REPORT

AIR QUALITY ASSESSMENT: WALLARAH 2 COAL PROJECT

International Environmental Consultants

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1 INTRODUCTION

This report has been prepared by Holmes Air Sciences for International Environmental Consultants (IEC). It provides an air quality and greenhouse gas assessment for the proposed Wallarah 2 Coal Project (W2CP) to be developed by the Wyong Areas Coal Joint Venture (WACJV). This study has been undertaken for inclusion in an Environmental Assessment conducted as a requirement for a Part 3A submission to the Department of Planning.

The Project comprises an underground longwall mine, a coal handling plant, rail loop and loading infrastructure, an underground drift facility and ventilation shafts, and gas and water management facilities.

The assessment is based on the use of a computer-based dispersion model to predict ground-level dust concentrations and deposition levels in the vicinity of the surface facilities. To assess the effect that the dust emissions would have on existing air quality, the dispersion model predictions have been compared to relevant air quality goals. Dispersion modelling has been carried out in accordance with the "*Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*" developed by the New South Wales Department of Environment, Climate Change and Water (DECCW) guidelines (**DEC, 2005**).

Odour and dust impacts have also been estimated in the vicinity of the upcast ventilation shaft at the Buttonderry site.

2 PROJECT DESCRIPTION

Figure 1 shows the location of the surface aspects of the Project. The closest major centre is Wyong which is situated approximately 9 km to the south of the Project site while residential areas occur approximately 2.5 km to the east of the Tooheys Road site and to the south and south west of the Buttonderry site. **Figure 2**2 shows a pseudo three dimensional representation of the local terrain.

Details of the main surface facilities and ventilation shaft are shown on **Figure 3** and **Figure 4**.

The main surface facilities, referred to as the Tooheys Road site include the following:

- Portal to the underground mining area
- Run-of-Mine (ROM) coal stockpile with 50,000 t capacity
- Conveyor to transport ROM coal to the crushing unit and to the transfer house
- Crushing unit comprising secondary sizer, screen and tertiary sizer
- Product stockpile with 250,000 t capacity
- Rail loop and loading facility

The upcast and downcast ventilation shafts are located at the Buttonderry site along with the main office facility.

A second downcast ventilation shaft, referred to as the Western Shaft, is proposed for location in the Wyong State Forest. This would be required by Mining Year 10. As this ventilation shaft is downcast only, there are no significant air quality impacts associated with this aspect of the project.

The mining process would see up to five million tonnes per year (t/y) of export quality coal extracted by longwall mining. Approximately 151 Mt of run of mine (ROM) coal would be extracted over a 40-year (approximately) period. Very little of the material extracted would be non-coal.

The drift conveyor would transport ROM coal from the underground areas to the surface where it would be discharged through a 4,000 t/h receival system. Raw coal would be stored in a 50,000 t surge stockpile and processed through a 2,000 t/h coal reclaim, crushing and stacking system. The processed coal would then be conveyed via a 2000 t/h overhead tripper which stacks crushed coal on a 250,000 t product stockpile. The rail loading system can handle 4,500 t/h and includes a loading bin of approximately 250 t capacity. For modelling purposes, it has been assumed that on the busiest day, 65,000 t of raw material would be processed and 40,000 t of product coal loaded. This provides a conservative estimate of peak operating conditions and has been used to predict potential peak short-term concentrations of particulate matter. On an average day, approximately 14,000 t of product coal would be loaded.

In terms of dust emissions, the more significant dust generating activities would be dozers working on stockpiles, loading of material and wind erosion from stockpiles.

Dust and odour will also be emitted from the upcast ventilation shaft. Two fans each at approximately 185 m^3/s capacity are proposed to ventilate the mine.

Mining activities would occur 24 hours per day, seven days a week.

3 AIR QUALITY ASSESSMENT CRITERIA

The project will result in the liberation of a number of classes of particulate matter (PM) described as total suspended particulate matter (TSP)[1], particulate matter with equivalent aerodynamic diameters 10 µm or less (PM_{10})[2] and particles with equivalent aerodynamic diameters of 2.5 µm and less ($PM_{2.5}$). It will also result in emissions from the ventilation shaft due to odour and dust in the mine ventilation air.

There will also be emissions from vehicles and underground equipment. These emissions will include carbon monoxide (CO) and minor quantities of sulfur dioxide (SO_2) nitrogen dioxide (NO_2) and particulate matter. In practice, these emissions will be minor and at levels that will not give rise to any substantive environmental impacts. For this reason, these pollutants (apart from particulate matter) are not considered further in this report. The focus of the report is on the potential impacts due to dust and odour.

3.1 Particulate matter

Table 1 and **Table 2** summarise the relevant air quality goals. The air quality goals relate to the total dust burden in the air and not just the dust from the Project. In other words, consideration

[1] TSP is particulate matter suspended in the air and measured using a high volume sampler operated according to AS2724.3-1984. The size range of particles is indeterminate and depends on the measurement conditions. TSP is usually taken to comprise particles in the size range up to 0 to 50 µm. Particles larger than 50 µm are generally too large to remain suspended in the air for long enough to be considered as air pollutants.

[2] A particle is said to have an equivalent aerodynamic diameter of x µm if its dynamical behavior in the atmosphere is the same as a sphere of diameter x and with density 1 g/cm^3.

of background levels needs to be made when using these goals to assess impacts. The assessment criteria are designed to protect human health as well as to protect against nuisance effects.

Table 1. Air quality standards/goals for particulate matter concentrations (Source: DEC, 2005)

Pollutant	Standard/Goal	Averaging Period	Agency
Total suspended particulate matter (TSP)	90 $\mu g/m^3$	Annual mean	National Health and Medical Research Council (NSW DEC, 2005)
Particulate matter < 10 μm (PM_{10})	50 $\mu g/m^3$	24-hour maximum	NSW DEC (2005) (assessment criteria)
	30 $\mu g/m^3$	Annual mean	NSW DEC (2005) (long-term reporting goal)

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

μm – micrometre

Ambient air quality standards for $PM_{2.5}$ have been developed as part of the National Environment Protection Measures (Air-NEPMs), but at this stage, these are not part of the NSW DECC's assessment criteria, which uses PM_{10} as the primary criterion for assessing the health effects of particulate matter.

3.2 Dust deposition

In addition to health impacts, airborne dust also has the potential to cause nuisance impacts by depositing on surfaces and possibly vegetation/crops. **Table 2** shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective. The criteria for dust fallout levels are set to protect against nuisance impacts (**DEC, 2005**).

Table 2. DECCW criteria for dust (insoluble solids) fallout

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

3.3 Odour

The determination of air quality criteria for odour and their use in the assessment of odour impact is recognised as a difficult topic in air pollution science. The topic has received considerable attention in the past five years and the procedures for assessing odour impacts using dispersion models have been refined considerably.

There are two factors that need to be considered:

1. what "level of exposure" to odour is considered acceptable to meet current community standards in NSW and
2. how can dispersion models be used to determine if a source of odour meets the criteria which are based on this acceptable level of exposure.

The term "level of exposure" has been used to reflect the fact that odour impacts are determined by several factors. The most important factors (the so-called **FIDOL** factors) are:

- the **F**requency of the exposure
- the **I**ntensity of the odour
- the **D**uration of the odour episodes
- the **O**ffensiveness of the odour, and
- the **L**ocation of the source

In determining the offensiveness of an odour it needs to be recognised that for most odours the context in which an odour is perceived is also relevant. Some odours, for example the smell of sewage, hydrogen sulfide, butyric acid, landfill gas etc., are likely to be judged offensive regardless of the context in which they occur. Other odours such as the smell of jet fuel may be acceptable at an airport, but not in a house, and diesel exhaust may be acceptable near a busy road, but not in a restaurant.

In summary, whether or not an individual considers an odour to be a nuisance will depend on the FIDOL factors outlined above and although it is possible to derive formulae for assessing odour annoyance in a community, the response of any individual to an odour is still unpredictable. Odour criteria need to take account of these factors.

The DECCW framework documents include some recommendations for odour criteria. The criteria have been refined by DECCW to take account of population density in the area. **Table 3** lists the odour certainty thresholds, to be exceeded not more than 1% of the time, for different population densities.

The difference between odour criteria is based on considerations of risk of odour impact rather than differences in odour acceptability between urban and rural areas. For a given odour level there will be a wide range of responses in the population exposed to the odour. In a densely populated area there will therefore be a greater risk that some individuals within the community will find the odour unacceptable than in a sparsely populated area.

The criteria assume that 7 odour units at the 99th percentile would be acceptable to the average person, but as the number of exposed people increases there is a chance that sensitive individuals would be exposed. The criterion of 2 odour units at the 99th percentile is considered to be acceptable for the whole population. This criterion has been considered for the W2CP as a conservative approach. In practice the population density would be less than 2000 in the potentially affected area and an odour criterion of 3 would be appropriate.

Table 3. Impact assessment criteria for complex mixtures of odorous air pollutants

Population of affected community	Odour performance criteria (nose response odour certainty units at the 99th percentile)
Single residence (≤~2)	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/ schools and hospitals	2

It is common practice to use dispersion models to determine compliance with odour criteria. This introduces a complication because Gaussian dispersion models are only able to directly predict concentrations over an averaging period of three-minutes or greater. The human nose, however, responds to odours over periods of the order of a second or so. During a three-minute period, odour levels can fluctuate significantly above and below the mean depending on the nature of the source.

To determine more rigorously the ratio between the one-second peak concentrations and three-minute and longer period average concentrations (referred to as the peak-to-mean ratio) that might be predicted by a Gaussian dispersion model, the DECCW commissioned a study by Katestone Scientific Pty Ltd (see **Katestone 1995** and **1998**). This study recommended peak-to-mean ratios for a range of source types. The ratio is also dependent on atmospheric stability and the distance from the source. A summary table of these ratios is presented in **Appendix A**.

The DECCW Technical Framework for odour assessment (**DEC 2006a** and **2006b**) and *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (**DEC, 2005**) take account of this peaking factor and the criteria shown in **Table 3** are based on nose-response time.

4 REVIEW OF METEOROLOGICAL CONDITIONS

The rate at which pollutants are dispersed is dependent on meteorological conditions including wind speed, wind direction, atmospheric stability class[3] and mixed-layer height[4]. This section describes the dispersion meteorology and climate of the study area. It provides information on prevailing wind patterns as well as historical data on temperature, humidity and rainfall. Hourly meteorological data are required by the dispersion model used in this study. The source of these data is discussed below.

4.1 Wind speed and direction

Hourly wind speed and wind direction data are available from the Charmhaven Sewage Treatment Plant (STP) collected from June 1998 to May 1999 and from the Buttonderry landfill collected over the same period. The Charmhaven STP is located approximately 22 km to the southeast from the nearest boundary of the Tooheys Road site. The Buttonderry Landfill is located approximately 1.5 km to the northeast from the northern boundary of the Buttonderry site. Both sites are shown on 1**.**

Seasonal and annual wind roses are presented in **Figure** 5 and **Figure 6**. The wind roses show that over the year the winds from Charmhaven are most commonly from the southwest. This pattern persists throughout the year particularly in autumn and winter. In summer winds from the eastern sectors are also common and to a lesser extent in spring.

At Buttonderry, the dominant winds are from the north and northwest with east-southeast winds also occurring in spring and to a lesser extent summer and autumn.

Measurements of sigma-theta (a measure of the fluctuation of the wind direction) were also included in the data collected. These data were used to assign stability class.

In addition, meteorological data were collected at the Tooheys Road site in 2007. The data did not include any measure of sigma-theta and were not used for dispersion modelling purposes. However windroses prepared from the data (see **Figure 7**) show broadly similar wind patterns to Charmhaven data with southwesterlies in winter and northeasterlies in summer.

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[3] In dispersion modelling stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme (as used in this study) there are six stability classes, A through to F. Class A relates to unstable conditions, such as might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

[4] The term mixed-layer height, refers to the height above the ground through which ground-based emissions will eventually be dispersed once a plume has been thoroughly mixed. An elevated plume, initially above the mixed-layer height will remain isolated from the ground until such time as the mixed-layer height reaches the height of the plume. In general the mixed-layer height will increase during the day as the sun causes convection to deepen the turbulent layer of the atmosphere close to the ground. Mixed-layer height will also increase if the wind speed increases because higher wind speeds will increase turbulence as the wind blows over the rough ground.

4.2 Stability class

Stability is usually assigned according to six classes, A to F (see Footnote 3). The frequency of occurrence of each stability category expected in the project area is shown **Table 4**. The relatively high frequency of stable atmospheric conditions (E+F, over 40% for both sites) means that emissions will disperse slowly for a significant proportion of the time. Joint wind speed, wind direction and stability class frequency tables for the Charmhaven and Buttonderry sites are presented in **Appendix B**.

Table 4. Frequency of occurrence of stability classes

Stability class	Percentage frequency of occurrence	
	Charmhaven	**Buttonderry**
A	14.3	22.8
B	9.8	4.2
C	12.8	4.4
D	20.7	27.2
E	11.9	18.2
F	30.5	23.3
Total	**100.0**	**100.0**

4.3 Local climatic conditions

The Bureau of Meteorology also collects climatic information in the vicinity of the study area. A range of climatic information collected from Norah Head Lighthouse (located approximately 13 km to the southeast of the Project area) is presented in **Table 5** (**Bureau of Meteorology, 2008**).

Temperature and humidity data consisting of monthly averages of 9 am and 3 pm observations are presented in **Table 5**. Also presented are monthly averages of maximum and minimum temperatures and rainfall data consisting of mean and median monthly rainfall and the average number of rain days per month. The latter data are required for estimating emissions from wind erosion sources.

Table 5. Climate information for the study area

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean 9 am dry-bulb temperature (deg C)	22.1	22.1	21.3	19.3	16	13.2	12.3	13.8	16.4	18.5	19.4	21.4	18
Mean 9 am wet-bulb temperature (deg C)	19.9	20.2	19.1	17	14	11.3	10.4	11.3	13.3	15.5	16.8	18.8	15.6
Mean 9 am humidity (%)	82	83	81	79	79	78	77	72	70	72	76	78	77
Mean 3 pm dry-bulb temperature (deg C)	23.7	23.9	23	21.2	18.8	16.6	16.1	17.1	18.4	19.6	20.9	23	20.2
Mean 3 pm wet-bulb temperature (deg C)	20.7	21.1	20	18.1	15.6	13.4	12.6	13.2	14.4	16.1	17.7	19.6	16.9
Mean 3 pm relative humidity (%)	76	77	75	73	71	69	66	63	65	70	73	73	71
Mean daily maximum temperature (deg C)	25	25.2	24.4	22.7	20.1	17.7	17.2	18.4	20.2	21.8	22.6	24.8	21.7
Mean daily minimum temperature (deg C)	19.3	19.6	18.4	15.7	12.9	10.2	9.3	9.9	11.9	14.2	16	18.2	14.6
Mean rainfall (mm)	106.4	142	129	118.1	132.2	126.5	80.4	69.4	73.7	72.7	96.5	80.6	1227
Median rainfall (5th decile) (mm)	86	107.9	114.3	89.1	115.6	102.7	68.6	43	54.6	56.9	103.4	66.2	1196
Mean number of rain days	12.2	11.9	13	11.2	12.9	11.3	9.9	9.1	9.8	11	12.7	10.7	135.6

Climate averages for Station: 061273 NORAH HEAD LIGHTHOUSE. Commenced: 1969; Last record: 2004; Latitude (deg S): -33.2815; Longitude (deg E): 151.5759; State: NSW. Source: ***Bureau of Meteorology (2008)***

Temperature data show that February is typically the warmest month with a mean daily maximum of 25.2 °C. July is the coldest month with a mean daily minimum of 9.3°C.

Rainfall data collected at Norah Head show that February is the wettest month with an average rainfall of 142 mm over 12 rain days. Annually the area experiences, on average, 1227 mm of rain, which falls on 136 days.

5 REVIEW OF EXISTING AIR QUALITY

Emissions from the project will comprise PM_{10}, TSP and larger particles that will contribute to deposited particulate matter. As discussed in **Section 3**, there will be emissions of CO and small quantities of NO_2 from diesel equipment and blasting and trace amounts of SO_2, but in practice these sources are too small and too widely dispersed to give rise to significant concentrations of these pollutants and will not be considered in detail in this assessment.

Air quality standards and goals refer to pollutant levels which include the contribution from specific projects and existing sources. To fully assess impacts against all the relevant air quality standards and goals it is necessary to have information or estimates on existing dust concentration and deposition levels in the area in which the project is likely to contribute to these levels. This section discusses the existing air quality environment.

An Environmental Monitoring Program for the project commenced in 1996 providing monthly averages of dust fallout levels. Dust concentrations were also measured by high volume air samplers (HVAS). Air monitoring was discontinued in early 2004 but recommenced in late 2006. Recent and historical data are summarised in reports by ERM (**ERM, 2008, 2009**). **Figure 8** shows the locations of the relevant monitoring sites in the area surrounding the project sites. Available data commencing in 1999 from the two relevant high volume air samplers and eight dust deposition gauges are provided below.

5.1 Dust Concentration

TSP and PM_{10} concentrations are measured in the study area by high volume air samplers. The monitoring results will include all background sources relevant to that location, including any contribution which may occur from local activities. Sources of particulate matter in the area would include mining activities, traffic on unsealed roads, local building and construction activities, rural land uses including farming and animal grazing activities and to a lesser extent traffic from the other local roads.

Exceedances of the PM_{10} 24-hour goal of 50 $\mu g/m^3$ are commonly measured during periods of hot dry days in summer. Bushfires and dust storms can also contribute to very high PM_{10} concentrations.

This is reflected in the level of exceedances of the 24-hour average goal, five of which are permitted in any one year under the NEPM.

A summary of the monitoring data is presented in **Table 6**. As noted above there was a gap in data collection between 2003 and 2006. HVAS C is located at the Buttonderry site and HVAS E at the Tooheys Road site. The data were collected on a six-day cycle and for most years data collection was not complete. Nevertheless the data provide an estimate of existing air quality which is typical of a relatively clean semi-rural environment subject on occasions to bushfires.

Annual average concentrations of TSP and annual average and 24-hour maximum PM_{10} are generally below the relevant air quality goals. Any exceedances are shown in red.

Table 6. Measured TSP and PM_{10} concentrations at Tooheys Road and Buttonderry sites ($\mu g/m^3$)

YEAR	HVAS C	HVAS E	HVAS C		HVAS E	
	TSP	TSP	PM_{10}		PM_{10}	
	Annual Average	Annual Average	Annual Average	Maximum 24-hour	Annual Average	Maximum 24-hour
Goal	90 $\mu g/m^3$		30 $\mu g/m^3$	50 $\mu g/m^3$	30 $\mu g/m^3$	50 $\mu g/m^3$
1999	24*	21*	10*	14*	9*	14*
2000	20*	26*	11*	30*	12*	**66*[1]***
2001	27*	30	12*	33*	13	32
2002	64*	61	**38***	**116*[2]**	24	**85[3]**
2003	29	42	12	44	21	49
2006/2007	16*	22*	21*	48*[1]	31*	**73*[4]**
2008	17*	32*	11*	38*	17*	**62*[1]**

[1] One exceedance during the annual period
[2] Four exceedances during the annual period
[3] Six exceedances during the annual period
[4] Two exceedances during the annual period
[*] Less than 12 months of data available

The annual average TSP concentration was below the annual average air quality goal of 90 $\mu g/m^3$ throughout the entire monitoring period. The highest annual average was 64 $\mu g/m^3$ measured in 2002 by HVAS C and 61 $\mu g/m^3$ also measured in 2002 by HVAS E. As discussed, that year was affected by bushfires.

In 2002, the annual average PM_{10} concentration at HVAS C was higher than the goal, but these data were collected over November and December only (and therefore the value does not represent a true annual average) and were affected by bushfires. Maximum 24-hour concentrations also occurred during this period at both HVAS C and HVAS E. As noted above, it is not uncommon for 24-hour PM_{10} concentrations to be affected by widespread airshed events such as bushfires and dust storms.

The highest 24-hour average PM_{10} concentration was 116 $\mu g/m^3$ at HVAS C. Other PM_{10} concentrations above the 50 $\mu g/m^3$ DECCW goal were:

- 66 $\mu g/m^3$ at HVAS-E measured on 14 September 2000
- 85 $\mu g/m^3$ at HVAS-E measured on 1 January 2002
- 121 $\mu g/m^3$ at HVAS-E measured on 9 November 2002, and
- 73 $\mu g/m^3$ at HVAS-E measured on 20 January 2003
- 62 $\mu g/m^3$ at HVAS-E measured in October 2008

In their 2007 State of the Environment Report, Wyong Shire Council has published TSP and $PM_{2.5}$ monitoring data collected by Delta Electricity at Wyee in recent years (www.wyongsc.nsw.gov.au). This station is approximately three kilometres north-northeast of the Tooheys Road site and to date the measured levels are generally within relevant air quality goals although there was a slight exceedance of the long-term average $PM_{2.5}$ NEPM goal.

5.2 Dust Deposition

Dust deposition data have been collected in the area surrounding the Project since September 1996. The locations of the relevant dust deposition gauges are shown in **Figure 8**. The data from 1997 expressed as insoluble solids are presented in **Table** 7. Monitoring ceased in 2004 and recommenced in 2007. Data marked with an asterisk indicates less than a full year of data is available.

There appears to be little spatial variation for the annual averages with the majority of readings below the air quality goal of 4 g/m^2/month.

Table 7. Dust deposition in the study area

Insoluble solids (g/m^2/month)										
Gauge	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2006-2007**	**2008**
D1			1.6*	1.3	1.1*	2.2*	2.4*	3.5*	2.0*	1.8*
D3	1.2	0.8	0.8	0.9	0.8*	1.6*	1.5*	1.6*	2.1*	1.0
D4	0.8	0.6	0.8	0.7	0.4				1.3*	0.7
D5	1.1	0.5	0.6	0.7	0.9*	0.8	1.0*	0.8*	1.1*	0.8
D6	1.5	2.9	2.7	1.9	3.0*	2.3*	1.9*	1.9*		
D8			0.2*	4.8	3.2*	1.2	1.8*	2.3*	2.9*	2.1*
D10				1.0*	2.3	1.9	0.9*	1.7*		
D11				1.4	2.3	2.9			2.8	2.2*
D20	2.6	0.9	0.9	1.0	0.9*	5.2*	1.1*	1.1*		

*less than 12 months of data available

Summary of Existing Air Quality

The measured dust deposition and suspended particulate levels in the Project area are considered typical of a rural area remote from industrial emission sources. As discussed, air quality in the area is largely determined by emissions from natural sources, road traffic and community and agricultural activities. From time to time particulate matter levels would be expected to be affected by smoke from bushfires and dust from regional dust storms.

Analysis of the monitoring data provided above, has led to the following conclusions about the existing air quality environment:

- Annual average insoluble solid deposition rates are below the air quality goal
- Annual average TSP concentrations at the monitoring locations are below air quality goals
- Annual average PM_{10} concentrations at the monitoring locations are below air quality goals
- There are several occasions on which PM_{10} concentrations have exceeded the 24-hour maximum air quality goal. This is largely due to widespread events such as bushfires.

For assessment of the air quality impacts due to a project the general approach recommended by the DECCW is to add dispersion model predictions to existing background levels. The result is then compared with the relevant air quality goal. As discussed above, the monitoring data will represent the cumulative effect of all the dust sources relevant to the monitoring locations, including agricultural activities and other local sources.

From the monitoring data available it has been assumed that the following conservative background concentrations would apply at the nearest receptors:

- Annual average TSP of 42 $\mu g/m^3$ (maximum measured in years not affected by bushfires)
- Annual average PM_{10} of 21 $\mu g/m^3$ (maximum measured in years not affected by bushfires)
- Annual average dust deposition of 2 g/m^2/month

In addition, the DECCW guidelines require an assessment against 24-hour PM_{10} concentrations. This assessment adopts the approach that the predicted 24-hour average PM_{10} concentration from the development should be less than 50 $\mu g/m^3$ at the nearest receptors. This approach assumes that best practice will be used to control dust from the mining activities.

In addition, this report has accessed continuous PM_{10} data collected by the DECCW at Beresfield near Newcastle to provide a contemporaneous background dataset for dust modelling purposes. In the year June 1998 to May 1999, the maximum 24-hour average and annual average PM_{10} concentrations were 38.9 and 16.5 $\mu g/m^3$ respectively. These data were used to assess the potential short-term impacts of dust emissions from the ventilation shaft.

6 EMISSION SOURCES

Dust emissions will arise from both the construction of the mine and during the operation of the mine. Dust emissions have been estimated by analysing the activities taking place in the project area. The fraction of fine, inhalable and coarse particles for each activity has been taken into account for the dispersion modelling.

The operations which apply in each case have been combined with emission factors developed, both locally and by the US EPA, to estimate the amount of dust produced by each activity. These emission factors applied are considered to be the most up to date methods for determining dust generation rates.

Details on the activities and estimated dust emissions during the construction and operational stages of the mine are discussed below. Calculations of dust emissions are presented in **Appendix C**.

6.1 Construction Stage

The development of the mine would include construction of the following:

- haul roads
- surface infrastructure
- pit top entry
- pit access road
- dams
- rail loop, and

- light vehicle road

The construction phase of the project is estimated to take approximately 80 weeks requiring approximately 643,000 cubic metres of material to be excavated as summarised in **Table 8** and **Table 9**. For assessment purposes, it has been assumed that the construction phase would take place over one year. This is likely to be a conservative assumption.

Table 8. Cut and fill quantities for Tooheys Road

Element	Cut* (m^3)	Fill (m^3)
Rail loop and spur	331,939	128,610
Tooheys Rd intersection and mine access road	10,039	43,429
Product stockpile pad	9,805	265,311
Product dam	16,311	8,828
Mine operations dam	23,409	19,440
Raw coal pad	18,120	22,034
Administration area and yard	19,086	66,532
Access road and access tracks	2,550	104,318
Drift	153,153	
TOTAL	**584,412**	**658,502**

*Cut and fill quantities subject to detailed design. Cut quantities include an assumed bulking factor of 1.1

Table 9. Cut and fill quantities for Buttonderry site

Element	Cut* (m^3)	Fill (m^3)
Pit-top facilities area	23,902	45,080
Downcast shaft	22,117	0
Upcast shaft	12,441	0
Ballast hole	281	0
TOTAL	**58,740**	**45,080**

*Cut and fill quantities subject to detailed design. Cut quantities include an assumed bulking factor of 1.1

Estimated dust emissions are summarised in **Table 10**. As discussed above, the details of the calculations are provided in **Appendix C**. No specific dust control measures apart from watering of the haul roads have been included in the emission estimates for the construction activities, however it has been assumed that a reactive strategy would be employed to ensure dust emissions were well controlled. Details of this would be included in an environmental management plan which would be developed for the construction phase of the Project.

Table 10. Estimated dust emissions during construction

Activity	TSP emission rate (kg/y)
Tooheys Road site	
Dozer clearing vegetation	11,274
Haulage	4,870
Loading of cut material from surface	2,255
Dumping of all materials	2,541
Wind erosion	24,528
TOTAL	**45,468**
Buttonderry site	
Dozer clearing vegetation	3,382
Haulage	490
Loading of cut material from surface	227
Dumping of all materials	227
Wind erosion	14,016
TOTAL	**18,341**

6.2 Operational Stage

Estimated dust emission totals during the operational stage of the mine are presented in **Table 11**. These estimates assume some control of dust emissions is achievable through the use of watering sprays on stockpiles, enclosure of conveyors on three sides and partial enclosure of the coal processing plant.

Table 11. Estimated dust emissions during mine operation

Mining Activities	TSP emission rate (kg/y)
Annual rate of mining	
Dozers on ROM stockpiles	16,911
Dozers on product stockpiles	16,911
Unloading ROM coal at pile	1,412
Additional ROM rehandle pile to conveyor	1,412
Loadout product coal to train	1,412
Reclaim coal to transfer house	1,412
Loadout coal to product stockpile	1,412
Coal Processing	2,541
WE ROM stockpile	3,504
WE Product stockpile	11,213
TOTAL	***58,137***
Peak rate of mining and processing ***(used for peak 24-hour PM_{10} predictions only)***	
Dozers on ROM stockpiles	51,437
Dozers on product stockpiles	51,437
Unloading ROM coal at pile	6,698
Additional ROM rehandle pile to conveyor	6,698
Loadout product coal to train	4,122
Reclaim coal to transfer house	4,122
Loadout coal to product stockpile	4,122
Coal Processing	12,056
WE ROM stockpile	3,504
WE Product stockpile	11,213
TOTAL	***155,408***

6.3 Ventilation shaft emissions

The ventilation shaft design assumed that the shaft is at an angle of 30 degrees to the horizontal with a final height of 4 metres at the emission point. The total air flow is 370 m^3/s with an exit velocity of 10 m/s and an effective vertical velocity of 5.1 m/s [sin(30) x 10 m/s].

The shaft would be a source of particulate matter and odour. The precise concentration of particulate matter in the ventilation air is unknown and will depend on a number of factors, in particular the effectiveness of dust controls within the mine. Measurements of respirable dust concentrations (PM_7) made at an underground mine at Angus Place were taken at five static locations underground in September 2005, and represent the levels which would be ventilated through the shaft (see **Appendix D**). The average of these measurements is 960 $\mu g/m^3$. This value needs to be adjusted to represent PM_{10} and a technical paper by the NSW Minerals Council suggests an increase of the PM_7 concentration by approximately 50%[5] would be suitable (**NSW Minerals Council, 2000, Figure2.4b**). This would equate to an in-stack PM_{10} concentration of 1,440 $\mu g/m^3$. Therefore the estimated dust emission from the ventilation system, working at 370 m^3/s, is 0.53 g/s [370 m^3/s x 1.44 x 10^{-3} g/m^3]. This emission rate has been used to assess the effects of particulate matter emissions from the vent.

Again, since the ventilation shaft is not yet operating, it is not possible to use site specific odour measurements and to assess odour emissions it has been assumed that the odour level in the ventilation air is 62 ou which was also used for the Angus Place study (**Holmes Air Sciences, 2006**). At 370 m^3/s the total odour emission rate is 22,940 $ou.m^3/s$ [370 m^3/s x 62 ou].

[5] More detailed discussion on this approach can be found in Appendix D.

When odour is assessed using the DECCW's assessment procedures the odour emission rate needs to be adjusted by certain factors that take account of the difference between the time interval over which a human being detects an odour and the averaging time that the dispersion model prediction relates to. As discussed in **Section 3.3** these factors are referred to as peak-to-mean factors and vary depending on the nature of the source and the dispersion conditions. For the current assessment the ventilation shaft is referred to as a surface point source with peak-to-mean factors in the range 4 to 7 in the far-field (see **Appendix A**).

Table 12. Modelling parameters used for the ventilation shaft

Parameter	Value
X-coord (MGA)	352187
Y-coord (MGA)	6323078
Shaft height (m)	4 (30 degree angle)
Shaft diameter (m)	6.8
Temperature (°C)	20
Exit velocity (m/s	10
Vertical exit velocity (m/s)	5.1
Flow rate (m^3/s)	370
In-vent odour concentration (ou)	62
Odour emission rate ($ou.m^3/s$)	22,940
Peaking factors A B C class stability far field D E F class stability far field	 4 7
Modelled odour emission rate ($ou.m^3/s$) A B C class stability far field D E F class stability far field	 91.760 160,580
PM_{10} emission rate (g/s)	0.53

7 APPROACH TO ASSESSMENT

This section provides a brief explanation of how the dust and odour modelling was undertaken. It is provided so that technical reviewers can appreciate how the modelling of different particle size categories was carried out.

The model used was AUSPLUME. The modelling has been based on the use of three particle-size categories (0 to 2.5 μm - referred to as FP (fine particles or $PM_{2.5}$), 2.5 to 10 μm - referred to as CM (coarse matter) and 10 to 30 μm - referred to as the Rest). Mass emission rates in each of these size ranges have been determined using the factors derived from the **SPCC (1986)** study and TSP emission rates calculated using emission factors derived from **US EPA (1985)** and **NERDDC (1988)** work (see **Appendix C**).

The distribution of particles in each particle size range is as follows:

- $PM_{2.5}$ (FP) is 0.0468 of the TSP
- $PM_{2.5\text{-}10}$ (CM) is 0.3440 of TSP
- $PM_{10\text{-}30}$ (Rest) is 0.6090 of TSP.

Modelling was undertaken using three source groups. Each group corresponded to a particle size category. Each source in the group was assumed to emit at the full TSP emission rate and to deposit from the plume in accordance with the deposition rate appropriate for particles with an aerodynamic diameter equal to the geometric mean of the limits of the particle size range, except for the $PM_{2.5}$ group, which was assumed to have a particle size of 1 μm. The predicted concentration in the three plot output files for each group were then combined according to the weightings above to determine the concentration of PM_{10} and TSP. An example of an AUSPLUME output file is provided in **Appendix E**.

Dust concentrations and depositions rates have been predicted in the vicinity of the proposed mine. Dust sources have been modelled as volume sources located according to the above ground site layout.

The modelling has been performed using the Charmhaven meteorological data (for the Tooheys Road site) and Buttonderry data (for the Buttonderry site) discussed in **Section 4** and the dust emission estimates from **Section 6.** The modelling has taken account of annual average production rates to determine long-term impacts and peak production rates to estimate short-term concentrations. The latter is considered to be a worst-case assessment given that the emission estimates are based on the maximum coal production rate.

Modelling of odour and dust emissions from the mine ventilation shaft was also carried out using AUPLUME. In this case the Buttonderry meteorological data were used.

8 MODEL PREDICTIONS AND ASSESSMENT OF IMPACTS

8.1 Construction impacts

Figures 10 to **17** show the predicted maximum 24-hour PM_{10} concentrations, the predicted annual average TSP, PM_{10} concentrations, and the predicted annual average dust (insoluble solids) deposition rates during construction activities at both the Buttonderry and Tooheys Road sites.

In assessing air quality impacts, it is necessary to add the estimated contribution from the Project to the existing background. **Table 13** summarises the predicted concentration and deposition rates at sensitive receptors due to the construction activities at the Tooheys Road and Buttonderry sites.

The predicted levels are all low. When background levels are added, there are no predicted exceedances of air quality goals. The cumulative impacts of Tooheys Road and Buttonderry construction activities would also not cause exceedances of the goals.

The maximum predicted 24-hour average PM_{10} considered on its own, without background is 3.9 $\mu g/m^3$. However if this is added to the maximum 24-hour average of 38.9 $\mu g/m^3$ measured at Beresfield, the goal would still not be exceeded.

At this stage, the details of the construction activities are not finalised, however there is a substantial margin between the modelling results and any impact levels. An air quality management plan would be developed for each construction site and off-site dust impacts controlled to acceptable levels.

Table 13. Predicted dust concentrations and deposition rates at sensitive receptors during construction activities

	24-hour maximum PM_{10} ($\mu g/m^3$)	Annual average PM_{10} ($\mu g/m^3$)		Annual average TSP ($\mu g/m^3$)		Dust deposition ($g/m^2/month$)	
Goal	50 $\mu g/m^3$	30 $\mu g/m^3$		90 $\mu g/m^3$		4 $g/m^2/month$	
Assumed Background	-	21		42		2	
	Tooheys Road Site						
Receptor	Prediction	Prediction	Plus Background	Prediction	Plus Background	Prediction	Plus Background
P1	0.6	0.03	21.03	0.04	42.03	0.00	2.00
P2	0.6	0.04	21.04	0.05	42.05	0.01	2.01
P3	1.2	0.09	21.09	0.11	42.10	0.01	2.01
P4	0.8	0.07	21.07	0.08	42.07	0.00	2.00
P5	0.5	0.05	21.05	0.06	42.05	0.00	2.00
P6	0.6	0.08	21.07	0.09	42.08	0.00	2.00
P7	0.9	0.13	21.13	0.16	42.14	0.01	2.01
P8	1.3	0.17	21.17	0.21	42.19	0.02	2.02
P9	1.2	0.18	21.18	0.22	42.20	0.03	2.03
P10	0.8	0.09	21.09	0.11	42.10	0.01	2.01
R1	0.3	0.02	21.02	0.03	42.02	0.00	2.00
R2	0.3	0.02	21.02	0.02	42.02	0.00	2.00
R3	0.2	0.02	21.02	0.02	42.02	0.00	2.00
R4	0.2	0.02	21.02	0.02	42.02	0.00	2.00
R5 (Blue Haven)	1.0	0.04	21.04	0.05	42.05	0.01	2.01
	Buttonderry Site						
P1	0.1	0.01	21.01	0.01	42.01	0.00	2.00
P2	0.1	0.01	21.01	0.01	42.01	0.00	2.00
P3	0.2	0.02	21.02	0.02	42.02	0.00	2.00
P4	0.3	0.03	21.03	0.04	42.04	0.00	2.00
P5	0.3	0.03	21.03	0.03	42.03	0.01	2.01
P6	0.1	0.01	21.01	0.01	42.01	0.00	2.00
P7	0.1	0.01	21.01	0.01	42.01	0.00	2.00
P8	0.1	0.01	21.01	0.01	42.01	0.00	2.00
P9	0.1	0.01	21.01	0.01	42.01	0.00	2.00
P10	0.1	0.00	21.00	0.00	42.00	0.00	2.00
R1	3.6	0.52	21.52	0.80	42.80	0.18	2.18
R2	4.0	0.92	21.92	1.46	43.46	0.28	2.28
R3	1.2	0.29	21.29	0.45	42.45	0.09	2.09
R4	1.4	0.12	21.12	0.19	42.19	0.05	2.05
R5 (Blue Haven)	0.1	0.01	21.01	0.01	42.01	0.00	2.00

8.2 Particulate matter impacts during operation

Figures18 to **22** present the predicted dust concentration and deposition rate due to the project surface operations at the Tooheys Road site. The predicted maximum 24-hour PM_{10}

concentrations for busiest day and average throughput are compared in **Figure 18** and **Figure 19.** In both cases there is compliance with the DECCW 24-hour PM_{10} goal of 50 µg/m^3 at the nearest residences. The predicted levels at sensitive receptors are summarised in **Table 14.**

The predicted annual average PM_{10}, TSP and dust deposition rates will all comply with air quality goals at the nearest residences when added to the assumed background concentrations of the respective pollutants.

Table 14. Predicted dust concentrations and deposition rates at sensitive receptors due to mining activities

	24-hour maximum PM_{10} (µg/m^3)		Annual average PM_{10} (µg/m^3)		Annual average TSP (µg/m^3)		Dust deposition (g/m^2/month)	
Goal	50 µg/m^3		30 µg/m^3		90 µg/m^3		4 g/m^2/month	
Assumed Background	-		21		42		2	
Receptor	Busiest day	Average day	Prediction	Plus Background	Prediction	Plus Background	Prediction	Plus Background
P1	8.0	2.7	0.2	21.2	0.2	42.2	0.01	2.01
P2	10.9	3.8	0.3	21.3	0.3	42.3	0.01	2.01
P3	28.7	9.7	0.6	21.6	0.7	42.7	0.02	2.02
P4	15.7	5.4	0.3	21.3	0.4	42.4	0.01	2.01
P5	7.4	2.8	0.2	21.2	0.2	42.2	0.00	2.00
P6	6.9	2.6	0.3	21.3	0.3	42.3	0.01	2.01
P7	14.7	5.4	0.5	21.5	0.6	42.6	0.02	2.02
P8	12.6	5.0	0.7	21.7	0.8	42.8	0.03	2.03
P9	17.2	5.8	0.7	21.7	0.8	42.8	0.04	2.04
P10	10.1	3.4	0.5	21.5	0.5	42.5	0.02	2.02
R1	4.2	1.5	0.1	21.1	0.1	42.1	0.00	2.00
R2	4.4	1.6	0.1	21.1	0.1	42.1	0.00	2.00
R3	3.3	1.2	0.1	21.1	0.1	42.1	0.00	2.00
R4	3.1	1.2	0.1	21.1	0.1	42.1	0.00	2.00
R5 (Blue Haven)	8.6	2.9	0.3	21.3	0.3	42.3	0.01	2.01

8.3 Particulate matter impacts from the ventilation shaft

Figure 23 and **Figure 24**present the predicted maximum 24-hour and annual average PM_{10} concentrations due to the ventilation shaft emissions. It has been assumed that all particulate emissions are PM_{10}. The 24-hour PM_{10} concentrations including contemporaneous background are also presented, using the continuous hourly data from Beresfield collected over the same time period as the meteorological data. There are no exceedances of the goal. The annual PM_{10} measured at Beresfield was 16.5 $\mu g/m^3$ for that period. The more conservative value of 21 $\mu g/m^3$ was used as the background in this case.

Table 15 presents the predicted PM_{10} levels at sensitive receptors due to ventilation shaft emissions. All predicted levels due to the vent alone are low.

Table 15. Predicted PM_{10} concentrations at sensitive receptors due to ventilation shaft emissions

	24-hour maximum PM_{10} ($\mu g/m^3$)		Annual average PM_{10} ($\mu g/m^3$)	
	50 $\mu g/m^3$		30 $\mu g/m^3$	
Background	Contemporaneous hourly concentration		21 $\mu g/m^3$	
Receptor	Vent alone	Vent plus background	Vent alone	Vent plus background
P1	0.6	39.1	0.15	21.15
P2	0.8	39.1	0.20	21.20
P3	0.8	39.2	0.20	21.20
P4	1.4	39.4	0.35	21.35
P5	1.0	39.1	0.20	21.20
P6	0.7	39.0	0.07	21.07
P7	0.7	39.0	0.08	21.08
P8	0.7	39.0	0.08	21.08
P9	0.6	39.0	0.07	21.07
P10	0.4	39.0	0.05	21.05
R1	2.1	40.4	0.25	21.25
R2	2.9	39.2	0.44	21.44
R3	0.8	38.9	0.18	21.18
R4	0.6	38.9	0.09	21.09
R5 (Blue Haven)	0.4	39.0	0.09	21.09

Figure 25 presents the predicted maximum 24-hour PM_{10} concentrations including background concentrations. The predictions are dominated by the background contributions and do not exceed the 24-hour goal of 50 $\mu g/m^3$.

The cumulative impacts of the dust emissions from the ventilation shaft and the dust emissions from the Tooheys Road surface facilities will also not result in any exceedances of the goals (see **Table 14)**.

8.4 Odour

The predicted 99-percentile 1-hour average odour levels due to emissions of odour from the ventilation shaft are shown in **Figure 26.**

Predicted 99th percentile odour levels at specific receptors are summarised in **Table 16.** The modelling predicts generally low levels of odour with compliance with the most stringent 2 odour unit 99th percentile goal at all receptors. In practice the levels are likely to be lower than this for the assumed emission rate as the modelling cannot fully take into account the initial dispersion of the emissions. It is proposed to direct the vent away from the residences to the south and to shield it behind terrain.

It is also possible that the odour levels in the vent and total emission rates could be higher than that assumed in the modelling. The total odour emission rate of 22,940 is approximately half the average measured for the Dartbook Underground Coal Mine that is 49,300 ou.m^3/s (**Holmes Air Sciences, 2003)** however for most residences, a doubling of the odour emission rate would not cause any exceedance of the most stringent goal and would not result in exceedances of the 3 ou goal which would be appropriate for the population density in the area.

It is recommended that options to retrofit the vent if required with a vertical ventilation stack are considered in the detailed design stage.

Table 16. Predicted 99th percentile odour levels at sensitive receptors

Receptor	99th percentile odour level (ou)
P1	0.5
P2	0.8
P3	0.7
P4	1.4
P5	1.2
P6	0.7
P7	0.7
P8	0.7
P9	0.6
P10	0.4
R1	0.7
R2	1.2
R3	0.4
R4	0.3
R5 (Blue Haven)	0.3

9 GREENHOUSE GAS EMISSIONS

This section examines the scientific principles that relate greenhouse gases (GHG) to the global warming effect and estimates emissions of GHGs associated with the Project.

9.1 Science of global warming

It is considered that the most authoritative and comprehensive documents dealing with the science of global warming are the technical assessment reports produced approximately every five years by the Intergovernmental Panel on Climate Change (IPCC). To date, the IPCC has published four technical assessment reports, the most recent being in 2007 (**IPCC, 2007**). These documents are essentially the scientific community's consensus view on climate change. The reports also provide a useful database that is necessary to understand the significance of various human activities in the context of climate change. In summary, the IPCC reports provide well written information critical to understanding the science of global warming. They include quantitative information on the production and fate of greenhouse gases and estimates of the expected increases in global temperatures for a range of scenarios intended to cover a range of possible futures. These scenarios are chosen to illustrate the range of uncertainty in the predictions of temperature increases. The Garnaut Climate Change Review, commissioned by Australia's Commonwealth, State and Territory governments, released a final report in September 2008 which suggests that emissions are tracking at the upper bounds of the scenarios modelled by the IPCC (**Garnaut, 2008**).

The temperature of the earth's atmosphere is determined almost entirely[6] by the balance in radiation received from the sun and that re-radiated to outer space (see for example **IPCC, 2001**).

The parts of the radiation spectrum through which the earth can re-radiate and lose energy to outer space depends on the composition of the atmosphere. Certain gases including water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and a range of other gases absorb electromagnetic energy in the infrared spectrum. Solar radiation from the sun contains most of its energy in the infrared, visible and ultraviolet parts of the spectrum.

Sunlight passes through the atmosphere and warms both the atmosphere and the earth's surface. Clouds and the earth's surface directly reflect some of the sun's radiation back to space, but much of the sun's radiation is absorbed by the earth's surface and some by the atmosphere, which are warmed. The warmed earth and its atmosphere then reradiate this energy back to space. For the average global temperature to remain constant, the incoming radiation from the sun must be balanced by the outgoing energy radiated from the earth and atmosphere.

Global warming (and the associated climate change) occurs because of the changing composition of the atmosphere, namely the increasing concentrations of GHGs, in particular CO_2, CH_4 and N_2O. These gases reduce the parts of the electromagnetic spectrum through which energy can be re-radiated from the earth. In response, the earth's temperature must increase to allow the rate of energy loss from the earth to increase and thereby allow the incoming and outgoing radiation to be brought back into balance.

In summary, GHGs absorb electromagnetic energy and change the radiation balance of the earth causing the temperature to increase so that the radiation balance is restored.

[6] The words "almost entirely" are used because the residual heat from the earth's formation and from the decay of radioactive elements in the earth have some effect on the earth's temperature.

Without the presence of any GHGs, the earth's average temperature would be extremely cold (-18 ^{o}C) (**Seinfeld and Pandis, 1998**) and most of the planet would be uninhabitable. However, the effect of increasing greenhouse gases is to change existing climates and this will place stresses on current ecological systems that have adapted to current climate regimes.

Increasing concentrations of CO_2, CH_4 and other GHGs will cause the temperature of the atmosphere to increase but, because the earth transports heat from the equator towards the poles in a complicated way via ocean currents and winds, the precise effect of increasing concentrations is difficult to estimate for any particular location.

The cause of the increasing concentrations of CO_2 and CH_4 is largely attributable to the increase in the worldwide use of fossil fuels to provide energy for increasing populations, which also have increasing per capita consumptions of energy. However, land clearing on a global scale is also an important cause in the change in the concentrations of CO_2.

9.2 Quantifying greenhouse effects

Scientific publications sometimes refer to the quantity of carbon stored in the atmosphere or may refer to the equivalent quantity of carbon dioxide. In this context, 1.0 tonne (t) of carbon is the same as 3.67 t of CO_2. Most of the analysis in this report will refer to CO_2 rather than carbon, as this appears to be the most common approach used in Australia.

The estimated quantity of carbon dioxide stored in the atmosphere now is approximately 3,000 Gigatonnes (Gt). The International Energy Agency (**IEA, 2009**) estimates that in 2006, the global emissions of CO_2 from burning fossil fuels were 29,195.4 Mt per year, of which Australia's emissions of CO_2 from burning fossil fuels were 417.06 Mt CO_2 (i.e. 1.4% of the global anthropogenic, or human-related, total).

Because the relationship between global warming and greenhouse gas concentrations is not linear[7] there is no accepted method to determine the contribution that a given emission of greenhouse gases might make to global warming.

To understand this point it is useful to consider the following discussion from Section 1.3.1 of the Second Scientific Assessment Report prepared by the IPCC (**IPCC, 1996**).

> *"The amount of carbon dioxide in the atmosphere has increased by more than 25% in the past century and since the beginning of the industrial revolution, an increase which is known to be in large part due to the combustion of fossil fuels and the removal of forests (Chapter 2 [*of the report*]). In the absence of controls, projections are that the future rate of increase in carbon dioxide amount may accelerate and concentrations could double from pre-industrial values within the next 50 to 100 years (**IPCC, 1994**).*
>
> *The increased amount of carbon dioxide is leading to climate change and will produce, on average, a global warming of the Earth's surface because of its enhanced greenhouse effect – although the magnitude and significance of the effects are not yet fully resolved. If, for instance, the amount of carbon dioxide in the atmosphere were suddenly doubled, but with other things remaining the same, the outgoing long-wave radiation would be reduced by about 4 Wm^{-2}. To restore the radiative balance, the atmosphere must warm up and, in the absence of other changes, the warming at the surface and throughout the*

[7] The warming effect of a given quantity of greenhouse gases to the atmosphere is less and less as the concentration become higher and higher.

troposphere would be about 1.2 °C. However, many other factors will change, and various feedbacks come into play (see Section 1.4.1 [of the report]*), so the best estimate of the average global warming for doubled carbon dioxide is 2.5 °C (**IPCC, 1990**). Such a change is very large by historical standards and would be associated with major climate changes around the world.*

Note if carbon dioxide were removed from the atmosphere altogether, the change in out going radiation would be about 30 Wm^{-2} – 7 to 8 times as big as the change for doubling – and the magnitude of the temperature change would be similarly enhanced. The reason is that the carbon dioxide absorption is saturated over part of the spectral region where it absorbs, so the amount of absorption changes at a much smaller rate than the concentration of the gas (Chapter 2 [of the report]*). If the concentrations of carbon dioxide are more than doubled, then the relationship between radiative forcing and concentration is such that each further doubling provides a further radiative forcing of about 4 Wm^{-2}."*

9.3 Greenhouse gas inventories

Greenhouse gas inventories are calculated according to a number of different methods. The procedures specified under the Kyoto Protocol United Nations Framework Convention on Climate Change are the most common.

The protocol nominates the following GHGs:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs); and
- Perfluorocarbons (PFCs).

From the point of view of the Project, only CO_2, CH_4 and N_2O are relevant.

CO_2 and N_2O are formed and released during the combustion of gaseous, liquid and solid fuels. They are liberated when fuels are burnt in diesel powered equipment and in the generation of the electrical energy that will be used by the Project. Fugitive emissions from underground mines involve the release of CH_4 and CO_2. during the mining process when coal seams are fractured. Residual gases are also release from post mining activities. Off-site transport and the final end-use of the coal will also be sources of GHG emissions.

Inventories of greenhouse gas emissions can be calculated using published emission factors. Different gases have different greenhouse warming effects (referred to as warming potentials) and emission factors take into account the global warming potentials of the gases created during combustion.

The global warming potentials assumed in the Department of Climate Change (**DCC, 2009a**) emission factors are as follows.

- CO_2 – 1.
- CH_4 – 21.
- N_2O – 310.
- NO_2 – not included.

When the global warming potentials are applied to the estimated emissions then the resulting estimate is referred to in terms of CO_2-equivalent emissions.

9.4 Emission factors

The National Greenhouse Accounts (NGA) Factors published by the Department of Climate Change (**DCC, 2009a**) have been used to convert fuel usage and electricity consumption into CO_2-equivalent emissions. The relevant emission factors are summarised in **Table 17.**

Table 17:Summary of greenhouse gas emission factors

Type of Fuel and Electricity	Emission factor		Scope	Source
Mining and extraction				
Diesel - on-site transport activities[a]	2.7	t CO_2-e/kL	1	Table 4 (**DCC, 2009a**)
	0.2	t CO_2-e/kL	3	Table 38 (**DCC, 2009a**)
Electricity[b]	0.89	kg CO_2-e/kWh	2	Table 39 (**DCC, 2009a**)
	0.18	kg CO_2-e/kWh	3	
Extraction of coal (gassy underground mine)	305	kg CO_2-e/tonne ROM	1	Table 6 (**DCC 2009a**)
Fugitive emissions from post mining activities	14	kg CO_2-e/tonne ROM	1	Table 7 (**DCC 2009a**)
Transport of product coal				
Rail transport	12.3	g CO_2-e/t-km	3	**QR Network Access (2002)**
Fuel oil (ship transport)	73.1	kg CO_2-e/GJ	1	Table 4 (**DCC, 2009a**)
	5.3	kg CO_2-e/GJ	3	Table 38 (**DCC, 2009a**)
Usage of product coal				
Burning coal in a power station	88.43	kg CO_2-e/GJ	3	Table 1 (**DCC, 2009a**)

Notes:

(a) The emission factors for diesel usage include Scope 1 emissions which are associated with burning the fuel and Scope 3 emissions which are associated with producing the diesel.

(b) The emission factors for electrical energy include Scope 2 emissions (i.e. those associated with generating the electricity) and Scope 3 emissions (those associated with producing the fuel for the power station and the distribution losses involved in delivering electricity to the mine).

9.5 Diesel use

The mine will consume quantities of diesel in mining the panel. It is estimated that 0.19 litres of diesel will be consumed per tonne of ROM coal mined. For 151 Mt this would equate to 28,690,000 litres [151 x 10^6 t x 0.19 t/l]. Each litre of diesel fuel burnt is assumed to result in the release of 2.9 kg of CO_2-e. Total CO_2-e emissions are therefore 83,201 t [28,690,000 l x 2.9 kg/l x 1/1000 kg/t].

9.6 Electricity consumption

Typically underground coal mining requires approximately 11 kWh/t of coal. The production from the panels is estimated to be 151 Mt. This would result in the use of 1,661,000,000 kWh of electrical energy, which in turn would result in the emission of 1,777,270 t CO_2-e [1.07 kg CO_2-e/kWh x1,661,000,000 kWh x 1/1000 kg/t]. This includes the emission for the full fuel cycle in generating the electricity. The Scope 2 and 3 components would be 1,478,290 and 298,980 t of CO_2-e respectively.

9.7 Extraction of coal

The **DCC (2009)** publication (Table 6 in the report) suggests values for gassy underground mines in NSW of 305 kg CO_2-e per tonne of raw coal during mining and 14 kg CO_2-e per tonne of raw coal post mining (Table 7). The production from the panels is estimated to be 151 Mt, making total emissions of 48,109,000 t CO_2-e [(305 + 14) kg CO_2-e/t x 151 x 10^6 t x 1/1000 kg/t]. Post mining, the residual emission are estimated to be 14 kg CO_2-e per tonne of raw coal making total emissions of kg CO_2-e [14 kg CO_2-e/t x 151 x 10^6 t]

9.8 Transport of the coal

The round trip to transport coal by rail to the port is estimated to 123.6 km. According to a study commissioned by **QR Network Access** (**2002**) the Australian average CO_2-e rate for rail transport is 0.0123 kg/net tonne-km. For transporting 151 Mt, the CO_2-e emission would be 114,781 t [151 x 10^6 x 123.6/2 km x 0.0123 kg/tonne-km x 1/1000 kg/t].

Most of the coal will be exported to North Asia with a one-way shipping distance of approximately 8400 km. Emissions were estimated as follows:

- Average ship capacity of 89,000 t (**Boyle, 2009**)
- Freight shipping energy efficiency is equal to 4.16 t.km/MJ (**The Allen Consulting Group, 2001**)
- Ships are assumed to burn heavy fuel oil

Total emission for the transportation of 151 Mt are therefore 23,904,461 t [151 x 10^6 t x 8400 km x 1/4.16 MJ/t.km x (73.1 + 5.8) kg/GJ x 1/1000 MJ/GJ x 1/1000 kg/t]

9.9 End use of the coal

Data from W2CP indicates that average specific energy of the coal from W2CP will be 26.21 MJ/kg and according to the **DCC (2009a)** (Table 1) the Scope 1 emission factor for power stations burning black coal is 88.43 kg CO_2-e/GJ. Thus if a nominal 151 Mt of ROM coal is burnt in a NSW Power Station and assuming that the dry ash-free carbon content is 82% then the CO_2-e emission would be 287,631,757 t [151 x 10^6 t x 26.21 GJ/t x 88.43 kg/GJ x 0.82 x 1/1000 kg/t]. This accounting for the final combustion of the coal would cover any oxidation or spontaneous combustion which could occur.

9.10 Summary

The total greenhouse gas emissions in tonnes of CO_2-e, from each of the sources discussed above are summarised in **Table 18.** These are the emissions for the life of the project. The emissions from the end use of the coal are approximately 86% of the total emissions.

Table 18 Greenhouse gas emissions summary for life of the mine

Source	Emissions (t of CO_2-e)			
	Scope 1	Scope 2	Scope 3	Total
Diesel usage	77463		5738	83,201
Electricity usage		1,478,290	298,980	1,767,270
Coal extraction	48,109,300			48,109,000
Transport by rail		114,781		114,781
Transport by sea		23,904,461		23,904,461
End use of the coal			287,631,757	287,631,757
TOTAL				**361,080,470**

9.11 Effect of greenhouse gas emissions

In November 2006, the NSW Land and Environment Court handed down a landmark decision (the judgement of Her Honour Pain J in the matter of *Gray v The Minister for Planning and ors NSWLEC 720*) which requires all new industry developments to undertake a global warming impact study in the context of the principles of ecologically sustainable development (ESD).

For the purposes of this report, the ESD principles have been taken to be those defined by the Department of Planning (**DUAP, 2000**), which are as follows.

1. The precautionary principle – namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
2. Inter-generational equity – namely, that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
3. Conservation of biological diversity and ecological integrity.
4. Improved valuation and pricing of environmental resources.

To assess the effects of the greenhouse gas emissions associated with the Project, it is useful to consider the contribution of total emissions from both mining and burning of the coal to global warming. For these purposes, it is assumed that all the coal in W2CP is mined in forty years.

As the relationship between global warming and greenhouse gas concentrations is not linear[8] there is no accepted method to determine the contribution that a given emission of greenhouse gases might make to global warming.

To understand this point it is useful to consider the discussion from Section 1.3.1 of the Second Assessment Report prepared by the IPCC (**IPCC, 1996**), which explains the relationship between the concentration of greenhouse gases and global temperature.

At any period in time, it would be reasonable simply to compare the estimated total emission of CO_2-equivalent from the various activities for the year when W2CP is mined (9.025 = 361/40

[8] The warming effect of a given quantity of greenhouse gases to the atmosphere is less and less as the concentration becomes higher and higher (see Section 1.3 of **IPCC (1996)**).

Mtpa), with the estimated equivalent global emission of 27 Gtpa[9]. On this basis, the emission of 9 Mtpa from the mining and burning of coal from the Project is estimated to be 0.031% of global CO_2-equivalent annual emissions (based on estimated global emissions for 2003). Thus, the Project could be considered to contribute 0.031% to the increase in global temperatures caused by the increase in greenhouse gas emissions as they are currently. This invites the question as to what temperature rise might be attributed to the greenhouse gases arising from the Project.

It is also relevant to note that the Project's annual Scope 1, 2 and 3 emissions of 9.025 Mt are approximately 1.6% of the 553 Mt that was estimated to be Australia's net greenhouse gas emissions for 2008 and 2.2% of the 416 Mt that was estimated to be the Australian energy sector's emissions for 2008 (**DCC 2009b**). It should also be noted that the estimates for Australia's emissions do not include off-shore end-use Scope 3 emissions which make up approximately 86% of the W2CP emissions. If these are excluded from the W2CP estimate, the Project emissions are approximately 0.2% of the 2008 net Australian greenhouse emissions and approximately 0.3% of the 2008 energy sector emissions.

Based on the IPPC estimate, a doubling of the CO_2-equivalent concentration in the atmosphere would lead to a 2.5 °C increase in global average temperature, and that the current global CO_2 load is 2,750 Gt, we can estimate that the total emissions from the Project would lead to an increase in global temperature of 0.000328 °C [$(361 \times 10^6 / 2{,}750 \times 10^9) \times 2.5$ °C].

There will clearly be no measurable environmental effect due to the emissions of greenhouse gases from the Project even when the customer's use of the coal is taken into account. Any environmental assessment would conclude that the effects of the emissions from the Project are unmeasurable.

In practice of course, the effects of global warming and associated climate change are the cumulative effect of many thousands of such sources and it is the cumulative effects that pose a threat to ESD principles.

10 CONCLUSIONS

The Project has been assessed to identify potential impacts due to emissions of dust, odour and greenhouse gases as a result of underground mining.

Concentrations of dust and deposition rates of dust from the construction phase of the project are predicted to be well within DECCW air quality criteria.

During the operational phase of the project, air quality impacts for particulate matter are in compliance with long-term goals when background is taken into account, and in compliance with the short-term 24-hour PM_{10} goal when the project is considered on its own.

Further mitigation measures, such as dust suppression spray watering of the stockpiles will reduce the short-term impacts further.

The modelled vent configuration was at an angle of 30 degrees to the horizontal. This would result in acceptable air quality impacts of both particulate matter and odour, based on the emission assumptions. It is recommended that a contingency be incorporated into the vent design to retrofit with a vertical stack if required.

[9] Estimate for 2003 taken from http://cdiac.ornl.gov/ftp/ndp030/global.1751_2003.ems

There will be emissions of greenhouse gas emissions as a result of the Project and as a result of burning the coal that will be produced by the Project (i.e. the coal from W2CP). These emissions will not by themselves have any significant impact on global warming. However the Project should use all practicable means to reduce greenhouse gas emissions through efficient use of fuel and electricity.

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APPENDIX A

PEAK TO MEAN TABLES

A.1 PEAK TO MEAN RATIOS

The following table shows recommended factors for estimating peak concentrations in flat terrain (Katestone Scientific 1995 and 1998) (Source DEC, 2005).

Table A1 – Factors for estimating peak concentration in flat terrain

Type	Pasquill-Gifford stability class	Near field P/M60*	Far field P/M60*
Area	A, B, C, D	2.5	2.3
	E, F	2.3	1.9
Line	A – F	6	6
Surface wake-free point	A, B, C	12	4
	D, E, F	25	7
Tall wake-free point	A, B, C	17	3
	D, E, F	35	6
Wake-affected point	A – F	2.3	2.3
Volume	A – F	2.3	2.3

*Ratio of peak 1-second average concentrations to mean 1-hour average concentrations

APPENDIX B

Joint Wind Speed, Wind Direction and Stability Class Frequency Tables

STATISTICS FOR FILE: \\Kerry6000\jobs\Wallarah\met\CharmhavenWH2.AUS
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.004682	0.001639	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006320
NE	0.003745	0.003043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006788
ENE	0.002692	0.000585	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.003394
E	0.004916	0.002809	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007725
ESE	0.005735	0.003277	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009012
SE	0.004916	0.004448	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009363
SSE	0.003745	0.003628	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.007491
S	0.003394	0.003277	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006671
SSW	0.005735	0.003394	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.009246
SW	0.009714	0.003043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012757
WSW	0.007374	0.002341	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.009949
W	0.007491	0.002341	0.000351	0.000000	0.000000	0.000000	0.000000	0.000000	0.010183
WNW	0.005852	0.001287	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.007257
NW	0.004213	0.001522	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005735
NNW	0.004096	0.001639	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.005969
N	0.004565	0.001522	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006086
CALM									0.019312
TOTAL	0.082865	0.039794	0.001287	0.000000	0.000000	0.000000	0.000000	0.000000	0.143258

MEAN WIND SPEED (m/s) = 1.25
NUMBER OF OBSERVATIONS = 1224

PASQUILL STABILITY CLASS 'B'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000585	0.003043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003628
NE	0.001053	0.005033	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006086
ENE	0.000468	0.004565	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005033
E	0.001404	0.011353	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012757
ESE	0.001404	0.010417	0.000351	0.000000	0.000000	0.000000	0.000000	0.000000	0.012172
SE	0.000234	0.009363	0.001873	0.000000	0.000000	0.000000	0.000000	0.000000	0.011470
SSE	0.000351	0.007842	0.005033	0.000117	0.000000	0.000000	0.000000	0.000000	0.013343
S	0.000117	0.004331	0.001522	0.000000	0.000000	0.000000	0.000000	0.000000	0.005969
SSW	0.000117	0.003628	0.000468	0.000000	0.000000	0.000000	0.000000	0.000000	0.004213
SW	0.002107	0.001990	0.000585	0.000000	0.000000	0.000000	0.000000	0.000000	0.004682
WSW	0.003277	0.003043	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.006437
W	0.000351	0.002809	0.000585	0.000585	0.000000	0.000000	0.000000	0.000000	0.004331
WNW	0.000468	0.000936	0.001287	0.000000	0.000000	0.000000	0.000000	0.000000	0.002692
NW	0.000117	0.000819	0.000585	0.000000	0.000000	0.000000	0.000000	0.000000	0.001522
NNW	0.000351	0.000351	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.000936
N	0.000468	0.001873	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002341
CALM									0.000000
TOTAL	0.012875	0.071395	0.012640	0.000702	0.000000	0.000000	0.000000	0.000000	0.097612

MEAN WIND SPEED (m/s) = 2.31
NUMBER OF OBSERVATIONS = 834

PASQUILL STABILITY CLASS 'C'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000585	0.002458	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.003277
NE	0.000585	0.009012	0.000702	0.000000	0.000000	0.000000	0.000000	0.000000	0.010300
ENE	0.000234	0.005735	0.002341	0.000000	0.000000	0.000000	0.000000	0.000000	0.008310
E	0.001287	0.008193	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.009714
ESE	0.000351	0.006788	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.007257
SE	0.000234	0.002341	0.001053	0.000000	0.000000	0.000000	0.000000	0.000000	0.003628
SSE	0.000000	0.000585	0.003511	0.000351	0.000000	0.000000	0.000000	0.000000	0.004448
S	0.000117	0.001756	0.005501	0.000585	0.000000	0.000000	0.000000	0.000000	0.007959
SSW	0.000000	0.006086	0.007842	0.001639	0.000000	0.000000	0.000000	0.000000	0.015566
SW	0.001873	0.010534	0.003277	0.000702	0.000000	0.000000	0.000000	0.000000	0.016386
WSW	0.005384	0.008895	0.002692	0.000585	0.000000	0.000000	0.000000	0.000000	0.017556
W	0.000468	0.004448	0.002107	0.001404	0.000000	0.000000	0.000000	0.000000	0.008427
WNW	0.000234	0.000819	0.001404	0.001053	0.000000	0.000000	0.000000	0.000000	0.003511
NW	0.000234	0.000819	0.001639	0.000468	0.000000	0.000000	0.000000	0.000000	0.003160
NNW	0.000117	0.001522	0.001287	0.001053	0.000000	0.000000	0.000000	0.000000	0.003979
N	0.001053	0.002575	0.000936	0.000234	0.000000	0.000000	0.000000	0.000000	0.004799
CALM									0.000000
TOTAL	0.012757	0.072566	0.034878	0.008076	0.000000	0.000000	0.000000	0.000000	0.128277

MEAN WIND SPEED (m/s) = 2.76
NUMBER OF OBSERVATIONS = 1096

PASQUILL STABILITY CLASS 'D'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001170	0.003745	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.005150
NE	0.001404	0.009831	0.001522	0.000000	0.000000	0.000000	0.000000	0.000000	0.012757
ENE	0.001287	0.002224	0.003160	0.000000	0.000117	0.000000	0.000000	0.000000	0.006788
E	0.000000	0.000117	0.000117	0.000000	0.000000	0.000117	0.000000	0.000000	0.000351
ESE	0.000117	0.000234	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.000468
SE	0.000000	0.000702	0.000468	0.000000	0.000000	0.000000	0.000000	0.000000	0.001170
SSE	0.000000	0.000468	0.001287	0.000234	0.000000	0.000000	0.000000	0.000000	0.001990
S	0.000351	0.001990	0.003745	0.000702	0.000000	0.000000	0.000000	0.000000	0.006788
SSW	0.000936	0.009246	0.009597	0.003862	0.000117	0.000000	0.000000	0.000000	0.023759
SW	0.005501	0.028324	0.017790	0.006320	0.000351	0.000000	0.000000	0.000000	0.058287
WSW	0.004213	0.035581	0.003979	0.001873	0.000702	0.000000	0.000000	0.000000	0.046348
W	0.001404	0.007491	0.002809	0.001404	0.001873	0.000000	0.000000	0.000000	0.014981
WNW	0.000351	0.002341	0.003043	0.001287	0.001873	0.000351	0.000000	0.000000	0.009246
NW	0.000234	0.001639	0.002224	0.001053	0.001170	0.000117	0.000000	0.000000	0.006437
NNW	0.000351	0.002926	0.001053	0.000000	0.000351	0.000000	0.000000	0.000000	0.004682
N	0.000702	0.005033	0.002107	0.000000	0.000000	0.000000	0.000000	0.000000	0.007842
CALM									0.000000
TOTAL	0.018024	0.111891	0.053254	0.016737	0.006554	0.000585	0.000000	0.000000	0.207046

MEAN WIND SPEED (m/s) = 2.95
NUMBER OF OBSERVATIONS = 1769

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001404	0.001990	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003394
NE	0.005033	0.007608	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012640
ENE	0.006905	0.006320	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.013226
E	0.005384	0.002458	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007842
ESE	0.002458	0.004448	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006905
SE	0.002458	0.004565	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007022
SSE	0.000585	0.002926	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003511
S	0.000234	0.003862	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004096
SSW	0.001522	0.004096	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005618
SW	0.008193	0.005033	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.013226
WSW	0.011353	0.013577	0.000117	0.000000	0.000000	0.000000	0.000000	0.000000	0.025047
W	0.001873	0.003043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004916
WNW	0.001404	0.002107	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003511
NW	0.001639	0.000351	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001990
NNW	0.000819	0.000819	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001639
N	0.001170	0.002458	0.000234	0.000000	0.000000	0.000000	0.000000	0.000000	0.003862
CALM									0.000117
TOTAL	0.052434	0.065660	0.000351	0.000000	0.000000	0.000000	0.000000	0.000000	0.118563

MEAN WIND SPEED (m/s) = 1.68
NUMBER OF OBSERVATIONS = 1013

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.004799	0.000468	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005267
NE	0.003979	0.000585	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004565
ENE	0.005150	0.000468	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005618
E	0.006905	0.001522	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008427
ESE	0.006086	0.002809	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008895
SE	0.007374	0.005735	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.013109
SSE	0.007842	0.004799	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012640
S	0.007022	0.002809	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009831
SSW	0.013109	0.002692	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.015801
SW	0.031835	0.003160	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.034995
WSW	0.041550	0.002107	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.043656
W	0.027856	0.001522	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.029377
WNW	0.017205	0.000585	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.017790
NW	0.011002	0.000351	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.011353
NNW	0.009129	0.000468	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009597
N	0.007257	0.001756	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009012
CALM									0.065309
TOTAL	0.208099	0.031835	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.305243

MEAN WIND SPEED (m/s) = 0.95
NUMBER OF OBSERVATIONS = 2608

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.013226	0.013343	0.000468	0.000000	0.000000	0.000000	0.000000	0.000000	0.027037
NE	0.015801	0.035112	0.002224	0.000000	0.000000	0.000000	0.000000	0.000000	0.053137
ENE	0.016737	0.019897	0.005618	0.000000	0.000117	0.000000	0.000000	0.000000	0.042369
E	0.019897	0.026451	0.000351	0.000000	0.000000	0.000117	0.000000	0.000000	0.046816
ESE	0.016152	0.027973	0.000585	0.000000	0.000000	0.000000	0.000000	0.000000	0.044710
SE	0.015215	0.027154	0.003394	0.000000	0.000000	0.000000	0.000000	0.000000	0.045763
SSE	0.012523	0.020248	0.009949	0.000702	0.000000	0.000000	0.000000	0.000000	0.043422
S	0.011236	0.018024	0.010768	0.001287	0.000000	0.000000	0.000000	0.000000	0.041316
SSW	0.021419	0.029143	0.018024	0.005501	0.000117	0.000000	0.000000	0.000000	0.074204
SW	0.059223	0.052083	0.021653	0.007022	0.000351	0.000000	0.000000	0.000000	0.140332
WSW	0.073151	0.065543	0.007140	0.002458	0.000702	0.000000	0.000000	0.000000	0.148993
W	0.039443	0.021653	0.005852	0.003394	0.001873	0.000000	0.000000	0.000000	0.072214
WNW	0.025515	0.008076	0.005852	0.002341	0.001873	0.000351	0.000000	0.000000	0.044007
NW	0.017439	0.005501	0.004448	0.001522	0.001170	0.000117	0.000000	0.000000	0.030197
NNW	0.014864	0.007725	0.002809	0.001053	0.000351	0.000000	0.000000	0.000000	0.026802
N	0.015215	0.015215	0.003277	0.000234	0.000000	0.000000	0.000000	0.000000	0.033942
CALM									0.084738
TOTAL	0.387055	0.393141	0.102411	0.025515	0.006554	0.000585	0.000000	0.000000	1.000000

MEAN WIND SPEED (m/s) = 1.86
NUMBER OF OBSERVATIONS = 8544

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 14.3%
B : 9.8%
C : 12.8%
D : 20.7%
E : 11.9%
F : 30.5%

STATISTICS FOR FILE: \\Kerry6000\jobs\Wallarah\met\Buttonderry\ButtonderryJun98-May99_rev.aus
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000457	0.001941	0.001826	0.000457	0.000000	0.000000	0.000000	0.000000	0.004680
NE	0.000913	0.002511	0.002283	0.000228	0.000000	0.000000	0.000000	0.000000	0.005936
ENE	0.000571	0.001826	0.003082	0.001027	0.000000	0.000000	0.000000	0.000000	0.006507
E	0.001712	0.005708	0.005708	0.003196	0.000000	0.000000	0.000000	0.000000	0.016324
ESE	0.002968	0.008904	0.009018	0.003539	0.000000	0.000000	0.000000	0.000000	0.024429
SE	0.002055	0.006164	0.004110	0.004566	0.000000	0.000000	0.000000	0.000000	0.016895
SSE	0.002511	0.006393	0.003425	0.001826	0.000000	0.000000	0.000000	0.000000	0.014155
S	0.003196	0.006279	0.004110	0.000685	0.000000	0.000000	0.000000	0.000000	0.014269
SSW	0.003653	0.006507	0.002511	0.000457	0.000000	0.000000	0.000000	0.000000	0.013128
SW	0.004224	0.008676	0.003311	0.001941	0.000000	0.000000	0.000000	0.000000	0.018151
WSW	0.005479	0.006735	0.001484	0.001256	0.000000	0.000000	0.000000	0.000000	0.014954
W	0.004909	0.005594	0.000571	0.000114	0.000000	0.000000	0.000000	0.000000	0.011187
WNW	0.003539	0.003196	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.006963
NW	0.004566	0.015753	0.009361	0.000685	0.000000	0.000000	0.000000	0.000000	0.030365
NNW	0.002626	0.011644	0.006507	0.000685	0.000000	0.000000	0.000000	0.000000	0.021461
N	0.001256	0.003767	0.002626	0.000114	0.000000	0.000000	0.000000	0.000000	0.007763
CALM									0.000457
TOTAL	0.044635	0.101598	0.060160	0.020776	0.000000	0.000000	0.000000	0.000000	0.227626

MEAN WIND SPEED (m/s) = 2.69
NUMBER OF OBSERVATIONS = 1994

PASQUILL STABILITY CLASS 'B'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
ENE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
E	0.000000	0.000000	0.000000	0.000457	0.000000	0.000000	0.000000	0.000000	0.000457
ESE	0.000228	0.004452	0.004110	0.002397	0.000000	0.000000	0.000000	0.000000	0.011187
SE	0.000114	0.000228	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000571
SSE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
S	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
SSW	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000228
SW	0.000685	0.000799	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.001712
WSW	0.002169	0.004452	0.001598	0.001484	0.000000	0.000000	0.000000	0.000000	0.009703
W	0.001712	0.002055	0.001941	0.001142	0.000000	0.000000	0.000000	0.000000	0.006849
WNW	0.000114	0.001027	0.000342	0.000114	0.000000	0.000000	0.000000	0.000000	0.001598
NW	0.000571	0.004795	0.002511	0.000342	0.000000	0.000000	0.000000	0.000000	0.008219
NNW	0.000114	0.000571	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.001370
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CALM									0.000000
TOTAL	0.006050	0.018379	0.011644	0.005936	0.000000	0.000000	0.000000	0.000000	0.042009

MEAN WIND SPEED (m/s) = 2.95
NUMBER OF OBSERVATIONS = 368

PASQUILL STABILITY CLASS 'C'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
ENE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
E	0.000000	0.000342	0.000457	0.000342	0.000000	0.000000	0.000000	0.000000	0.001142
ESE	0.000000	0.001941	0.003995	0.003311	0.000000	0.000000	0.000000	0.000000	0.009247
SE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SSE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
S	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
SSW	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SW	0.000228	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000342
WSW	0.001941	0.002854	0.000799	0.000000	0.000000	0.000000	0.000000	0.000000	0.005594
W	0.002626	0.004452	0.001941	0.001256	0.000000	0.000000	0.000000	0.000000	0.010274
WNW	0.000913	0.001712	0.001256	0.001826	0.000000	0.000000	0.000000	0.000000	0.005708
NW	0.000457	0.003995	0.003995	0.000342	0.000000	0.000000	0.000000	0.000000	0.008790
NNW	0.000000	0.001598	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.002283
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CALM									0.000114
TOTAL	0.006279	0.017009	0.013128	0.007078	0.000000	0.000000	0.000000	0.000000	0.043607

MEAN WIND SPEED (m/s) = 3.04
NUMBER OF OBSERVATIONS = 382

PASQUILL STABILITY CLASS 'D'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
ENE	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
E	0.000000	0.000228	0.001598	0.000228	0.000913	0.000114	0.000000	0.000000	0.003082
ESE	0.000228	0.006164	0.009475	0.002283	0.002740	0.000228	0.000000	0.000000	0.021119
SE	0.000114	0.000000	0.003311	0.003653	0.001941	0.000114	0.000000	0.000000	0.009132
SSE	0.000000	0.000000	0.001941	0.001484	0.001027	0.000000	0.000000	0.000000	0.004452
S	0.000000	0.000000	0.001941	0.001370	0.000342	0.000000	0.000000	0.000000	0.003653
SSW	0.000000	0.000000	0.001370	0.001484	0.000571	0.000228	0.000000	0.000000	0.003653
SW	0.000457	0.000228	0.001256	0.000457	0.001484	0.000913	0.000000	0.000000	0.004795
WSW	0.005936	0.007648	0.003082	0.002397	0.002626	0.000457	0.000000	0.000000	0.022146
W	0.037329	0.021689	0.004224	0.002055	0.002740	0.002055	0.000114	0.000000	0.070205
WNW	0.025342	0.010616	0.005365	0.002283	0.001826	0.000571	0.000000	0.000000	0.046005
NW	0.005365	0.016096	0.027169	0.009817	0.000913	0.000000	0.000000	0.000000	0.059361
NNW	0.001941	0.007991	0.007420	0.006164	0.001027	0.000000	0.000000	0.000000	0.024543
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CALM									0.000228
TOTAL	0.076712	0.070662	0.068151	0.033676	0.018151	0.004680	0.000114	0.000000	0.272374

MEAN WIND SPEED (m/s) = 3.09
NUMBER OF OBSERVATIONS = 2386

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000000	0.000000	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
NE	0.000000	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
ENE	0.000000	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
E	0.000114	0.000571	0.000799	0.000000	0.000000	0.000000	0.000000	0.000000	0.001484
ESE	0.000457	0.003539	0.001941	0.000000	0.000000	0.000000	0.000000	0.000000	0.005936
SE	0.000342	0.001027	0.000799	0.000000	0.000000	0.000000	0.000000	0.000000	0.002169
SSE	0.000114	0.000571	0.001826	0.000000	0.000000	0.000000	0.000000	0.000000	0.002511
S	0.000000	0.000913	0.001712	0.000000	0.000000	0.000000	0.000000	0.000000	0.002626
SSW	0.000228	0.001256	0.001598	0.000000	0.000000	0.000000	0.000000	0.000000	0.003082
SW	0.000913	0.001256	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.002397
WSW	0.010274	0.006963	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.017352
W	0.045434	0.014498	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.059932
WNW	0.029452	0.007991	0.000571	0.000114	0.000000	0.000000	0.000000	0.000000	0.038128
NW	0.009361	0.011644	0.007648	0.000342	0.000000	0.000000	0.000000	0.000000	0.028995
NNW	0.001370	0.004795	0.009132	0.001142	0.000000	0.000000	0.000000	0.000000	0.016438
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CALM									0.000457
TOTAL	0.098059	0.055251	0.026484	0.001598	0.000000	0.000000	0.000000	0.000000	0.181849

MEAN WIND SPEED (m/s) = 1.82
NUMBER OF OBSERVATIONS = 1593

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001370	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001598
NE	0.001712	0.000342	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002055
ENE	0.001598	0.000571	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002169
E	0.003653	0.002740	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006393
ESE	0.005023	0.007763	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012785
SE	0.005594	0.006849	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012443
SSE	0.003767	0.003539	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007306
S	0.003425	0.004909	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008333
SSW	0.004452	0.006849	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.011301
SW	0.007306	0.007306	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.014612
WSW	0.015868	0.004680	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.020548
W	0.030251	0.004680	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.034932
WNW	0.028995	0.003653	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.032648
NW	0.022374	0.010959	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.033333
NNW	0.010274	0.016667	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.026941
N	0.002283	0.001598	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003881
CALM									0.001256
TOTAL	0.147945	0.083333	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.232534

MEAN WIND SPEED (m/s) = 1.44
NUMBER OF OBSERVATIONS = 2037

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001826	0.002169	0.001941	0.000457	0.000000	0.000000	0.000000	0.000000	0.006393
NE	0.002626	0.002968	0.002283	0.000228	0.000000	0.000000	0.000000	0.000000	0.008105
ENE	0.002169	0.002511	0.003082	0.001027	0.000000	0.000000	0.000000	0.000000	0.008790
E	0.005479	0.009589	0.008562	0.004224	0.000913	0.000114	0.000000	0.000000	0.028881
ESE	0.008904	0.032763	0.028539	0.011530	0.002740	0.000228	0.000000	0.000000	0.084703
SE	0.008219	0.014269	0.008447	0.008219	0.001941	0.000114	0.000000	0.000000	0.041210
SSE	0.006393	0.010502	0.007192	0.003311	0.001027	0.000000	0.000000	0.000000	0.028425
S	0.006849	0.012100	0.007763	0.002055	0.000342	0.000000	0.000000	0.000000	0.029110
SSW	0.008562	0.014612	0.005479	0.001941	0.000571	0.000228	0.000000	0.000000	0.031393
SW	0.013813	0.018379	0.005023	0.002397	0.001484	0.000913	0.000000	0.000000	0.042009
WSW	0.041667	0.033333	0.007078	0.005137	0.002626	0.000457	0.000000	0.000000	0.090297
W	0.122260	0.052968	0.008676	0.004566	0.002740	0.002055	0.000114	0.000000	0.193379
WNW	0.088356	0.028196	0.007763	0.004338	0.001826	0.000571	0.000000	0.000000	0.131050
NW	0.042694	0.063242	0.050685	0.011530	0.000913	0.000000	0.000000	0.000000	0.169064
NNW	0.016324	0.043265	0.024429	0.007991	0.001027	0.000000	0.000000	0.000000	0.093037
N	0.003539	0.005365	0.002626	0.000114	0.000000	0.000000	0.000000	0.000000	0.011644
CALM									0.002511
TOTAL	0.379680	0.346233	0.179566	0.069064	0.018151	0.004680	0.000114	0.000000	1.000000

MEAN WIND SPEED (m/s) = 2.38
NUMBER OF OBSERVATIONS = 8760

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 22.8%
B : 4.2%
C : 4.4%
D : 27.2%
E : 18.2%
F : 23.3%

APPENDIX C

Estimated Dust Emissions

ESTIMATED DUST EMISSIONS

WALLARAH 2 COAL PROJECT

OPERATIONAL STAGE

Introduction

The dust emission inventory has been estimated using the emission factors and the mine plan information provided. Emission factors have been developed using emission factor equations provided in the **US EPA (1985)** (and subsequent updates) publication referred to as AP-42 and from factors determined by **NERDDC (1988)**.

Estimated emissions are presented for all significant dust generating activities associated with the operation of the mine. Annual throughput is 5Mt ROM coal and the busiest day would process 65,000 t of ROM coal and load out 40,000 t of product.

It has been assumed (as a worst case assessment) that mining activities occur 24 hours per day, 7 days per week. Dust from wind erosion is assumed to occur over 24 hours per day, but wind erosion is also assumed to be proportional to the third power of wind speed. Generally, this will mean that most wind erosion occurs in the day when wind speeds are highest.

Loading and unloading coal to stockpile

Coal will be loaded and unloaded to the stockpiles from the conveyor. Each tonne of material loaded will generate a certain amount of dust, depending on the wind speed and the moisture content. Equation 1 (**US EPA, 1995B, 13.2.4-3**) shows the relationship between these variables.

Equation 1

$$E_{TSP} = k \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right) \quad \text{kg/t}$$

where,

k = 0.74

U = wind speed (m/s)

M = moisture content (%)

[where 0.25 ≤ M ≤ 4.8]

A "wind speed factor", [that is the $(U/2.2)^{1.3}$ part of Equation 1], will vary from hour to hour. This factor has been calculated for each hour in the meteorological data file and an annual average determined to be approximately 0.86.

Assuming a moisture content of 5% E_{TSP} is calculated to be 0.00028 kg/t. The total emissions from unloading the material to the stockpile based on the busiest day from the conveyor will therefore be approximately 6,698 kg/y [0.00028 kg/t x 65000 t/d x 365 d/y]. On an average day the emissions per unload would be 1412 kg [0.00028 kg/t x

The same emission factor has been used for all load and reload activities including the processing plant where a total of six loading actions have been assumed and a 70% control factor for enclosure.

Dozers on coal

The **US EPA (1985 and updates)** emission factor equation has been used. It is given below in Equation 4.

Equation 4

$$E_{TSP} = 35.6 \times \frac{s^{1.2}}{M^{1.3}} \quad \text{kg/hour}$$

With a moisture content of 4% and a silt content of 2%, the emission rate becomes 11.7 kg/h.

Assuming work on both ROM and product stockpiles occurs 6 hours per day on the busiest day then the total emissions are 102,874 kg [2 x 6h/d x365d x 11.7 kg/h]. On an annual basis based on an average day, it has been assumed that the dozers would be working for 1440 hours making a total emission of 33,822 kg [2 x 1440 h x 11.7 kg/h].

Wind Erosion

Wind erosion from stockpiles

Assuming that the stockpile area is approximately 4.2 ha the annual dust emission will be approximately 14,717 kg/y [4.2ha x 0.4 kg/ha/h x 24 h/day x 365 day/y].

ESTIMATED DUST EMISSIONS

WALLARAH 2 COAL PROJECT

CONSTRUCTION STAGE

Introduction

It has been assumed (as a worst case assessment) that construction activities would take place over one year at both the Tooheys Road and the Buttonderry sites.

Loading and unloading excavated material

Excavated material will be loaded and unloaded. Each tonne of material loaded will generate a certain amount of dust, depending on the wind speed and the moisture content. Equation 1 (**US EPA, 1995B, 13.2.4-3**) shows the relationship between these variables.

Equation 1

$$E_{TSP} = k \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right) \quad \text{kg/t}$$

where,

k = 0.74

U = wind speed (m/s)

M = moisture content (%)

[where $0.25 \leq M \leq 4.8$]

A "wind speed factor", [that is the $(U/2.2)^{1.3}$ part of Equation 1], will vary from hour to hour. This factor has been calculated for each hour in the meteorological data file and an annual average determined to be approximately 0.86.

Assuming a moisture content of 4% E_{TSP} is calculated to be 0.00039 kg/t. The total emissions from loading of the material at Tooheys Road will therefore be approximately 2,225 kg/y [0.00039 kg/t x 584,412 m^3/y x 2.5 t/m^3 x 4 handlings] and for Buttonderry will be 227 kg/y [0.00039 kg/t x 58,740 m^3/y x2.5 m^3/t x 4 handlings]. Unloading of fill material has been estimated using the same equation.

Dozers on topsoil

The **US EPA (1985 and updates)** emission factor equation has been used. It is given below in Equation 4.

Equation 4

$$E_{TSP} = 35.6 \times \frac{s^{1.2}}{M^{1.3}} \qquad \text{kg/hour}$$

With a moisture content of 4% and a silt content of 2%, the emission rate becomes 11.7 kg/h

It has been assumed that the dozers would be working for 960 hours at the Tooheys Road site making a total emission of 11,274 kg [960 h x 11.7 kg/h] and for 288 hours at the Buttonderry site making a total emission of 3382 kg [288 h x 11.7 kg/h].

Wind Erosion

Assuming that the exposed area at Tooheys Road is approximately 7 ha the annual dust emission will be approximately 24,528kg/y [7.0 ha x 0.4 kg/ha/h x 24 h/day x 365 day/y]. At Buttonderry, the exposed area is assumed to be 4 ha making the total annual dust emissions 14,016 kg [4.0 ha x 0.4 kg/ha/h x 24 h/day x 365 day/y].

Haulage

It has been assumed that cut material will be hauled approximately 0.5 km at each site in 150 t trucks. Assuming an emission rate of 1 kg/vehicle kilometre (75% control of emissions through watering) haulage would result in 4870 kg dust at the Tooheys Road site [584,412 m^3/y x 2.5 t/m^3 / 150 t/v x 1 kg/vkm x 0.5 km] and 490 kg dust at the Buttonderry site [58,740 m^3/y x 2.5 t/m^3 / 150 t/v x 1 kg/vkm x 0.5 km)

```
DUST EMISSION CALCULATIONS V2
Peak operational emissions
 -------------------------------
-------------------------------
29-Apr-2008 15:49
  DUST EMISSION CALCULATIONS V2
 -------------------------------

 Output    emissions    file        :
C:\Jobs\Wallarah\ausplume\surface\fina
l\peak_op.src
 Meteorological    file             :
C:\Jobs\Wallarah\ausplume\met\Charmhav
enWH2.AUS
 Number of dust sources : 10
 Number of activities   : 10
 No-blast conditions    : None
 Wind sensitive factor  : 0.858 (0.862
adjusted for activity hours)
 Wind erosion factor    : 15.876

  -----ACTIVITY SUMMARY-----
 ACTIVITY NAME : Dozers on ROM
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 51437 kg/y
 FROM SOURCES  : 3
1 2 3
 HOURS OF DAY  :
0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0
1 0 0 0 1

 ACTIVITY NAME : Dozers on product
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 51437 kg/y
 FROM SOURCES  : 4
4 5 6 7
 HOURS OF DAY  :
0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0
1 0 0 0 1

 ACTIVITY NAME : Unloading ROM
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 6698 kg/y
 FROM SOURCES  : 3
1 2 3
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1

 ACTIVITY NAME : Loading ROM
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 6698 kg/y
 FROM SOURCES  : 3
1 2 3
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1

 ACTIVITY NAME : Loadout to train
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 4122 kg/y
 FROM SOURCES  : 1
8
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 0 0

 ACTIVITY  NAME  :  Reclaim  coal  to
transfer
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 4122 kg/y
 FROM SOURCES  : 1
9
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1

 ACTIVITY  NAME  :  Loadout  to  prodcut
stockpile
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 4122 kg/y
 FROM SOURCES  : 3
4 5 6
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1

 ACTIVITY NAME : Coal processing
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 12056 kg/y
 FROM SOURCES  : 1
10
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1

 ACTIVITY NAME : WE ROM
 ACTIVITY TYPE : Wind erosion
 DUST EMISSION : 3504 kg/y
 FROM SOURCES  : 3
1 2 3
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1

 ACTIVITY NAME : WE Product
 ACTIVITY TYPE : Wind erosion
 DUST EMISSION : 11231 kg/y
 FROM SOURCES  : 4
4 5 6 7
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1
```

ACTIVITY	TSP emission/year	Intensity	units	Emission factor	units	Variable 1	Units	Variable 2	units	Controls	Number of handlings
Operational Annual											
Dozers on ROM stockpiles	16,911	1,440	h/y	11.7	kg/h	2	silt content in %	4	moisture content in %		
Dozers on product stockpiles	16,911	1,440	h/y	11.7	kg/h	2	silt content in %	4	moisture content in %		
unloading ROM coal at pile	1,412	5,000,000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Additional ROM rehandle pile to conveyor	1,412	5,000,000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Loadout product coal to train	1,412	5,000,000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Reclaim coal to transfer house	1,412	5,000,000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Loadout coal to product stockpile	1,412	5,000,000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Coal Processing	2,541	5,000,000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %	0.3	6
WE ROM stockpile	3,504	1.00	ha	3504.0	kg/ha/y						
WE Product stockpile	11,213	3.20	ha	3504.0	kg/ha/y						
TOTAL	58,137										
Operational most intense day											
Dozers on ROM stockpiles	51,437	4,380	h/y	11.7	kg/h	2	silt content in %	4	moisture content in %		
Dozers on product stockpiles	51,437	4,380	h/y	11.7	kg/h	2	silt content in %	4	moisture content in %		
unloading ROM coal at pile	6,698	23725000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Additional ROM rehandle pile to conveyor	6,698	23725000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Loadout product coal to train	4,122	14600000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Reclaim coal to transfer house	4,122	14600000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Loadout coal to product stockpile	4,122	14600000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %		
Coal Processing	25,935	23725000	t	0.00028	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	5	moisture content of coal in %	0.3	6
WE ROM stockpile	3,504	1.00	ha	3504.0	kg/ha/y						
WE Product stockpile	11,213	3.20	ha	3504.0	kg/ha/y						
TOTAL	155,408										

ACTIVITY	TSP emission/year	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Controls	Number of handlings
Construction Tooheys Road											
Dozer clearing vegetatsion	11,274	960	h/y	11.7	kg/h	2	silt content in %	4	moisture content in %		
Haulage	4,870	1,461,030	t/y	0.00333	kg/t	150	t/truck load	0.5	km/return trip	1	kg/VKT
Loading of cut material from surface	2,255	1,461,030	t	0.00039	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	4	moisture content in %		4
Dumping of all material	2,541	1,646,255	t	0.00039	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	4	moisture content in %		4
Wind erosion	24,528	7.00	ha	3504.0	kg/ha/y						
TOTAL	45,468										
Construction Buttonderry											
Dozer clearing vegetatsion	3,382	288	h/y	11.7	kg/h	2	silt content in %	4	moisture content in %		
Haulage	490	146,850	t/y	0.00333	kg/t	150	t/truck load	0.5	km/return trip	1	kg/VKT
Loading of cut material from surface	227	146,850	t	0.00039	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	4	moisture content in %		4
Dumping of all material	227	146,850	t	0.00039	kg/t	0.86	average of (wind speed/2.2)^1.3 in m/s	4	moisture content in %		4
Wind erosion	14,016	4.00	ha	3504.0	kg/ha/y						
TOTAL	8,341										

APPENDIX D

On-site PM_7 measurements at Angus Place and the method for using these to estimate PM_{10} shaft emissions

Page 1 of 1

Coal Services Health
Linking health with industry

GRAVIMETRIC
AIRBORNE DUST
SAMPLING REPORT

NATA Accredited Laboratory
Number : 10782
NATA endorsed test report. This document shall not be reproduced, except in full.

UNDERGROUND - OTHER THAN LONGWALL

SPECIAL

Test no.	W 055/05
Mine	CENTENNIAL ANGUS PLACE P/L
Test date	13/SEP/2005
Seam	LITHGOW
Location of tests	930 PANEL
Type of working	1ST WORKING
Material being worked	COAL/COAL & STONE BANDS/STONE ROOF
General nature of work	ROOF BOLTING
Machine used	ROOF BOLTER
Machine info	

Sprays Venturi Other Not operating

Reverse Flush strainer N/A

Seam thickness (m) (if less than mining height)

Mining height (m) 3.20

Other dust supression methods

RESPIRABLE DUST REPORT

Time Started 08.30 hrs Finished 13.00 hrs Estimated production (Tonnes) 400

Filter no	Location/Comments		Respirator	Beard	Result (mg/m^3)	Alpha-Quartz (mg/m^3)
053275	STATIC-35m O/B AUX. FAN	STATIC SAMPLE		-	0.9	-
053276	STATIC-20m O/B AUX. FAN	STATIC SAMPLE		-	1.0	-
053277	STATIC-MIDWAY 26-25 C/T	STATIC SAMPLE		-	1.1	-
053278	STATIC-MIDWAY 27-26 C/T	STATIC SAMPLE		-	0.8	-
053279	STATIC-MIDWAY 25-24 C/T	STATIC SAMPLE		-	1.0	-

Remarks
LOCATION CONT: 27 C/T.

930 PANEL SAMPLED IN RETURN. FILTER NOS: 053275 & 053276 - 27 C/T.

BELTS DOWN 08:00 - 10:00.

NB: THIS IS AN INTERIM REPORT PENDING QUARTZ ANALYSIS FROM PICKFORD AND RHYDER ANALYTICAL LABORATORY.

Sampled by Chris Maw
Issued Date 21/Sep/2005

Weighed by Chris Maw - CS Health Lithgow Laboratory
Approved signatory Gary Mace (Manager - Environmental Monitoring)

VENTILATION INFORMATION

Ventilation type AUXILIARY LEFT

Airway dimensions Height (m) a) 3.4 b) 3.4 Width (m) a) 5.2 b) 5.2

	Reading #1	Reading #2	Reading #3
Air Velocity (m/s)	a) 1.6 b) 1.5	0.0	0.0
Quantity (m^3/s)	a) 28.3 b) 26.5	0.0	0.0

Ventilation readings are approximate only and are not covered by this laboratory's terms of accreditation.

Length of Brattice/Ventilation Tubes (m) From to Condition

Comments

Method for estimating PM_{10} emissions from PM_7 measurements

The five samples of respirable dust taken at the static locations underground were 0.9, 1.0, 1.1, 0.8 and 1.0 mg/m^3. The average of these values is therefore 0.96 mg/m^3 or 960 $\mu g/m^3$. This value was then taken to be the average concentration of respirable dust that is likely to be emitted to the ambient air via the mine's ventilation shaft. The assessment for this project, however, related to concentrations of PM_{10} and so the PM_7 measurements needed to be adjusted for the larger particle size group.

A technical paper by the NSW Minerals Council (as noted in **Section 6.3**), contains an analysis of some particulate measurements that were taken at various Hunter Valley coal mines and shows a scatter plot of the cumulative percentage mass of dust of different particle sizes, on a logarithmic scale (Figure 2-4b). This plot has been included below. It can be seen from this plot that the percentage of PM_7 particles is approximately 20% while about 30% of the mass is represented by PM_{10}. The increase in mass content from PM_7 to PM_{10} is therefore 50%.

The measured in-shaft PM_7 concentration of 960 $\mu g/m^3$ would therefore equate to a PM_{10} concentration of 1,440 $\mu g/m^3$. With a flow rate of 370 m^3/s, the PM_{10} emission rate from the ventilation shaft would therefore be approximately 0.53 g/s.

Scatter plots of cumulative particle size distributions made on dust emissions from open cut mining operations in the Hunter Valley, NSW

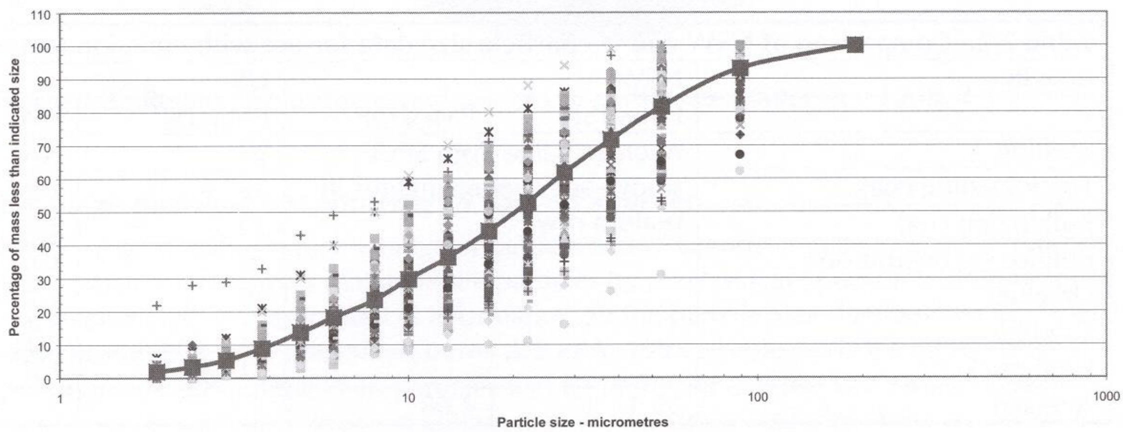

Figure 2-4(b)

APPENDIX E

AUSPLUME Output Files

AUSPLUME OUTPUT FILES

1

Wallarah 2 Peak Emissions

```
Concentration or deposition                         Concentration
Emission rate units                                 grams/second
Concentration units                                 microgram/m3
Units conversion factor                             1.00E+06
Constant background concentration                            0.00E+00
Terrain effects                                     Egan method
Plume depletion due to dry removal mechanisms included.
Smooth stability class changes?                     No
Other stability class adjustments ("urban modes")   None
Ignore building wake effects?                       Yes
Decay coefficient (unless overridden by met. file)  0.000
Anemometer height                                   10 m
Roughness height at the wind vane site              0.500 m
Use the convective PDF algorithm?                   No

                   DISPERSION CURVES
Horizontal dispersion curves for sources <100m high  Pasquill-Gifford
Vertical  dispersion  curves for sources <100m high  Pasquill-Gifford
Horizontal dispersion curves for sources >100m high  Briggs Rural
Vertical  dispersion  curves for sources >100m high  Briggs Rural
Enhance horizontal plume spreads for buoyancy?       Yes
Enhance  vertical  plume spreads for buoyancy?       Yes
Adjust horizontal P-G formulae for roughness height? Yes
Adjust  vertical  P-G formulae for roughness height? Yes
Roughness height                                     0.400m
Adjustment for wind directional shear                None

                   PLUME RISE OPTIONS
Gradual plume rise?                                  Yes
Stack-tip downwash included?                         Yes
Building downwash algorithm:                        Schulman-Scire method.
Entrainment coeff. for neutral & stable lapse rates 0.60,0.60
Partial penetration of elevated inversions?          No
Disregard temp. gradients in the hourly met. file?   No

and in the absence of boundary-layer potential temperature gradients
given by the hourly met. file, a value from the following table
(in K/m) is used:
```

Wind Speed Category	A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

(Stability Class)

```
WIND SPEED CATEGORIES
Boundaries between categories (in m/s) are:  1.54,  3.09,  5.14,  8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Rural" values (unless overridden by met. file)

AVERAGING TIMES
24 hours
```

Wallarah 2 Peak Emissions

SOURCE GROUPS

Group No.	Members						
1	1	2	3	4	5	6	7
	8	9	10				
2	11	12	13	14	15	16	17
	18	19	20				
3	21	22	23	24	25	26	27
	28	29	30				

1

Wallarah 2 Peak Emissions

SOURCE CHARACTERISTICS

VOLUME SOURCE: 1

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356017	6323887	24m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with
this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	1.0	2.50

VOLUME SOURCE: 2

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356065	6323866	29m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with
this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	1.0	2.50

VOLUME SOURCE: 3

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356112	6323839	32m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with
this emission factor.

```
                   Particle  Particle  Particle
                     Mass      Size     Density
                   fraction  (micron)   (g/cm3)
                  ______________________________
                     1.0000      1.0       2.50


                   VOLUME SOURCE: 4

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356478  6324454            28m             3m         60m            2m

                (Constant) emission rate = 1.00E+00 grams/second

          Hourly multiplicative factors will be used with
          this emission factor.

                   Particle  Particle  Particle
                     Mass      Size     Density
                   fraction  (micron)   (g/cm3)
                  ______________________________
                     1.0000      1.0       2.50


                   VOLUME SOURCE: 5

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356542  6324443            27m             3m         60m            2m

                (Constant) emission rate = 1.00E+00 grams/second

          Hourly multiplicative factors will be used with
          this emission factor.

                   Particle  Particle  Particle
                     Mass      Size     Density
                   fraction  (micron)   (g/cm3)
                  ______________________________
                     1.0000      1.0       2.50


                   VOLUME SOURCE: 6

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356608  6324430            28m             3m         60m            2m

                (Constant) emission rate = 1.00E+00 grams/second

          Hourly multiplicative factors will be used with
          this emission factor.

                   Particle  Particle  Particle
                     Mass      Size     Density
                   fraction  (micron)   (g/cm3)
                  ______________________________
                     1.0000      1.0       2.50


                   VOLUME SOURCE: 7

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356690  6324414            29m             3m         60m            2m

                (Constant) emission rate = 1.00E+00 grams/second

          Hourly multiplicative factors will be used with
          this emission factor.

                   Particle  Particle  Particle
                     Mass      Size     Density
                   fraction  (micron)   (g/cm3)
                  ______________________________
                     1.0000      1.0       2.50
```

```
                    VOLUME SOURCE: 8

  X(m)     Y(m)      Ground Elevation     Height   Hor. spread   Vert. spread
356234  6324499             35m            10m         60m            2m

               (Constant) emission rate = 1.00E+00 grams/second

         Hourly multiplicative factors will be used with
         this emission factor.

                    Particle  Particle  Particle
                      Mass      Size    Density
                    fraction  (micron)  (g/cm3)
                   -----------------------------
                      1.0000      1.0      2.50

                    VOLUME SOURCE: 9

  X(m)     Y(m)      Ground Elevation     Height   Hor. spread   Vert. spread
356340  6324480             32m             5m         60m            2m

               (Constant) emission rate = 1.00E+00 grams/second

         Hourly multiplicative factors will be used with
         this emission factor.

                    Particle  Particle  Particle
                      Mass      Size    Density
                    fraction  (micron)  (g/cm3)
                   -----------------------------
                      1.0000      1.0      2.50

                    VOLUME SOURCE: 10

  X(m)     Y(m)      Ground Elevation     Height   Hor. spread   Vert. spread
356136  6323990             24m             8m         60m            2m

               (Constant) emission rate = 1.00E+00 grams/second

         Hourly multiplicative factors will be used with
         this emission factor.

                    Particle  Particle  Particle
                      Mass      Size    Density
                    fraction  (micron)  (g/cm3)
                   -----------------------------
                      1.0000      1.0      2.50

                    VOLUME SOURCE: 11

  X(m)     Y(m)      Ground Elevation     Height   Hor. spread   Vert. spread
356017  6323887             24m             3m         60m            2m

               (Constant) emission rate = 1.00E+00 grams/second

         Hourly multiplicative factors will be used with
         this emission factor.

                    Particle  Particle  Particle
                      Mass      Size    Density
                    fraction  (micron)  (g/cm3)
                   -----------------------------
                      1.0000      5.0      2.50

                    VOLUME SOURCE: 12

  X(m)     Y(m)      Ground Elevation     Height   Hor. spread   Vert. spread
356065  6323866             29m             3m         60m            2m
```

```
          (Constant) emission rate = 1.00E+00 grams/second

      Hourly multiplicative factors will be used with
      this emission factor.

                Particle  Particle  Particle
                  Mass      Size    Density
                fraction  (micron)  (g/cm3)
               ____________________________
                  1.0000      5.0      2.50


                VOLUME SOURCE: 13

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356112  6323839            32m             3m        60m             2m

          (Constant) emission rate = 1.00E+00 grams/second

      Hourly multiplicative factors will be used with
      this emission factor.

                Particle  Particle  Particle
                  Mass      Size    Density
                fraction  (micron)  (g/cm3)
               ____________________________
                  1.0000      5.0      2.50


                VOLUME SOURCE: 14

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356478  6324454            28m             3m        60m             2m

          (Constant) emission rate = 1.00E+00 grams/second

      Hourly multiplicative factors will be used with
      this emission factor.

                Particle  Particle  Particle
                  Mass      Size    Density
                fraction  (micron)  (g/cm3)
               ____________________________
                  1.0000      5.0      2.50


                VOLUME SOURCE: 15

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356542  6324443            27m             3m        60m             2m

          (Constant) emission rate = 1.00E+00 grams/second

      Hourly multiplicative factors will be used with
      this emission factor.

                Particle  Particle  Particle
                  Mass      Size    Density
                fraction  (micron)  (g/cm3)
               ____________________________
                  1.0000      5.0      2.50


                VOLUME SOURCE: 16

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356608  6324430            28m             3m        60m             2m

          (Constant) emission rate = 1.00E+00 grams/second

      Hourly multiplicative factors will be used with
      this emission factor.
```

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	5.0	2.50

VOLUME SOURCE: 17

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356690	6324414	29m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	5.0	2.50

VOLUME SOURCE: 18

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356234	6324499	35m	10m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	5.0	2.50

VOLUME SOURCE: 19

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356340	6324480	32m	5m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	5.0	2.50

VOLUME SOURCE: 20

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356136	6323990	24m	8m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	5.0	2.50

VOLUME SOURCE: 21

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356017	6323887	24m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	17.3	2.50

VOLUME SOURCE: 22

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356065	6323866	29m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	17.3	2.50

VOLUME SOURCE: 23

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356112	6323839	32m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	17.3	2.50

VOLUME SOURCE: 24

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356478	6324454	28m	3m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	17.3	2.50

VOLUME SOURCE: 25

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356542	6324443	27m	3m	60m	2m

```
        (Constant) emission rate = 1.00E+00 grams/second

  Hourly multiplicative factors will be used with
  this emission factor.

             Particle  Particle  Particle
               Mass      Size    Density
             fraction  (micron)  (g/cm3)
            ------------------------------
               1.0000     17.3      2.50


             VOLUME SOURCE: 26

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356608  6324430            28m             3m        60m            2m

        (Constant) emission rate = 1.00E+00 grams/second

  Hourly multiplicative factors will be used with
  this emission factor.

             Particle  Particle  Particle
               Mass      Size    Density
             fraction  (micron)  (g/cm3)
            ------------------------------
               1.0000     17.3      2.50


             VOLUME SOURCE: 27

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356690  6324414            29m             3m        60m            2m

        (Constant) emission rate = 1.00E+00 grams/second

  Hourly multiplicative factors will be used with
  this emission factor.

             Particle  Particle  Particle
               Mass      Size    Density
             fraction  (micron)  (g/cm3)
            ------------------------------
               1.0000     17.3      2.50


             VOLUME SOURCE: 28

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356234  6324499            35m            10m        60m            2m

        (Constant) emission rate = 1.00E+00 grams/second

  Hourly multiplicative factors will be used with
  this emission factor.

             Particle  Particle  Particle
               Mass      Size    Density
             fraction  (micron)  (g/cm3)
            ------------------------------
               1.0000     17.3      2.50


             VOLUME SOURCE: 29

  X(m)     Y(m)     Ground Elevation    Height   Hor. spread   Vert. spread
356340  6324480            32m             5m        60m            2m

        (Constant) emission rate = 1.00E+00 grams/second

  Hourly multiplicative factors will be used with
  this emission factor.

             Particle  Particle  Particle
```

Mass fraction	Size (micron)	Density (g/cm3)
1.0000	17.3	2.50

VOLUME SOURCE: 30

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
356136	6323990	24m	8m	60m	2m

(Constant) emission rate = 1.00E+00 grams/second

Hourly multiplicative factors will be used with this emission factor.

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
1.0000	17.3	2.50

1

Wallarah 2 Peak Emissions

RECEPTOR LOCATIONS

The Cartesian receptor grid has the following x-values (or eastings):

```
350500.m  350750.m  351000.m  351250.m  351500.m  351750.m  352000.m
352250.m  352500.m  352750.m  353000.m  353250.m  353500.m  353750.m
354000.m  354250.m  354500.m  354750.m  355000.m  355250.m  355500.m
355750.m  356000.m  356250.m  356500.m  356750.m  357000.m  357250.m
357500.m  357750.m  358000.m  358250.m  358500.m  358750.m  359000.m
359250.m  359500.m  359750.m  360000.m
```

and these y-values (or northings):

```
6320500.m 6320750.m 6321000.m 6321250.m 6321500.m 6321750.m 6322000.m
6322250.m 6322500.m 6322750.m 6323000.m 6323250.m 6323500.m 6323750.m
6324000.m 6324250.m 6324500.m 6324750.m 6325000.m 6325250.m 6325500.m
6325750.m 6326000.m 6326250.m 6326500.m
```

DISCRETE RECEPTOR LOCATIONS (in metres)

No.	X	Y	ELEVN	HEIGHT	No.	X	Y	ELEVN	HEIGHT
1	359375	6323779	6.0	0.0	9	355889	6325247	56.0	0.0
2	357804	6322326	26.0	0.0	10	356489	6325518	53.0	0.0
3	356974	6322380	44.0	0.0	11	357210	6326279	45.0	0.0
4	356226	6322869	28.0	0.0	12	352840	6322917	28.0	0.0
5	354769	6322842	45.0	0.0	13	352625	6322679	31.0	0.0
6	353933	6323793	46.0	0.0	14	352206	6322679	52.0	0.0
7	354951	6325287	60.0	0.0	15	351896	6322849	42.0	0.0
8	355511	6325219	55.0	0.0					

METEOROLOGICAL DATA : AUSPLUME Modelling File (Met MANAGER)

HOURLY VARIABLE EMISSION FACTOR INFORMATION

The input emission rates specfied above will be multiplied by hourly varying factors entered via the input file:
C:\Jobs\Wallarah\ausplume\surface\final\peak_op.src
For each stack source, hourly values within this file will be added to each declared exit velocity (m/sec) and temperature (K).

```
Title of input hourly emission factor file is:
AUSPLUME Variable emissions file (Met MANAGER)

             HOURLY EMISSION FACTOR SOURCE TYPE ALLOCATION
             ---------------------------------------------

Prefix 1      allocated: 1
Prefix 2      allocated: 2
Prefix 3      allocated: 3
Prefix 4      allocated: 4
Prefix 5      allocated: 5
Prefix 6      allocated: 6
Prefix 7      allocated: 7
Prefix 8      allocated: 8
Prefix 9      allocated: 9
Prefix 10     allocated: 10
Prefix 11     allocated: 11
Prefix 12     allocated: 12
Prefix 13     allocated: 13
Prefix 14     allocated: 14
Prefix 15     allocated: 15
Prefix 16     allocated: 16
Prefix 17     allocated: 17
Prefix 18     allocated: 18
Prefix 19     allocated: 19
Prefix 20     allocated: 20
Prefix 21     allocated: 21
Prefix 22     allocated: 22
Prefix 23     allocated: 23
Prefix 24     allocated: 24
Prefix 25     allocated: 25
Prefix 26     allocated: 26
Prefix 27     allocated: 27
Prefix 28     allocated: 28
Prefix 29     allocated: 29
Prefix 30     allocated: 30
```

Odour Model (Vent Shaft) 4 m stack

Concentration or deposition	Concentration
Emission rate units	OUV/second
Concentration units	Odour_Units
Units conversion factor	1.00E+00
Constant background concentration	0.00E+00
Terrain effects	Egan method
Smooth stability class changes?	No
Other stability class adjustments ("urban modes")	None
Ignore building wake effects?	Yes
Decay coefficient (unless overridden by met. file)	0.000
Anemometer height	10 m
Roughness height at the wind vane site	0.300 m
Use the convective PDF algorithm?	No

DISPERSION CURVES

Horizontal dispersion curves for sources <100m high	Pasquill-Gifford
Vertical dispersion curves for sources <100m high	Pasquill-Gifford
Horizontal dispersion curves for sources >100m high	Pasquill-Gifford
Vertical dispersion curves for sources >100m high	Pasquill-Gifford
Enhance horizontal plume spreads for buoyancy?	Yes
Enhance vertical plume spreads for buoyancy?	Yes
Adjust horizontal P-G formulae for roughness height?	Yes
Adjust vertical P-G formulae for roughness height?	Yes
Roughness height	0.400m
Adjustment for wind directional shear	None

PLUME RISE OPTIONS

Gradual plume rise?	Yes
Stack-tip downwash included?	Yes
Building downwash algorithm:	PRIME method.
Entrainment coeff. for neutral & stable lapse rates	0.60,0.60
Partial penetration of elevated inversions?	No
Disregard temp. gradients in the hourly met. file?	No

and in the absence of boundary-layer potential temperature gradients given by the hourly met. file, a value from the following table (in K/m) is used:

Wind Speed Category	Stability Class A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

WIND SPEED CATEGORIES
Boundaries between categories (in m/s) are: 1.54, 3.09, 5.14, 8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Rural" values (unless overridden by met. file)

AVERAGING TIMES
1 hour

1

Odour Model (Vent Shaft) 4 m stack

SOURCE CHARACTERISTICS

STACK SOURCE: STK

```
   X(m)     Y(m)   Ground Elev.  Stack Height  Diameter Temperature  Speed
  352187  6323078        50m           4m        6.80m       20C     5.1m/s

                            No building wake effects.

          Emission rates by stability and wind speed, in OUV/second:

 Wind speeds (m/s): < 1.5   1.5_ 3.1  3.1_ 5.1  5.1_ 8.2  8.2_10.8    >10.8
    Stability A:  9.18E+04  9.18E+04  9.18E+04  9.18E+04  9.18E+04  9.18E+04
    Stability B:  9.18E+04  9.18E+04  9.18E+04  9.18E+04  9.18E+04  9.18E+04
    Stability C:  9.18E+04  9.18E+04  9.18E+04  9.18E+04  9.18E+04  9.18E+04
    Stability D:  1.61E+05  1.61E+05  1.61E+05  1.61E+05  1.61E+05  1.61E+05
    Stability E:  1.61E+05  1.61E+05  1.61E+05  1.61E+05  1.61E+05  1.61E+05
    Stability F:  1.61E+05  1.61E+05  1.61E+05  1.61E+05  1.61E+05  1.61E+05

                    No gravitational settling or scavenging.

 _____________________________________________________________________________

1                  _________________________________________

                        Odour Model (Vent Shaft)  4 m stack

                                 RECEPTOR LOCATIONS

                   _________________________________________

 The Cartesian receptor grid has the following x-values (or eastings):
 350500.m  350750.m  351000.m  351250.m  351500.m  351750.m  352000.m
 352250.m  352500.m  352750.m  353000.m  353250.m  353500.m  353750.m
 354000.m  354250.m  354500.m  354750.m  355000.m  355250.m  355500.m
 355750.m  356000.m  356250.m  356500.m  356750.m  357000.m  357250.m
 357500.m  357750.m  358000.m  358250.m  358500.m  358750.m  359000.m
 359250.m  359500.m  359750.m  360000.m

 and these y-values (or northings):
6320500.m 6320750.m 6321000.m 6321250.m 6321500.m 6321750.m 6322000.m
6322250.m 6322500.m 6322750.m 6323000.m 6323250.m 6323500.m 6323750.m
6324000.m 6324250.m 6324500.m 6324750.m 6325000.m 6325250.m 6325500.m
6325750.m 6326000.m 6326250.m 6326500.m


 DISCRETE RECEPTOR LOCATIONS (in metres)

 No.     X       Y    ELEVN  HEIGHT       No.     X       Y    ELEVN  HEIGHT
  1  359375 6323779     6.0    0.0         9  355889 6325247    56.0    0.0
  2  357804 6322326    26.0    0.0        10  356489 6325518    53.0    0.0
  3  356974 6322380    44.0    0.0        11  357210 6326279    45.0    0.0
  4  356226 6322869    28.0    0.0        12  352840 6322917    28.0    0.0
  5  354769 6322842    45.0    0.0        13  352625 6322679    31.0    0.0
  6  353933 6323793    46.0    0.0        14  352206 6322679    52.0    0.0
  7  354951 6325287    60.0    0.0        15  351896 6322849    42.0    0.0
  8  355511 6325219    55.0    0.0

 _____________________________________________________________________________

        METEOROLOGICAL DATA :  AUSPLUME Modelling File (Met MANAGER)

 _____________________________________________________________________________


1           Peak values for the 100 worst cases  (in Odour_Units)
                    Averaging time = 1 hour

  Rank     Value   Time Recorded        Coordinates
                     hour,date        (* denotes polar)

     1   2.68E+01   15,05/01/99   (352250, 6323000,    0.0)
     2   2.54E+01   15,19/01/99   (352250, 6323000,    0.0)
     3   2.53E+01   15,22/09/98   (352250, 6323000,    0.0)
     4   2.51E+01   18,18/01/99   (352250, 6323000,    0.0)
     5   2.51E+01   14,05/01/99   (352250, 6323000,    0.0)
     6   2.50E+01   17,05/01/99   (352250, 6323000,    0.0)
     7   2.50E+01   16,05/01/99   (352250, 6323000,    0.0)
```

8	2.49E+01	18,05/01/99	(352250,	6323000,	0.0)
9	2.48E+01	17,18/01/99	(352250,	6323000,	0.0)
10	2.46E+01	13,05/01/99	(352250,	6323000,	0.0)
11	2.44E+01	16,25/10/98	(352250,	6323000,	0.0)
12	2.43E+01	18,06/01/99	(352250,	6323000,	0.0)
13	2.43E+01	17,04/01/99	(352250,	6323000,	0.0)
14	2.40E+01	16,22/09/98	(352250,	6323000,	0.0)
15	2.40E+01	15,27/11/98	(352250,	6323000,	0.0)
16	2.39E+01	14,22/09/98	(352250,	6323000,	0.0)
17	2.36E+01	16,18/01/99	(352250,	6323000,	0.0)
18	2.32E+01	13,05/10/98	(352250,	6323000,	0.0)
19	2.32E+01	17,17/02/99	(352250,	6323000,	0.0)
20	2.29E+01	23,05/07/98	(352250,	6323000,	0.0)
21	2.28E+01	19,18/01/99	(352250,	6323000,	0.0)
22	2.26E+01	15,18/01/99	(352250,	6323000,	0.0)
23	2.25E+01	17,05/10/98	(352250,	6323000,	0.0)
24	2.22E+01	17,25/10/98	(352250,	6323000,	0.0)
25	2.22E+01	16,28/01/99	(352250,	6323000,	0.0)
26	2.18E+01	17,28/01/99	(352250,	6323000,	0.0)
27	2.18E+01	18,17/02/99	(352250,	6323000,	0.0)
28	2.18E+01	16,04/01/99	(352250,	6323000,	0.0)
29	2.17E+01	17,19/01/99	(352250,	6323000,	0.0)
30	2.17E+01	16,17/09/98	(352250,	6323000,	0.0)
31	2.17E+01	13,27/11/98	(352250,	6323000,	0.0)
32	2.15E+01	10,17/01/99	(352250,	6323000,	0.0)
33	2.15E+01	14,27/11/98	(352250,	6323000,	0.0)
34	2.15E+01	10,21/07/98	(352250,	6323000,	0.0)
35	2.15E+01	14,05/10/98	(352250,	6323000,	0.0)
36	2.13E+01	16,15/02/99	(352250,	6323000,	0.0)
37	2.13E+01	16,17/02/99	(352250,	6323000,	0.0)
38	2.13E+01	16,09/02/99	(352250,	6323000,	0.0)
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FIGURES

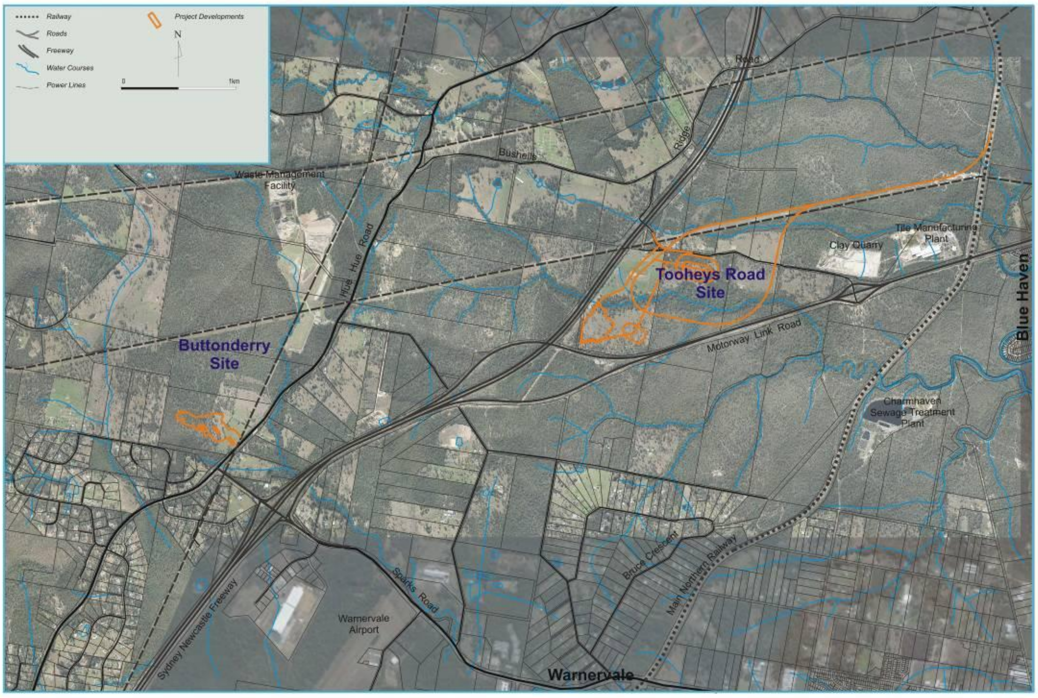

Figure 1 Location of study area

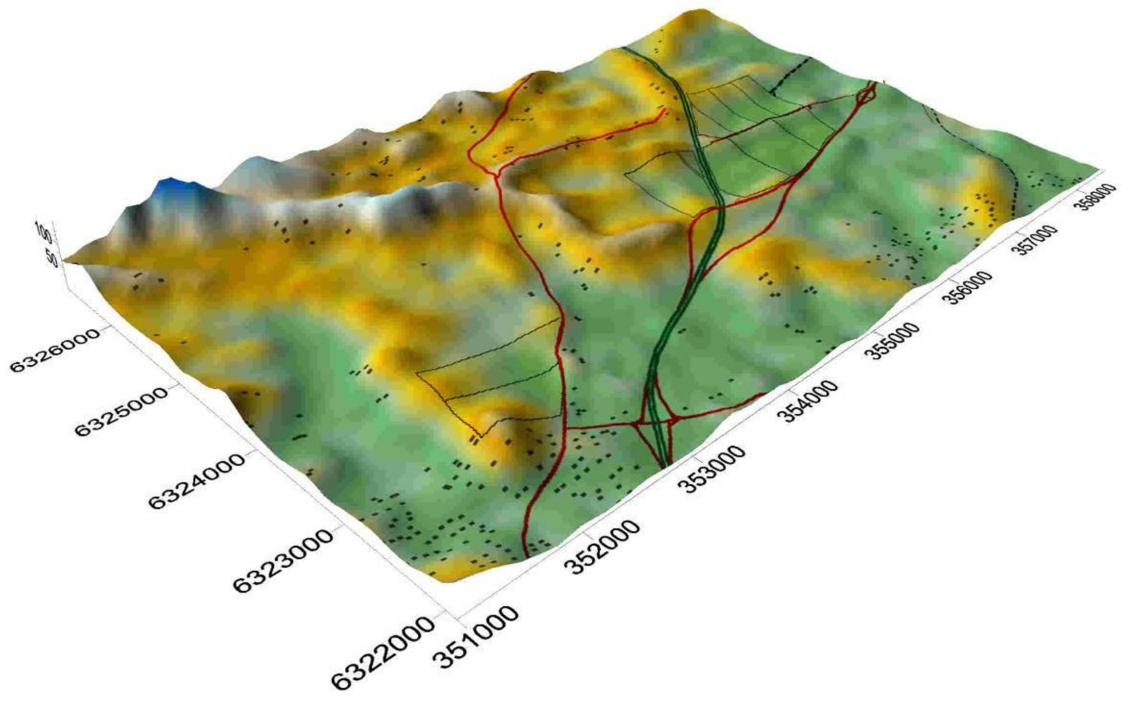

Figure 2 Pseudo 3-dimensional representation of local area

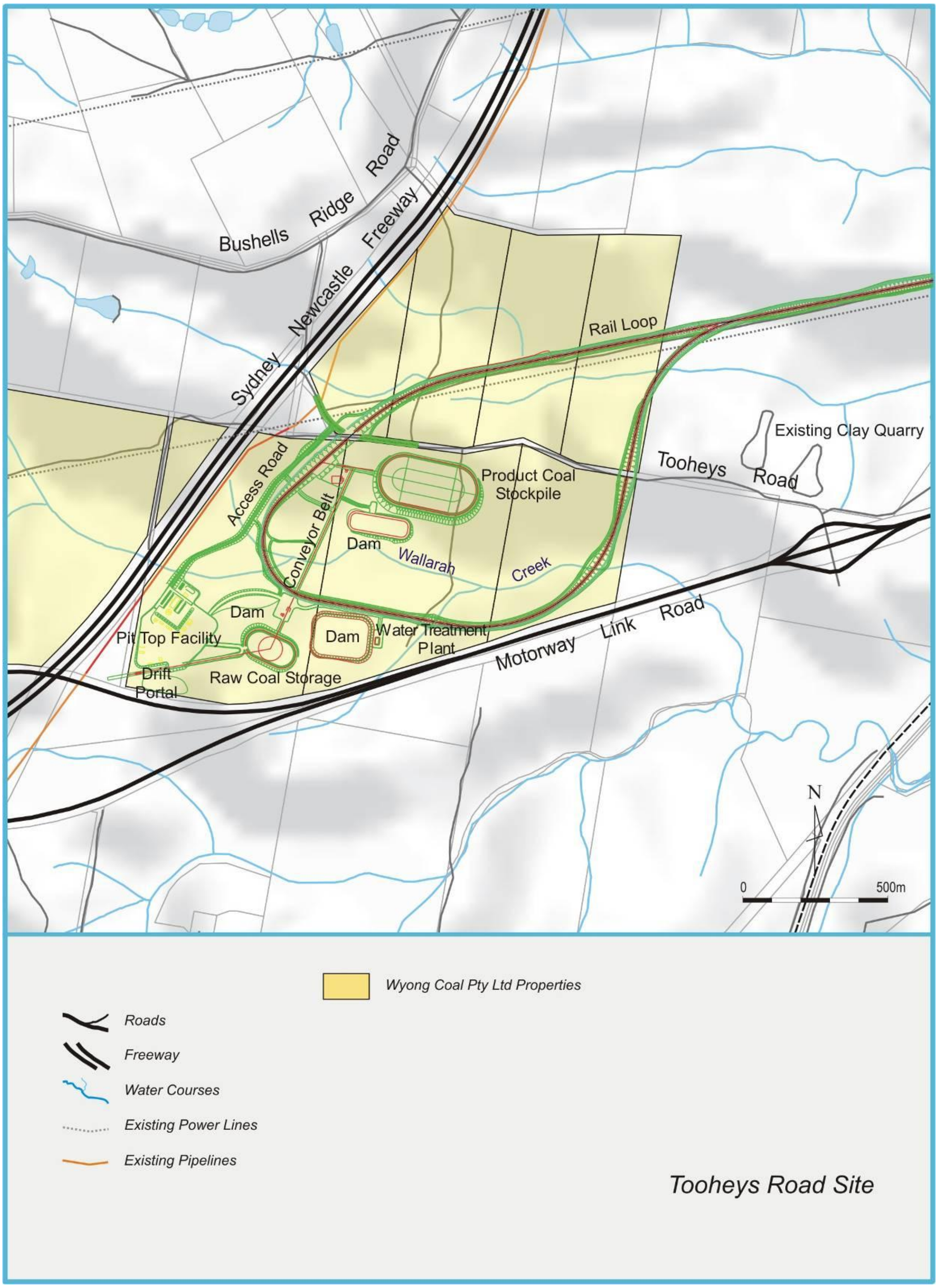

Figure 3 Proposed layout of surface facilities

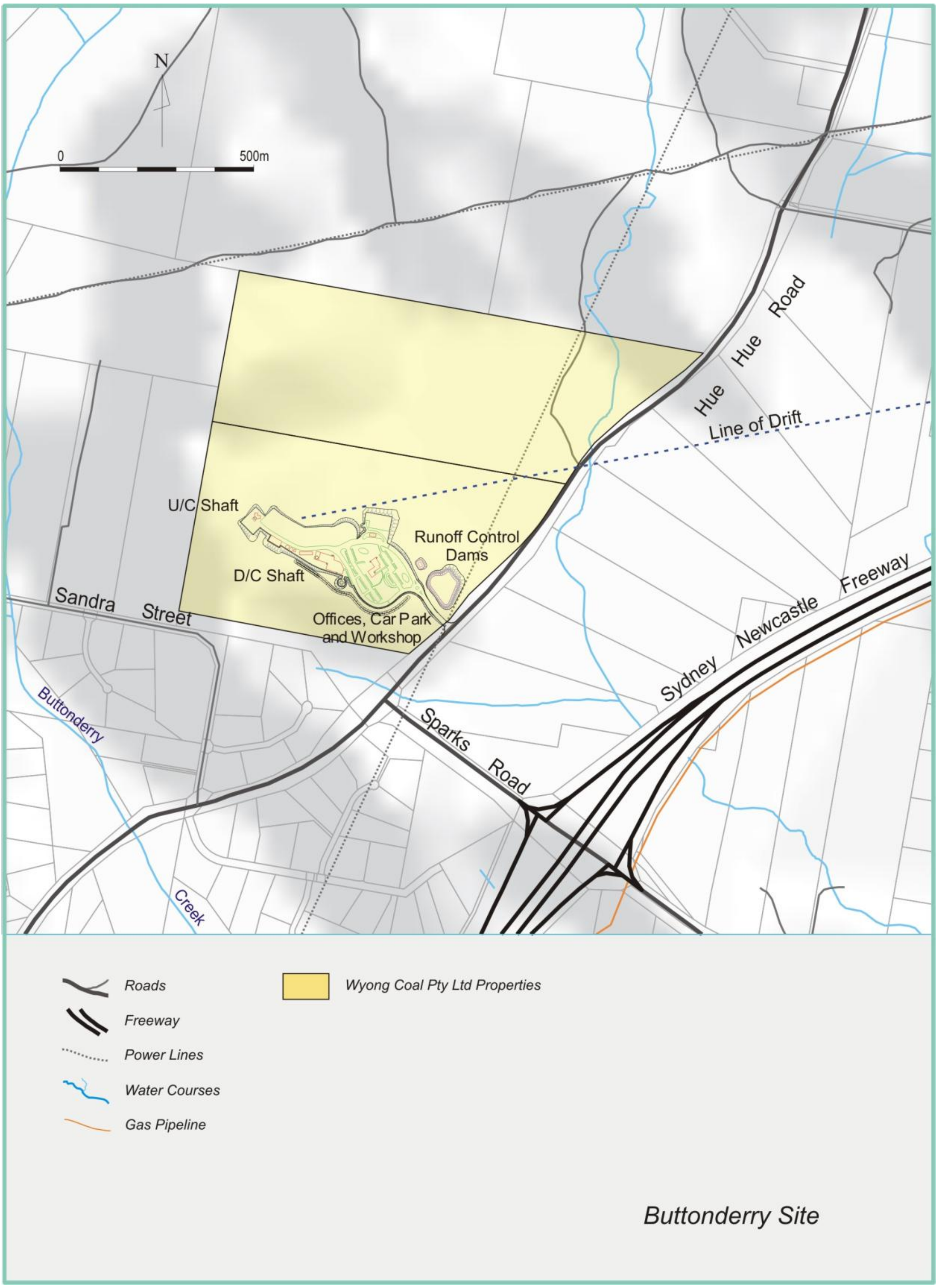

Figure 4 Proposed layout of ventilation shaft

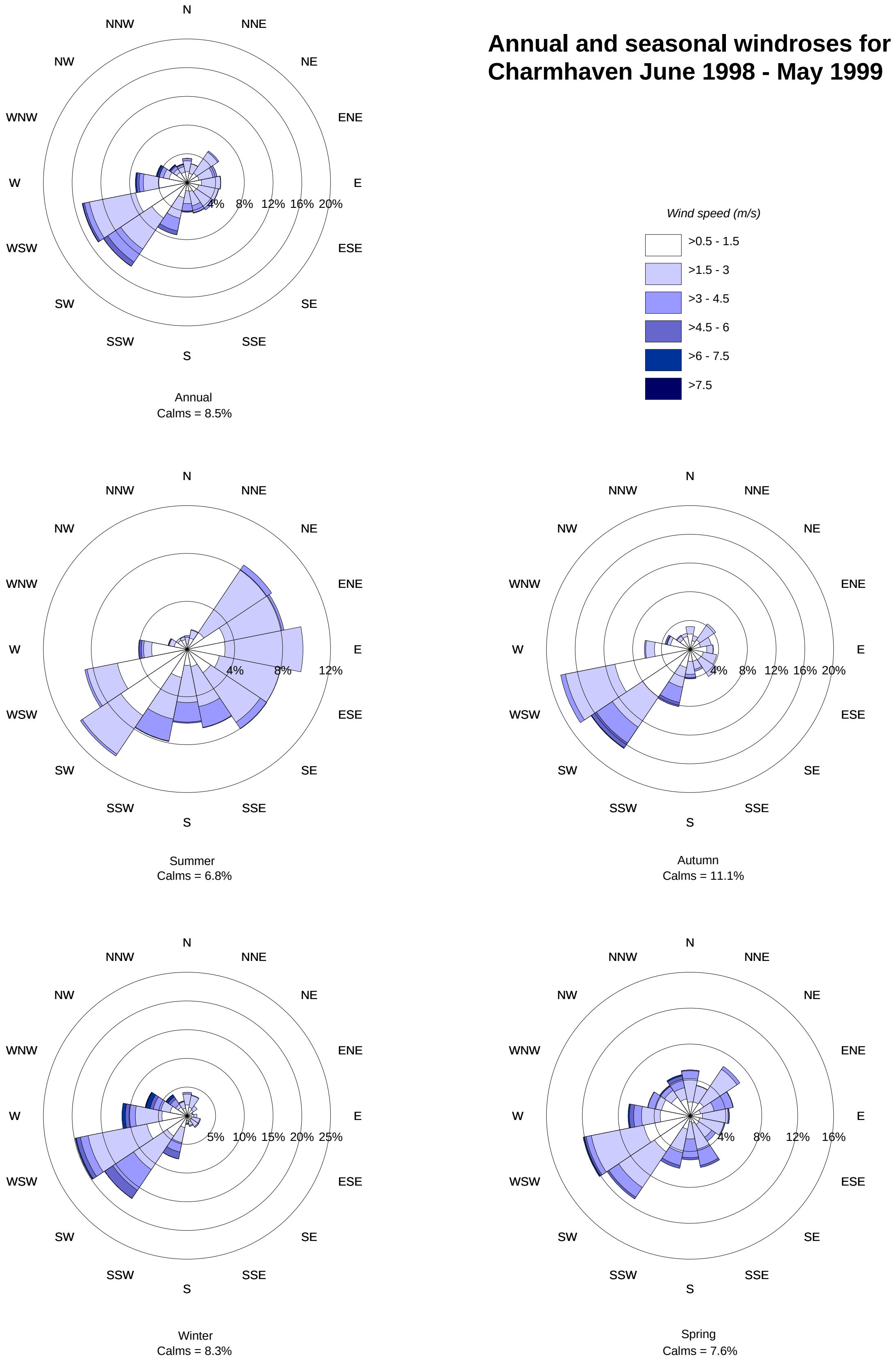

Figure 5 Annual and seasonal windroses for Charmhaven 1998/1999

Figure 6 Annual and seasonal windroses Buttonderry 1998/1999

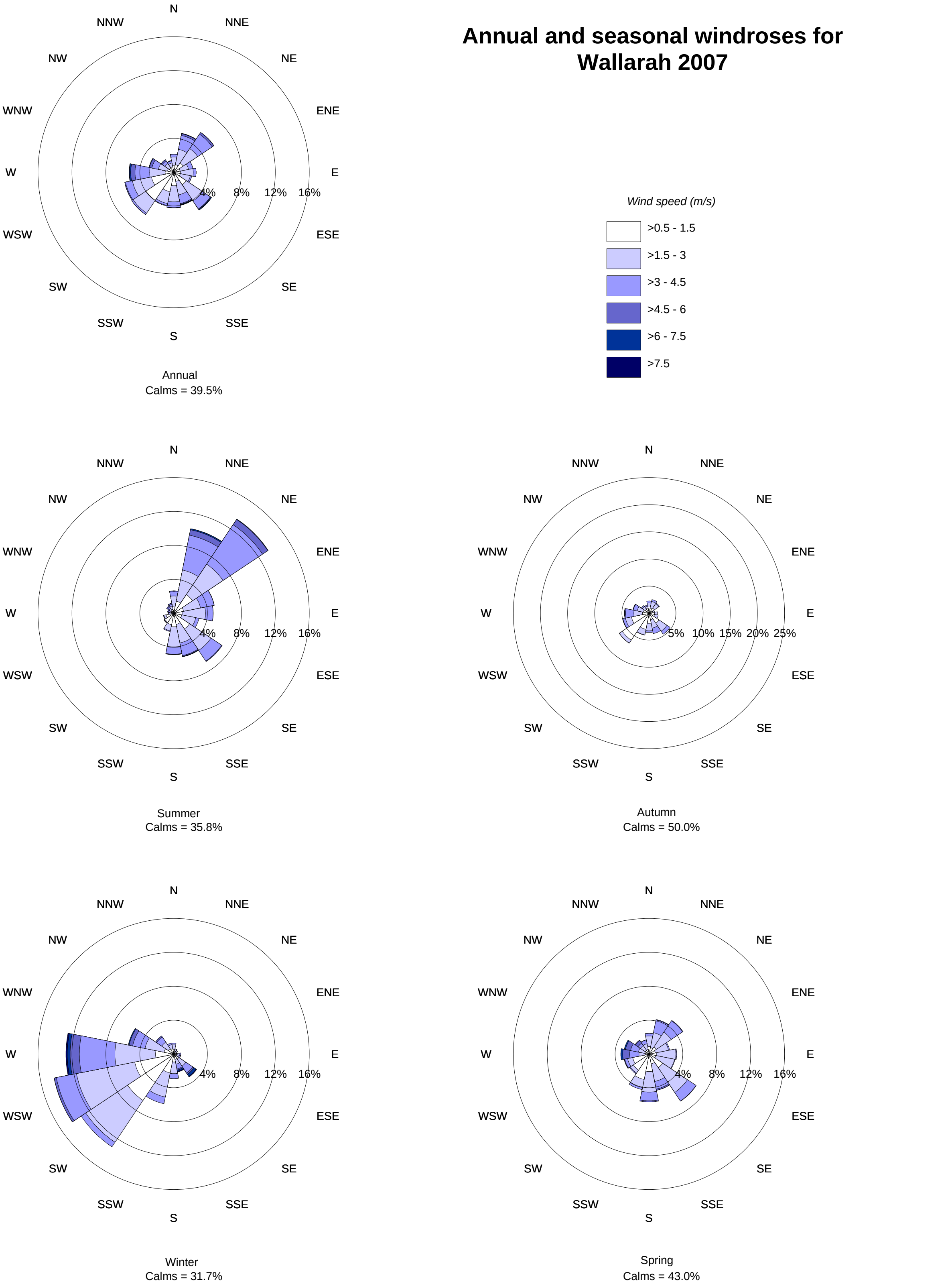

Figure 7 Annual and seasonal windroses Wallarah 2007

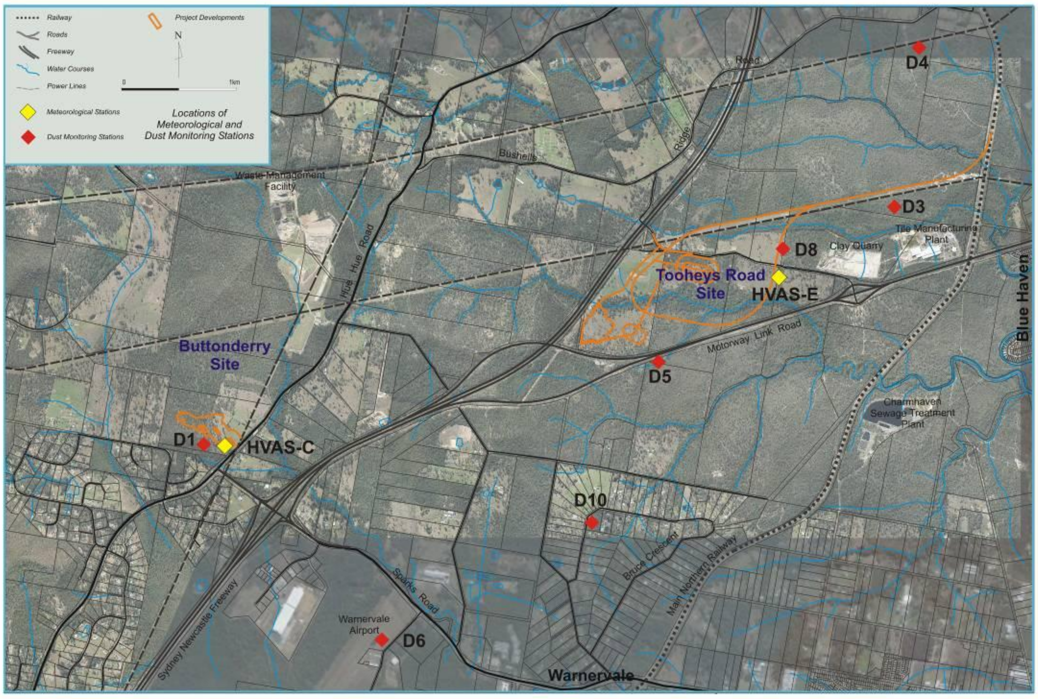

Figure 8 Location of dust and meteorological monitoring equipment

Figure 9 Location of special receptors

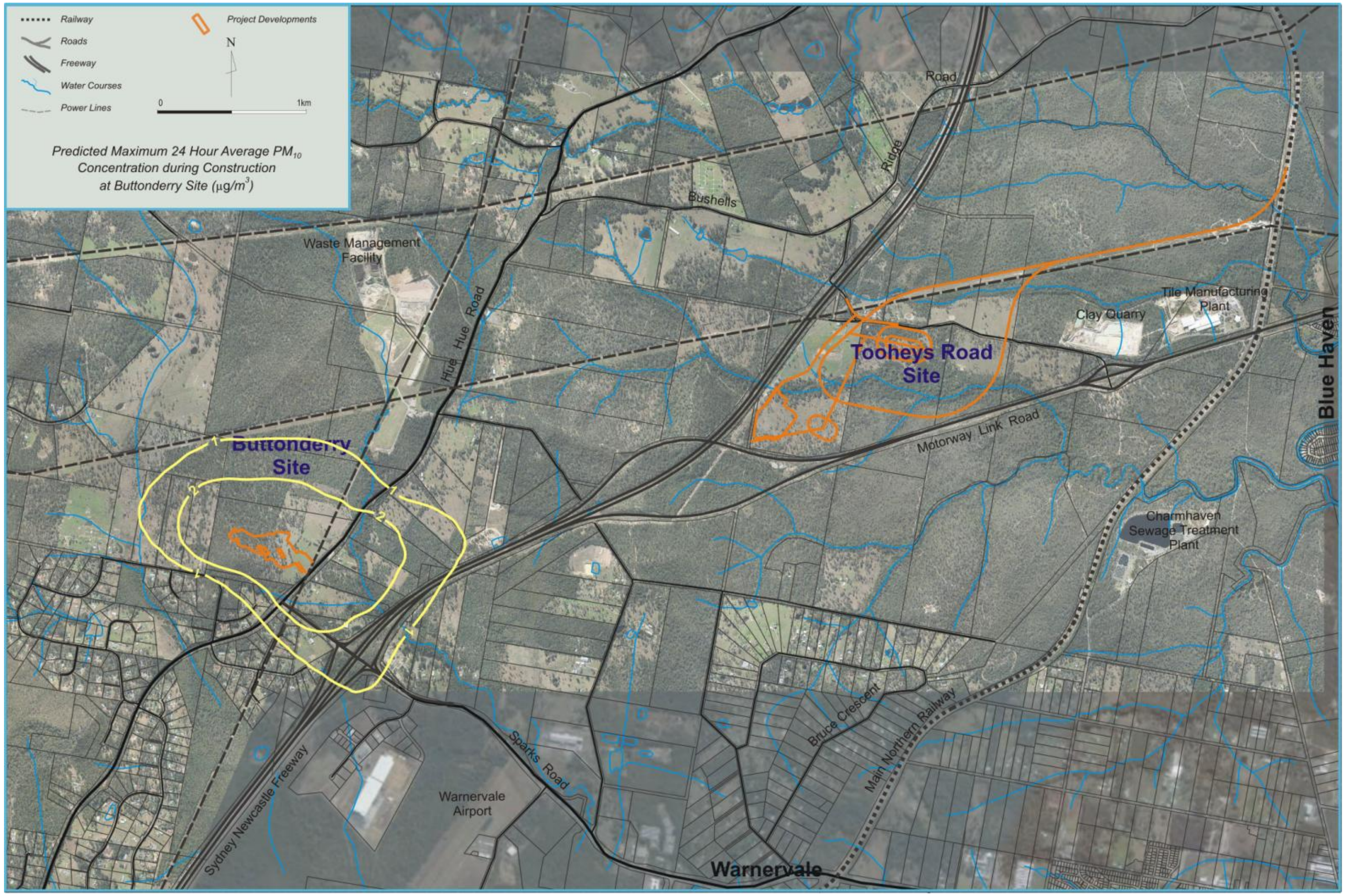

Figure 10 Predicted maximum 24-hour average PM_{10} concentration during construction at the Buttonderry site($\mu g/m^3$)

Figure 11 Predicted annual average PM_{10} concentration during construction at the Buttonderry site ($\mu g/m^3$)

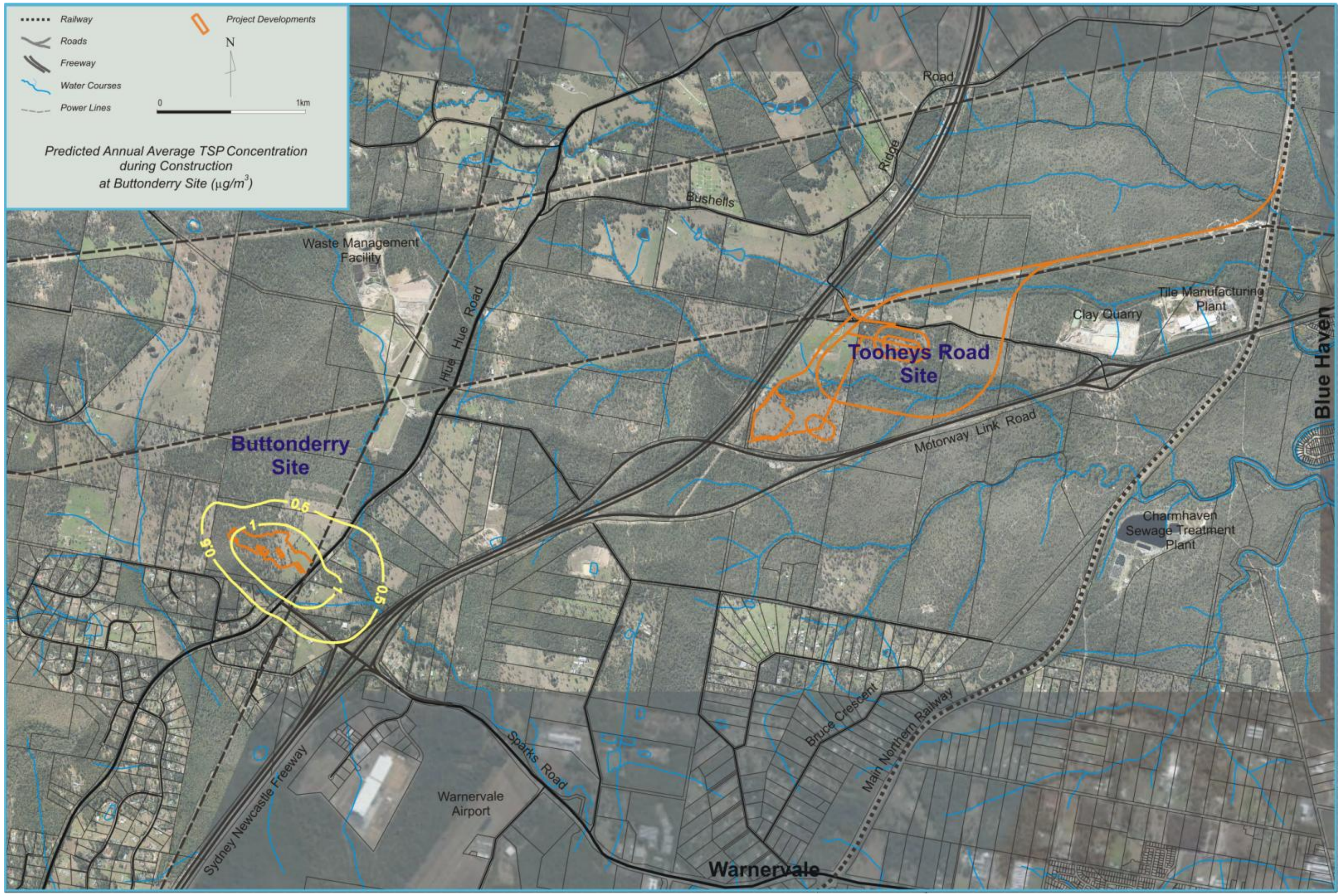

Figure 12 Predicted annual average TSP concentration during construction at the Buttonderry site (μg/m³)

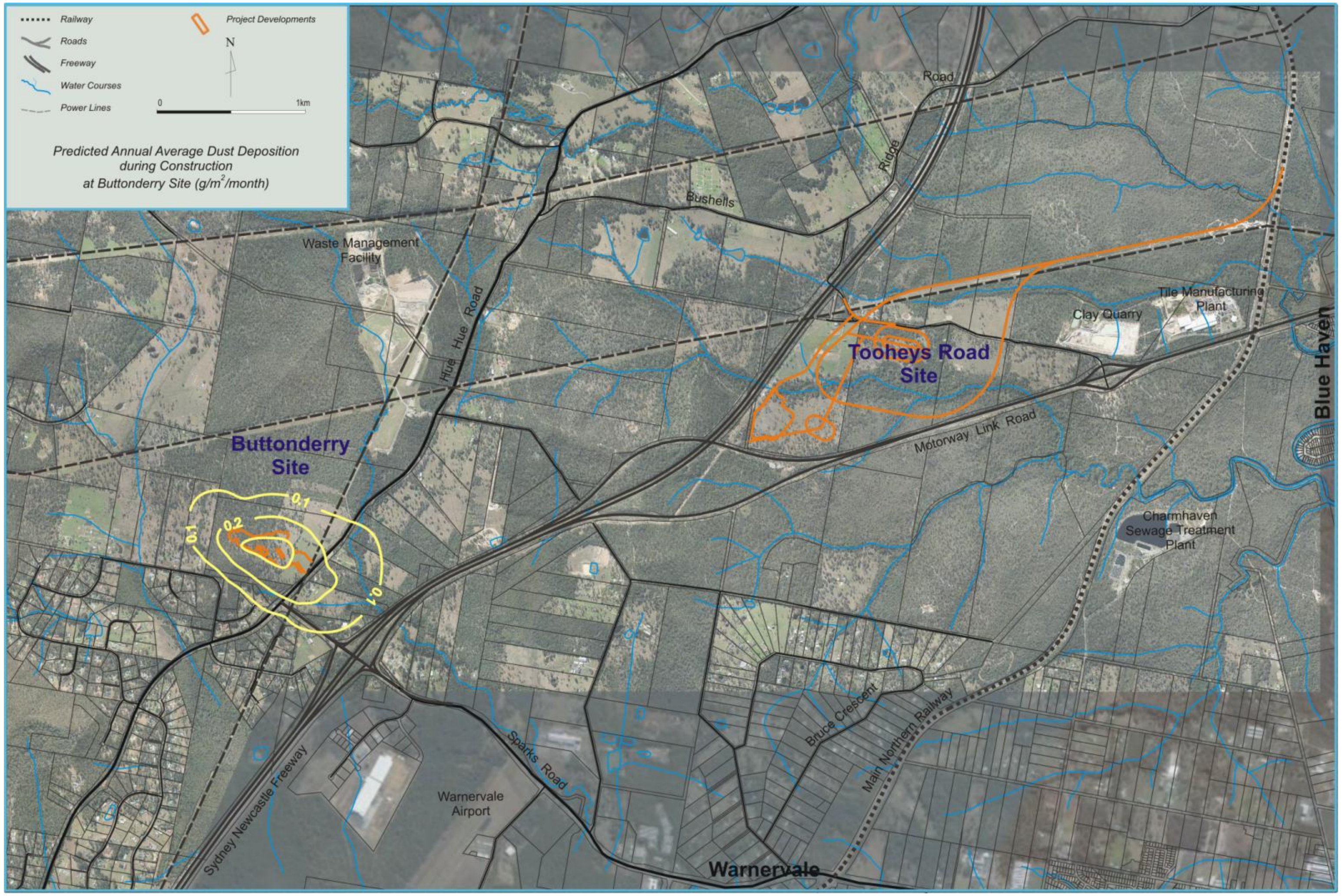

Figure 13 Predicted annual average dust deposition construction at the Buttonderry site (g/m^2/month)

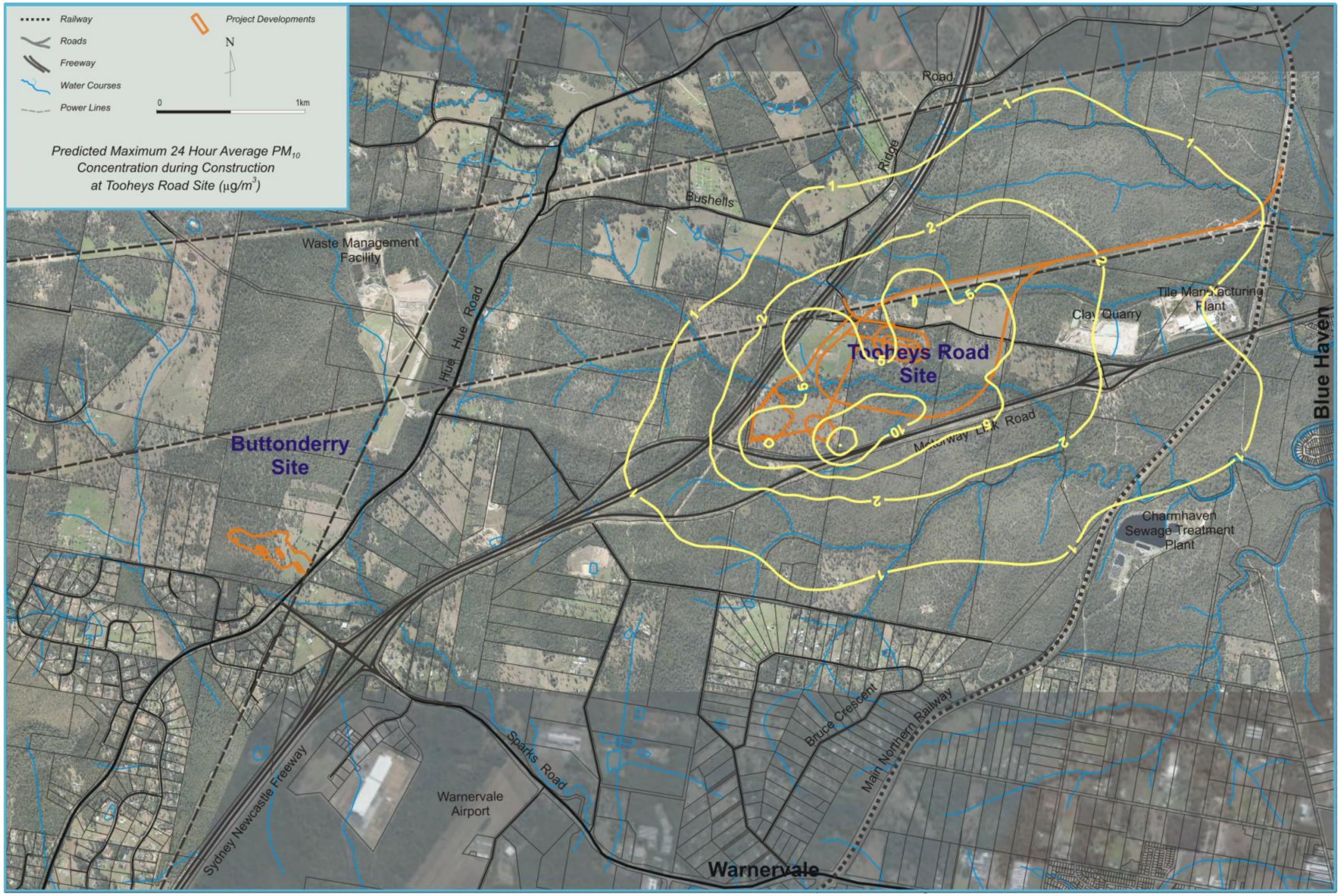

Figure 14 **Predicted maximum 24-hour average PM_{10} concentration during construction at the Tooheys Road site($\mu g/m^3$)**

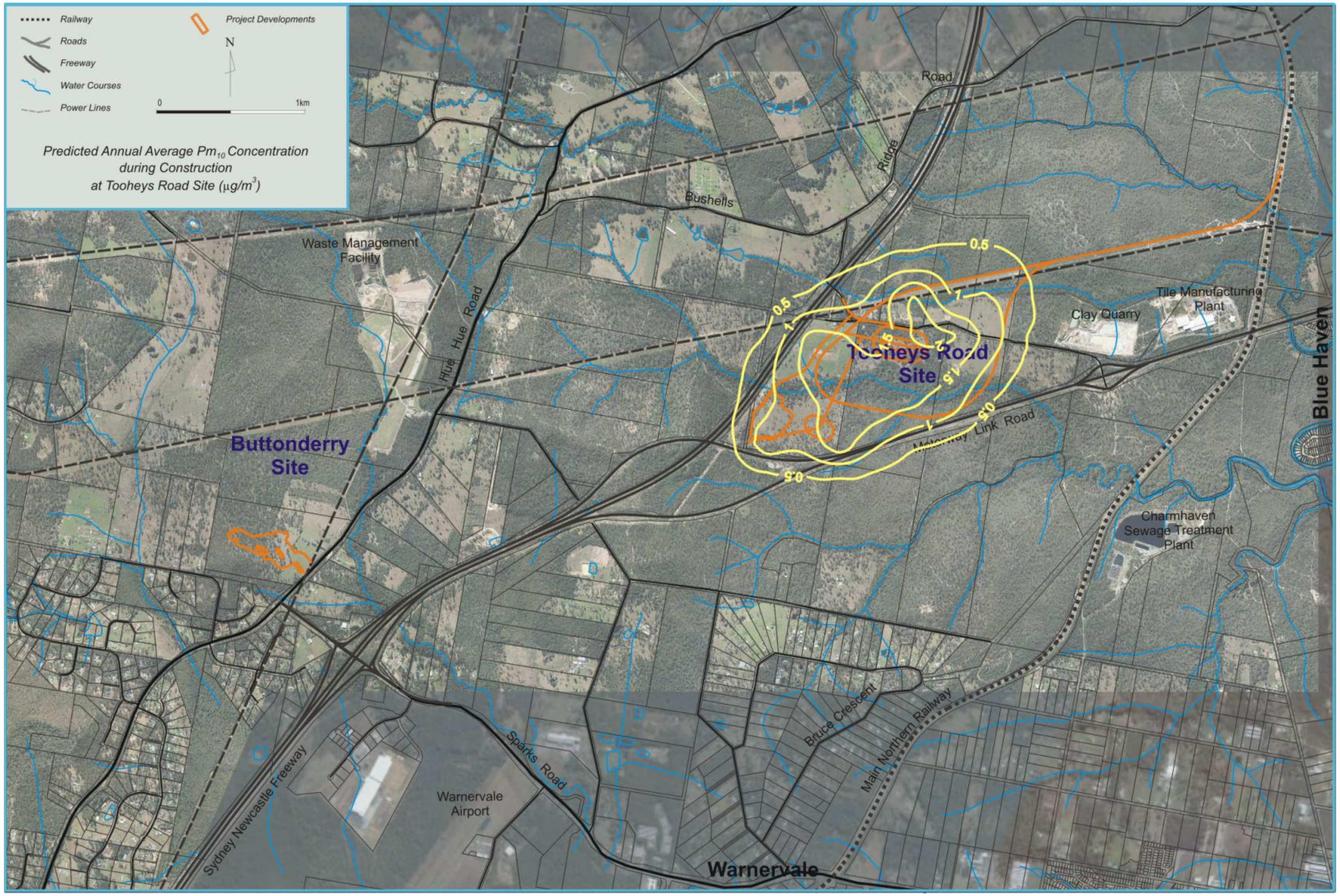

Figure 15 Predicted annual average PM_{10} concentration during construction at the Buttonderry site ($\mu g/m^3$)

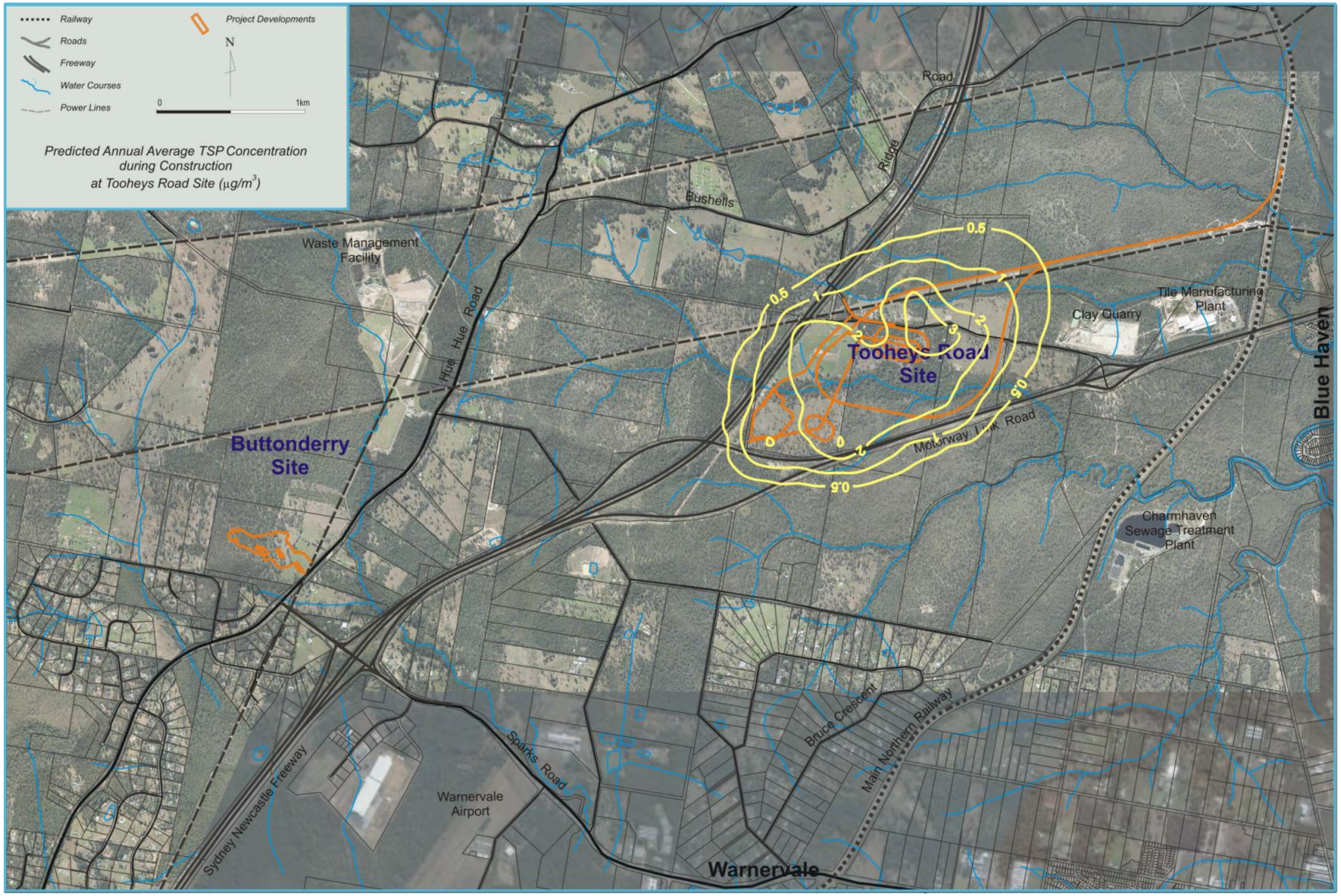

Figure 16 Predicted annual average TSP concentration during construction at the Buttonderry site ($\mu g/m^3$)

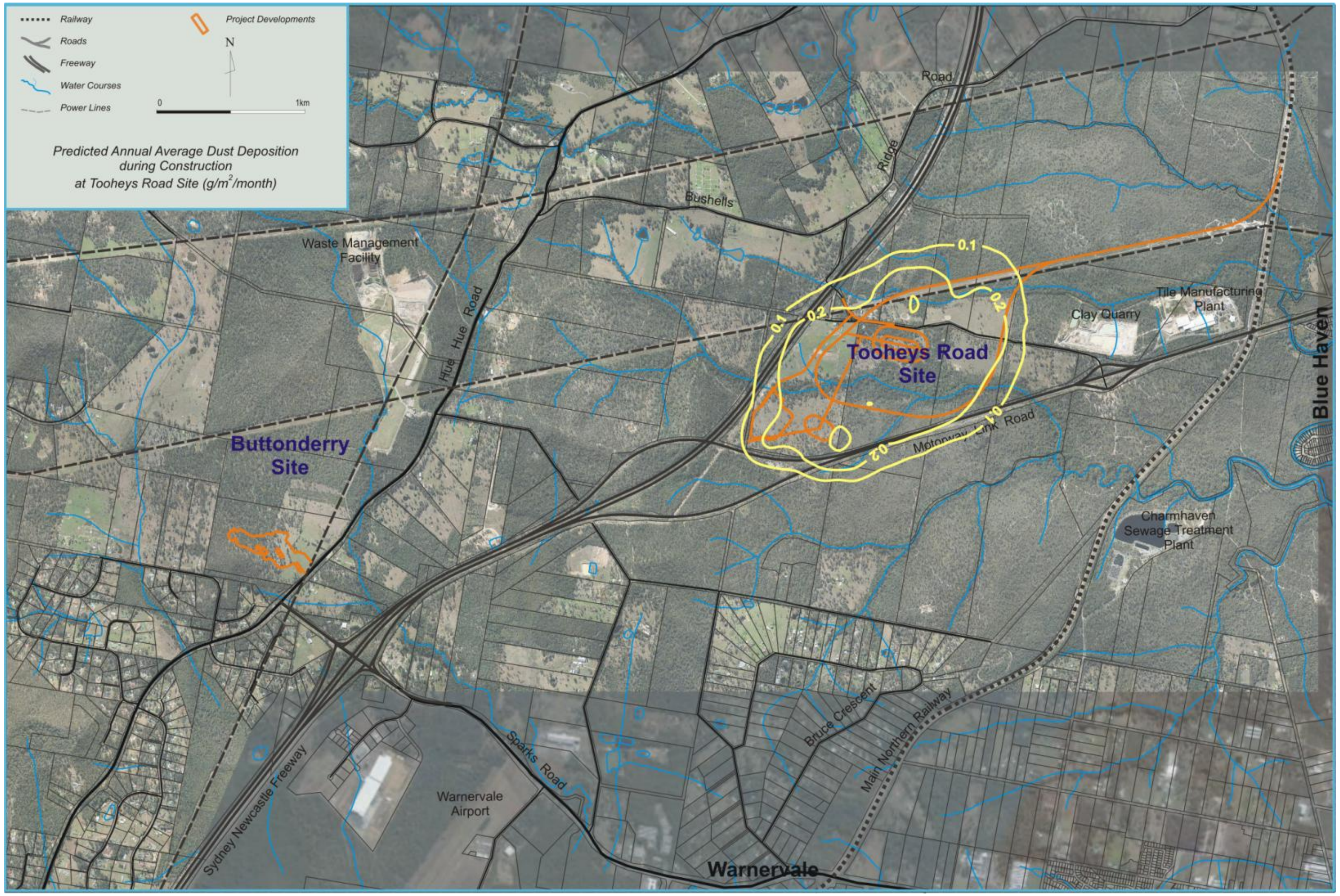

Figure 17 Predicted annual average dust deposition during construction at the Buttonderry site (g/m^2/month)

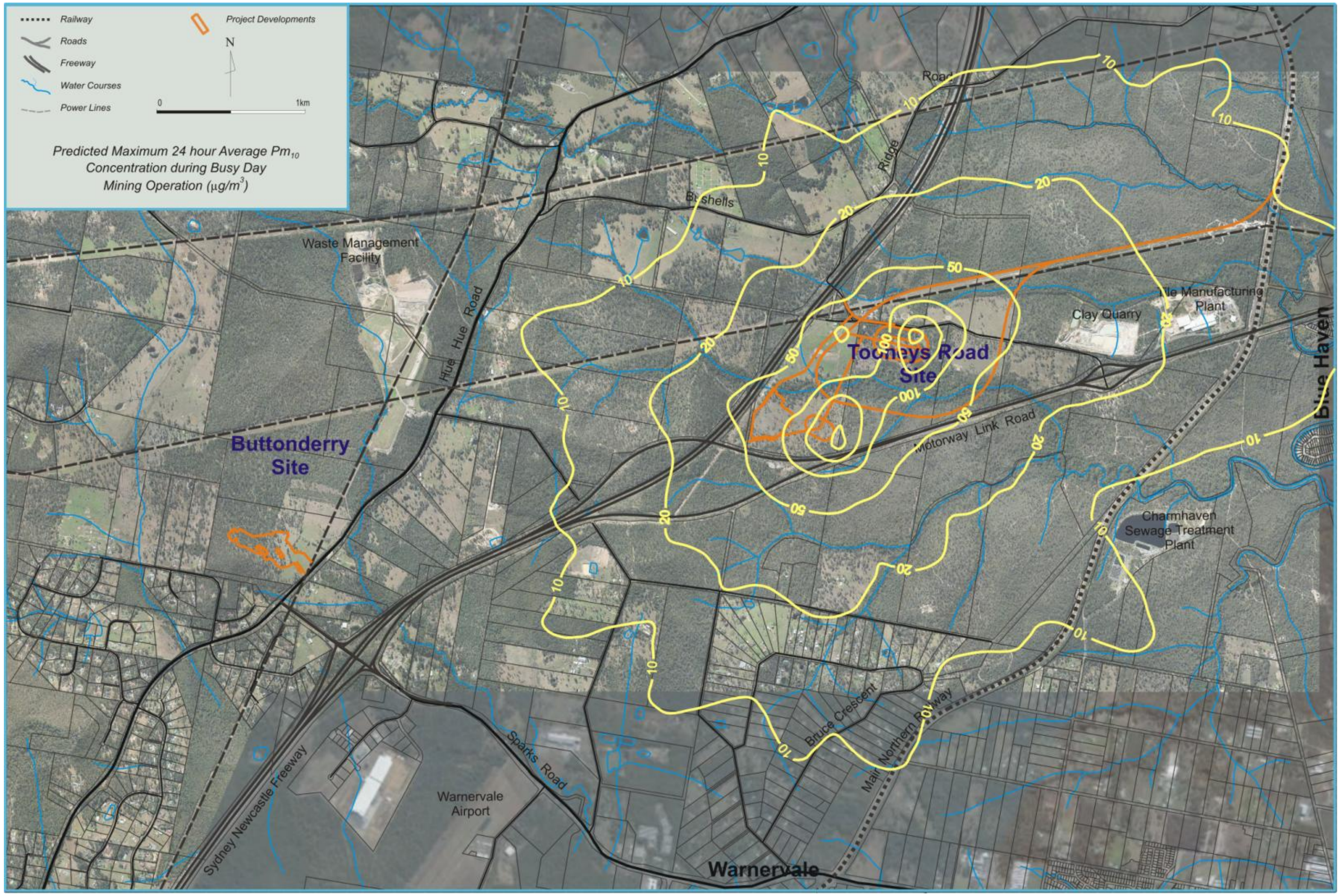

Figure 18 **Predicted maximum 24-hour average PM_{10} concentration during mine operation ($\mu g/m^3$) – busy day**

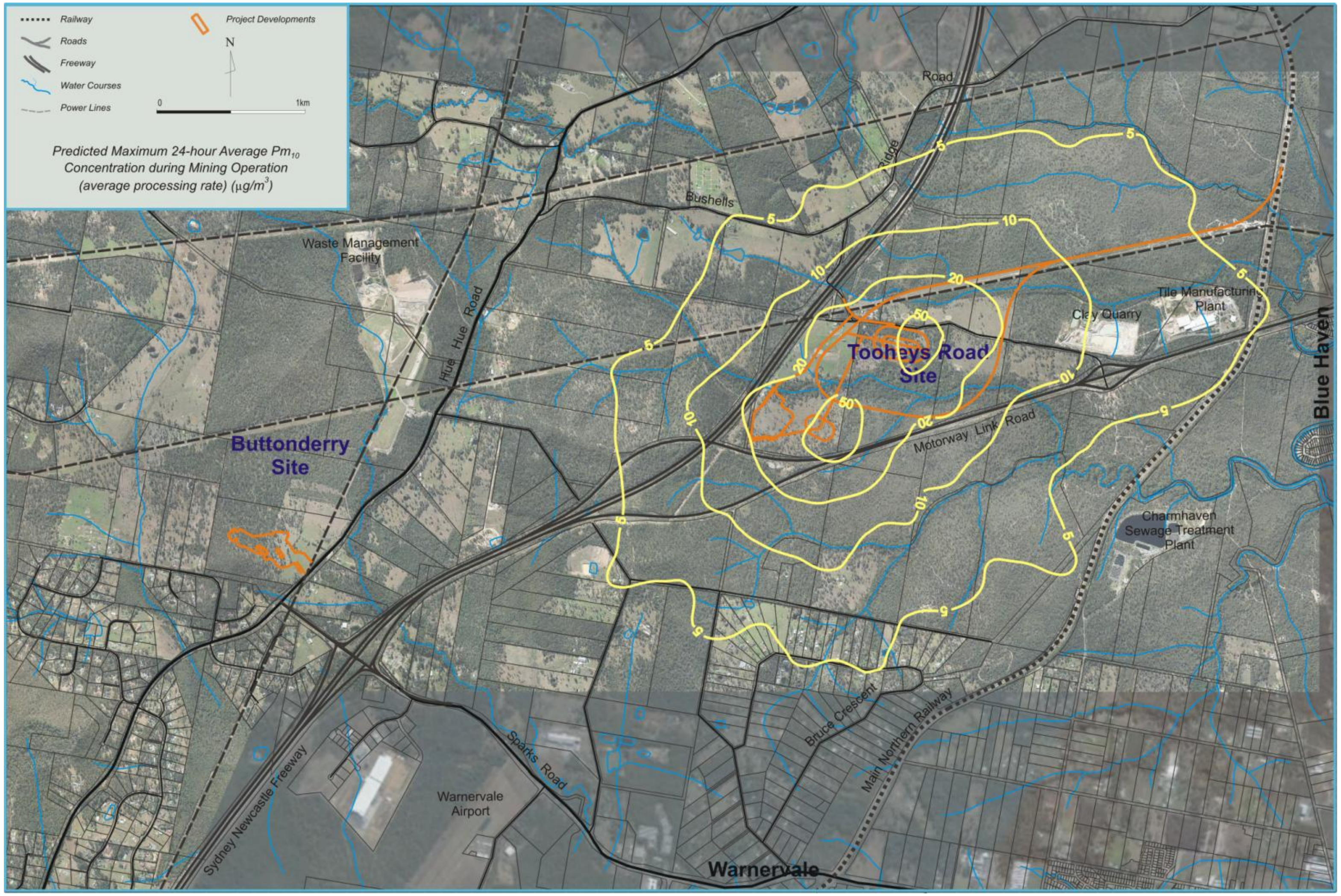

Figure 19 Predicted maximum 24-hour average PM_{10} concentration during mine operation ($\mu g/m^3$) – average day

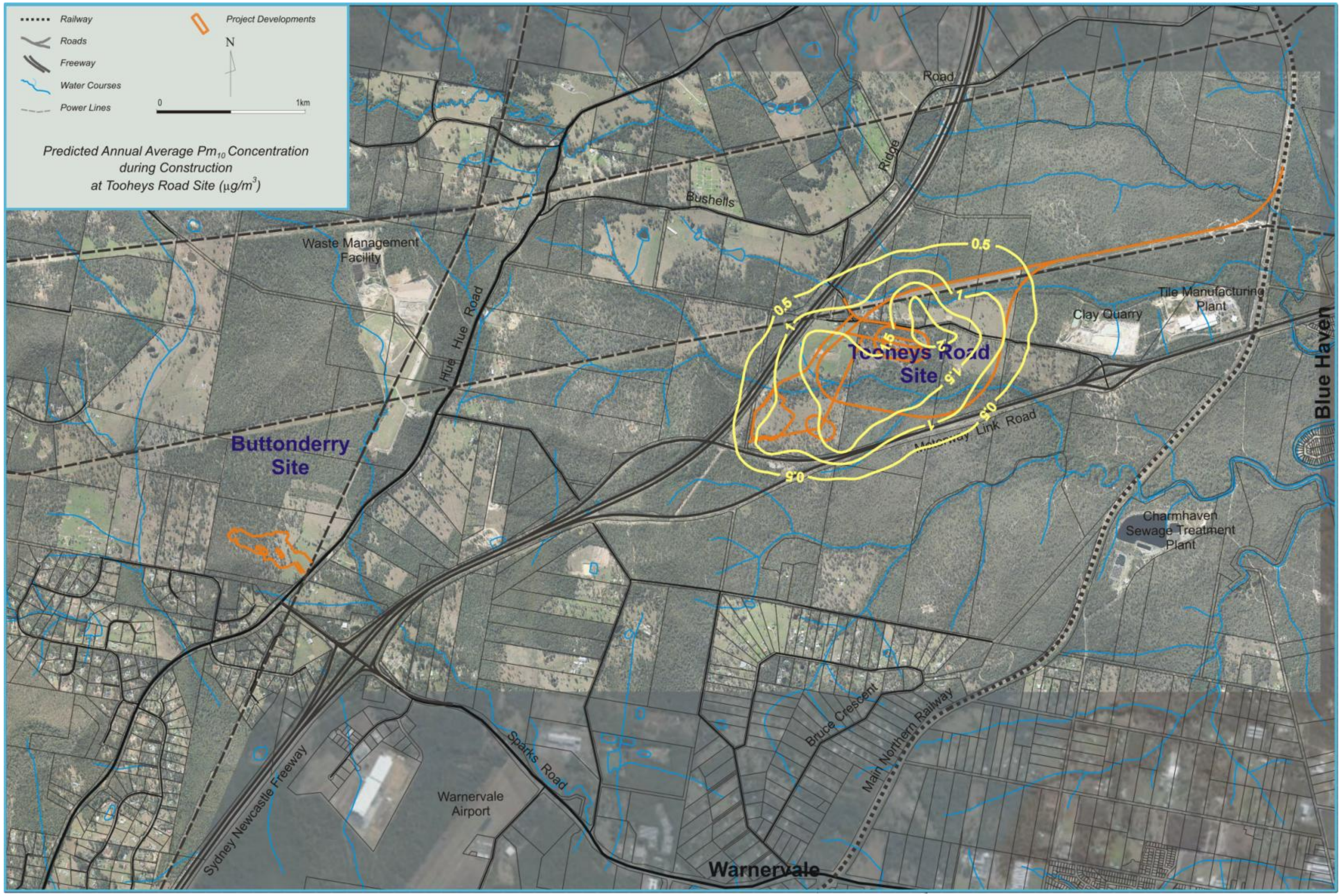

Figure 20 Predicted annual average PM_{10} concentration during mine operation ($\mu g/m^3$)

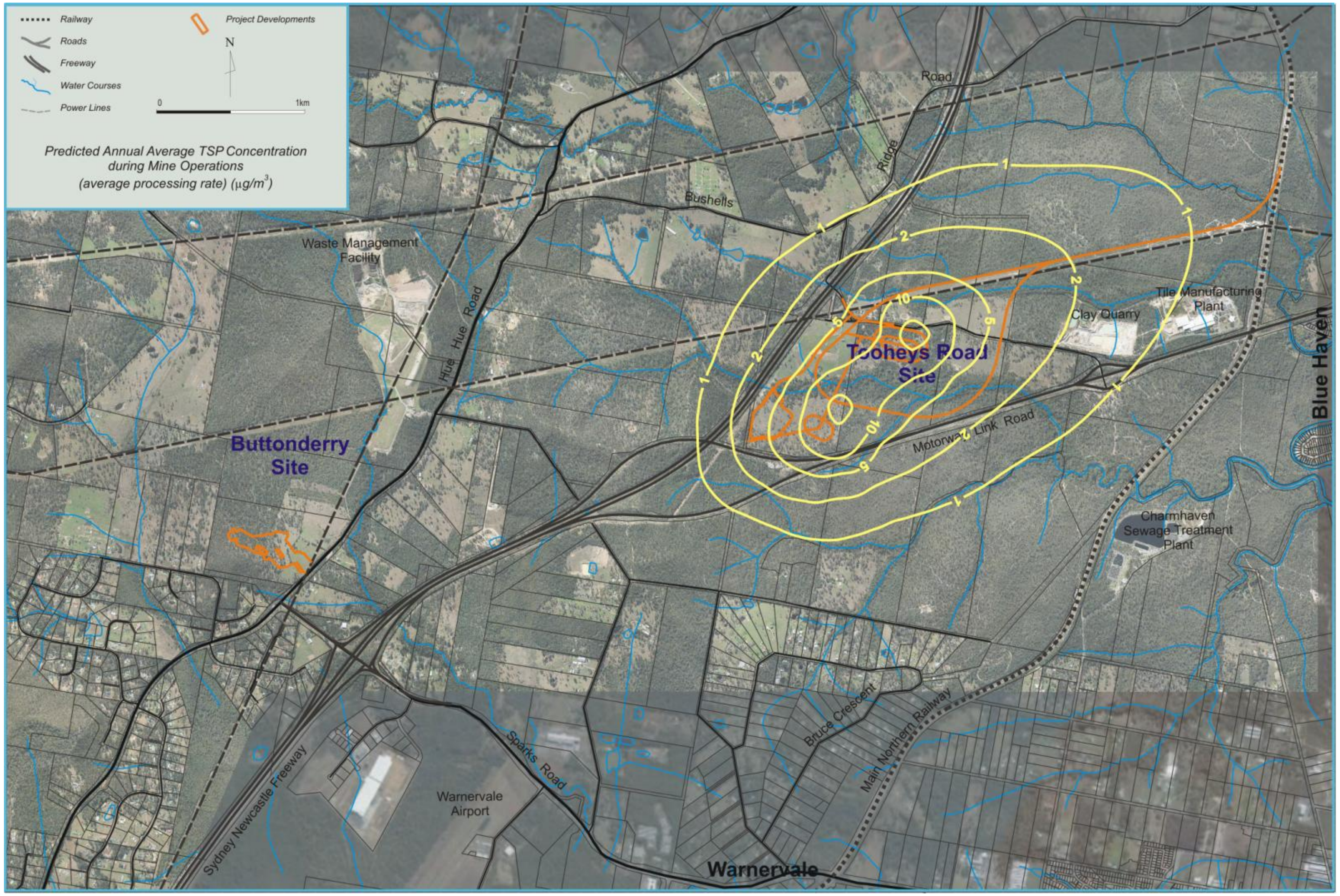

Figure 21 Predicted annual average TSP concentration during mine operation (µg/m³)

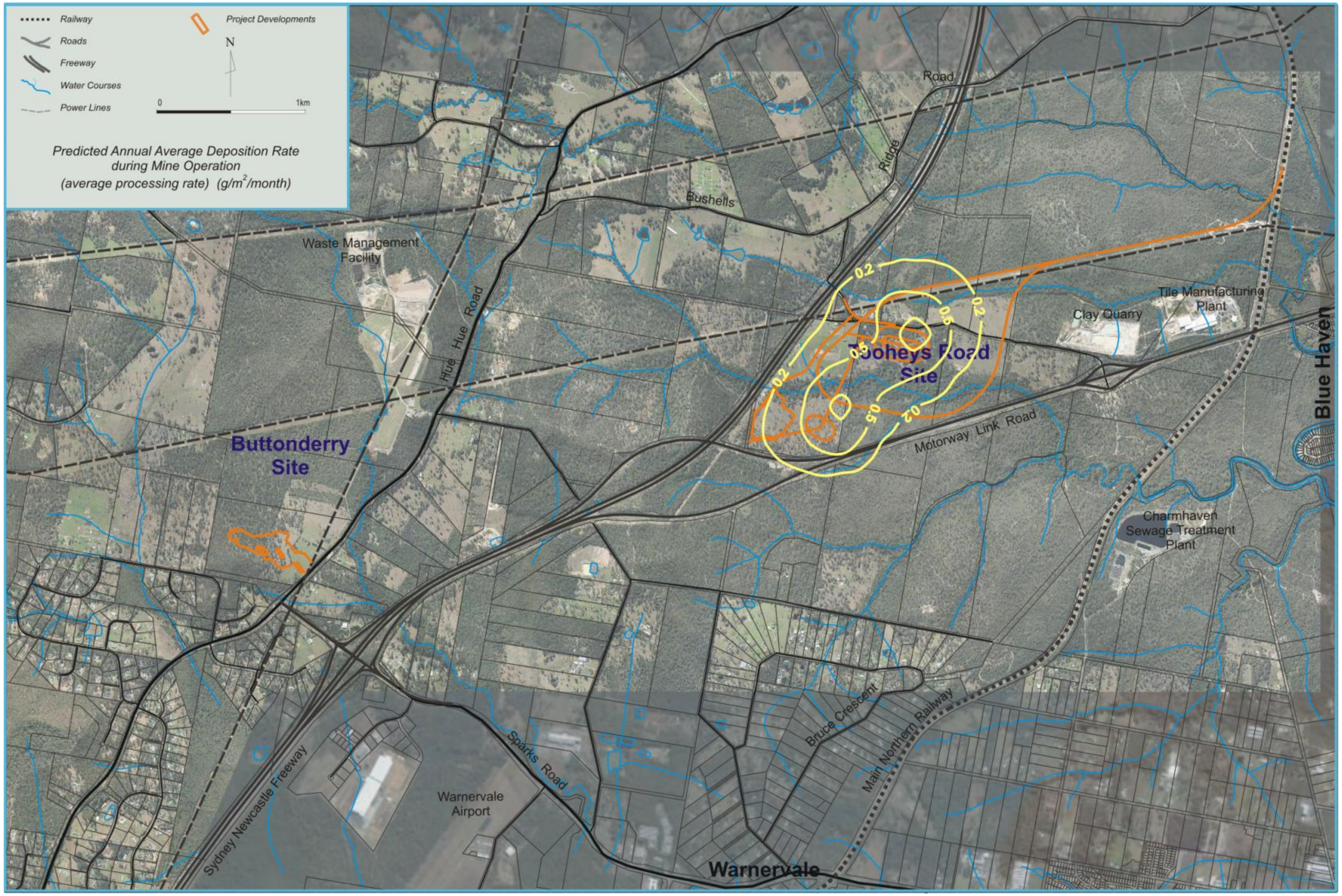

Figure 22 Predicted annual average dust deposition during mine operation (g/m^2/month)

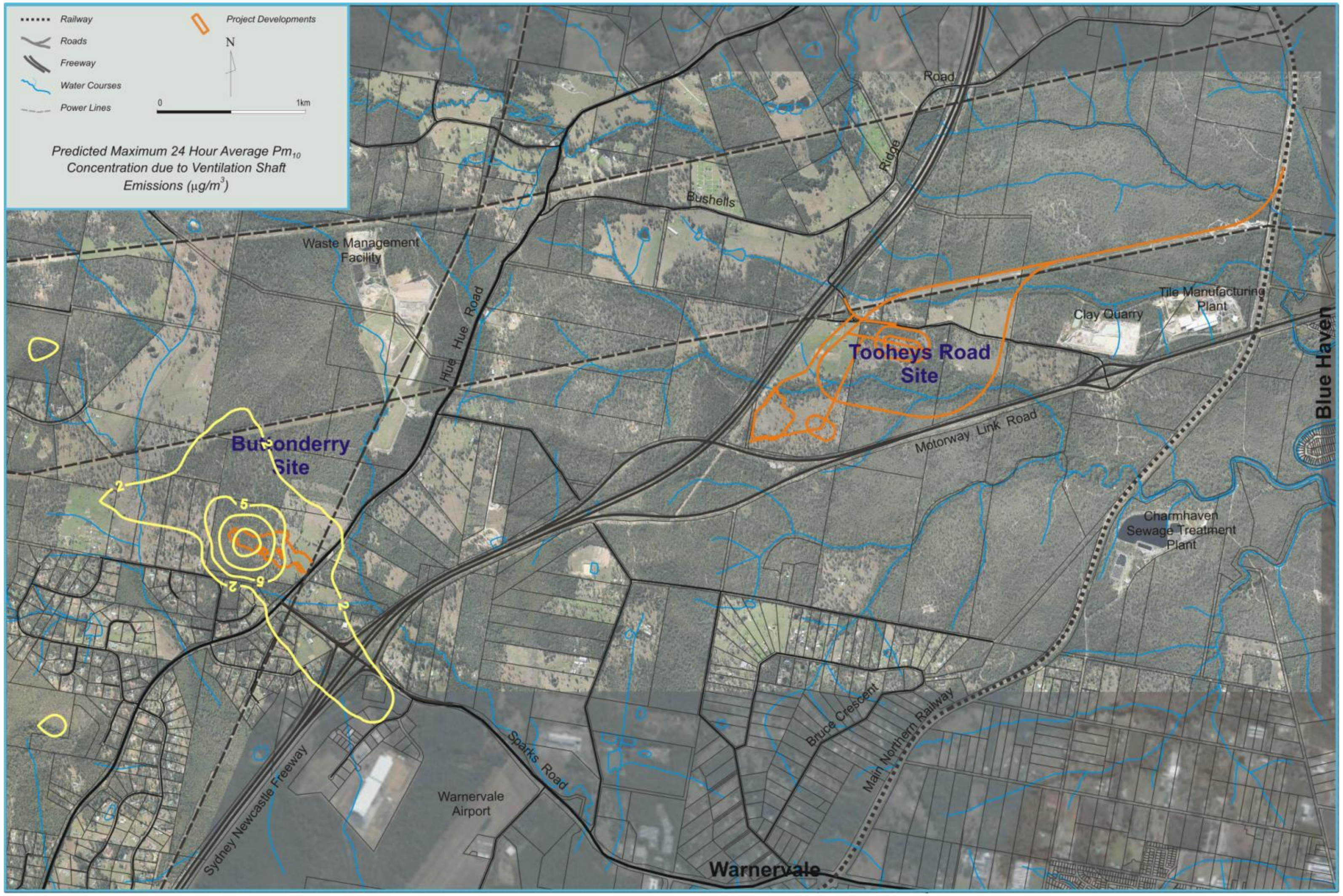

Figure 23 **Predicted maximum 24-hour average PM_{10} concentration due to ventilation shaft emissions ($\mu g/m^3$)**

Figure 24 Predicted annual average PM_{10} concentration due to ventilation shaft emissions ($\mu g/m^3$)

Figure 25 **Predicted maximum 24-hour average PM_{10} concentration due to ventilation shaft emissions plus background ($\mu g/m^3$)**

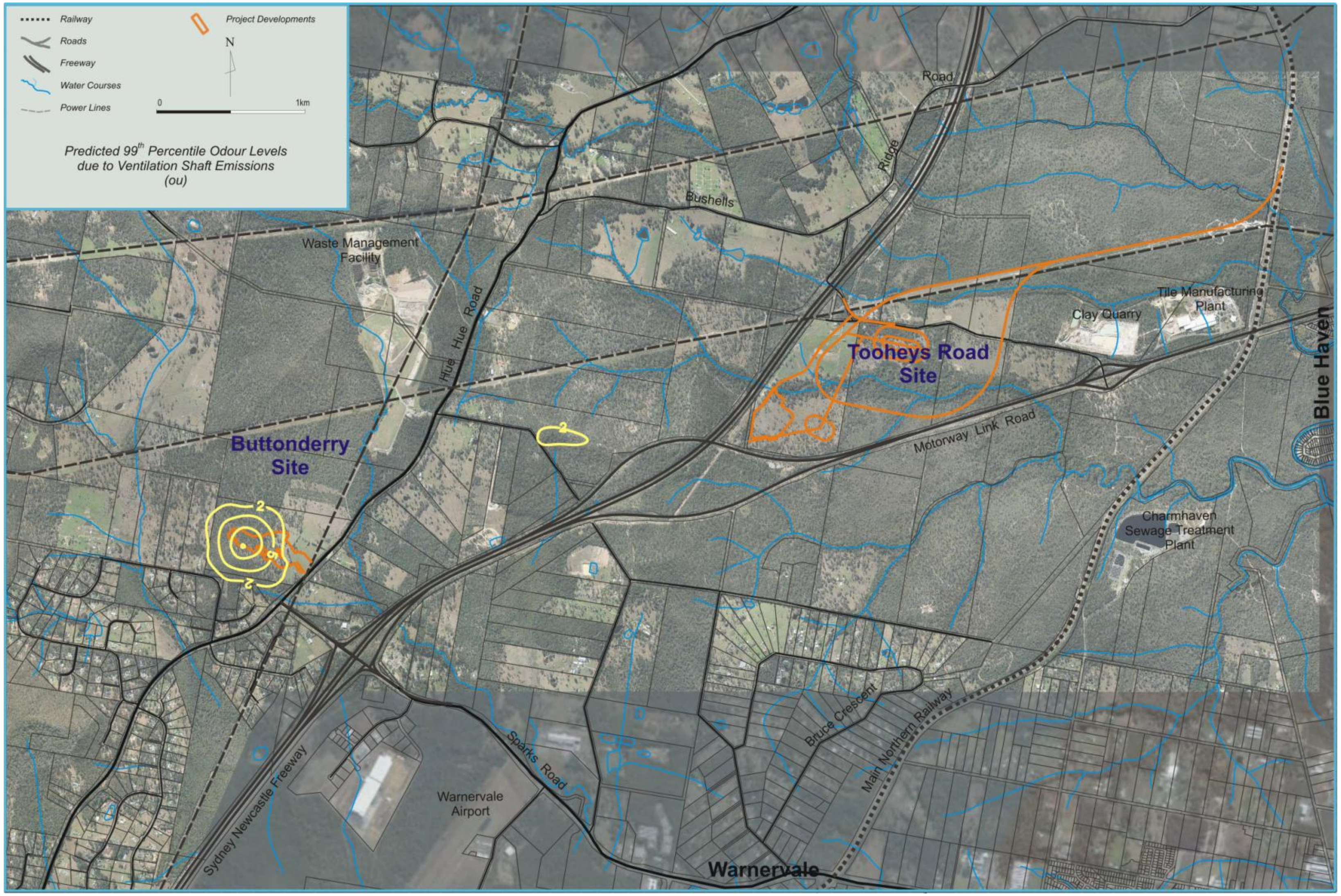

Figure 26 Predicted 99th percentile odour levels due to ventilation shaft emissions (ou) -