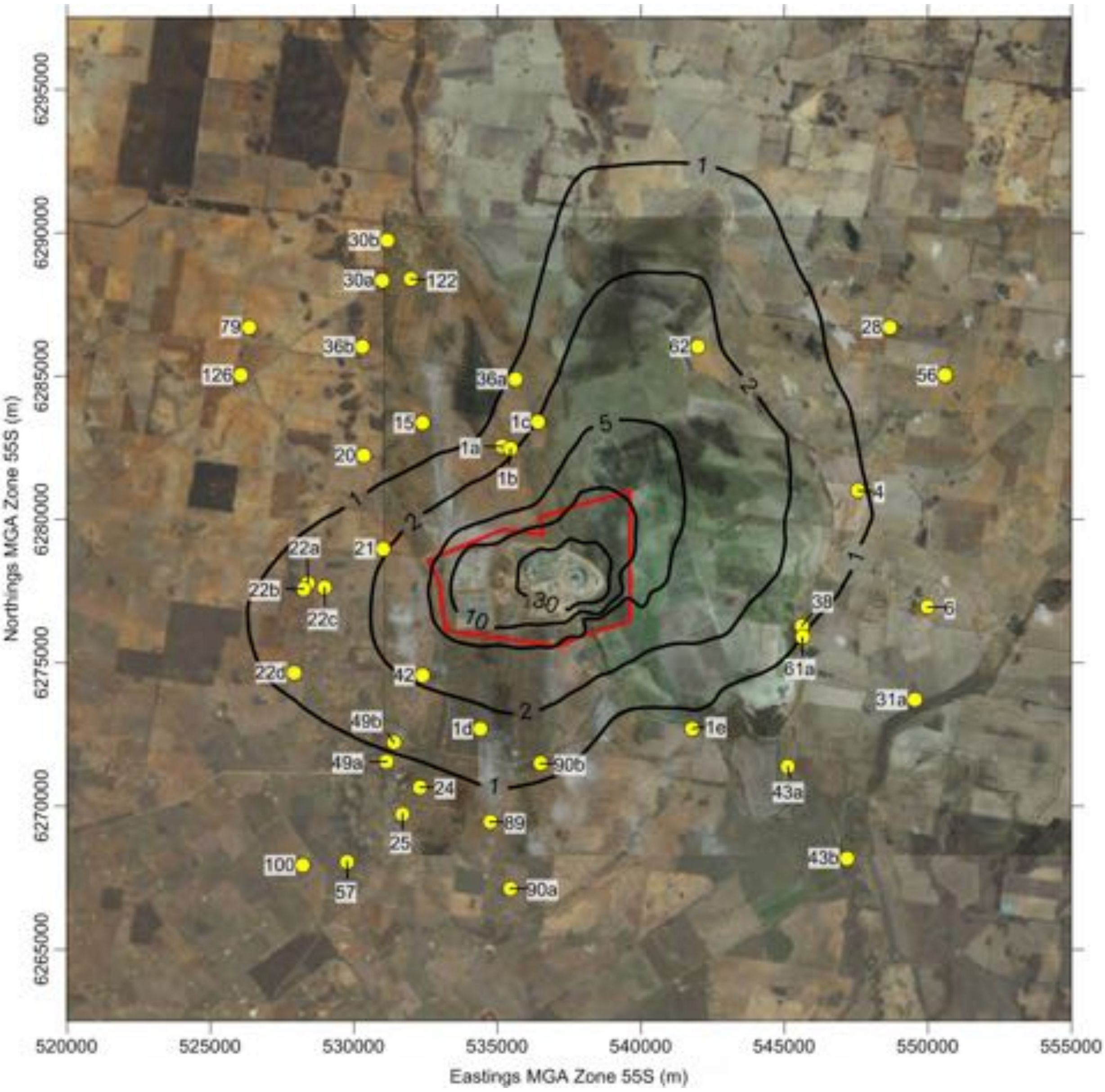
Pollutant: PM_{10}	**Location:** Cowal	**Scenario:** Year 18 – Modification	**Percentile:** 100th	**Averaging Time:** 24-hour
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** 50	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.8: Predicted maximum 24-hour average PM_{10} concentrations in Year 18 (2022) – Modification Only



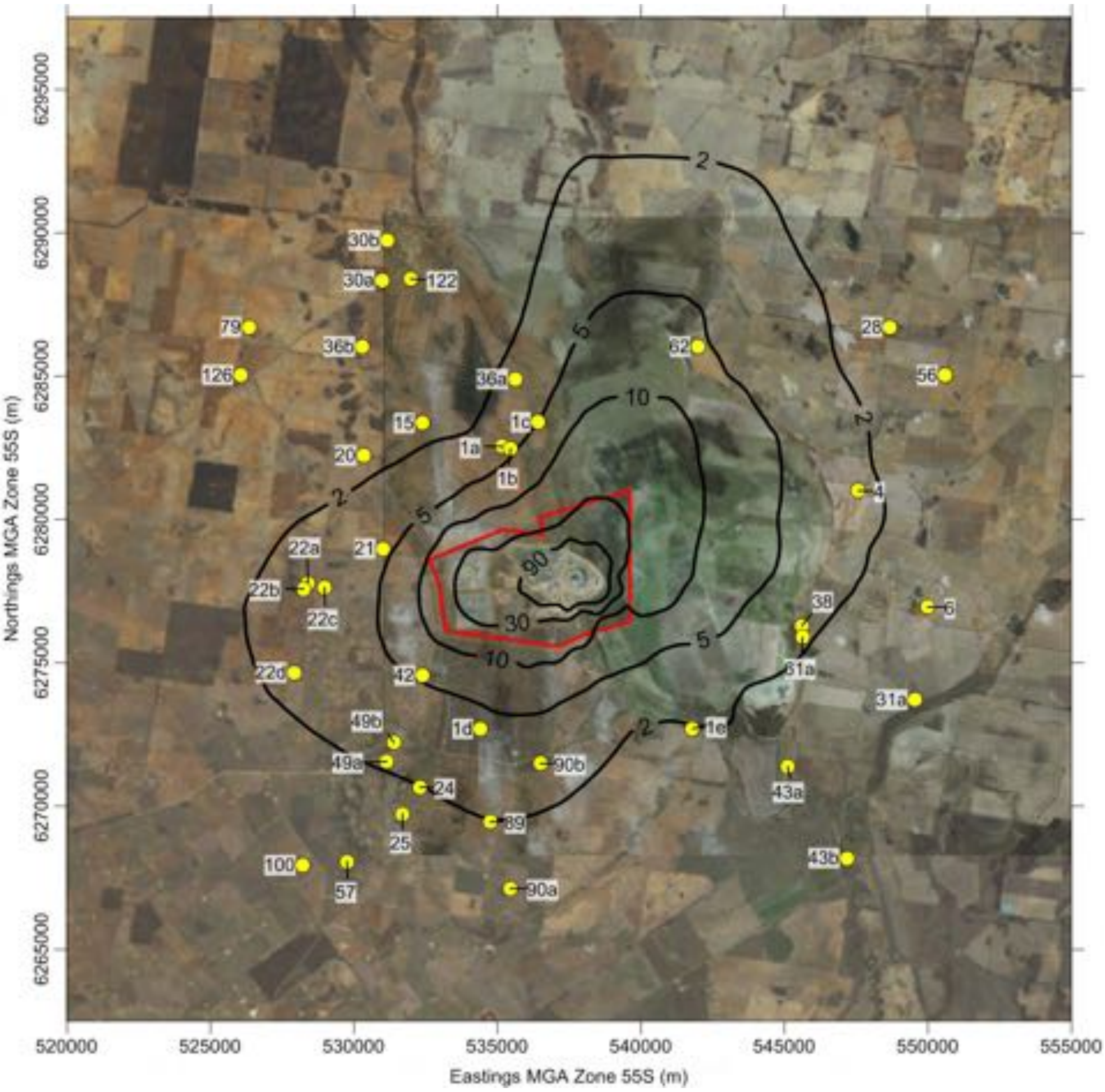
Pollutant: $PM_{2.5}$	**Location:** Cowal	**Scenario:** Year 18 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.9: Predicted annual average $PM_{2.5}$ concentrations in Year 18 (2022) – Modification Only



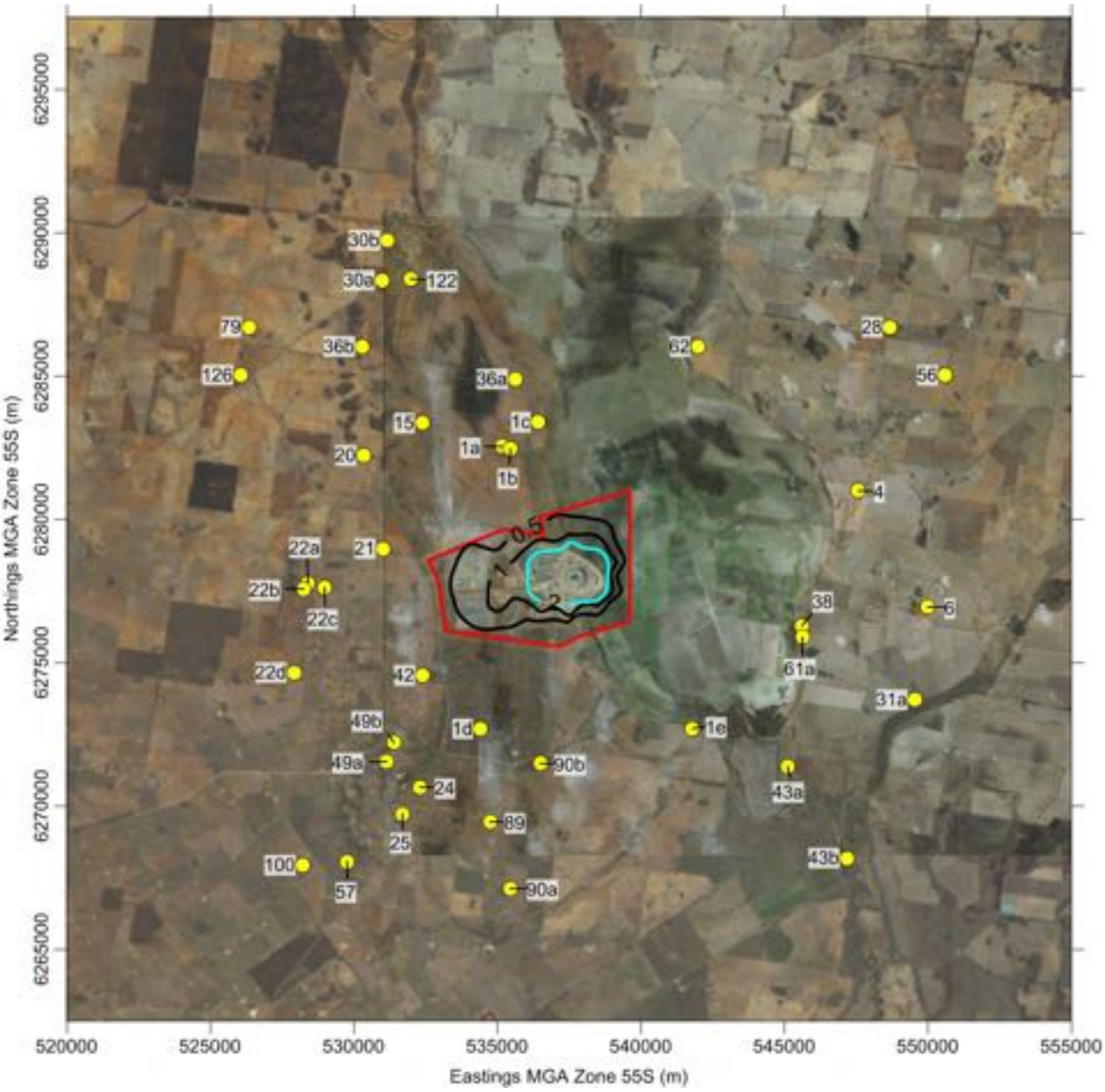
Pollutant: PM$_{10}$	**Location:** Cowal	**Scenario:** Year 18 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** μg/m^3	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.10: Predicted annual average PM$_{10}$ concentrations in Year 18 (2022) – Modification Only



Pollutant: TSP	**Location:** Cowal	**Scenario:** Year 18 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** N/A	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.11: Predicted annual average TSP concentrations in Year 18 (2022) – Modification Only



Pollutant: Deposition	**Location:** Cowal	**Scenario:** Year 18 – Modification	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** g/m^2/month	**Criterion:** 2	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.12: Predicted annual average dust deposition in Year 18 (2022) – Modification Only

8.3 Cumulative annual average

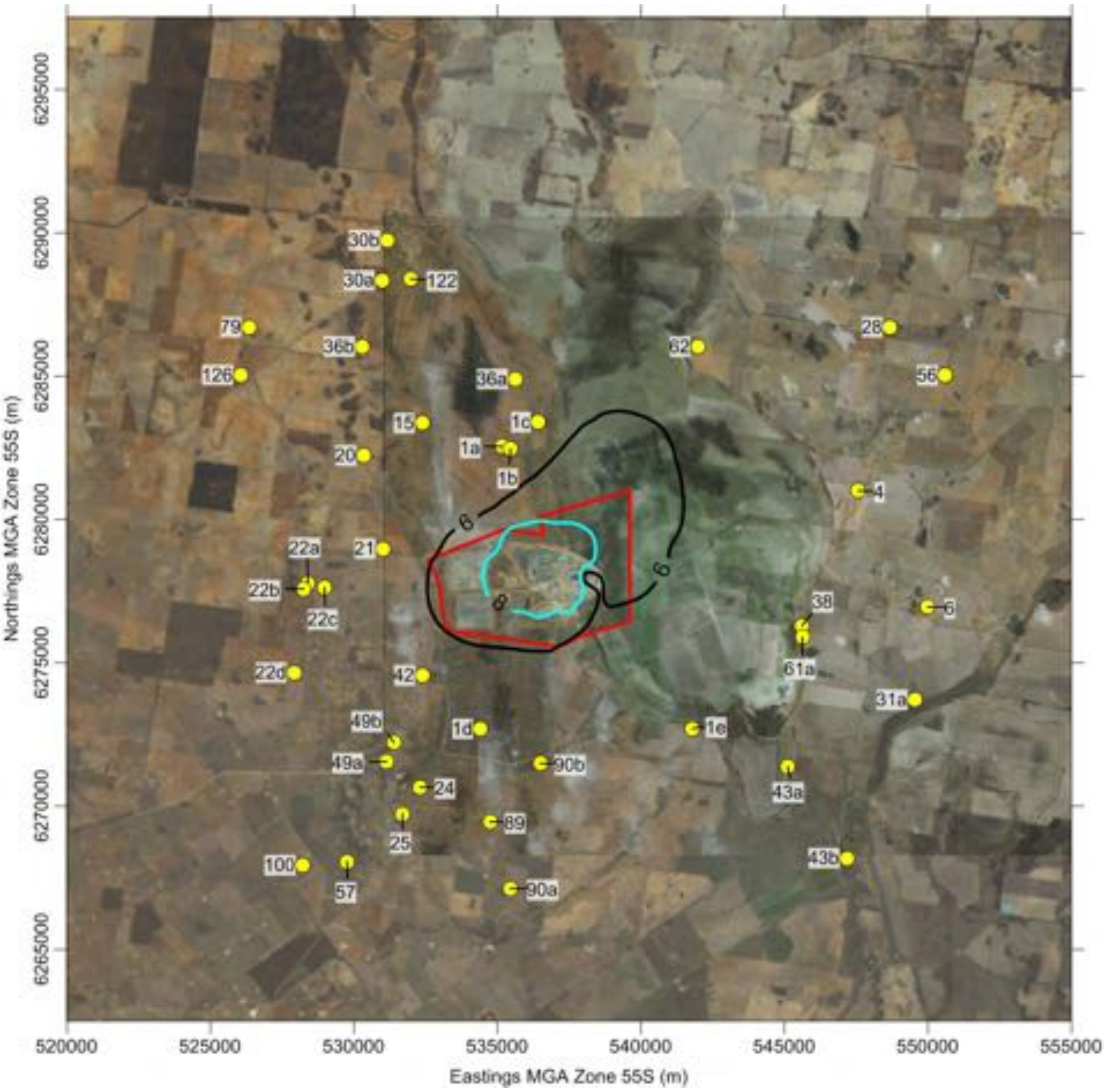
8.3.1 Year 14 (2018)

A summary of the predicted concentration and deposition levels due to the operations of the Modification in Year 14 combined with the estimated background levels (as per Section 5.2.3) is presented in Table 8.3. The contour plots across the modelling domain are presented in Figure 8.13 to Figure 8.16.

There are no predicted exceedances of the relevant standards/criteria at any of the private or mine-owned residential properties. These results include consideration of the extent of the 30 $\mu g/m^3$ PM_{10}, 90 $\mu g/m^3$ TSP and 4 g/m^2/month dust deposition contours in relation to privately-owned land (i.e. assessment against the voluntary acquisition criteria described in Table 4.4 applicable to 25% of land).

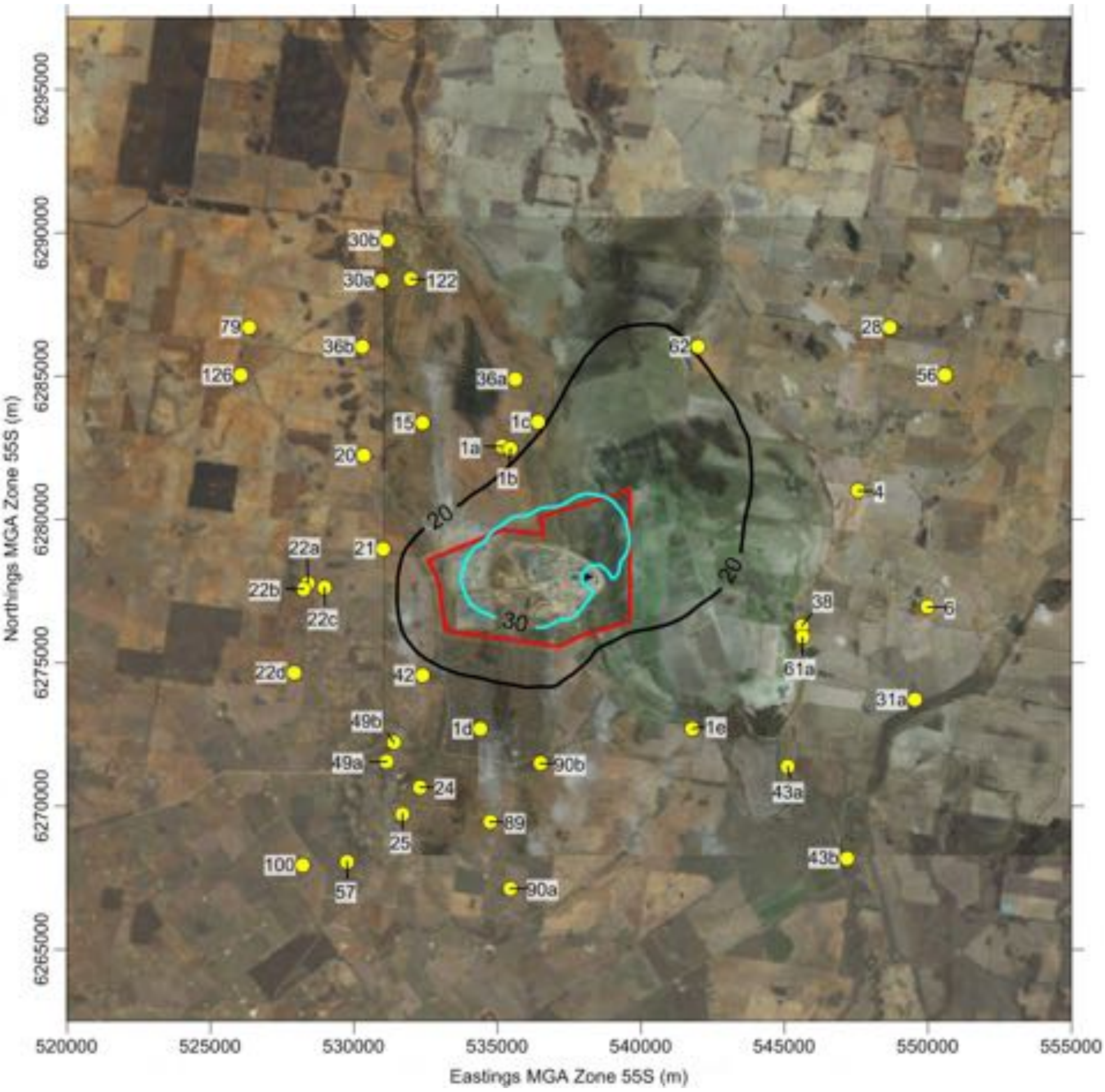
Table 8.3: Predicted concentrations and dust deposition levels at individual residences for Year 14 (2018) – Cumulative

Receptor ID	Annual average			
	$PM_{2.5}$ (μg/m³)	PM_{10} (μg/m³)	TSP (μg/m³)	Dust deposition (g/m²/month)
Criteria/Standard	**8**	**30**	**90**	**4**
1a	5.5	19.0	46.7	2.6
1b	5.6	19.4	47.8	2.6
1c	5.6	19.4	47.9	2.6
1d	5.5	18.6	46.1	2.6
1e	5.4	17.8	44.0	2.5
4	5.4	18.2	44.7	2.6
6	5.4	17.6	43.3	2.5
15	5.4	17.6	43.5	2.5
20	5.4	17.7	43.6	2.5
21	5.6	19.2	47.1	2.6
22a	5.5	18.3	44.8	2.5
22b	5.5	18.3	44.7	2.5
22c	5.5	18.4	45.1	2.5
22d	5.4	18.2	44.6	2.5
24	5.4	17.9	44.1	2.5
25	5.4	17.7	43.7	2.5
28	5.4	17.8	43.6	2.5
30a	5.3	17.3	42.6	2.5
30b	5.3	17.3	42.6	2.5
31a	5.3	17.4	42.9	2.5
36a	5.4	18.3	45.0	2.6
36b	5.3	17.3	42.7	2.5
38	5.4	18.2	44.7	2.5
42	5.6	19.4	47.8	2.6
43a	5.3	17.5	43.2	2.5
43b	5.3	17.3	42.6	2.5
49a	5.4	18.0	44.3	2.5
49b	5.4	18.1	44.7	2.6
56	5.4	17.7	43.4	2.5
57	5.3	17.5	43.2	2.5
61a	5.4	18.1	44.4	2.5
62	5.6	19.8	48.5	2.6
79	5.3	17.2	42.5	2.5
89	5.4	17.8	44.0	2.5
90a	5.3	17.6	43.4	2.5
90b	5.4	18.2	45.1	2.6
100	5.3	17.5	43.0	2.5
122	5.3	17.3	42.7	2.5
126	5.3	17.3	42.5	2.5



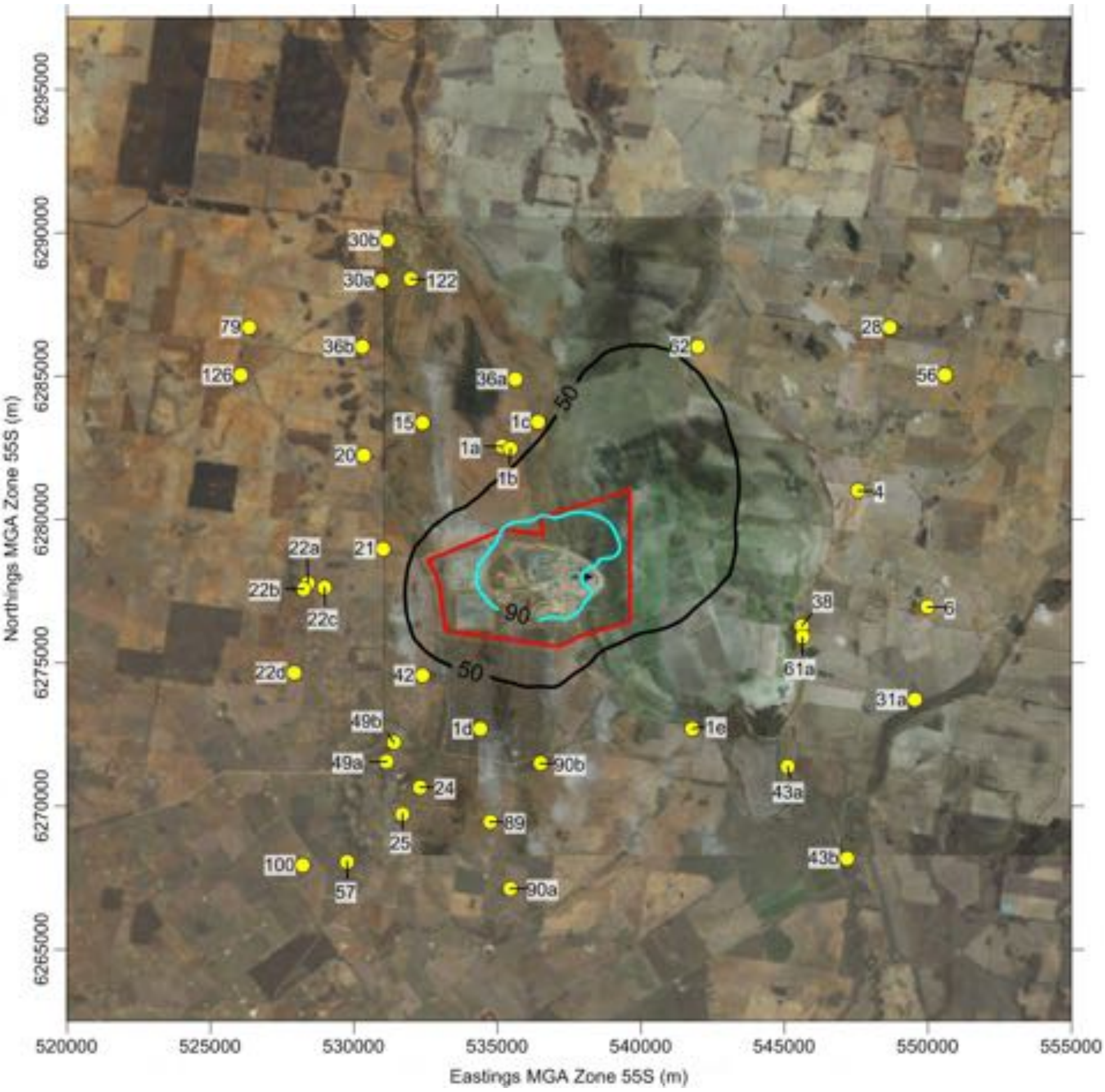
Pollutant: $PM_{2.5}$	**Location:** Cowal	**Scenario:** Year 14 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Standard:** 8	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.13: Predicted annual average $PM_{2.5}$ concentrations in Year 14 (2018) – Cumulative



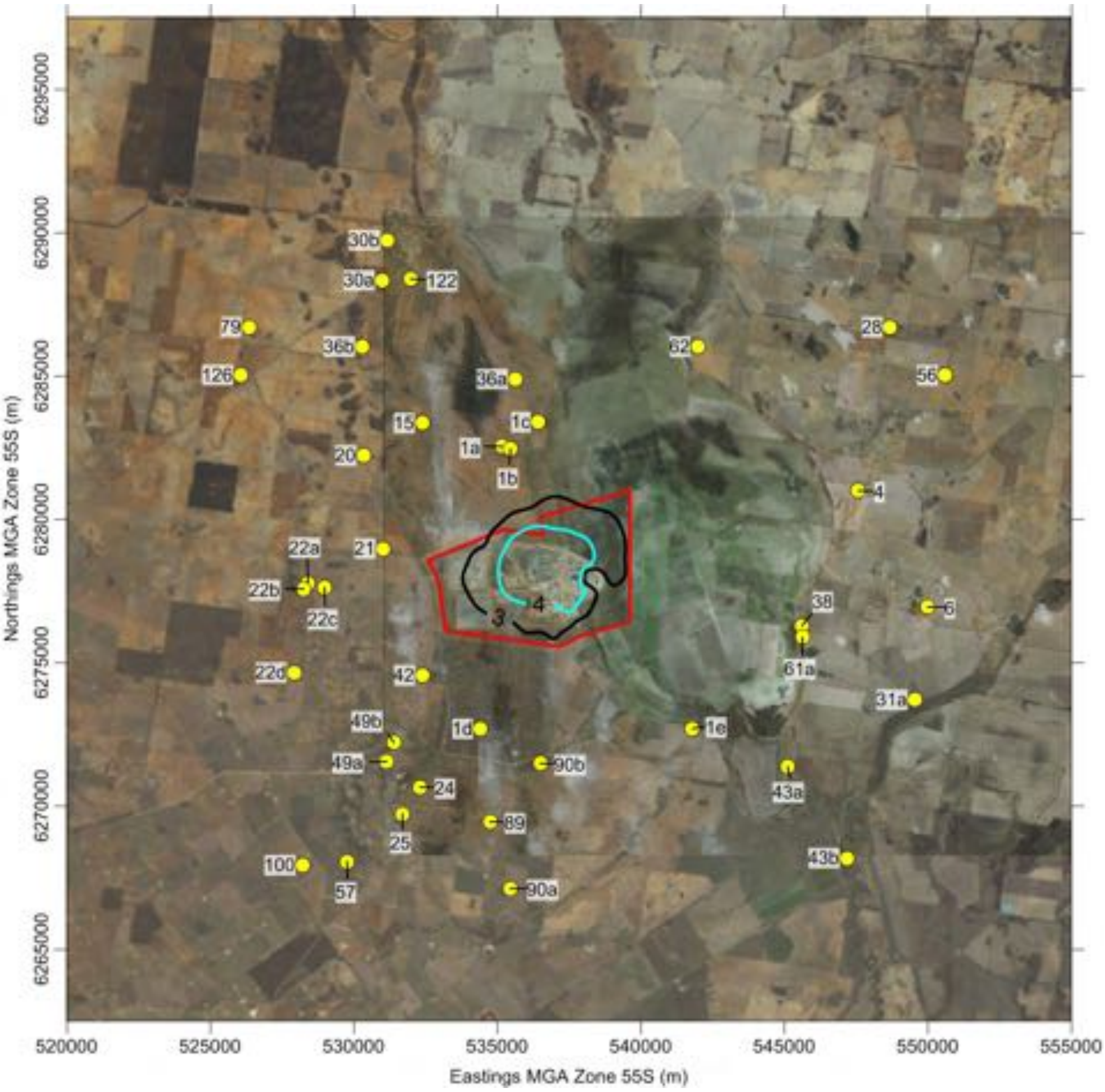
Pollutant: PM$_{10}$	**Location:** Cowal	**Scenario:** Year 14 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** 30	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.14: Predicted annual average PM$_{10}$ concentrations in Year 14 (2018) – Cumulative



Pollutant: TSP	**Location:** Cowal	**Scenario:** Year 14 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** 90	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.15: Predicted annual average TSP concentrations in Year 14 (2018) – Cumulative



Pollutant: Deposition	**Location:** Cowal	**Scenario:** Year 14 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** g/m^2/month	**Criterion:** 4	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.16: Predicted annual average dust deposition in Year 14 (2018) – Cumulative

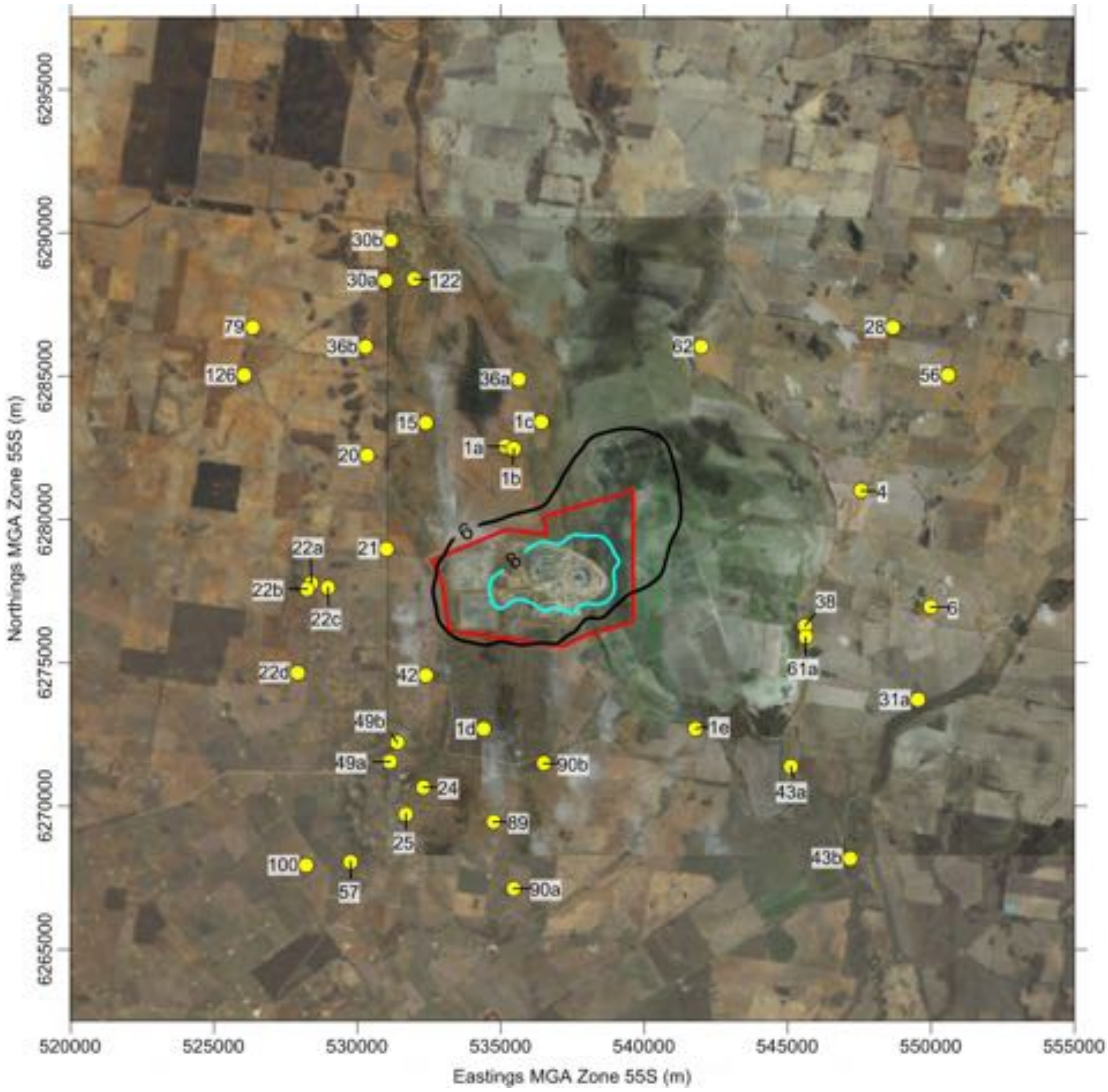
8.3.2 Year 18 (2022)

A summary of the predicted concentration and deposition levels due to the operations of the Modification in Year 18 combined with the estimated background levels (as per Section 5.2.3) is presented in Table 8.4. The contour plots across the modelling domain are presented in Figure 8.17 to Figure 8.20.

There are no predicted exceedances of the relevant standards/criteria at any of the private or mine owned residential properties. These results include consideration of the extent of the 30 $\mu g/m^3$ PM_{10}, 90 $\mu g/m^3$ TSP and 4 g/m^2/month dust deposition contours in relation to privately-owned land (i.e. assessment against the voluntary acquisition criteria described in Table 4.4 applicable to 25% of land).

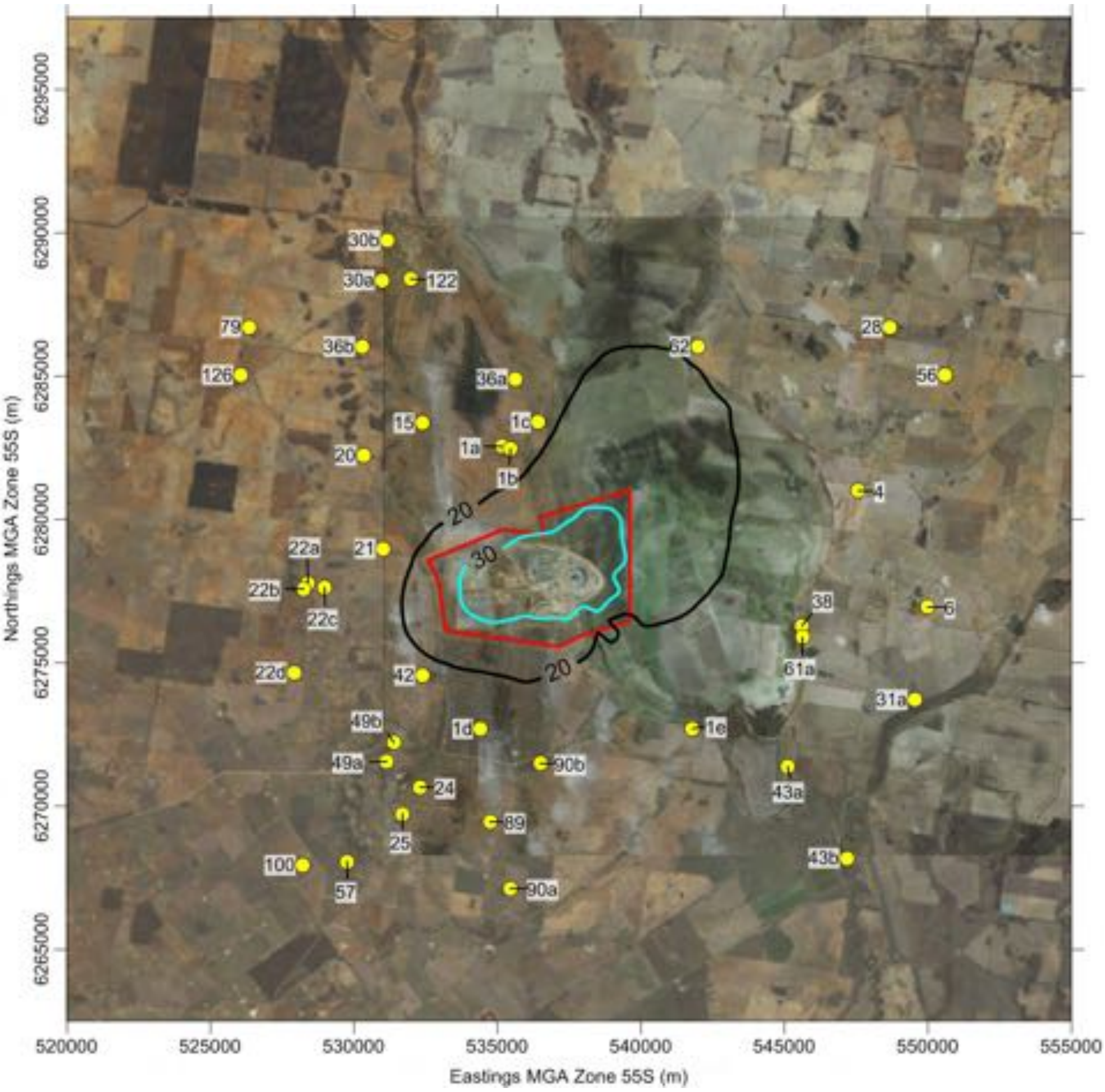
Table 8.4: Predicted concentrations and dust deposition levels at individual residences for Year 18 (2022) – Cumulative

Receptor ID	Annual average			
	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	TSP (µg/m³)	Dust deposition (g/m^2/month
Criteria/Standard	**8**	**30**	**90**	**4**
1a	5.5	18.6	45.8	2.6
1b	5.5	18.8	46.5	2.6
1c	5.5	19.0	47.0	2.6
1d	5.5	18.5	45.8	2.6
1e	5.4	17.7	43.8	2.5
4	5.4	18.1	44.3	2.5
6	5.4	17.6	43.2	2.5
15	5.4	17.6	43.5	2.5
20	5.4	17.7	43.5	2.5
21	5.5	18.9	46.4	2.6
22a	5.4	18.2	44.6	2.5
22b	5.4	18.2	44.6	2.5
22c	5.5	18.3	44.9	2.5
22d	5.4	18.1	44.4	2.5
24	5.4	17.8	44.0	2.5
25	5.4	17.7	43.6	2.5
28	5.4	17.7	43.4	2.5
30a	5.3	17.3	42.6	2.5
30b	5.3	17.3	42.6	2.5
31a	5.3	17.4	42.9	2.5
36a	5.4	18.1	44.6	2.6
36b	5.3	17.3	42.7	2.5
38	5.4	18.1	44.4	2.5
42	5.6	19.2	47.4	2.6
43a	5.3	17.5	43.1	2.5
43b	5.3	17.3	42.6	2.5
49a	5.4	17.9	44.1	2.5
49b	5.4	18.1	44.5	2.6
56	5.4	17.6	43.2	2.5
57	5.3	17.5	43.1	2.5
61a	5.4	18.0	44.2	2.5
62	5.6	19.5	47.7	2.6
79	5.3	17.2	42.5	2.5
89	5.4	17.8	44.0	2.5
90a	5.3	17.6	43.3	2.5
90b	5.4	18.1	44.9	2.6
100	5.3	17.4	42.9	2.5
122	5.3	17.3	42.7	2.5
126	5.3	17.3	42.5	2.5



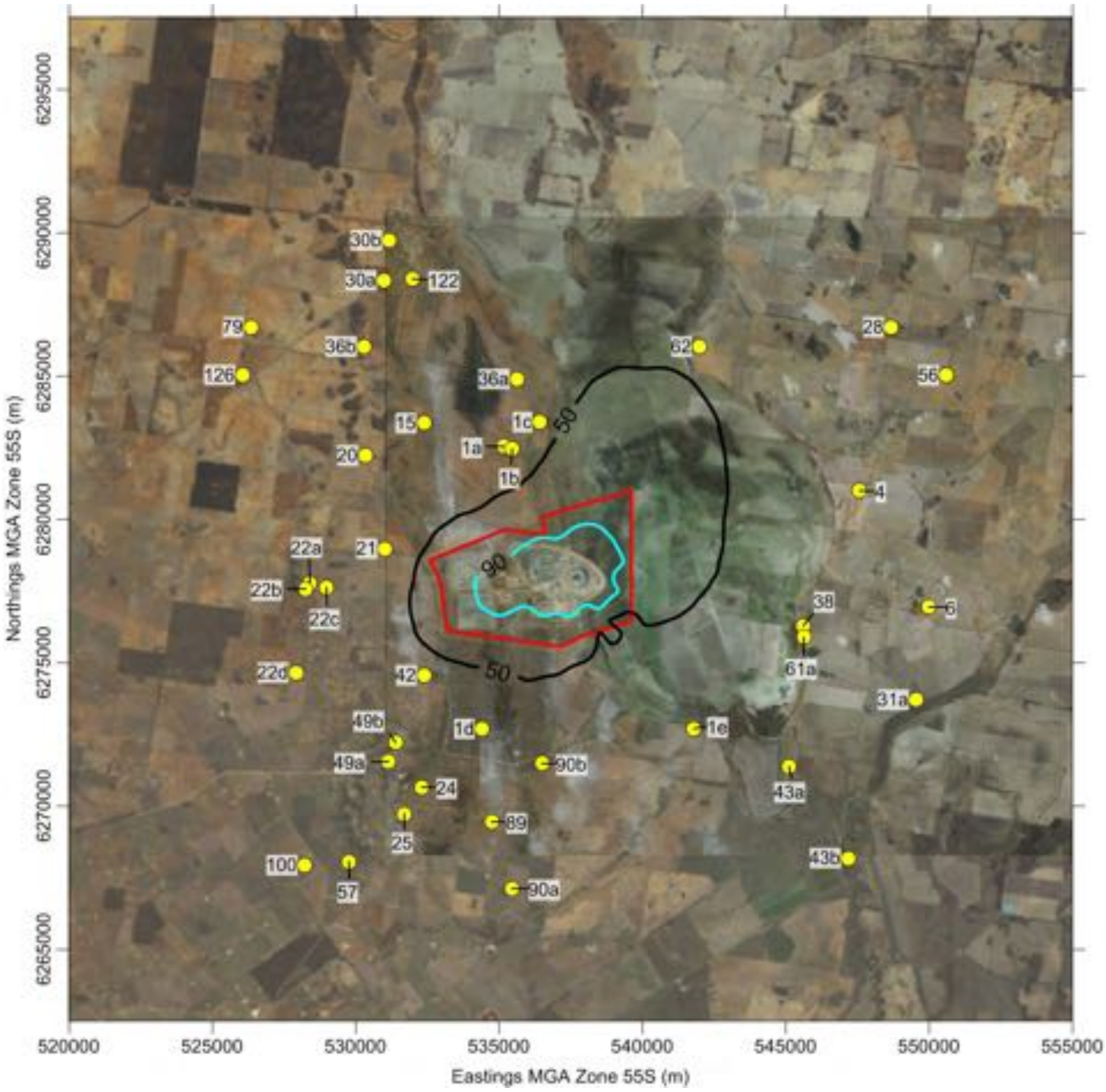
Pollutant: $PM_{2.5}$	**Location:** Cowal	**Scenario:** Year 18 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Standard:** 8	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.17: Predicted annual average $PM_{2.5}$ concentrations in Year 18 (2022) – Cumulative



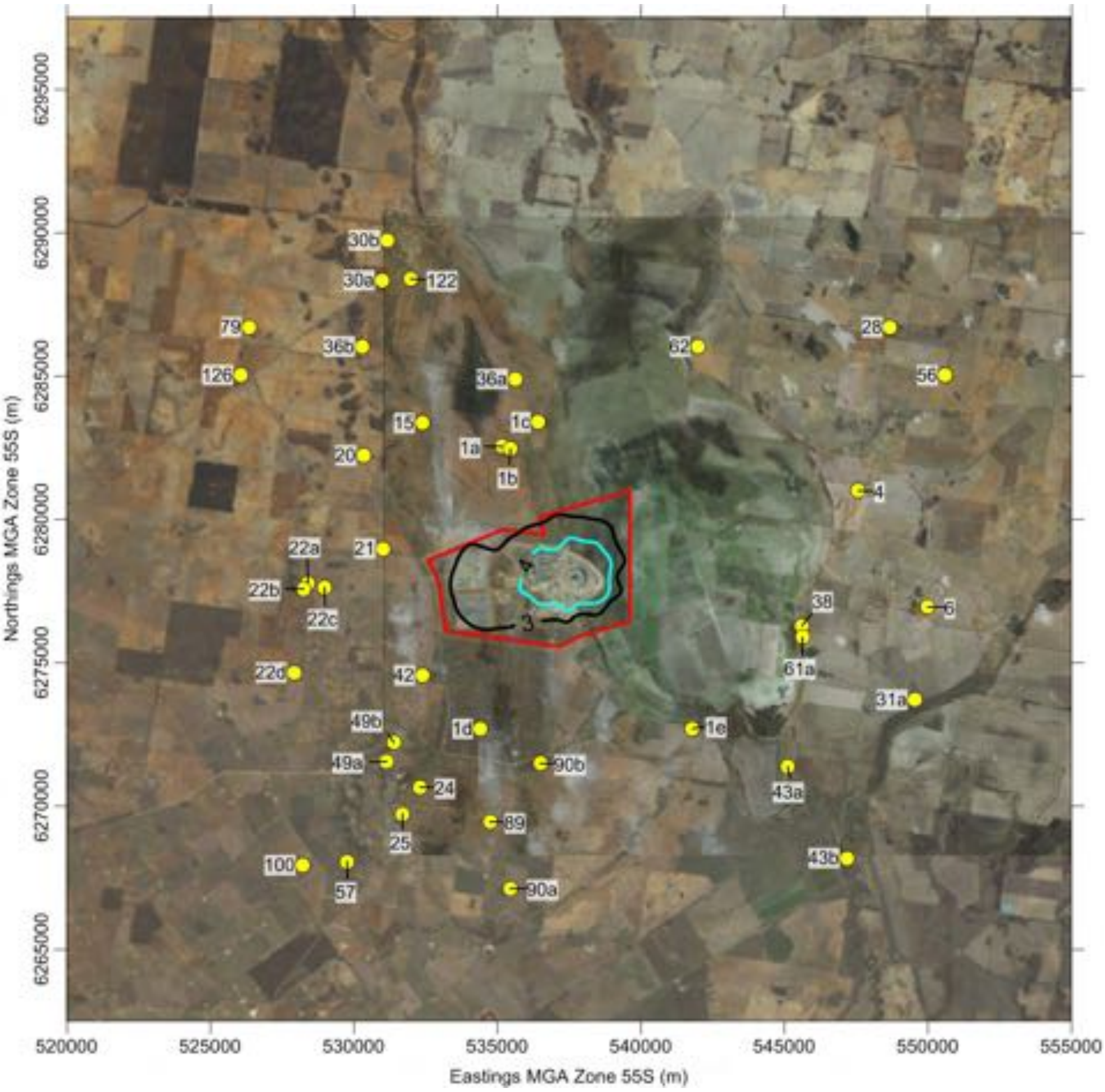
Pollutant: PM_{10}	**Location:** Cowal	**Scenario:** Year 18 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** $\mu g/m^3$	**Criterion:** 30	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.18: Predicted annual average PM_{10} concentrations in Year 18 (2022) – Cumulative



Pollutant: TSP	**Location:** Cowal	**Scenario:** Year 18 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** µg/m^3	**Criterion:** 90	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.19: Predicted annual average TSP concentrations in Year 18 (2022) – Cumulative



Pollutant: Deposition	**Location:** Cowal	**Scenario:** Year 18 – Cumulative	**Percentile:** 100th	**Averaging Time:** Annual
Model: CALPUFF	**Units:** g/m^2/month	**Criterion:** 4	**Met Data:** 2015	**Plot:** J. Barnett

Figure 8.20: Predicted annual average dust deposition in Year 18 (2022) – Cumulative

8.4 Cumulative 24-hour average

Difficulties in predicting cumulative 24-hour impacts are compounded by the day-to-day variability in ambient dust levels and the spatial and temporal variation in any other anthropogenic activity and natural events (for example agricultural activity, dust storms, bushfires etc., and including mining in the future). Monitoring data (presented in Section 5.2) show that in many cases the worst-case inferred 24-hour average PM_{10} concentrations are strongly influenced by other sources in an area, which are essentially unpredictable. Mining operations also contribute to elevated inferred 24-hour average PM_{10} concentrations, however, they are likely to be more localised. The variability in inferred 24-hour average PM_{10} concentrations can be clearly seen in the data collected at the HVAS monitor shown in Figure 5.6.

It is not expected that the CGO contribution to cumulative 24-hour PM_{10} concentrations would increase materially due to the Modification, given the following:

- The Modification is an extension to the mine life of the existing CGO, and would not include an increase in production.
- As operations would continue to occur within the existing ML 1535, the Modification would not move sources of dust emissions materially closer to private receivers.

In addition, there are no other existing or known proposed industrial sources of dust emissions in the vicinity of the CGO.

Given the above, no additional potential 24-hour PM_{10} impacts are expected during the life of the Modification (i.e. in addition to the existing approved operations).

The existing CGO has been operating since 2004 and monitoring indicates that the inferred 24-hour average PM_{10} concentrations (inferred from the TSP concentrations) are generally below the NSW EPA's assessment criterion of 50 $\mu g/m^3$ (Section 5.2.1).

Notwithstanding the above, this assessment considered the potential 24-hour PM_{10} impacts associated with the Modification consistent with the methodologies presented in the Approved Methods (i.e. the Level 1 and Level 2 approaches). However, these involve the use of measured contemporaneous PM_{10} concentrations (i.e. daily measured PM_{10} concentrations with corresponding meteorological data). No suitable data is currently available near the site. Any monitored background concentrations would also include contributions from the existing operations at the CGO, which when added to the predicted concentrations for the Modification would result in double counting.

As such, neither the Level 1 or Level 2 approach is considered to be appropriate or representative of potential cumulative 24-hour PM_{10} impacts for the Modification.

In lieu of a contemporaneous assessment, a simple analysis of the daily predictions has been carried out using the available monitoring data. Figure 8.21 shows a time series of the predicted 24-hour average PM_{10} concentrations at the most affected private residence (Residence 21) for modelled years 14 and 18. The maximum prediction is 35 $\mu g/m^3$ in Year 14, decreasing to 24 $\mu g/m^3$ in Year 18. For the majority of the time the predicted levels are well below 10 $\mu g/m^3$. This can be seen more clearly when the values are ranked from highest to lowest as shown in Figure 8.22, showing that predictions due to the Modification are zero for more than half of the time.

It is therefore unlikely that any short-term exceedances would be as a result of the Modification, but rather due to regional dust events such as those discussed in Section 5.2.1.

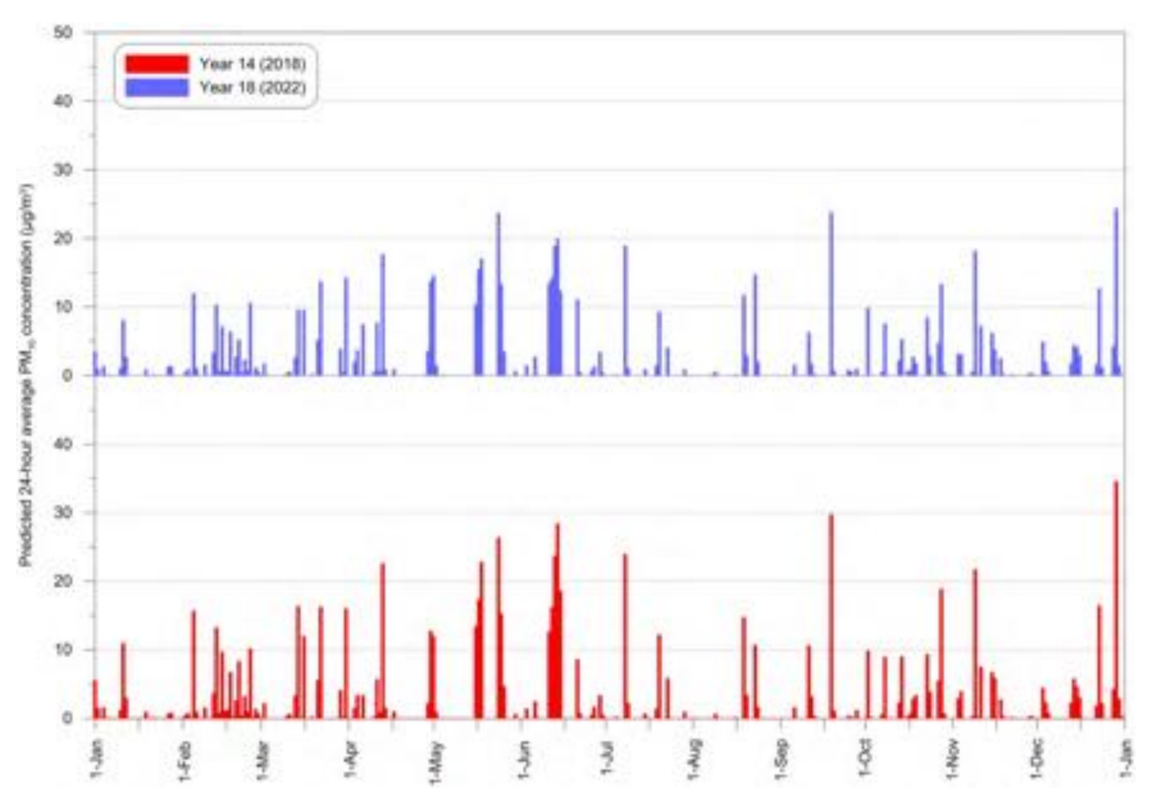


Figure 8.21: Daily predicted 24-hour average PM$_{10}$ concentrations at Residence 21

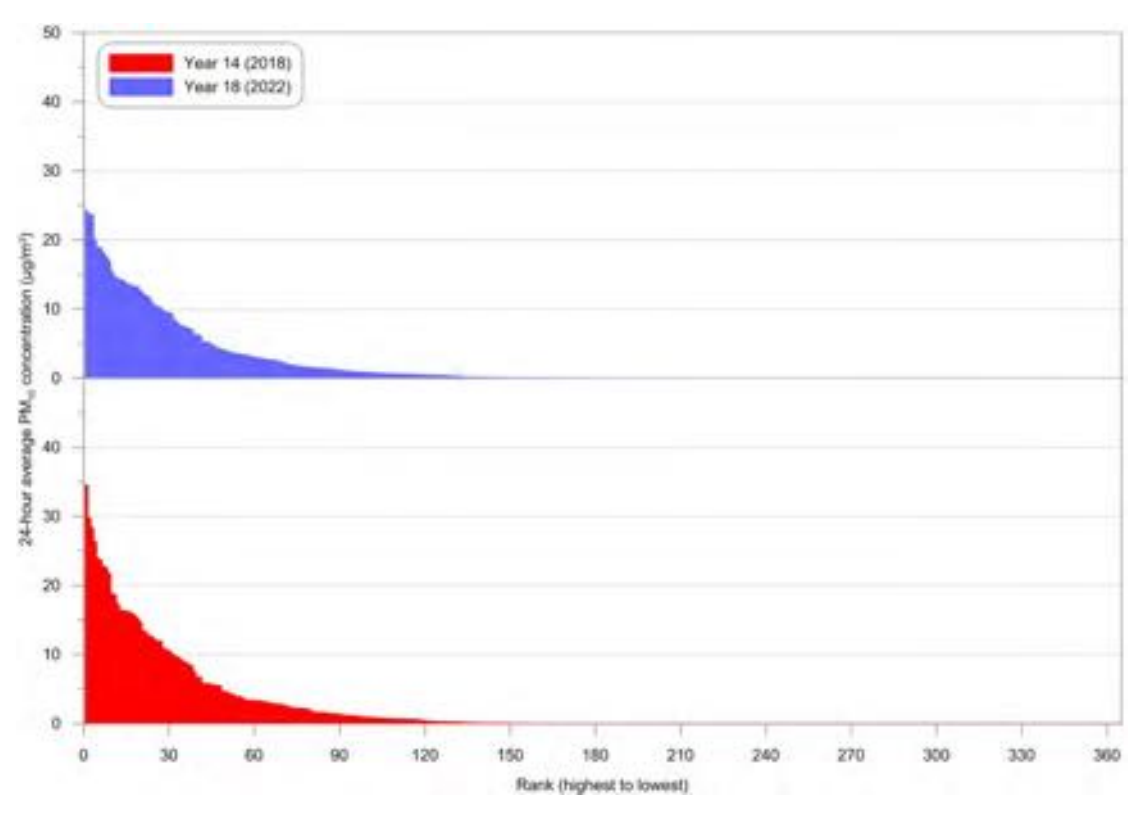


Figure 8.22: Predicted 24-hour average PM$_{10}$ concentrations at Residence 21, ranked from highest to lowest

9. Greenhouse gas assessment

9.1 Introduction

Greenhouse gas emissions have been estimated based on the methods outlined in the following documents.

- The World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard Revised Edition ("the GHG Protocol"; WRI/WBCSD, 2004).
- National Greenhouse and Energy Reporting (Measurement) Determination 2008.
- The Commonwealth Department of Environment and Energy (DEE) National Greenhouse Accounts (NGA) Factors August 2015 (DEE, 2016).

The GHG Protocol establishes an international standard for accounting and reporting of GHG emissions. The GHG Protocol has been adopted by the International Standard Organisation, endorsed by GHG initiatives (such as the Carbon Disclosure Proposal) and is compatible with existing GHG trading schemes.

Three 'scopes' of emissions (scope 1, scope 2 and scope 3) are defined for GHG accounting and reporting purposes, as described below and summarised in Figure 9.1. This terminology has been adopted in Australian GHG reporting and measurement methods and has been employed in this assessment.

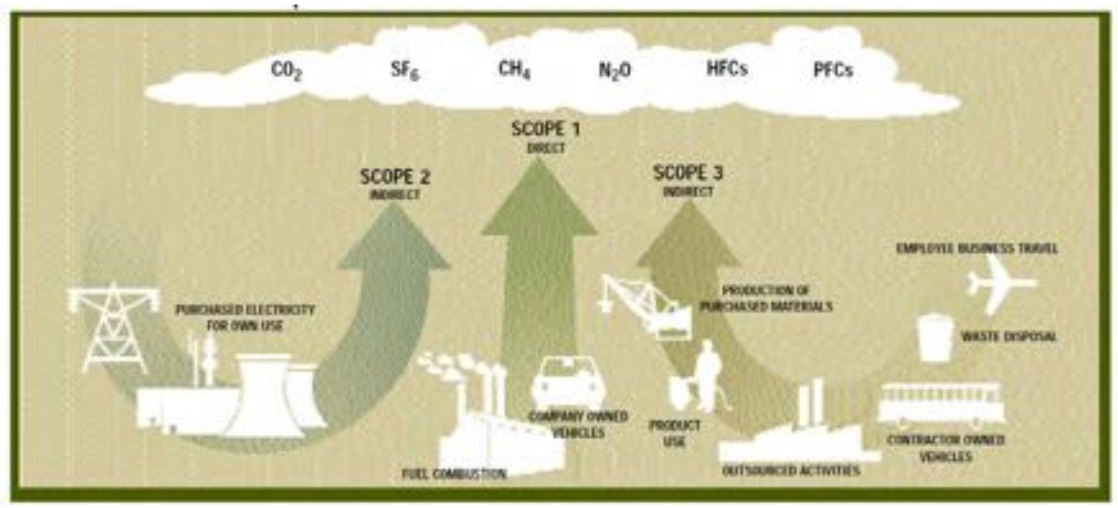


Figure 9.1: Overview of scopes and emissions across a reporting entity

9.2 Methodology

1) Scope 1: Direct Greenhouse Gas Emissions

Direct GHG emissions are defined as those emissions that occur from sources that are owned or controlled by the reporting entity. Direct GHG emissions are those emissions that are principally the result of the following types of activities undertaken by an entity:

- Generation of electricity, heat or steam.
- Physical or chemical processing.
- Transportation of materials, products, waste and employees.
- Fugitive emissions.

2) Scope 2: Energy Product Use Indirect Greenhouse Gas Emissions

Scope 2 emissions are a category of indirect emissions that account for GHG emissions from the generation of purchased energy products (principally, electricity, steam/heat and reduction materials used for smelting) by the entity. Scope 2 in relation to the Modification covers purchased electricity, defined as electricity that is purchased or otherwise brought into the organisational boundary of the entity.

3) Scope 3: Other Indirect Greenhouse Gas Emissions

Scope 3 emissions are defined as those emissions that are a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity. Some examples of scope 3 activities provided in the GHG Protocol are extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

The GHG Protocol provides that reporting scope 3 emissions is optional. If an organisation believes that scope 3 emissions are a significant component of the total emissions inventory, these can be reported along with scope 1 and scope 2. However, the GHG Protocol notes that reporting scope 3 emissions can result in double counting of emissions and can also make comparisons between organisations and/or products difficult because reporting is voluntary. Double counting needs to be avoided when compiling national inventories under the Kyoto Protocol. The GHG Protocol also recognises that compliance regimes are more likely to focus on the “point of release” of emissions (i.e. direct emissions) and/or indirect emissions from the purchase of electricity.

Scope 3 emissions have not been included in this assessment.

9.3 Greenhouse gas emission estimates

Inventories of GHG emissions can be calculated using published emission factors. Different gases have different greenhouse warming effects (referred to as global warming potentials) and emission factors take into account the global warming potentials of the gases created during combustion. The estimated emissions are referred to in terms of carbon dioxide equivalent, or CO_2-e, emissions by applying the relevant global warming potential. The greenhouse gas assessment has been conducted using the NGA Factors, published by the DEE (2016).

Proposal-related GHG sources included in the assessment are as follows.

- Fuel consumption (diesel, unleaded petrol [ULP], liquid petroleum gas [LPG] and explosives) during extraction and processing – scope 1.
- Indirect emissions associated with on-site electricity use – scope 2.

The CGO including the Modification is 16 years (2017 – 2032). Diesel and electricity usage values have been provided. It is assumed that LPG, ULP and explosive usage would vary between years of operation relative to extraction and production rates.

A summary of annual GHG emissions is provided in Table 9.1. Detailed information on the calculation of greenhouse gas emissions from the Modification are provided in Appendix B.

Table 9.1: Summary of estimated annual average CO_2-e (tonnes)

Type of fuel	Scope 1	Scope 2	Total
Diesel	39,500	-	39,500
Unleaded petrol	22	-	22
Propane (used as LPG)	820	-	820
Explosives	465	-	465
Electricity	-	203,195	203,195
Total	**40,807**	**203,195**	**244,002**

The Modification's contribution to projected climate change, and the associated impacts, would be in proportion with its contribution to global GHG emissions. Average annual scope 1 and scope 2 emissions from the Modification (approximately 0.24 Mt CO_2-e) would represent approximately 0.041% of Australia's commitment for annual emissions under the Kyoto Protocol (591.5 Mt CO_2-e/annum) and a very small portion of global GHG emissions, given that Australia contributed approximately 1.15% of global GHG emissions in 2014 (PBL Netherlands Environmental Assessment Agency, 2015).

10. Monitoring and mitigation measures

10.1 Monitoring

The existing CGO air quality monitoring program includes:

- an on-site meteorological station;
- a network of static dust gauges within and surrounding the CGO area (including gauges proximal to nearby residences, bird breeding areas, native flora areas and Lake Cowal);
- TSP monitoring to the north of the CGO; and
- an air quality monitoring review program as part of the AQMP.

The existing air quality monitoring review program would be continued for the Modification.

10.2 Mitigation measures

Emissions associated with the operation of the Modification would be generated from two primary sources as follows:

- wind blown dust from exposed areas and from disturbed locations where there is no vegetation cover; and
- dust generated by mining activities including the mechanical disturbance of soils, waste rock and ore when using conventional mining equipment, including the haulage of materials within ML 1535.

Air quality management and mitigation measures are currently implemented at the CGO in accordance with the CGO AQMP (Evolution, 2015a) to control windblown and mine generated dust. These management and mitigation measures include the procedures outlined in Table 10.1 and Table 10.2. These measures would continue for the Modification.

Table 10.1: Management methods for exposed areas dust sources

Source	Mitigation measures
General areas disturbed by mining	Only the minimum area necessary for mining will be disturbed. Exposed areas will be reshaped, topsoiled and revegetated as soon as practicable in accordance with Development Consent Condition 2.4(b), to minimise the generation of wind erosion dust.
Waste emplacement areas	Exposed active work areas on waste emplacement surfaces will be watered to suppress dust where practicable. Rehabilitation (i.e. reshaping, topsoil placement and revegetation) of waste emplacement areas will be conducted progressively, as soon as practicable following completion of landform, in accordance with Development Consent Condition 2.4(b).
Tailings storage facilities	During non-operational periods, dust suppression measures will be undertaken to minimise dust emissions from dry exposed areas on the surface of the tailings storage facilities.
Soil stockpiles	Long-term soil stockpiles will be revegetated with a cover crop.
Material handling and ore stockpiles	Prevention of truck overloading to reduce spillage during ore loading/unloading and hauling. The coarse ore stockpile will be protected by a hood to prevent wind erosion of its surface. The surface of all stockpiles will be sufficiently treated to minimise dust emissions. Such treatment may include application of a dust suppressant, regular dust suppression watering or establishment of vegetation on longer term stockpiles (e.g. the low grade ore stockpile).

Source: Evolution (2015b).

Table 10.2: Management measures for mining generated dust sources

Source	Mitigation measures
Haul roads	All roads and trafficked areas will be watered and/or treated with an alternative dust suppressant (using water trucks or other methods) and regularly maintained (using graders) to minimise the generation of dust. Routes will be clearly marked. Obsolete roads will be ripped and re-vegetated.
Minor roads	Development of minor roads will be limited and the locations of these will be clearly defined and within approved surface disturbance areas. Regularly used minor roads will be watered and/or treated with an alternative dust suppressant (using water trucks or other methods) and regularly maintained. Obsolete minor roads will be ripped and re-vegetated.
Materials handling	Prevention of truck overloading to reduce spillage during ore loading/unloading and hauling. A water spray dust suppression system will be used at the primary crusher bin during truck dumping of raw ore. Freefall height during ore/waste stockpiling will be limited.
Soil stripping	Soil stripping will be limited to areas required for mining operations.
Drilling	Dust aprons will be lowered during drilling for collection of fine dust. Water injection or dust suppression sprays will be used when high levels of dust are being generated.
Blasting	Fine material collected during drilling will not be used for blast stemming. Adequate stemming will be used at all times. Blasting will only occur following an assessment of weather conditions by the Environmental Manager to ensure that wind speed and direction will not result in excess dust emissions from the site towards adjacent residences (refer to the Blast Management Plan (Evolution, 2015c) for further information).
Equipment maintenance	Emissions from mobile equipment exhausts will be minimised by the implementation of a maintenance programme to service equipment in accordance with the equipment manufacturer specifications

Source: Evolution (2015b).

11. Conclusions

This report has assessed the potential impacts on air quality from the continued operations at the CGO associated with the Modification. Dispersion modelling was conducted to predict ground level dust concentration and deposition levels due to the dust generating activities that would occur for the 'worst case' impacts years as part of the Modification.

Predictions were made at the nearest residential receptors surrounding the mine and compared with the relevant assessment criteria and national standards. Cumulative impacts were also considered, taking into account the effects of other non-mining sources of dust.

Dispersion modelling results indicated that predicted emissions for operations at the CGO incorporating the Modification would comply with relevant annual average and 24-hour average $PM_{2.5}$, PM_{10}, TSP and dust deposition assessment criteria and standards at all nearby residential properties. In addition, no impacts on more than 25% of privately-owned land were predicted. No additional potential 24-hour impacts are expected during the life of the Modification (that is, in addition to the existing approved CGO operations).

The assessment has taken a conservative approach by considering the worst case operating conditions. The predicted concentrations and deposition levels due to the proposed activities are therefore likely to be higher than measured concentrations and deposition levels in practice. Notwithstanding, dust control would be a key part of the operation. Day-to-day dust management and best practice control measures would be part of the standard operating procedures to keep both emissions and resulting ground level concentrations as low as possible.

Evolution would continue to manage potential impacts associated with the CGO through a range of dust controls in accordance with the AQMP, which would be revised and updated for the Modification as required.

GHG emissions for the CGO including the Modification, as a result of fuel use, explosives use and electricity consumption, have been estimated. Evolution would continue to calculate and report annual GHG emissions and energy consumption from the CGO in accordance with existing regulatory requirements.

12. References

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Appendix A

Emission estimation

The dust emission inventories have been prepared for each modelling year using the operational description of the proposed modification.

Estimated emissions are presented for all significant dust generating activities associated with the operations. The relevant emission factors used for the study are described below. With the exception of blasting and activities on the TSF lifts, activities have been modelled for 24 hours per day.

Dust from wind erosion is assumed to occur over 24-hours per day, however, wind erosion is also assumed to be proportional to the third power of wind speed. This will mean that most wind erosion occurs during the day when wind speeds are highest.

Drilling

Emissions from drilling for each particle size fraction were estimated using the US EPA AP42 emission factors given below.

$E_{TSP} = 0.59$ kg/blast

$E_{PM10} = 0.52 \times E_{TSP}$ kg/blast

$E_{PM2.5} = 0.03 \times E_{TSP}$ kg/blast

Blasting

Emissions from blasting for each particle size fraction were estimated using the US EPA AP42 emission factors given below.

$E_{TSP} = 0.00022 \times A^{1.5}$ kg/blast

$E_{PM10} = 0.52 \times 0.00022 \times A^{1.5}$ kg/blast

$E_{PM2.5} = 0.03 \times 0.00022 \times A^{1.5}$ kg/blast

Where:

A = area to be blasted in m^2

Loading material / dumping overburden

Each tonne of material loaded will generate a quantity of dust that will depend on the wind speed and the moisture content. The equation below shows the relationship between these variables and the appropriate k-factor for each particle size fraction.

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

Where:

k = 0.74 for TSP
k = 0.35 for PM_{10}
k = 0.053 for $PM_{2.5}$
U = wind speed (m/s)
M = moisture content (%)

Hauling material on unsealed surfaces

The emission estimates of wheel generated dust are based the US EPA AP42 emission factor equations for unpaved surfaces at industrial sites, as shown below.

$E_{TSP} = (0.4536/1.6093) \times 4.9 \times [(s/12)^{0.7} \times ((W/1.1023)/3)^{0.45}]$ kg/VKT

$E_{PM10} = (0.4536/1.6093) \times 1.5 \times [(s/12)^{0.9} \times ((W/1.1023)/3)^{0.45}]$ kg/VKT

$E_{PM2.5} = (0.4536/1.6093) \times 0.15 \times [(s/12)^{0.9} \times ((W/1.1023)/3)^{0.45}]$ kg/VKT

Where:

s = silt content of road surface
W = mean vehicle weight in metric tonnes

The mean vehicle weight used in the emissions estimates is an average of the loaded and unloaded gross vehicle mass, to account for one empty trip and one loaded trip.

Dozers

Emissions from dozers have been calculated using the US EPA AP42 emission factor equations shown below.

$E_{TSP} = 2.6 \times (s^{1.2}/M^{1.3})$ kg/hour

$E_{PM10} = 0.3375 \times (s^{1.5}/M^{1.4})$ kg/hour

$E_{PM2.5} = 0.105 \times E_{TSP}$ kg/hour

Where:

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

Wind erosion

The default US EPA AP42 emission factors for wind erosion on exposed surfaces are shown below for each particle size fraction

$E_{TSP} = 850$ kg/ha/year

$E_{PM10} = 0.5 \times E_{TSP}$ kg/ha/year

$E_{PM2.5} = 0.075 \times E_{TSP}$ kg/ha/year

Grading roads

Estimates of emissions from grading roads have been made using the US EPA AP42 emission factor equations for each particle size fraction, as shown below.

$E_{TSP} = 0.0034 \times S^{2.5}$ kg/km

$E_{PM10} = 0.00336 \times S^{2}$ kg/km

$E_{PM2.5} = 0.0001054 \times S^{2.5}$ kg/km

Where,

S = speed of the grader in km/h (taken to be 8 km/h)

The following tables provide a summary of the variables used to calculate TSP emissions for each modelling year. These variables include such things as haul road distances, silt and moisture contents vehicle payloads, vehicle weights and the volumes of material handled. Similar tables for PM_{10} and $PM_{2.5}$ can be provided if required, but will include the same variables. The differences between the particle size fractions are in the emission equations themselves which have been provided above.

Estimated emissions for Year 14 (2018)

ACTIVITY	TSP emission (kg/y)	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Variable 3	units	Variable 4	units	Variable 5	units	Variable 6	units
2018 - Year 14																	
Drilling	8,098	45,750	holes/y	0.590	kg/hole											70	% control
Blasting	28,808	183	blasts/y	157	kg/blast	8,000	Area of blast in square metres										
Waste - Excavators loading haul trucks	5,084	22,140,000	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Hauling to northern waste dump	1,184,098	20,372,900	t/y	0.2906	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	9.8	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Hauling to southern waste dump	0	0	t/y	0.3677	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	12.4	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Hauling to northern TSF stockpile	93,044	1,120,600	t/y	0.4152	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	14.0	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Hauling to southern TSF stockpile	50,612	646,500	t/y	0.3914	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	13.2	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Unloading at northern waste dump	4,678	20,372,900	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Unloading at southern waste dump	0	0	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Unloading at northern TSF stockpile	257	1,120,600	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Unloading at southern TSF stockpile	148	646,500	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Loading trucks at northern TSF stockpile	257	1,120,600	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Loading trucks at southern TSF stockpile	148	646,500	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Hauling from northern TSF stockpile to TSF embankment	80,054	1,120,600	t/y	0.3572	kg/t	45	payload (tonnes)	52	Average vehicle mass (tonnes)	5.7	km/return trip	2.82	kg/VKT	5	% silt content	80	% control
Waste - Hauling from southern TSF stockpile to TSF embankment	44,564	646,500	t/y	0.3447	kg/t	45	payload (tonnes)	52	Average vehicle mass (tonnes)	5.5	km/return trip	2.82	kg/VKT	5	% silt content	80	% control
Waste - Unloading at northern TSF embankment	257	1,120,600	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Unloading at southern TSF embankment	148	646,500	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Waste - Dozer on northern TSF embankment	1,564	3,121	h/y	1.00	kg/h	9.2	moisture content in %	5.0	silt content							50	% control
Waste - Dozer on southern TSF embankment	1,564	3,121	h/y	1.00	kg/h	9.2	moisture content in %	5.0	silt content							50	% control
Waste - Dozers in pit	2,864	5,716	h/y	1.00	kg/h	9.2	moisture content in %	5.0	silt content							50	% control
Waste - Dozers on northern waste dump/min waste stockpiles	2,864	5,716	h/y	1.00	kg/h	9.2	moisture content in %	5.0	silt content							50	% control
Waste - Dozers on southern waste dump	0	0	h/y	1.00	kg/h	9.2	moisture content in %	5.0	silt content							50	% control
Ore - Loading mineral waste ore to haul trucks	2,069	1,110,000	t/y	0.00186	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.1	moisture content in %								
Ore - Hauling mineral waste ore to northern dump	77,527	1,110,000	t/y	0.3492	kg/t	136	payload (tonnes)	181.0	Average vehicle mass (tonnes)	9.6	km/return trip	4.95	kg/VKT	5	% silt content	80	% control
Ore - Unloading mineral waste ore to northern dump	2,069	1,110,000	t/y	0.00186	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.1	moisture content in %								
Ore - Loading ore to haul trucks	17,169	9,210,000	t/y	0.00186	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.1	moisture content in %								
Ore - Hauling ore to ROM pad	562,859	9,210,000	t/y	0.3056	kg/t	136	payload (tonnes)	181.0	Average vehicle mass (tonnes)	8.4	km/return trip	4.95	kg/VKT	5	% silt content	80	% control
Ore - Unloading ore to ROM pad	5,151	9,210,000	t/y	0.00186	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.1	moisture content in %							70	% control
Ore - Rehandling ore	3,090	5,526,000	t/y	0.00186	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.1	moisture content in %							70	% control
Ore - Crushing and screening	15,657	9,210,000	t/y	0.00170	kg/t												
Ore - Loading to coarse ore stockpile	4,116	7,360,000	t/y	0.00186	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.1	moisture content in %							70	% control
Grading roads	10,783	35,040	km/y	0.62	kg/km	4,380	h/y	8	speed of graders in km/h							50	% control
Wind erosion - Open pit	93,500	110	ha	850	kg/ha/y												
Wind erosion - Northern dump	124,950	147	ha	850	kg/ha/y												
Wind erosion - Southern dump	29,750	35	ha	850	kg/ha/y												
Wind erosion - Stockpiles and exposed areas	127,500	150	ha	850	kg/ha/y												
Wind erosion - Northern TSF lift construction area	51,000	60	ha	850	kg/ha/y												
Wind erosion - Southern TSF (half of total area)	25,500	30	ha	850	kg/ha/y												
Northern TSF Lift - Hauling to Northern TSF	54,556	506,160	t/y	0.5389	kg/t	45	payload (tonnes)	51.9	Average vehicle mass (tonnes)	8.6	km/return trip	2.82	kg/VKT	5	% silt content	80	% control
Northern TSF Lift - Unloading soil at Northern TSF	116	506,160	t/y	0.00023	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	9.2	moisture content in %								
Northern TSF Lift - Dozer shaping soil	1,564	3,121	h/y	1.00	kg/h	9.2	moisture content in %	5.0	silt content							50	% control

Estimated emissions for Year 18 (2022)

ACTIVITY	TSP emission (kg/y)	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Variable 3	units	Variable 4	units	Variable 5	units	Variable 6	units
2022 - Year 18																	
Drilling	8,098	45,750	holes/y	0.590	kg/hole											70	% control
Blasting	28,808	183	blasts/y	157	kg/blast	8,000	Area of blast in square metres										
Waste - Excavators loading haul trucks	20,917	10,760,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Hauling to northern waste dump	356,469	6,133,200	t/y	0.2906	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	9.8	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Hauling to southern waste dump	0	0	t/y	0.3677	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	12.4	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Hauling to northern TSF stockpile	241,220	2,905,200	t/y	0.4152	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	14.0	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Hauling to southern TSF stockpile	134,777	1,721,600	t/y	0.3914	kg/t	184	payload (tonnes)	225	Average vehicle mass (tonnes)	13.2	km/return trip	5.46	kg/VKT	5	% silt content	80	% control
Waste - Unloading at northern waste dump	11,923	6,133,200	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Unloading at southern waste dump	0	0	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Unloading at northern TSF stockpile	5,648	2,905,200	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Unloading at southern TSF stockpile	3,347	1,721,600	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Loading trucks at northern TSF stockpile	5,648	2,905,200	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Loading trucks at southern TSF stockpile	3,347	1,721,600	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Hauling from northern TSF stockpile to TSF embankment	207,543	2,905,200	t/y	0.3572	kg/t	45	payload (tonnes)	52	Average vehicle mass (tonnes)	5.7	km/return trip	2.82	kg/VKT	5	% silt content	80	% control
Waste - Hauling from southern TSF stockpile to TSF embankment	118,673	1,721,600	t/y	0.3447	kg/t	45	payload (tonnes)	52	Average vehicle mass (tonnes)	5.5	km/return trip	2.82	kg/VKT	5	% silt content	80	% control
Waste - Unloading at northern TSF embankment	5,648	2,905,200	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Unloading at southern TSF embankment	3,347	1,721,600	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Waste - Dozer on northern TSF embankment	11,367	3,121	h/y	7.28	kg/h	2.0	moisture content in %	5.0	silt content							50	% control
Waste - Dozer on southern TSF embankment	11,367	3,121	h/y	7.28	kg/h	2.0	moisture content in %	5.0	silt content							50	% control
Waste - Dozers in pit	20,819	5,716	h/y	7.28	kg/h	2.0	moisture content in %	5.0	silt content							50	% control
Waste - Dozers on northern waste dump/min waste stockpiles	10,409	2,858	h/y	7.28	kg/h	2.0	moisture content in %	5.0	silt content							50	% control
Waste - Dozers on southern waste dump	0	0	h/y	7.28	kg/h	2.0	moisture content in %	5.0	silt content							50	% control
Ore - Loading mineral waste ore to haul trucks	8,767	4,510,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Ore - Hauling mineral waste ore to northern dump	314,999	4,510,000	t/y	0.3492	kg/t	136	payload (tonnes)	181.0	Average vehicle mass (tonnes)	9.6	km/return trip	4.95	kg/VKT	5	% silt content	80	% control
Ore - Unloading mineral waste ore to northern dump	8,767	4,510,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Ore - Loading ore to haul trucks	20,373	10,480,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Ore - Hauling ore to ROM pad	640,474	10,480,000	t/y	0.3056	kg/t	136	payload (tonnes)	181.0	Average vehicle mass (tonnes)	8.4	km/return trip	4.95	kg/VKT	5	% silt content	80	% control
Ore - Unloading ore to ROM pad	6,112	10,480,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %							70	% control
Ore - Rehandling ore	3,667	6,288,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %							70	% control
Ore - Crushing and screening	17,816	10,480,000	t/y	0.00170	kg/t												
Ore - Loading to coarse ore stockpile	4,351	7,460,000	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %							70	% control
Grading roads	10,783	35,040	km/y	0.62	kg/km	4,380	h/y	8	speed of graders in km/h							50	% control
Wind erosion - Open pit	93,500	110	ha	850	kg/ha/y												
Wind erosion - Northern dump	102,850	121	ha	850	kg/ha/y												
Wind erosion - Southern dump	0	0	ha	850	kg/ha/y												
Wind erosion - Stockpiles and exposed areas	65,450	77	ha	850	kg/ha/y												
Wind erosion - Northern TSF lift (half of total area)	25,500	30	ha	850	kg/ha/y												
Wind erosion - Southern TSF construction area	51,000	60	ha	850	kg/ha/y												
Southern TSF Lift - Hauling to Southern TSF	123,799	1,148,580	t/y	0.5389	kg/t	45	payload (tonnes)	51.9	Average vehicle mass (tonnes)	8.6	km/return trip	2.82	kg/VKT	5	% silt content	80	% control
Southern TSF Lift - Unloading soil at Southern TSF	2,233	1,148,580	t/y	0.00194	kg/t	1.642	average of (wind speed/2.2)^1.3 in m/s	2.0	moisture content in %								
Southern TSF Lift - Dozer shaping soil	11,367	3,121	h/y	7.28	kg/h	2.0	moisture content in %	5.0	silt content							50	% control

Appendix B

Greenhouse gas emission calculations

Fuel consumption

Diesel

Greenhouse gas (GHG) emissions from diesel consumption were estimated using the following equation:

Equation 1:

$$E_{CO_2-e} = \frac{Q \times EF}{1000}$$

Where:

where:

E_{CO2-e}	Emissions of GHG from diesel combustion	(t CO_2-e)[1]
Q	Estimated combustion of diesel	(GJ)[2]
EF	Emission factor (scope 1) for diesel combustion	(kg CO_2-e/GJ)[3]

[1] tCO_2-e = tonnes of carbon dioxide equivalent

[2] GJ = gigajoules

[3] kg CO_2-e/GJ = kilograms of carbon dioxide equivalents per gigajoule

The quantity of diesel consumed (Q) each year is based on usage numbers provided by Evolution. The quantity of diesel consumed in GJ is calculated using an energy content factor for diesel of 38.6 gigajoules per kilolitre (GJ/kL). The Scope 1 emission factor is 69.9 kg CO_2 e/GJ (DEE, 2016). The estimated annual and total life of mine GHG emissions from diesel usage are presented in the table below.

Table B1: Estimated scope 1 CO_2-e (tonnes) for diesel consumption

Year	Usage (kL)	Emissions (t CO_2-e)
2017	23,689	64,466
2018	31,915	86,850
2019	30,703	83,553
2020	27,629	75,186
2021	29,342	79,848
2022	23,735	64,591
2023	18,516	50,388
2024	8,654	23,551
2025	5,526	15,039
2026	5,446	14,819
2027	5,056	13,758
2028	5,480	14,914
2029	4,895	13,320
2030	5,970	16,246
2031	4,837	13,164
2032	849	2,310
Total	**232,243**	**632,004**

Unleaded petrol

GHG emissions from unleaded petrol (ULP) consumption were estimated using Equation 1 as above.

The quantity of ULP consumed (Q) each year is based on usage numbers provided by Evolution. The quantity of ULP consumed in GJ is calculated using an energy content factor for gasoline (ULP) of 34.2 gigajoules per kilolitre (GJ/kL). The Scope 1 emission factor is 67.4 kg CO_2 e/GJ (DEE, 2016). The estimated annual and total life of mine GHG emissions from ULP usage are presented in the table below.

Table B2: Estimated scope 1 CO_2-e (tonnes) for unleaded petrol consumption

Year	Usage (kL)	Emissions (t CO_2-e)
2017	18	42
2018	21	50
2019	20	47
2020	17	41
2021	17	42
2022	14	33
2023	10	24
2024	5	13
2025	4	9
2026	4	9
2027	4	9
2028	4	9
2029	4	9
2030	4	9
2031	4	9
2032	1	3
Total	**151**	**360**

Propane (used as LPG)

GHG emissions from propane consumption were estimated using Equation 1 as above.

The quantity of propane consumed (Q) each year is based on usage numbers provided by Evolution. The quantity of propane consumed in GJ is calculated using an energy content factor for propane (as LPG) of 24.7 gigajoules per kilolitre (GJ/kL). The Scope 1 emission factor is 60.2 kg CO2 e/GJ (DEE, 2016). The estimated annual and total life of mine GHG emissions from propane usage are presented in the table below.

Table B3: Estimated scope 1 CO_2-e (tonnes) for propane consumption

Year	Usage (kL)	Emissions (t CO_2-e)
2017	983	1,531
2018	1,167	1,817
2019	1,099	1,711
2020	962	1,498
2021	973	1,516
2022	761	1,185
2023	569	886
2024	302	471
2025	220	342
2026	220	342
2027	220	342
2028	220	342
2029	220	342
2030	220	342
2031	220	342
2032	67	105
Total	**8,421**	**13,116**

Explosives use

GHG emissions from explosives usage were estimated using the following equation:

Equation 2:

$$E_{co2-e} = Q \times EF$$

Where:

where:		
$E_{CO2\text{-}e}$	Emissions of GHG from explosives	(t CO_2-e/annum)
Q	Estimated combustion of explosives	(t)
EF	Emission factor (scope 1) for explosive combustion	(t CO_2-e/tonne explosive)

Greenhouse gas emission factors were sourced from the NGA Factors February 2008. It is noted that the AGO Factors and Methods were replaced by the NGA Factors, however the emission factor for explosives was excluded from the latest version. Emissions from explosives do not have to be reported under the National Greenhouse and Energy Reporting System (NGERS).

The quantity of explosives consumed in each year is based on an explosives intensity rate (t explosives/waste rock), calculated from usage numbers provided by Evolution.

The scope 1 emission factor is 0.167 t CO_2-e/GJ. The estimated annual and total life of mine GHG emissions from explosive usage are presented in the table below.

Table B4: Estimated scope 1 CO_2-e (tonnes) for explosive use

Year	Usage (kL)	Emissions (t CO_2-e)
2017	6,695	1,118
2018	8,342	1,393
2019	7,759	1,296
2020	6,507	1,087
2021	6,618	1,105
2022	4,783	799
2023	3,107	519
2024	730	122
2025	0	0
2026	0	0
2027	0	0
2028	0	0
2029	0	0
2030	0	0
2031	0	0
2032	0	0
Total	**44,541**	**7,438**

Electricity consumption

GHG emissions from electricity consumption were estimated using the following equation:

Equation 3:

$$E_{CO_2-e} = \frac{Q \ \times EF}{1000}$$

Where:

where:

$E_{CO2\text{-}e}$	Emissions of GHG from electricity usage	(t CO_2-e/annum)[1]
Q	Estimated electricity usage	(kWh/annum)[2]
EF	Emission factor (scope 2) for electricity usage	(kg CO_2-e/kWh)[3]

[1] tCO_2-e = tonnes of carbon dioxide equivalent
[2] kWh = kilowatt hours per annum
[3] kg CO_2-e/kWh = kilograms of carbon dioxide equivalents per kilowatt hour

The quantity of electricity used (Q) each year is based on usage numbers provided by Evolution. The scope 2 emission factor is 0.84 kg CO_2 e/kWh (DEE, 2016). The estimated annual and total life of mine GHG emissions from electricity consumption are presented in the table below.

Table B5: Estimated scope 2 CO_2-e (tonnes) for electricity consumption

Year	Usage (kL)	Emissions (t CO_2-e)
2017	254,474,000	213,758
2018	249,724,000	209,768
2019	247,688,000	208,058
2020	254,474,000	213,758
2021	253,117,000	212,618
2022	249,724,000	209,768
2023	248,706,000	208,913
2024	253,456,000	212,903
2025	254,474,000	213,758
2026	254,474,000	213,758
2027	254,474,000	213,758
2028	254,474,000	213,758
2029	254,474,000	213,758
2030	254,474,000	213,758
2031	254,474,000	213,758
2032	77,699,000	65,267
Total	**3,870,380,000**	**3,251,119**