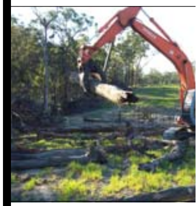

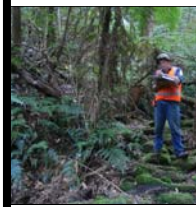

Air Quality Impact Assessment (SLR, 2011)

APPENDIX 7

global environmental solutions

Ventilation Air Methane Abatement Demonstration Project

Mandalong Mine

Air Quality Impact Assessment

Report Number 30-2517-R2

23 May 2011

Centennial Mandalong P/L
c/- GSSE
PO Box 907
Hamilton NSW 2303

Version: Revision 0

Ventilation Air Methane Abatement Demonstration Project

Mandalong Mine

Air Quality Impact Assessment

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Reference	Status	Date	Prepared	Checked	Authorised
30-2517-R2	Draft 2	8 April 2011	Martin Doyle	Gary Graham	Martin Doyle

EXECUTIVE SUMMARY

SLR Consulting Pty Ltd (SLR Consulting) has been commissioned by GSS Environmental (GSSE) on behalf of Centennial Mandalong Pty Ltd (Centennial Mandalong) to undertake an air quality impact assessment for the proposed Ventilation Air Methane Abatement Demonstration Project at the Mandalong Mine. The Mandalong Mine is an underground longwall mine with development consent approval for 6 Mtpa ROM coal extraction.

This report presents the Air Quality Impact Assessment (AQIA) for the proposed project.

Greenhouse gas (GHG) emissions from the Mandalong Mine are relatively high, with 1 Mt of carbon dioxide equivalent (CO_2-e) (direct emissions) produced each year. Methane has a global warming potential 21 times that of carbon dioxide (CO_2) if released unabated into the atmosphere. Methane released from the coal seam consists of high purity methane drainage gas (32 %) and high flow rate ventilation air methane or VAM (68 %). GHG emissions associated with the high purity methane can be reduced by gas flares (burning) and gas engines (power generation) and installation of both alternatives has already been approved. The reduction of GHG emissions associated with the high purity methane is outlined in the Modification to Development Consent (Holmes Air Sciences, 2008).

The GHG emissions associated with the VAM is more difficult to mitigate. Methane is only flammable in air when the temperature is above 595 ºC and the concentration exceeds 5 % (Cork, 2009). The methane concentration in VAM is however only 1 %, making it more difficult to mitigate than the high purity methane. Different alternatives are currently being researched by the industry. One abatement technique is to oxidise the methane in a VAM-RAB (Regenerative After Burner) unit where the VAM is progressively heated to 700 ºC through a series of chequer bricks until it reaches the combustion chamber with a temperature of 1,000 ºC. Oxidisation of the methane occurs in the high temperature chamber, with 99.9 % of the methane oxidised to carbon dioxide. The heat from the air is then transferred back to the chequer bricks before the air is emitted. Centennial Mandalong is seeking approval for the installation and operation of a single VAM-RAB unit and associated infrastructure without heat recovery or generation capability, as a demonstration project.

Although approval has already been granted for the gas engines and flares, a cumulative air quality assessment has been performed to assess the air quality impact of all equipment on site. Emissions of criteria air pollutants from the VAM-RAB are considered to be negligible in comparison with emissions from the approved gas flaring units and gas engines. The air quality impacts for the two different cases have therefore been assessed, representing worst case emissions from the flares and gas engines.

Air pollutant dispersion modelling indicates that maximum cumulative ground level concentrations from the gas engines and from the gas flares results in air quality criteria for NO_2, CO and SO_2 being achieved at all surrounding sensitive receptor locations. The predicted NO_2 concentrations are slightly higher for the gas engines than for the flares and will therefore constitute a worst case scenario.

No pollutant concentrations are contributed to by the operation of the VAM-RAB unit.

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1 INTRODUCTION

SLR Consulting Pty Ltd (SLR Consulting) has been commissioned by GSS Environmental (GSSE) on behalf of Centennial Mandalong Pty Ltd (Centennial Mandalong) to undertake an air quality impact assessment for the proposed Ventilation Air Methane Abatement Demonstration Project at the Mandalong Mine. Mandalong Mine is an underground longwall mine with development consent approval for 6 Mtpa ROM coal extraction.

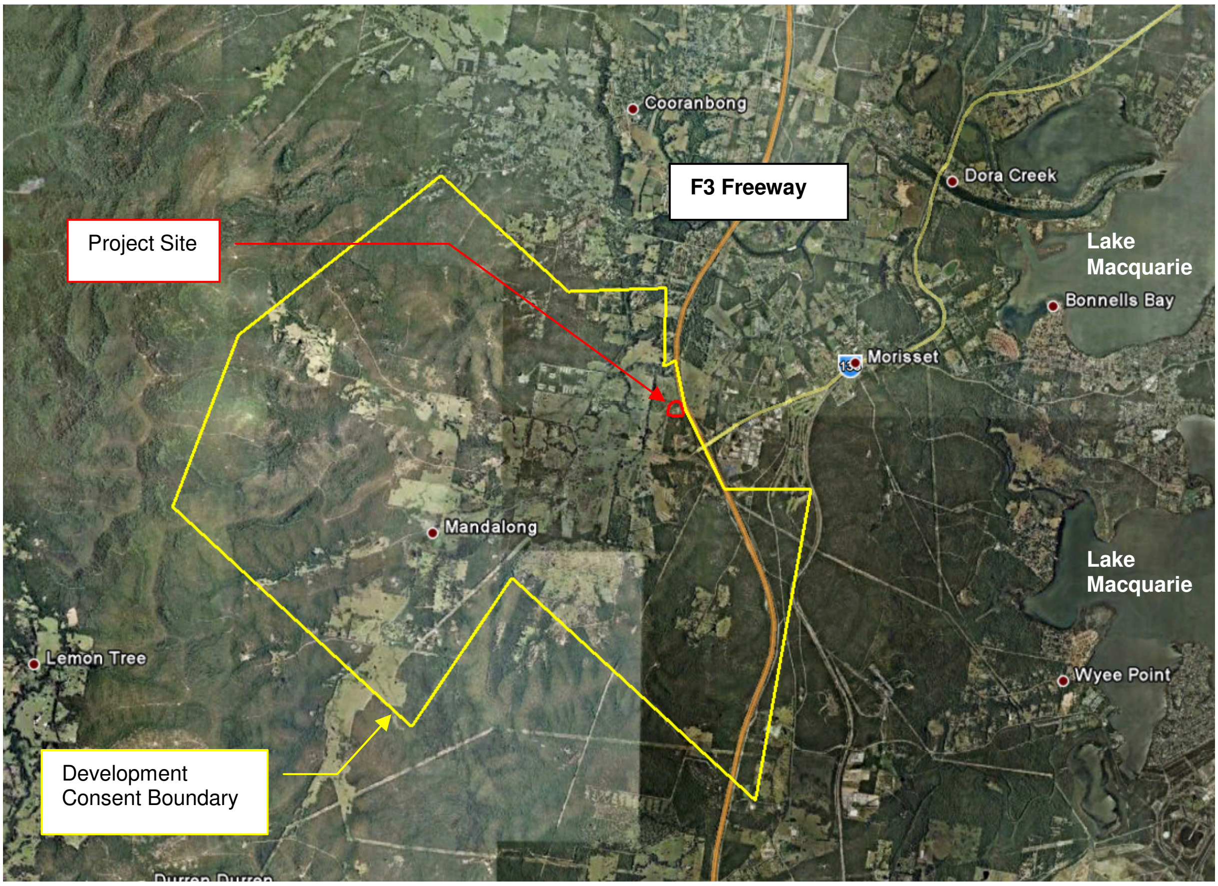
This report presents the Air Quality Impact Assessment (AQIA) for the proposed project.

1.1 Project Location

Mandalong Mine is located near Morisset, approximately 5 km west of Lake Macquarie, in the Newcastle Coalfield of New South Wales. The Project Site is bounded by the F3 Sydney–Newcastle Freeway to the east and Mandalong Road to the south.

Figure 1 illustrates the local setting of the Project Site.

Figure 1 Local Setting of Mandalong Mine



Source: Google Earth 2011

1.2 Project Overview

Greenhouse gas (GHG) emissions from the Mandalong Mine are estimated to be approximately 1 Mt of carbon dioxide equivalent (direct emissions) produced each year. Methane has a global warming potential 21 times that of carbon dioxide if released unabated into the atmosphere (IPCC, 1996). Methane released from the coal seam consists of high purity methane drainage gas (32 % of total flow) and high flow rate ventilation air methane or VAM (68 % of total flow). GHG emissions associated with the high purity methane can be reduced by gas flares and gas engines (power generation) The installation of both gas flares and gas engines at Mandalong Mine have previously been approved.

The GHG emissions associated with VAM is more difficult to mitigate. Methane is only flammable in air when the temperature is above 595ºC and the concentration exceeds 5 %(v/v) (Cork, 2009). The methane concentration in VAM is however only 1%(v/v), making it more difficult to mitigate than the high purity methane. Different alternatives are currently being researched by the industry. One abatement technique is to oxidise the methane in a VAM-RAB (Regenerative After Burner) unit where the VAM is progressively heated to 700ºC through a series of chequer bricks until it reaches the combustion chamber with a temperature of 1,000ºC. Oxidisation of the methane occurs in the combustion chamber, with approximately 99.9 % of the methane oxidised to carbon dioxide and water vapour. The heat from the air is then transferred back to the chequer bricks before the air is emitted to atmosphere through a dedicated emission stack. Centennial Mandalong is seeking approval for the installation and operation of a single VAM-RAB unit without heat recovery or generation capability, as a demonstration project.

1.3 Summary of Previous Air Quality Impact Assessments

1.3.1 Mandalong Mine Statement of Environmental Effects (SKM, 2004)

The Mandalong Mine Statement of Environmental Effects (SoEE) evaluated the air quality impact from both construction and operation of the methane drainage plant. Dust emissions during the construction phase were estimated to be minor. The impact of methane emissions from the mine ventilation system were evaluated with the AUSPLUME v5.4 dispersion model (as developed by the Environment Protection Authority (EPA) of Victoria) using meteorological data from the Mannering Park automatic weather station (AWS), located 8 km southeast of Mandalong. No exceedances of the Project goal for methane emission in the surrounding area were predicted.

1.3.2 Mandalong Mine Statement of Environmental Effects (Umwelt Australia, 2006)

The Mandalong SoEE prepared by Umwelt Australia assessed the proposed installation of enclosed gas flare units. The high purity methane captured in the methane drainage plant was proposed to be flared to reduce greenhouse gas emissions from the mine. No quantitative air quality impact assessment was carried out for the proposed gas flares.

Construction impacts were assumed to be minor given that the construction area had already been cleared for the construction of the methane drainage plant.

1.3.3 Mandalong Modification to Development Consent Environmental Assessment– Appendix E (Holmes Air Sciences, 2008)

The Modification to Development Consent Air Quality Assessment by Holmes Air Sciences evaluated the air quality impact from:

- A 2 Mtpa increase in production capacity, allowing for up to 6 Mtpa of ROM coal to be mined; and
- The construction and operation of multiple gas engines with a total power of 12 MW, fuelled by the high purity methane gas captured by the existing methane drainage plant.

The 2 Mtpa increase in ROM coal extraction was shown not to increase dust emissions for the mining operation, given that the extraction of coal and conveying of ROM coal takes place under ground.

Dust emission during the construction phase was expected to be minor assuming standard dust control measures were implemented.

Carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) emissions from the proposed gas engines were assessed utilising AUSPLUME, using meteorological data from the Awaba meteorological monitoring station located 6 km north of the gas engine site. It was shown that the highest predicted ground level concentrations were below the Project goals at all surrounding sensitive land uses.

Concentrations of NO_2 were predicted to be approaching the air quality criteria (1-hour maximum) at locations close to the F3 Freeway (245.6 µg/m^3 as compared with a criteria of 246 µg/m^3), but not representative of receptor locations or public exposure.

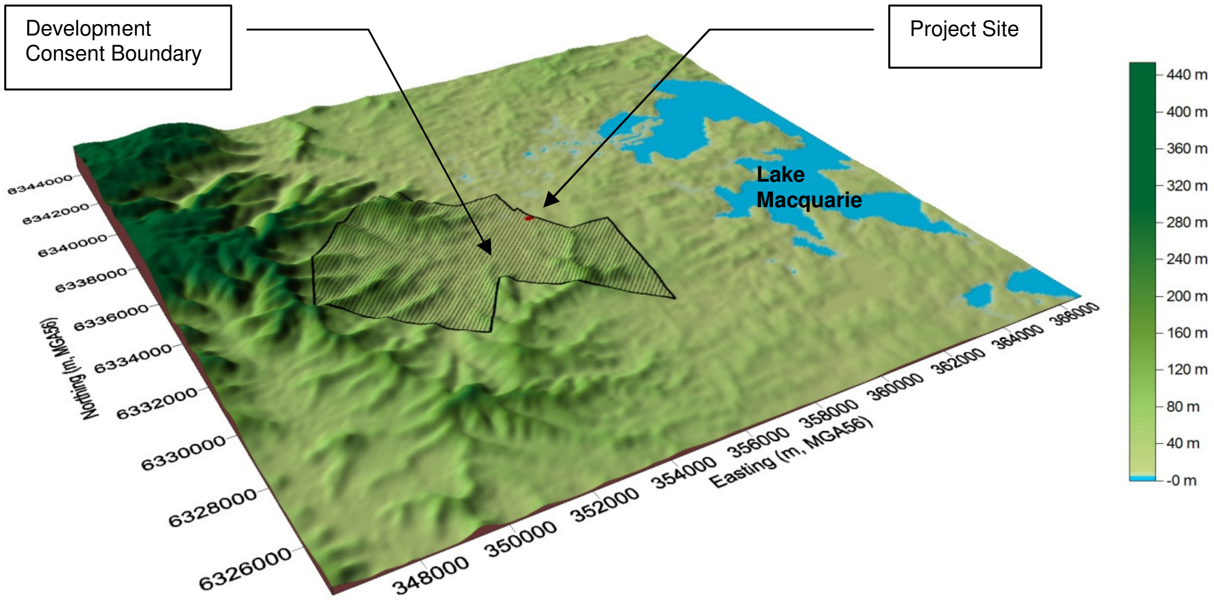
2 PROJECT SETTING

2.1 Local Topography

The Project Site and surrounding residences are located in undulating terrain, with elevated terrain located south and west of the site. The Project Site is situated at an approximate elevation of 10 m AHD, with a ridge running in a north-southerly direction located just south of the site. The land levels out to the east of the site towards Lake Macquarie.

The topography of the local region surrounding the Project Site is presented in **Figure 2**.

Figure 2 Local Topography



2.2 Sensitive Receptors

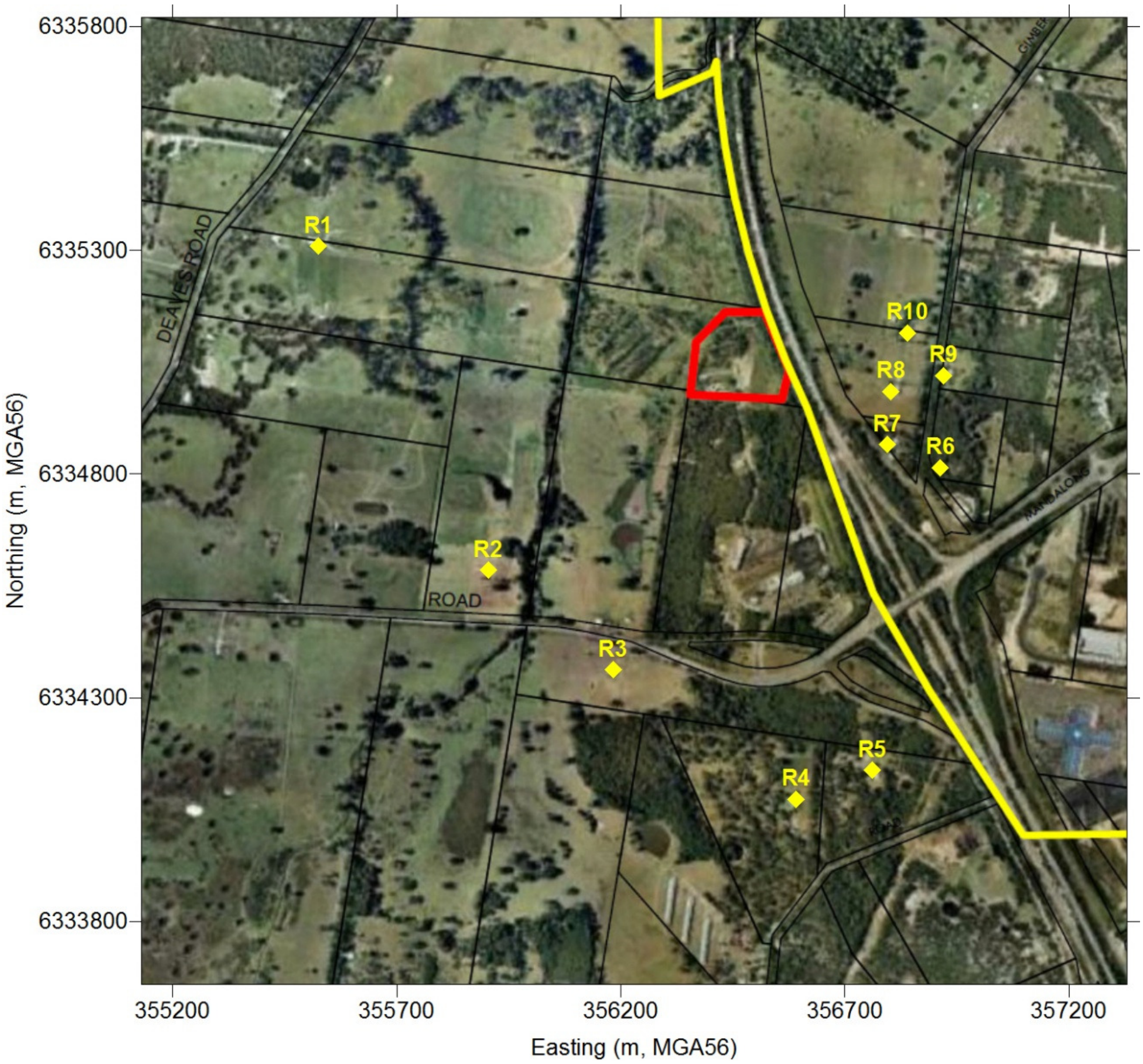
A number of residences are located in the area surrounding the Project Site. The nearest residences have been identified as sensitive receptor locations to be considered during the Air Quality Impact Assessment. A list of the nearest sensitive receptors in the immediate vicinity of the Project Site (R1 to R10) and their respective distances from the Project Site boundary are presented in **Table 1** and **Figure 3.**

Table 1 Nearest Sensitive Receptors

Receptor ID	Location	Ownership	Location (m, MGA56)		Distance (m) / Direction From Site Boundary	Elevation (m, AHD)
			Easting	Northing		
R1	61//9632	Private	355,525	6,335,309	850 / WNW	9
R2	2//557230	Private	355,904	6,334,585	560 / SW	9
R3	10//261891	Private	356,183	6,334,363	610 / SSW	14
R4	4//555891	Private	356,591	6,334,074	870 / S	37
R5	3//13318	Private	356,761	6,334,138	840 / SSE	25
R6	1//262159	Private	356,913	6,334,814	400 / ESE	23
R7	4//262159	Private	356,795	6,334,866	270 / ESE	19

Receptor ID	Location	Ownership	Location (m, MGA56)		Distance (m) / Direction From Site Boundary	Elevation (m, AHD)
			Easting	Northing		
R8	7//262159	Private	356,803	6,334,985	250 / E	16
R9	3//10720	Private	356,920	6,335,020	380 / E	18
R10	9//262159	Private	356,839	6,335,116	310 / E	14

Figure 3 Sensitive Receptors Surrounding the Project Site



3 AMBIENT AIR QUALITY CRITERIA

3.1 National Environment Protection Measure (NEPM) – Ambient Air Quality

In June 1998, the National Environment Protection Council (NEPC) of Environment Ministers agreed to set uniform standards for ambient air quality to apply to all States and Territories. These standards are contained in the NEPM for ambient air quality.

These NEPM goals were developed by the NEPC to be achieved within 10 years of commencement and set standards and goals for ambient levels of “criteria pollutants”.

The relevant NEPM standards, goals and advisory reporting standards applicable to this assessment are presented in **Table 1**.

Table 2 NEPM Standards, Goals and Advisory Reporting Standards for Pollutants

Pollutant	Averaging Period	Maximum Concentration	Maximum Allowable Exceedances
Carbon monoxide (CO)	8 hours	9.0 ppm (10 mg/m^3)	1 day a year
Nitrogen dioxide (NO_2)	1 hour 1 year	0.12 ppm (246 µg/m^3) 0.03 ppm (62 µg/m^3)	1 day a year none
Sulphur dioxide (SO_2)	1 hour 1 day 1 year	0.2 ppm (571 µg/m^3) 0.08 ppm (229 µg/m^3) 0.02 ppm (52 µg/m^3)	1 day a year 1 day a year none

3.2 World Health Organisation (WHO) Guidelines for Air Quality

The World Health Organisation (WHO) has published Air Quality Guidelines for Europe which address the effect of air pollution on human health and set an international standard for health based air quality guidelines. The WHO air quality guidelines are also being used as a starting point for the derivation of legally binding limit values in the European Union Air Quality Framework Directive and subsequent Daughter Directives, which have been amalgamated into Directive 2008/50/EC on Ambient Air Quality and Cleaner Air For Europe (“CAFE”).

In addition to guideline values, interim targets (IT) are given for each pollutant. The WHO state that these are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. These targets aim to promote a shift from high air pollutant concentrations, which have acute and serious health consequences, to lower air pollutant concentrations. If these targets were to be achieved, one could expect reductions in risks for acute and chronic health effects from air pollution. Progress towards the guideline values should, however, be the ultimate objective of air quality management and health risk reduction in all areas.

The relevant WHO air quality criteria are presented in **Table 3**.

Table 3 WHO Air Quality Guidelines

Pollutant	Air Quality Guideline	Averaging Time
Nitrogen Dioxide (NO_2)	40 µg/m^3	Annual
	200 µg/m^3	1-hour
Sulphur Dioxide (SO_2)	20 µg/m^3	24-hour
	500 µg/m^3	10-minute

3.3 NSW DECCW Impact Assessment Criteria

The NSW Office of Environment and Heritage (previously the NSW Department of Environment, Climate Change and Water [DECCW]) has established ground level air quality impact assessment criteria for key air pollutants to achieve appropriate environmental outcomes and to minimise associated risks to human health as published in the 2005 document, the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (the Approved Methods).

A summary of the impact assessment criteria is given in **Table 4**.

The impact assessment criteria are required to be applied as follows:

- At the nearest existing or likely future off-site sensitive receptor.
- The incremental impact (predicted impacts due to the pollutant source alone) for each pollutant must be reported in units and averaging periods consistent with the impact assessment criteria.
- Background concentrations must be included using the procedures specified in Section 5 of the Approved Methods.
- Total impact (incremental impact plus background) must be reported as the 100th percentile (maximum) in concentration or deposition units consistent with the impact assessment criteria and compared with the relevant impact assessment criteria.

3.4 Project Air Quality Goals

In view of the foregoing, the air quality goals adopted for this assessment, which conform to current NSW Office of Environment and Heritage (previously DECCW) and federal air quality criteria, are summarised in **Table 4**.

Table 4 Project Air Quality Goals

Pollutant	Averaging Time	Goal	Source
Nitrogen dioxide (NO_2)	1 hour	246 µg/m^3	NSW DECCW/NEPM
	Annual	62 µg/m^3	NSW DECCW/NEPM
Sulphur dioxide (SO_2)	10 minutes	712 µg/m^3	NSW DECCW
	1 hour	570 µg/m^3	NSW DECCW/NEPM[1]
	24 hours	228 µg/m^3	NSW DECCW/NEPM[1]
	Annual	60 µg/m^3	NSW DECCW/NEPM
Carbon monoxide (CO)	15 minutes	100 mg/m^3	NSW DECCW/WHO
	1 hour	30 mg/m^3	NSW DECCW/WHO
	8 hours	10 mg/m^3	NSW DECCW/NEPM[1]

Note 1: Maximum of 1 day of exceedence per year is permitted.

4 EXISTING AIR QUALITY ENVIRONMENT

Air quality monitoring is currently undertaken by the NSW Office of Environment and Heritage at three locations in the lower Hunter region, at Beresfield, Newcastle and Wallsend. Newcastle is the only station recording carbon monoxide (CO), while sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) monitoring are undertaken at all stations.

Newcastle and Wallsend were chosen to characterise the regional background air quality for alignment with previous reports. Monitoring data for 2006 was chosen in accordance with the Approved Methods, which states that a full year of monitoring data concurring with the meteorological data used in the modelling, should be selected.

Table 5 Regional Air Quality Data (2006)

Month	Newcastle CO (mg/m^3)		Wallsend NO_2 ($\mu g/m^3$)		Wallsend SO_2 ($\mu g/m^3$)		
	1 hour Maximum	8-hour Maximum	1 hour Maximum	Average	1 hour Maximum	24 hour Maximum	Average
Jan	1.0	0.9	41.0	10.3	37.2	8.6	2.9
Feb	1.0	0.5	59.5	10.3	62.9	14.3	2.9
Mar	1.5	0.6	49.2	12.3	57.2	8.6	2.9
Apr	1.6	1.1	63.6	20.5	74.4	8.6	2.9
May	2.3	1.9	71.8	20.5	165.9	25.7	2.9
Jun	3.6	2.8	65.6	24.6	65.8	17.2	5.7
Jul	2.3	1.3	63.6	22.6	111.5	25.7	5.7
Aug	2.6	2.1	84.1	26.7	57.2	17.2	5.7
Sep	2.5	1.0	86.1	20.5	77.2	25.7	5.7
Oct	1.1	0.8	61.5	14.4	62.9	8.6	2.9
Nov	1.3	0.8	51.3	14.4	82.9	14.3	2.9
Dec	0.6	0.5	57.4	12.3	54.3	5.7	2.9
Max Average	**3.6**	**2.8**	**86.1**	**18.5**	**165.9**	**25.7**	**2.9**

Note: Background data sourced from Holmes Air Sciences report (2008)

4.1 Background Air Quality for Assessment Purposes

For the purposes of assessing the potential air quality impacts of the project, an estimate of background air quality parameters is required. For each pollutant, the maximum background concentration has been selected, for each relevant averaging period.

This conservatively high estimate of background concentration has been used as per Section 5 of the Approved Methods.

The site-specific background air quality levels adopted for this assessment are presented in **Table 6**.

The Tropospheric Composition and Air Quality (TRAQ) tool, developed by the Roads and Traffic Authority (RTA) of New South Wales for estimating worst-case vehicle emission concentrations from a roadway, was used for the modelling of roadway emissions in the Holmes Report (2008). TRAQ modelling indicated that the background concentration of NO_2 within 50 m from the freeway is 190.6 µg/m^3. Holmes (2008) assumed that all six lanes of the F3 Freeway were at capacity, 100 km/h vehicle speeds and 15% heavy goods vehicles. As noted within Holmes (2008) this is an extreme worst case assessment of background NO_2 concentrations in the vicinity of the Freeway for receptors at or closer to the Freeway than 50 m. It is noted that along the stretch of Freeway close to the Mandlong Mine, there are 2 lanes in each direction, with exit lanes making up the third lane to the south of the Mandalong Mine. Vehicle speeds will be lower at these exit points and emissions expected to be lower than those assessed in Holmes (2008).

No sensitive receptors (R1 to R10) are noted to be closer than 80 m (R7) to the edge of the Freeway. Therefore, background concentrations used in the assessment of cumulative impacts within this report are those relating to a more rural environment.

Table 6 Background Air Quality used for Assessment Purposes

Air Quality Parameter	Averaging Period	Assumed Background Level
CO (mg/m^3)	15 minutes	4.8
	1 hour	3.6
	8 hours	2.8
NO_2 (µg/m^3)	1 hour	86.1
	Annual	18.5
SO_2 (µg/m^3)	10 minutes	237.4
	1 hour	165.9
	24 hours	25.7
	Annual	2.9

Note: Background concentrations identical to those used within Holmes (2008)

5 PREVAILING DISPERSION METEOROLOGY

5.1 Meteorological Data Availability

To adequately characterise the dispersion meteorology of the Project Site, monitoring data from the on-site meteorological station was sourced. The data from this monitoring station was used to characterise the local meteorology and provide the input datasets for the meteorological modelling undertaken. The following parameters, recorded at 1 hour intervals, were available from this station.

- Precipitation;
- Temperature;
- Relative Humidity;
- Wind Speed;
- Wind Direction;
- Vapour Pressure;
- Evaporation; and
- Solar Radiation.

Data at 1 hour intervals recorded between 2006 and 2009 was provided by the Centennial Mandalong. The wind speed and direction profiles for each year are presented in **Figure 4**. Seasonal wind roses for the Project Site are presented in **Appendix A**.

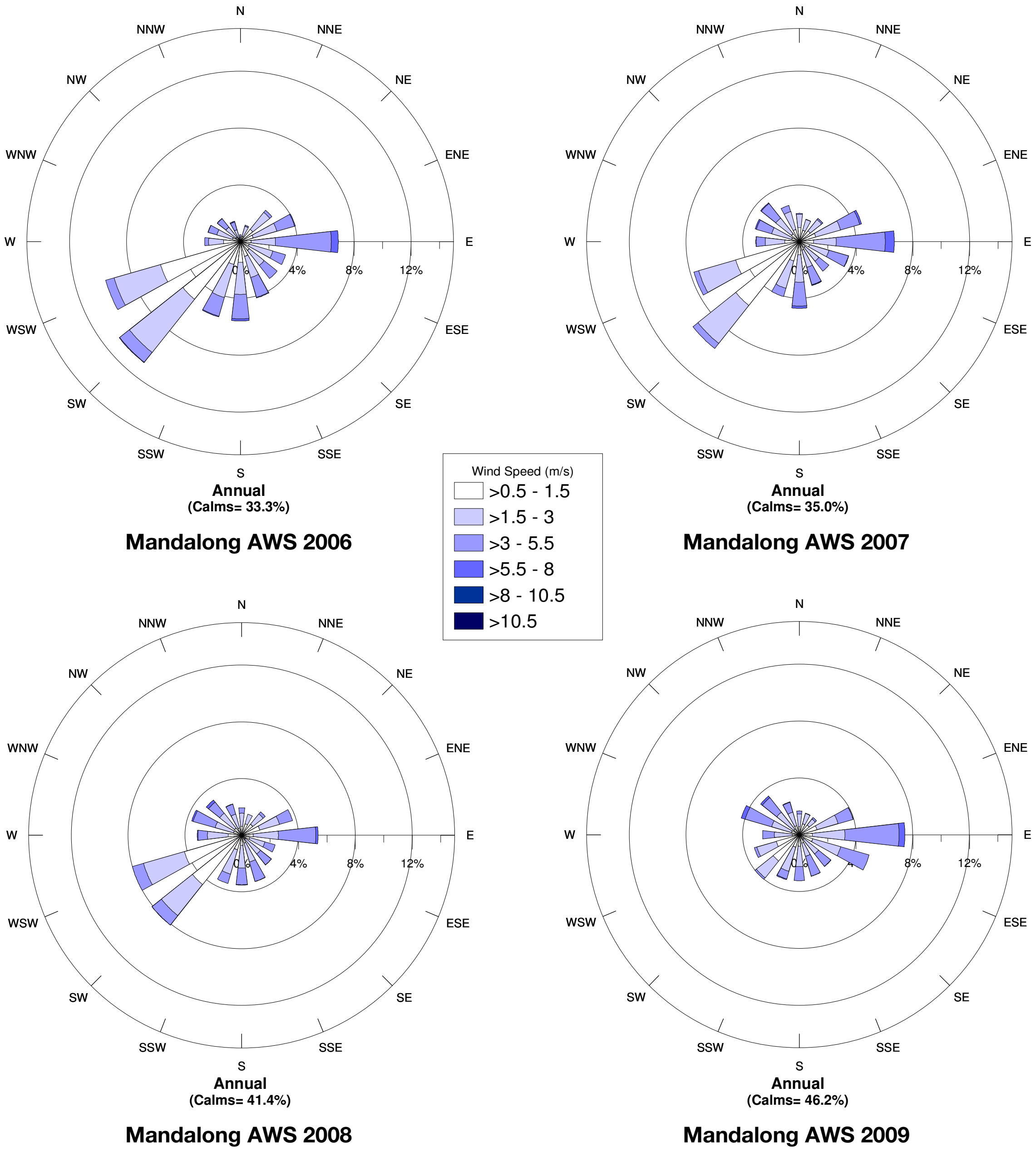
The Approved Methods state in Section 4.1 that for Level 2 air quality impact assessments such as this assessment, a site-specific meteorological dataset with at least 90% complete hourly observational data for a one year period must be used (i.e. for 8760 hours, a maximum of 876 hours missing). All datasets provided by the Centennial Mandalong had a data capture rate of greater than 90%.

The 2009 dataset displayed a lower frequency of southwest and west-southwest winds and a higher frequency of calm conditions than other years and was deemed to be unrepresentative of the local wind environment.

The 2006 dataset was selected for use in the dispersion modelling, to provide alignment with the previously conducted air quality assessment (Holmes, 2006). Additionally, this dataset appears to provide a good representation of local wind conditions, as shown in **Figure 4**.

The 2006 dataset has therefore been used in the dispersion modelling, in accordance with the requirements of the Approved Methods. This dataset is 99.8% complete, and where insufficient data was available for certain parameters, meteorological modelling was conducted as described in **Section 5.5**.

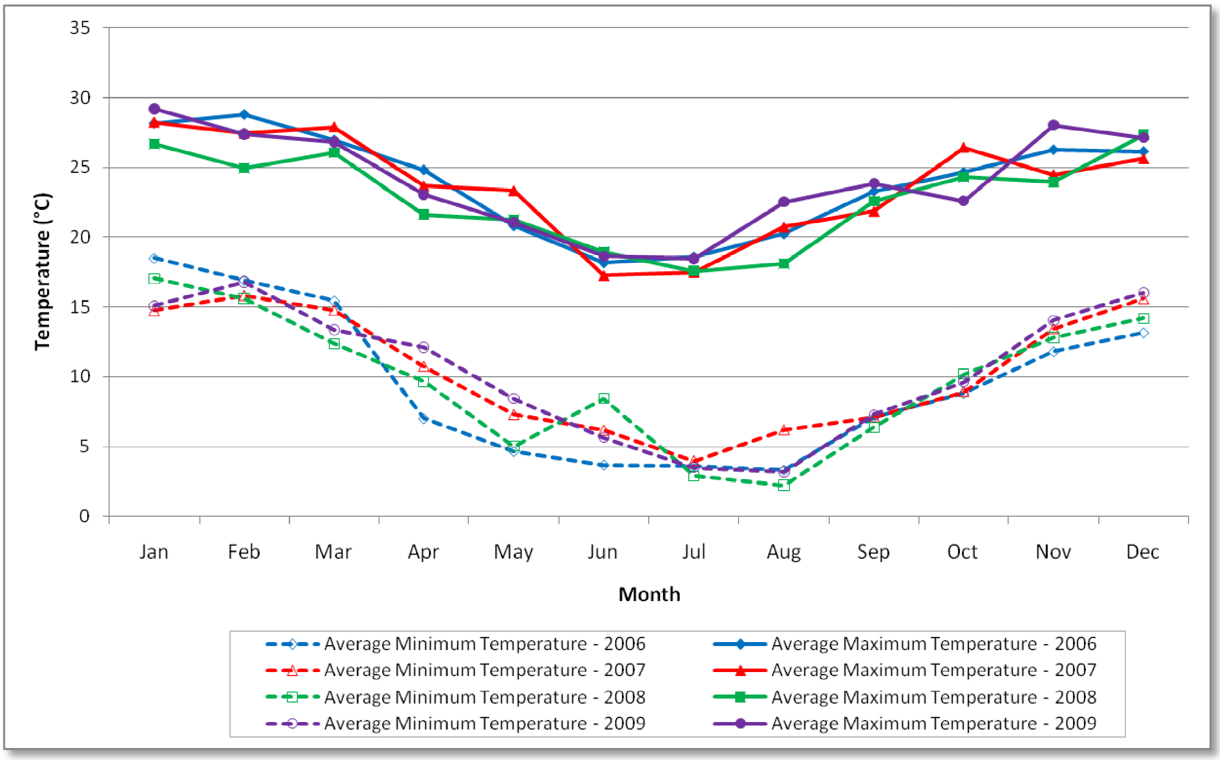
Figure 4 Annual Wind Rose Comparison – Mandalong Mine Weather Station



5.2 Temperature

Monthly mean maximum and minimum temperatures recorded at Mandalong Mine between 2006 and 2009 are presented in **Figure 5**. This data shows that average maximum temperatures in the region rarely exceed 30 °C. During the winter months the average maximum temperature falls to approximately 17 °C. Average minimum temperatures range from 17 °C in summer to 4 °C in winter.

Figure 5 Monthly Average Minimum and Maximum Temperatures

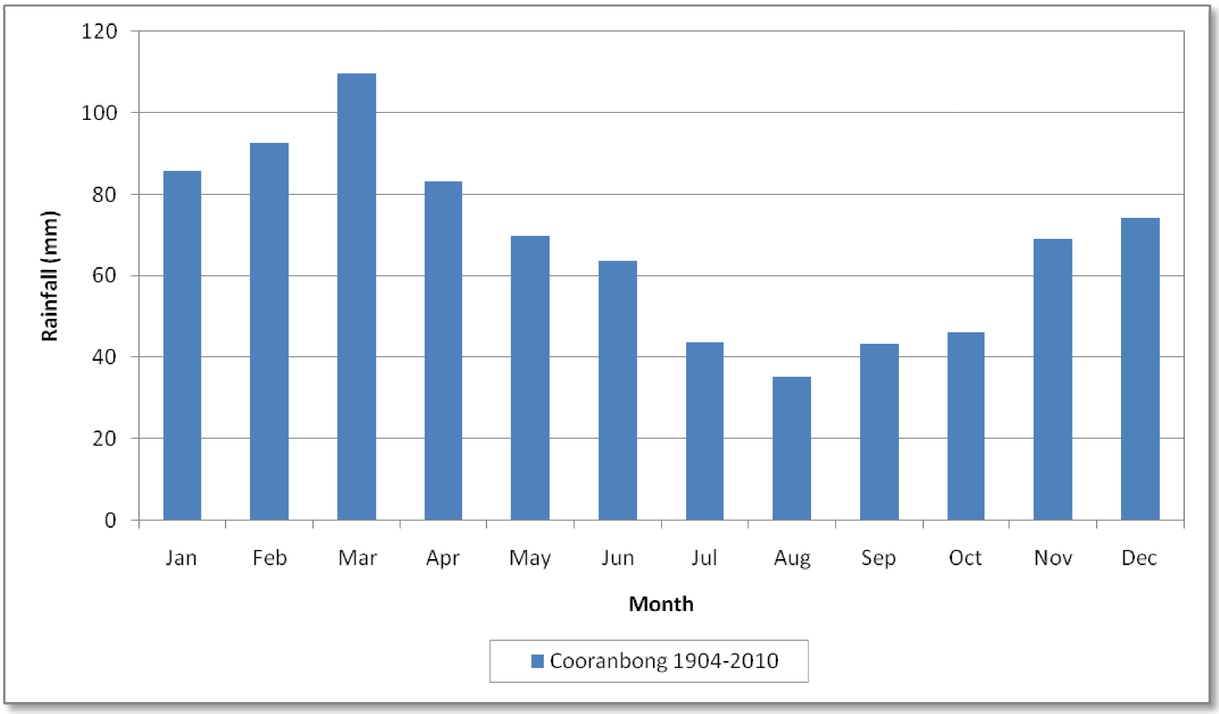


5.3 Rainfall

Precipitation is important in air pollution studies since it reduces the potential for fugitive dust emissions and represents an effective removal mechanism of atmospheric pollutants. A graph displaying the average monthly rainfall measured at Cooranbong between 1904 and 2010 (BoM 2011), located 6 km to the north of the Project Site, is presented in **Figure 6**. The Cooranbong dataset is considered to be a good representative of the rainfall in the local region.

Rainfall experienced in the region surrounding the Project Site can be described as moderate with the historical annual average rainfall recorded at Cooranbong totalling approximately 1,088 mm, compared to an annual average for the Project Site totalling approximately 1,063 mm, recorded between 2006 and 2009. Rainfall in the region is typically lower during the winter and spring months, with maxima generally experienced during late summer and early autumn.

Figure 6 Historic Monthly Mean (5th Decile) Rainfall at Cooranbong between 1904 and 2010



5.4 Relative Humidity

The relative humidity in the region surrounding the Project Site can be described as moderate. The mean 9 am relative humidity at the Project Site between 2006 and 2008 was between 78 % and 83 %, while the 3 pm relative humidity varies between 56 % and 63 % throughout the year. The humidity levels are higher in the morning compared to the afternoon.

5.5 Meteorological Modelling

TAPM, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), is a prognostic model which may be used to predict three-dimensional meteorological data and air pollution concentrations, with no local data inputs required.

The TAPM model predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations at user-defined levels within the atmosphere.

Additionally, the TAPM model may assimilate actual local wind observations so that they can optionally be included in a model solution. The wind speed and direction observations are used to realign the predicted solution towards the observation values. This function of accounting for actual meteorological observations within the region of interest is referred to as “data assimilation”.

Thus, direct measurements for hourly average wind speed and wind direction at the Mandalong Mine on-site meteorological station were input into the TAPM simulations to provide realignment to local and regional conditions.

Table 7 details the parameters used in the TAPM meteorological modelling for this assessment.

Table 7 Meteorological Parameters used for this Study

TAPM (v 4.0)	
Number of grids (spacing)	5 (30 km, 10 km, 3 km, 1 km, 300 m)
Number of grids point	25 x 25 x 25
Year of analysis	2006
Centre of analysis	Project Site (356,400 m E, 6,335,000 m S)
Data assimilation	Meteorological data assimilation using wind data from on-site station.

5.6 Meteorological Conditions

5.6.1 Wind Regime

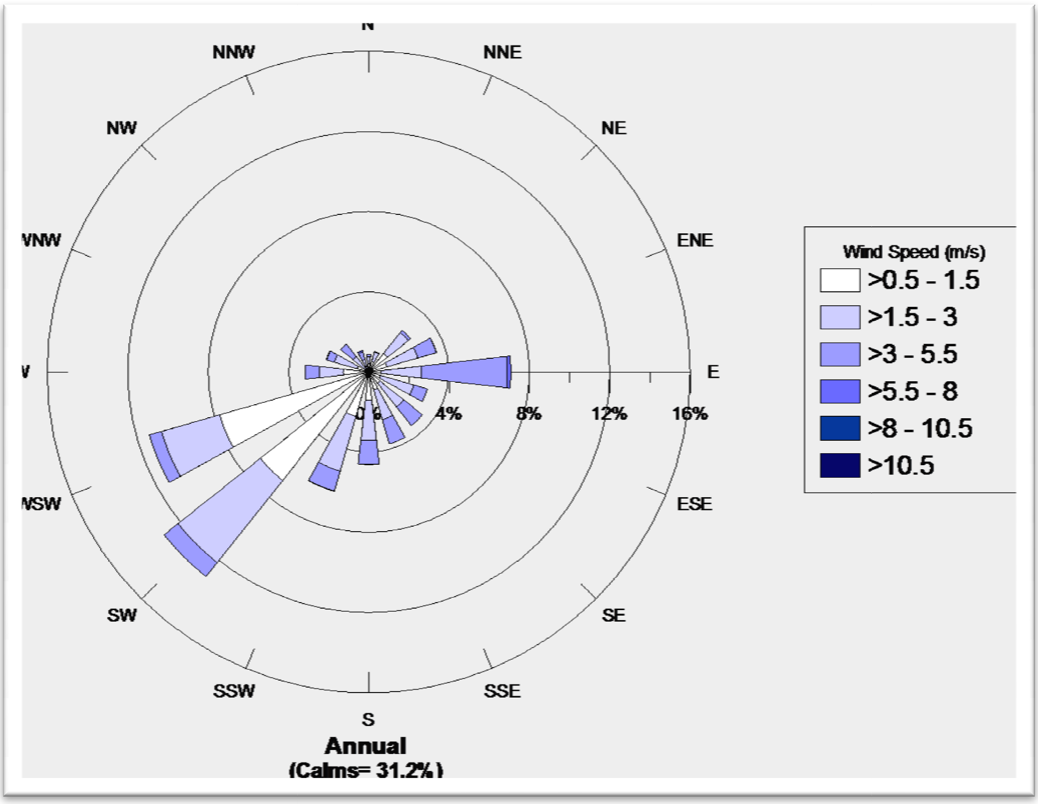
A summary of the 2006 annual wind behaviour experienced at the Project Site is presented as a wind rose in **Figure 7**.

Figure 7 indicates that winds experienced at the Project Site are predominantly light (between 1.5 m/s and 5.5 m/s) from the southwest to south-southwest (approximately 24 % combined) and from the west (approximately 7 %). Calm wind conditions (wind speed less than 0.5 m/s) were recorded approximately 31 % of the time throughout the dataset.

The seasonal variation in predicted wind behaviour at the mine site is presented in **Appendix B**. The seasonal wind roses indicate that:

- in spring, light winds are experienced predominantly from the south to west-southwest (approximately 31 % combined) and west (approximately 8 %);
- in summer, light to moderate winds are experienced predominantly from the east (approximately 16 %) and from southwest to south-southwest (approximately 23 % combined);
- in autumn, light winds are experienced predominantly from the west-southwest to southwest (approximately 28 % combined); and
- in winter, light winds are experienced from the west-southwest to southwest (approximately 35 % combined).

Figure 7 Annual Wind Rose for Project Site –2006



5.6.2 Atmospheric Stability and Mixing Depth

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Turner assignment scheme identifies six Stability Classes, “A” to “F”, to categorise the degree of atmospheric stability. These classes indicate the characteristics of the prevailing meteorological conditions and are used as input into various air dispersion models (refer to **Table 8**).

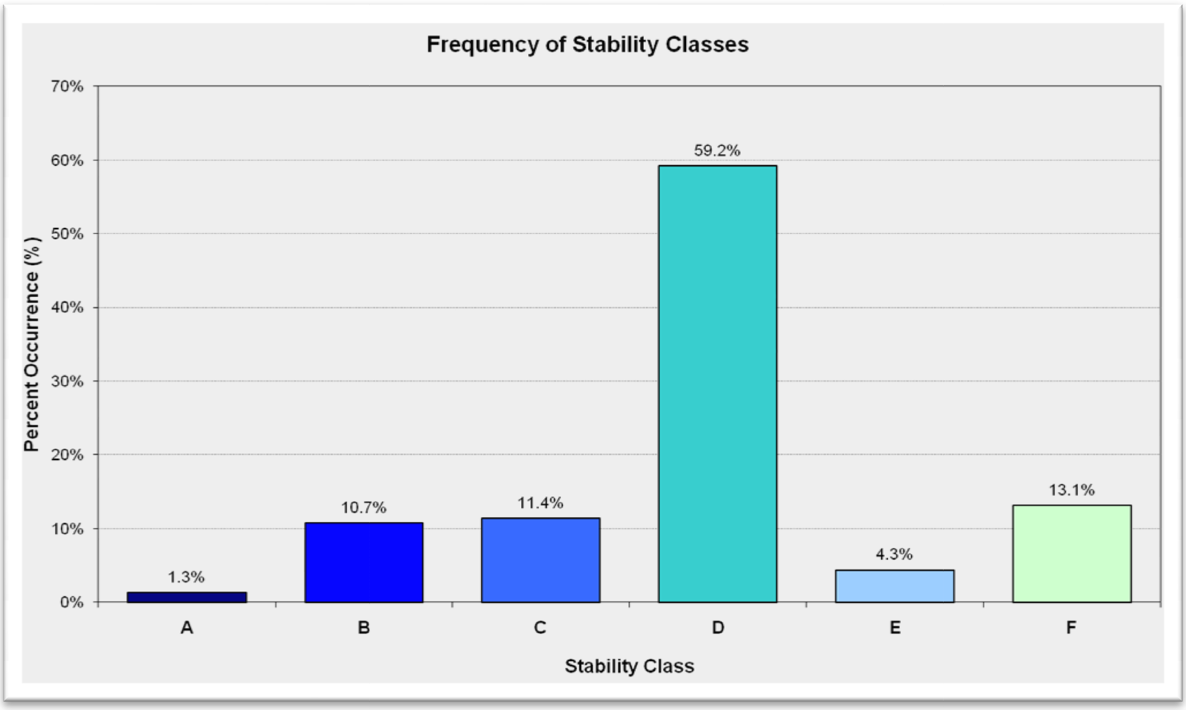
Table 8 Description of Atmospheric Stability Classes

Atmospheric Stability Class	Category	Description
A	Very unstable	Low wind, clear skies, hot daytime conditions
B	Unstable	Clear skies, daytime conditions
C	Moderately unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	High winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions

The calculated frequency of each stability class at the Project Site from during 2006 as predicted by TAPM is shown in **Figure 8**.

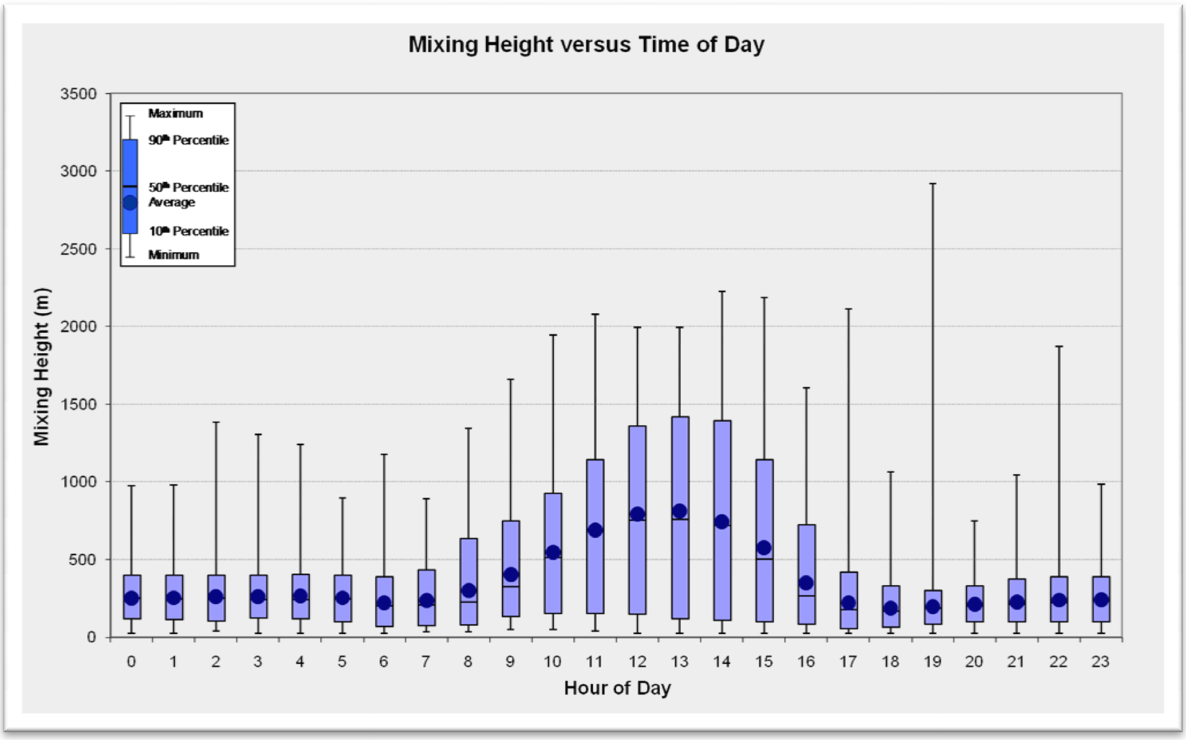
The results indicate a high frequency of conditions typical to Stability Class “D”. Stability Class “D” is indicative of neutral atmospheric conditions with a moderate level of atmospheric dispersion due to mechanical mixing.

Figure 8 TAPM Predicted Annual Stability Class Distributions for the Project Site during 2006



Diurnal variations in maximum and average mixing depths predicted by TAPM at the Project Site during 2006 are illustrated on **Figure 9**. It can be seen that an increase in the mixing depth during the morning, arising due to the onset of vertical mixing following sunrise, is apparent with maximum mixing heights occurring in the early afternoon, due to the dissipation of ground-based temperature inversions and the growth of the convective mixing layer.

Figure 9 TAPM Predicted Diurnal Variation in Mixing Depth for the Project Site during 2006



6 ATMOSPHERIC DISPERSION MODELLING

6.1 Model Selection

The current assessment utilises the CALPUFF (Version 6.2) modelling system run in screening mode using the single point meteorological input file, comprising of the data presented and discussed in **Section 5.** The advantages of using CALPUFF in screening mode (rather than using a steady state Gaussian dispersion model such as AUSPLUME) is its ability to handle calm wind conditions (wind speeds less than 0.5 m/s). AUSPLUME encounters problems due to the presence of calm conditions because of the inverse wind speed dependence within the Gaussian plume equation. Under calm conditions, AUSPLUME will assume a minimum wind speed which shoots the plume to the edge of the modelling grid, even though the plume may not have moved at all under actual dispersion conditions (DECCW 2005).

CALPUFF can handle these low wind speed conditions and will grow a plume by diffusion alone under zero wind speed conditions. Given the high percentage of calm conditions within the input meteorological dataset (approximately 31%), the use of CALPUFF in screening mode in place of AUSPLUME is considered appropriate in this assessment.

The potential influence of local topography, including natural and project related land forms, on the dispersion of pollutants has not been incorporated into the dispersion modelling process, other than through the application of published emission reduction factors. Consequently, the results obtained from dispersion modelling process should be viewed as conservative in this regard.

6.2 Modelling Scenario

Methane gas released from the coal seam during coal extraction represents 87 % of the total greenhouse gas emissions from Mandalong Mine. It is estimated that 32 % of the methane gas emissions come from high purity methane drained through the existing methane gas drainage plant and 68 % of emissions from ventilation air methane (VAM).

The following abatement plants are planned to reduce emissions from the high purity methane:

- Already approved enclosed methane gas flare units, to burn the methane and thereby reduce greenhouse gas emissions (not previously quantitatively assessed); and
- Already approved gas engines with up to 12 MW of capacity, to utilise the gas for power generation (previously assessed within Holmes (2008)).

The following abatement is planned for the VAM:

- A proposed VAM-RAB unit, capable of oxidising 10 m^3/s of VAM (approximately 3.33 % of total VAM).

To ensure that cumulative air quality impacts from the Mandalong Mine are appropriately assessed, two, separate scenarios have been modelled which take into consideration the operation of the approved gas flares and gas engines.

6.2.1 Case 1: Gas Flaring

As a worst case scenario for the operation of the gas flares, emissions from the gas flares are estimated assuming that 100 % of the methane from the drainage plant will be flared. In reality, gas engines are likely to be constructed first, negating the need to flare 100% of the gas.

6.2.2 Case 2: Gas Engines

If the power generation facility is implemented it is assumed that it is capable of utilising all methane drainage gas. The gas flare units will remain as back-up or for peak gas flows. As a worst case scenario for the operation of the gas engines, modelling has been carried out assuming that 100 % of the methane is combusted in the gas engines and that no methane will be flared.

6.3 Emission Factors

6.3.1 Gas Flaring

The air quality impact from the operation of the proposed enclosed gas flaring units has not been assessed in previous air quality assessments. The emissions from the gas flaring units have been estimated from the National Pollution Inventory (NPI) 2010 Emission Estimation Technique Manual, *Oil and Gas Exploration and Production*, as shown in **Table 9**.

Coal seam gas is generally relatively pure with negligible sulphur content. It has therefore been assumed that no SO_2 is formed when the drainage gas is flared.

The maximum flow rate from the methane drainage plant is 1,400 L/s (Umwelt, 2006). It has been assumed that all drainage gas will go through the gas flares.

Oxides of nitrogen (NO_X), comprised of nitric oxide (NO) and nitrogen dioxide NO_2, is formed in most combustion processes. NO will dominate the emissions but will eventually transform into NO_2. NO_2 is considered having the largest impact on human health. The rate of transformation depends on a number of factors. It has been assumed within this report that 20 % of emitted NO_X will form NO_2 by the time it reaches sensitive ground receptors. This is consistent with the assumptions made in Holmes Air Sciences (2008).

Table 9 Estimation of Emissions

Gas Flares	Emission Factor (kg emissions/ tonnes throughput)	Throughput (tonnes/year)	Emission (kg/year)	Emission (g/s)
CO	8.7	18,133[1]	157,757	5.00
NO_X	1.5	18,133[1]	27,200	0.1725

Note 1: From GHG Assessment (30-2517-R3), based on 32 % of methane emissions originating from high purity methane.

Stack exhaust velocity has been calculated from maximum flow rate and the exhaust temperature has been sourced from a similar enclosed gas flaring unit. The input parameters used in the modelling are summarised in **Table 10**. The locations for the proposed flares are assumed to be the same as the gas engines.

Table 10 Emission Data for Gas Flaring Units

Source	Location		Height[1] (m)	Diameter[1] (m)	Velocity (m/s)	Temperature (℃)
	Easting (m E)	Northing (m S)				
Gas Flare Unit 1	356,486	6,335,042	10	2	0.13	1,000
Gas Flare Unit 2	356,486	6,335,035	10	2	0.13	1,000
Gas Flare Unit 3	356,486	6,335,028	10	2	0.13	1,000
Gas Flare Unit 4	356,486	6,335,021	10	2	0.13	1,000
Gas Flare Unit 5	356,486	6,335,014	10	2	0.13	1,000
Gas Flare Unit 6	356,486	6,335,007	10	2	0.13	1,000

Note 1: From Umwelt Report on Gas Flaring Units, 2006

Table 11 Emission Rates for Each Gas Flaring Unit

Source	CO (g/s)	NO_x (g/s)
Gas Flare Unit	0.834	0.144

The gas flaring units are assumed to operate 24 hours a day, 7 days a week.

6.3.2 Gas Engines

It has been shown that the emissions from the six 2 MW gas engines would constitute a worst case scenario in terms of emissions (Holmes Air Sciences, 2008). The same configuration has therefore been used within this assessment. The emission data used in the dispersion modelling is summarised in **Table 12** and **Table 13**. Emission data has been estimated from monitoring of similar gas engines.

Table 12 Emission Data for Gas Engines

Source	Location		Height[1] (m)	Diameter[1] (m)	Velocity (m/s)	Temperature (℃)
	Easting (m E)	Northing (m S)				
Gas Engine 1	356,486	6,335,042	10	0.36	35	482
Gas Engine 2	356,486	6,335,035	10	0.36	35	482
Gas Engine 3	356,486	6,335,028	10	0.36	35	482
Gas Engine 4	356,486	6,335,021	10	0.36	35	482
Gas Engine 5	356,486	6,335,014	10	0.36	35	482
Gas Engine 6	356,486	6,335,007	10	0.36	35	482

Note 1: Emission data from Holmes Air Sciences AQ Assessment (2008)

Table 13 Emission Rates for Each Gas Engines

Source	CO (g/s)	NO_X (g/s)	SO_2 (g/s)
Gas Engine	1.3	0.58	0.024

Note: Emission data from Holmes Air Sciences AQ Assessment (2008)

The gas engines are assumed to operate 24 hours a day, 7 days a week.

6.3.3 VAM-RAB Unit

Construction

The disturbance area where the VAM-RAB demonstration project is proposed to be located is shown in **Appendix D**. The location of the proposed VAM-RAB unit in relation to existing ventilation fans and the existing mine ventilation plant is also shown.

The construction of the actual VAM-RAB unit will take place off site. Some civil and foundation work will however occur on site.

Foundations and civil work will take place for a period of approximately 4 weeks using the equipment listed below:

- Sheepsfoot roller;
- Truck and trailer (for fill);
- Small excavator;
- Concrete truck;
- Concrete pump;
- Concrete vibrator; and
- Hand held tools.

Given that all fill required will be sourced nearby and that the area is already partially cleared, the expected air quality impact from construction activity is expected to be minimal, assuming that standard mitigation measures are implemented. In addition, the demonstration project will lead to no increase in production and therefore no increase in particulate emissions.

Operations

Exhaust emissions from the VAM-RAB unit are summarised in **Table 14.**

Table 14 Exhaust Composition from One VAM-RAB Unit

Substance	Chemical Formula	Mass/Mass (%)	Volume/Volume (%)
Water	H_2O	13.6	20.2
Carbon dioxide	CO_2	0.8	0.5
Carbon monoxide	CO	0.0	0.0
Methane	CH_4	0.0	0.0
Nitrogen	N_2	68.5	65.2
Oxygen	O_2	17.1	14.2

Note: Chemical composition provided by Corky's.
Exhaust composition is valid under the assumptions that:
- there is no CO or CO_2 entering the RAB;
- the CH_4 concentration is 0.5 % M/M;
- the relative humidity at 20°C is 90 %; and
- there is a complete combustion in the VAM-RAB.

The stack emissions from the VAM-RAB unit consist predominantly of water, nitrogen and oxygen and will not pose a hazard to any surrounding sensitive receptors. The VAM is drawn through a conditioning duct where large particulates drop out of the ventilation air and it is assumed that no particulate matter is emitted from the VAM-RAB unit.

6.3.4 1/5th Power Law Ratio

CALPUFF has been modelled at hourly time-steps for the pollutants of concern. To determine concentrations on a sub-hourly basis, based on the 1-hour concentrations, the 1/5th power law has been applied, as follows:

$$C_1 = C_0 \times \left(\frac{t_0}{t_1} \right)^{0.2}$$

where,

- C_1 is the concentration of desired averaging time (10 or 15 minutes)
- C_0 is the concentration over original averaging time (60 minutes)
- t_1 is the desired averaging period (10 or 15 minutes)
- t_0 is the initial averaging period (60 minutes)

from (Turner, 1969).

7 AIR QUALITY IMPACT ASSESSMENT

7.1 Case 1: Gas Flaring

Table 15 shows the results of the dispersion modelling for the gas flares, using the emission rates calculated in **Section 6.3.1**, at each of the identified sensitive receptors. It is noted that emissions of criteria air pollutants from the VAM-RAB unit were shown to be minimal and therefore have not been included in the cumulative assessment.

Contour plots of the incremental increase in ground level concentration attributable to the modelled scenario are presented in **Appendix C**.

Table 15 Predicted Incremental Concentrations at Sensitive Receptors - Gas Flaring Alone

Receptor ID	CO (mg/m^3)			NO_2 (µg/m^3)		SO_2 (µg/m^3)			
	15-min	1-hour	8-hour	1-hour	Annual	10-min	1-hour	24-hour	Annual
R1	1.5	1.2	0.2	40.1	0.2	NA	NA	NA	NA
R2	1.6	1.2	0.4	41.8	0.3	NA	NA	NA	NA
R3	1.8	1.4	0.5	47.7	0.4	NA	NA	NA	NA
R4	2.0	1.5	0.4	53.3	0.3	NA	NA	NA	NA
R5	1.7	1.3	0.4	43.1	0.3	NA	NA	NA	NA
R6	3.0	2.2	1.1	77.1	1.0	NA	NA	NA	NA
R7	2.6	2.0	1.1	68.1	1.0	NA	NA	NA	NA
R8	2.5	1.9	0.9	64.9	1.7	NA	NA	NA	NA
R9	2.9	2.2	1.3	75.3	2.0	NA	NA	NA	NA
R10	2.2	1.6	0.8	56.3	2.5	NA	NA	NA	NA

The results of the assessment presented in **Table 15** have been paired with background concentrations provided in **Table 6**, to determine if cumulative impacts comply with Project goals. The results are summarised in **Table 16**.

Table 16 Highest Predicted Concentrations of Pollutants at Sensitive Receptors – Gas Flaring Alone

Pollutant	Averaging Time	Background Concentration	Maximum Predicted Concentration at Receptors R1 to R10	Cumulative Concentration	Assessment Criterion
CO (mg/m^3)	15 minutes	4.8	3.0	7.8	100
	1 hour	3.6	2.2	5.8	30
	8 hours	2.8	1.3	4.1	10
NO_2 (µg/m^3)	1 hour	86.1	77.1	163.2	246
	Annual	18.5	2.5	21.0	62

No exceedances of the Project criteria are predicted at any identified sensitive receptor location.

7.2 Case 2: Gas Engines

Table 17 shows the results of the dispersion modelling for the gas engines, using the emission rates calculated in **Section 6.3.2**, at each of the identified sensitive receptors. It is noted that emissions of criteria air pollutants from the VAM-RAB unit were shown to be minimal and therefore have not been included in the cumulative assessment.

Contour plots of the incremental increase in ground level concentration attributable to the modelled scenario are presented in **Appendix C**.

Table 17 Predicted Incremental Concentrations at Sensitive Receptors - Gas Engines Alone

Receptor ID	CO (mg/m^3)			NO_2 ($\mu g/m^3$)		SO_2 ($\mu g/m^3$)			
	15-min	1-hour	8-hour	1-hour	Annual	10-min	1-hour	24-hour	Annual
R1	0.3	0.3	0.1	23.0	0.2	6.8	4.8	0.5	<0.1
R2	0.3	0.2	0.1	20.3	0.2	6.0	4.2	0.5	<0.1
R3	0.4	0.3	0.1	28.7	0.2	8.5	5.9	0.5	<0.1
R4	0.4	0.3	0.1	26.1	0.2	7.7	5.4	0.5	<0.1
R5	0.3	0.2	0.1	21.2	0.2	6.3	4.4	0.5	<0.1
R6	0.4	0.3	0.1	26.2	0.2	7.8	5.4	0.9	<0.1
R7	0.4	0.3	0.1	24.0	0.2	7.1	5.0	0.9	<0.1
R8	0.3	0.3	0.2	22.7	0.3	6.7	4.7	1.4	0.1
R9	0.3	0.2	0.2	20.9	0.3	6.2	4.3	1.1	0.1
R10	0.3	0.2	0.1	19.7	0.3	5.8	4.1	0.7	0.1

The results of the assessment presented in **Table 17** have been paired with background concentrations provided in **Table 6**, to determine if cumulative impacts comply with Project goals. The results are summarised in **Table 18**.

Table 18 Highest Predicted Concentrations of Pollutants at Sensitive Receptors – Gas Engines Alone

Pollutant	Averaging Time	Background Concentration	Maximum Predicted Concentration at Receptors R1 to R10	Cumulative Concentration	Assessment Criterion
CO (mg/m^3)	15 minutes	4.8	0.4	5.2	100
	1 hour	3.6	0.3	3.9	30
	8 hours	2.8	0.2	3.0	10
NO_2 ($\mu g/m^3$)	1 hour	86.1	28.7	114.8	246
	Annual	18.5	0.3	18.8	62
SO_2 ($\mu g/m^3$)	10 minutes	237.4	7.8	245.2	712
	1 hour	165.9	5.9	171.8	570
	24 hours	29.5	1.4	30.9	228
	Annual	2.9	0.1	3.0	60

No exceedances of the Project criteria are predicted at any identified sensitive receptor location.

8 CONCLUSION

SLR Consulting Pty Ltd (SLR Consulting) has been commissioned by GSS Environmental (GSSE) on behalf of Centennial Mandalong Pty Ltd (Centennial Mandalong) to undertake an air quality impact assessment (AQIA) for the proposed greenhouse gas abatement demonstration plant at the Mandalong Mine.

GHG emissions associated with the high purity methane gas stream can be reduced by gas flares (burning) and gas engines (power generation) and installation of both alternatives has already been approved.

Centennial Mandalong is seeking approval for a single VAM-RAB (Regenerative After Burner) unit without heat recovery or generation capability, as a demonstration project.

To ensure that this AQIA takes into consideration the cumulative impacts from all existing and approved operations at the Mandalong Mine, air quality impacts for two different cases have been assessed. These two cases represent worst case emissions from the approved operation of the flares and gas engines. Emissions of air pollutants, carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2), from the VAM-RAB itself are considered to be negligible.

A full year of background monitoring data for 2006 from the Office of Environment and Heritage (previously DECCW) Newcastle and Wallsend air quality monitoring stations has been chosen for alignment with previous reports to characterise the regional background air quality. The maximum background concentration for each criteria pollutant and relevant averaging period was selected.

Air pollutant dispersion modelling indicates that maximum cumulative ground level concentrations from the gas engines and from the gas flares results in air quality criteria for NO_2, CO and SO_2 being achieved at all surrounding sensitive receptor locations. The predicted NO_2 concentrations are slightly higher for the gas engines than for the flares and will therefore constitute a worst case scenario.

No pollutant concentrations are contributed to by the operation of the VAM-RAB unit.

9 REFERENCES

The following documents and resources have been used in the production of this report:

- Annual Environmental Management Report (AEMR), Centennial Mandalong, 2009
- Annual Environmental Management Report (AEMR), Centennial Mandalong, 2010
- CCC14-005, VAM Preliminary Environmental Assessment (VAM PEA)
- Cork, D. Corky's VAM RAB Patent Script, 2009
- Mandalong Mine State of Environmental Effect (SoEE), SKM, 2004
- Mandalong Mine Modification to Development Consent Environmental Assessment (MDC EA), Air Quality, Holmes Air Sciences 2008
- Mandalong Mine Methane Flare SoEE, Umwelt Australia, 2006
- NSW Department of Environment, Climate Change and Water (DECCW), Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, 2005
- National Environmental Protection Council (NEPC), National Environmental Protection Measure for Ambient Air Quality, 1998
- National Health and Medical Research Council, 92nd Session, 1981
- National Pollutant Inventory Emission Estimation Technique Manual: Oil and Gas Exploration and Production, NPI 2010

10 CLOSURE

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

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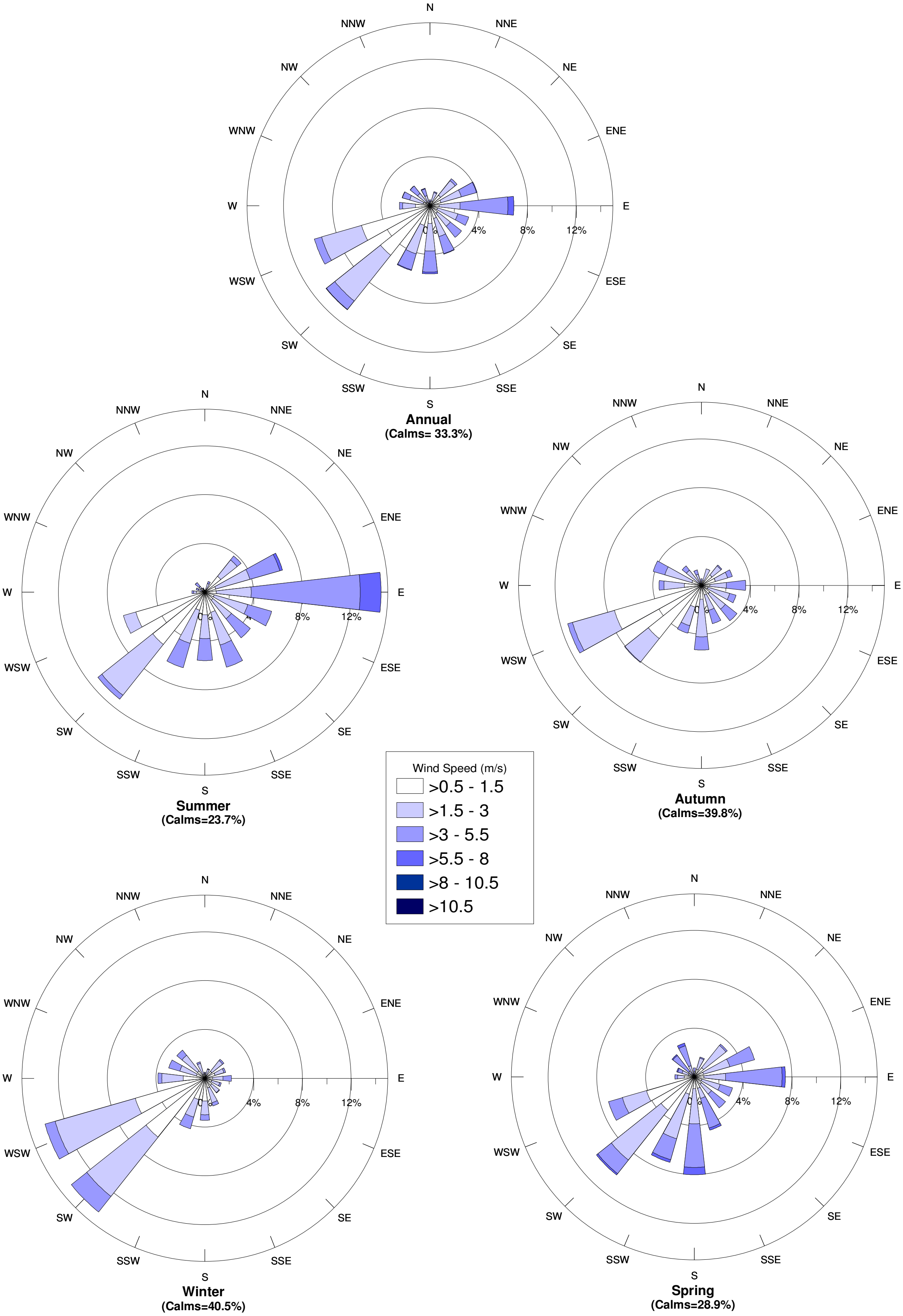
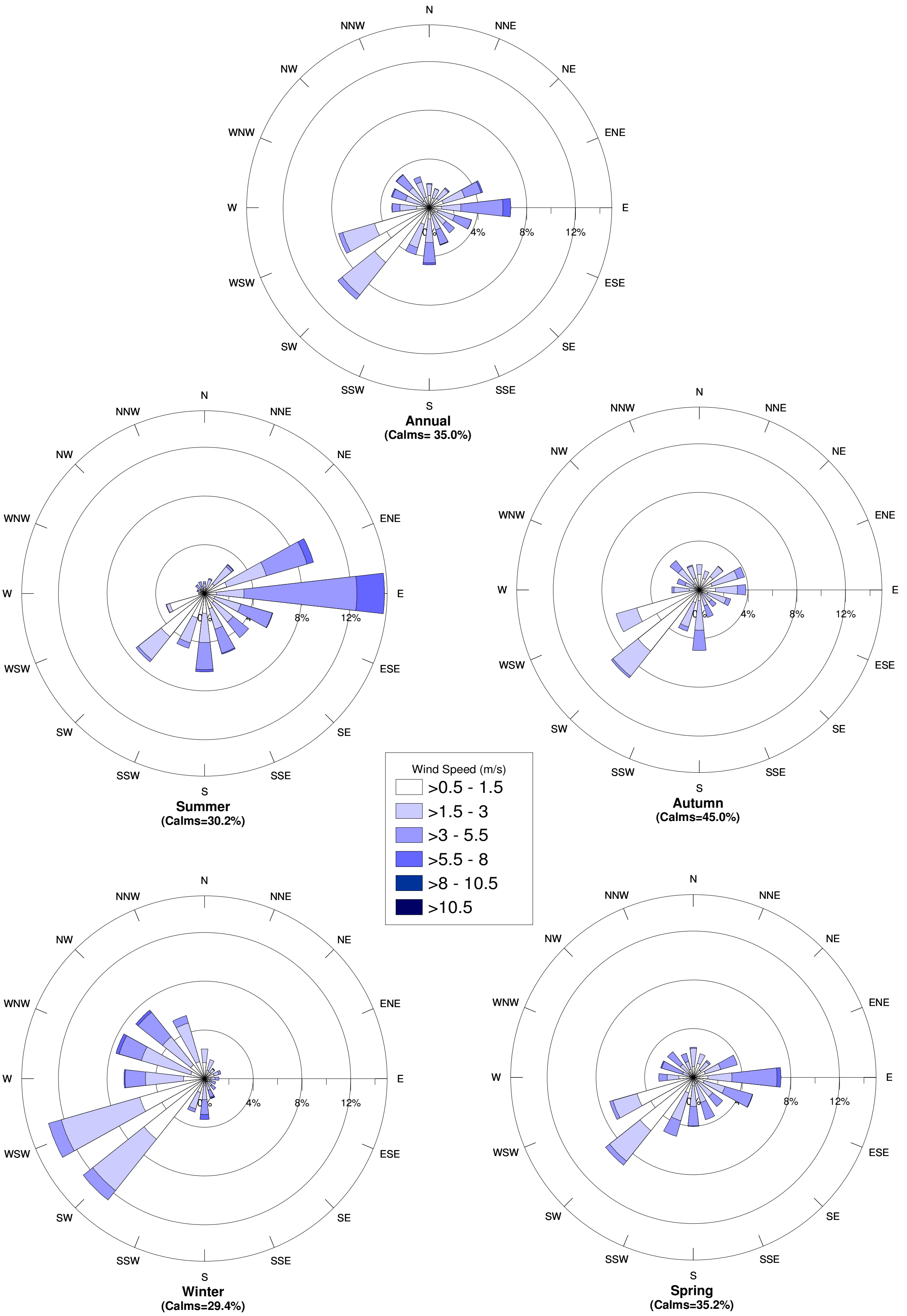
SLR Consulting disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

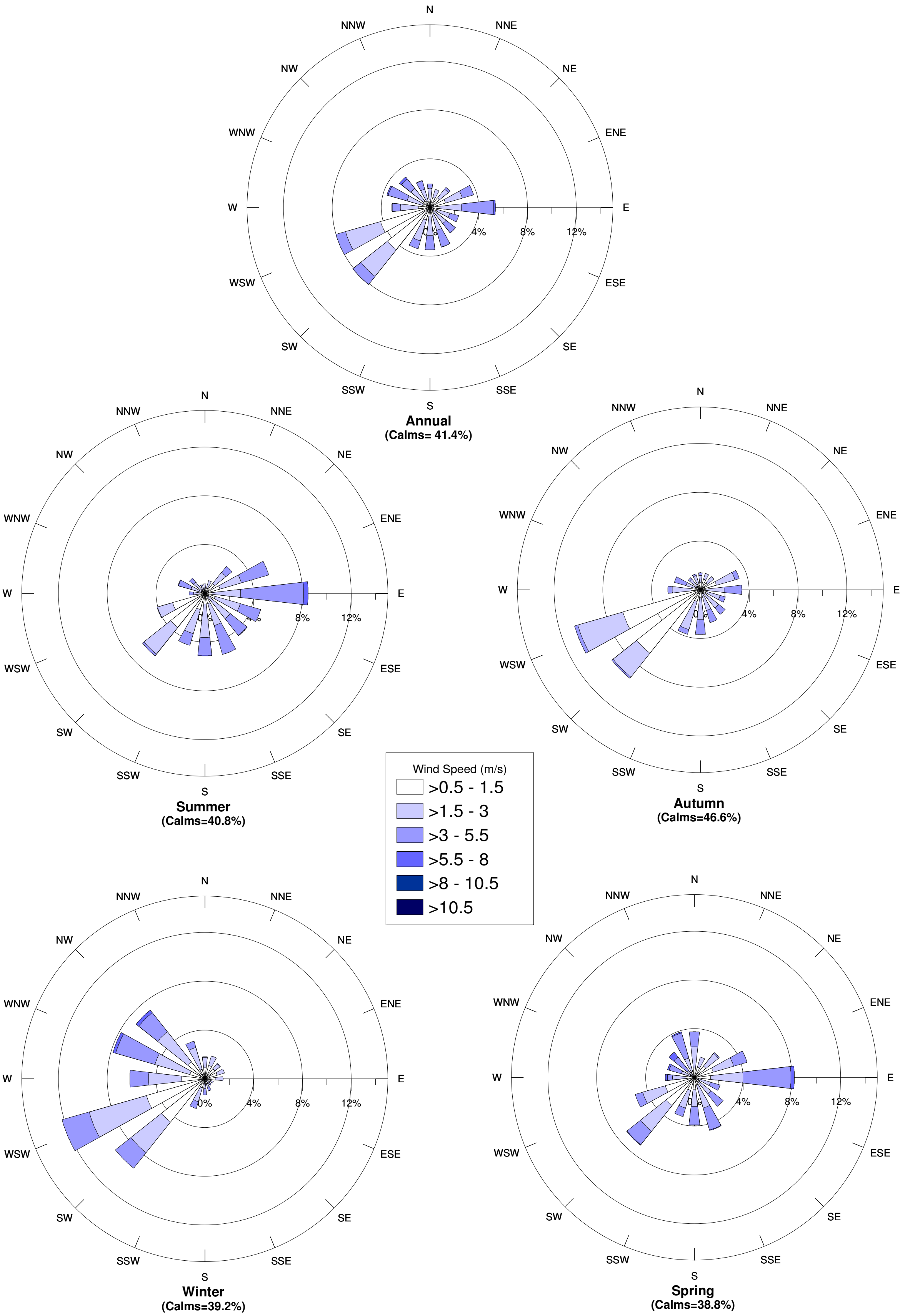
Appendix A, Figure A1: Seasonal Windroses Mandalong Mine, 2006



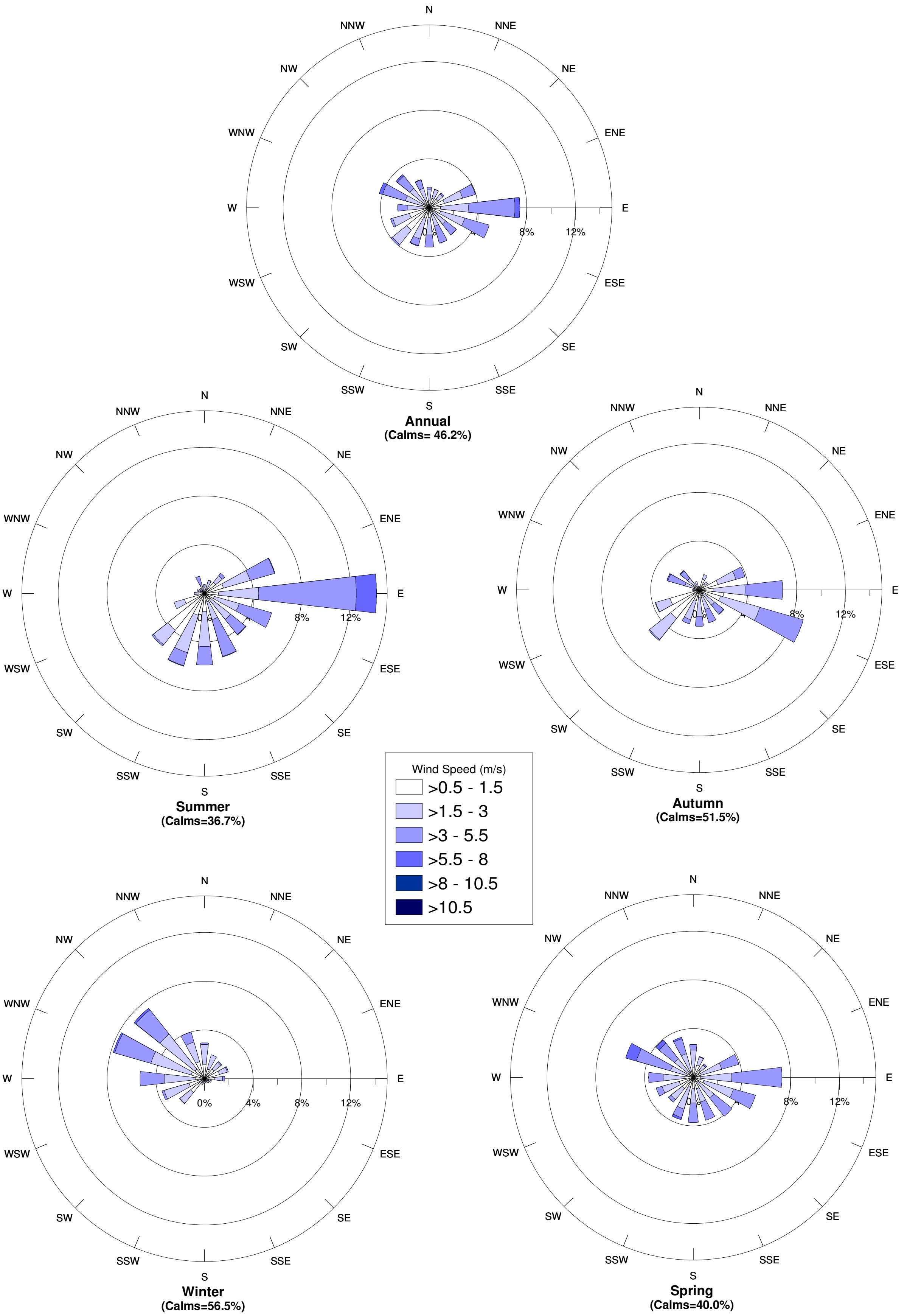
Appendix A, Figure A2: Seasonal Windroses Mandalong Mine, 2007



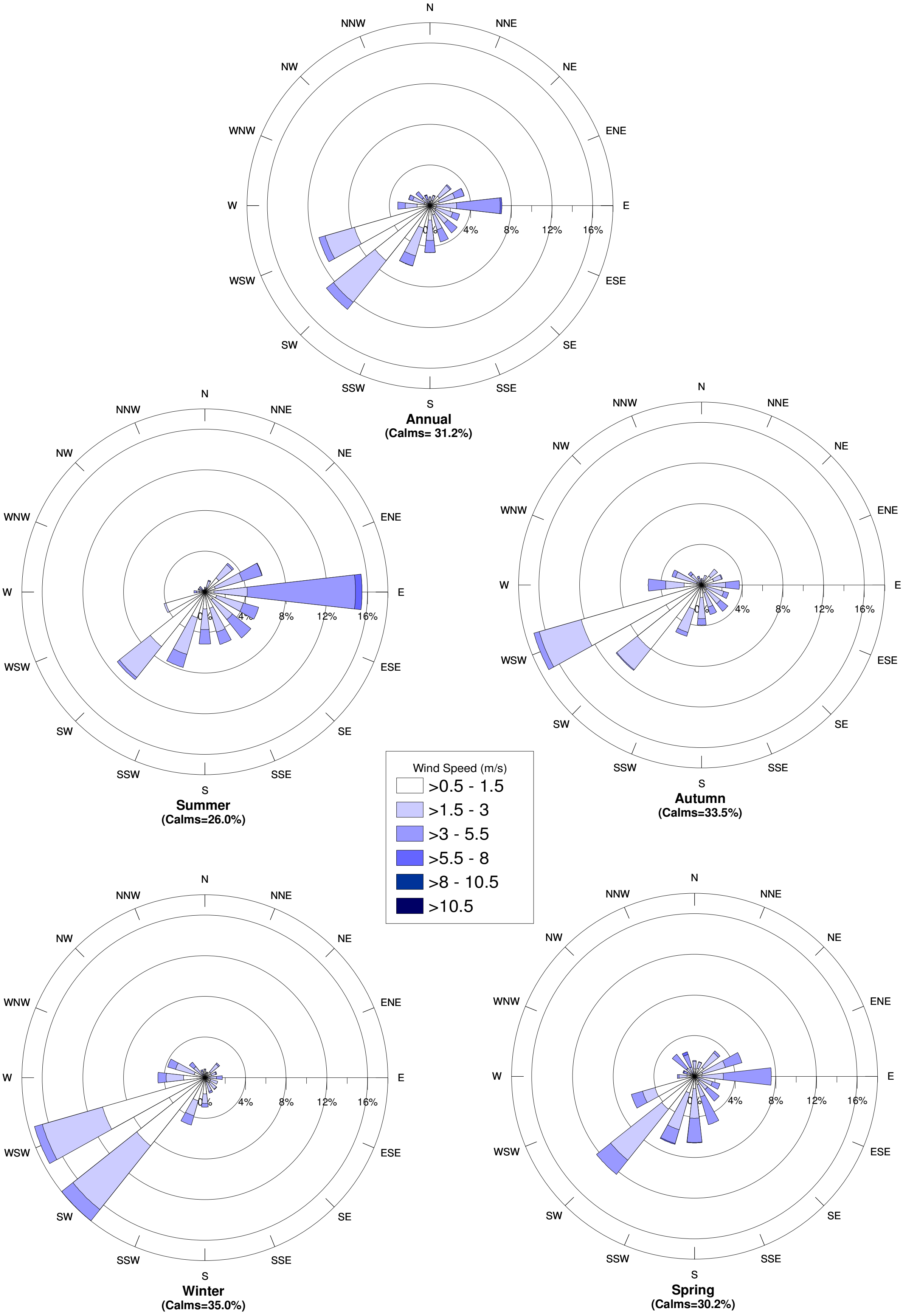
Appendix A, Figure A3: Seasonal Windroses Mandalong Mine, 2008



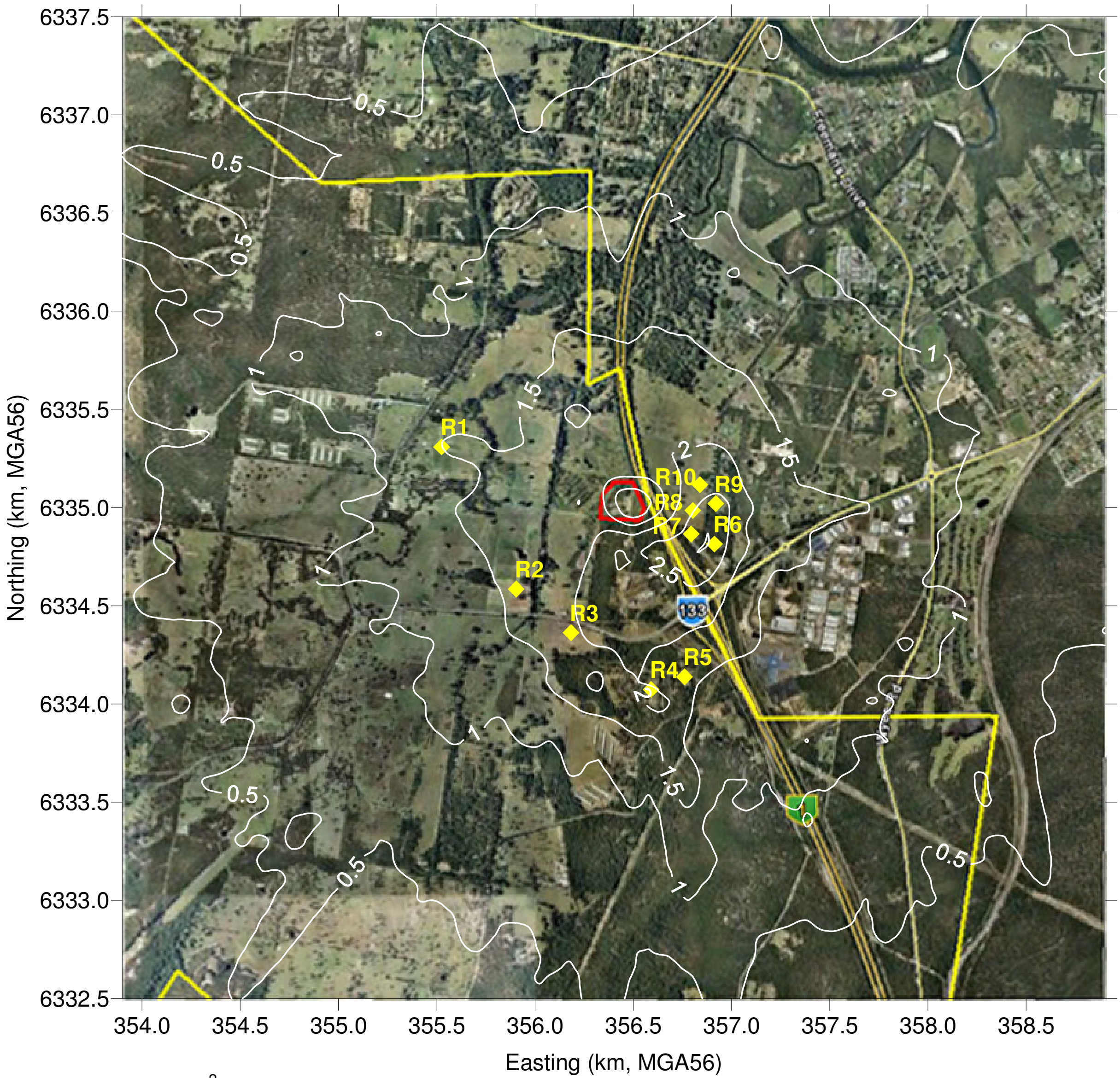
Appendix A, Figure A4: Seasonal Windroses Mandalong Mine, 2009



Appendix B, Figure B1: Seasonal Windroses Mandalong Mine, TAPM 2006

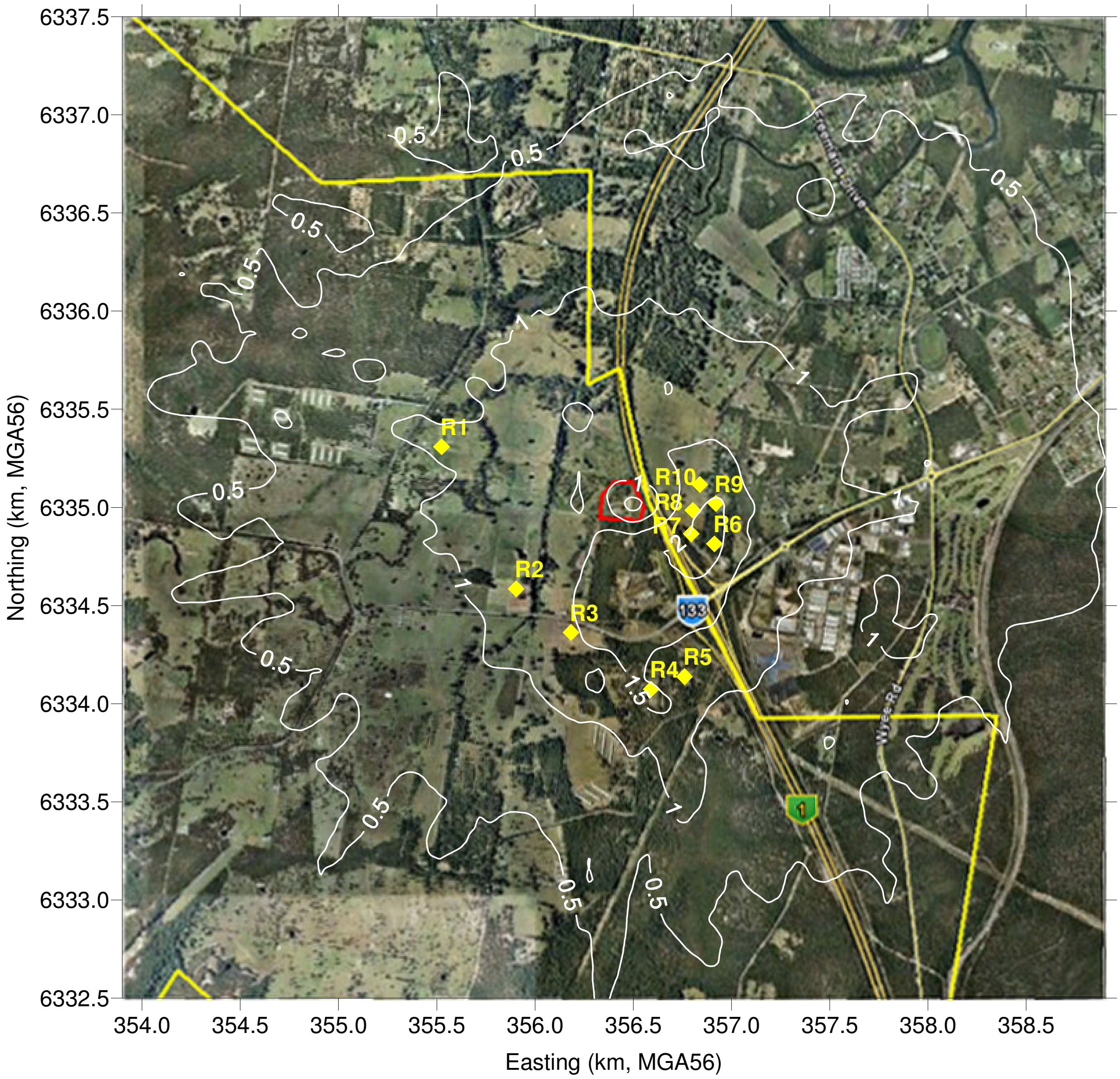


Appendix C, Figure C1: Case 1: Predicted Ground Level Concentrations of CO (mg/m^3 15-minute Average) – Gas Flaring



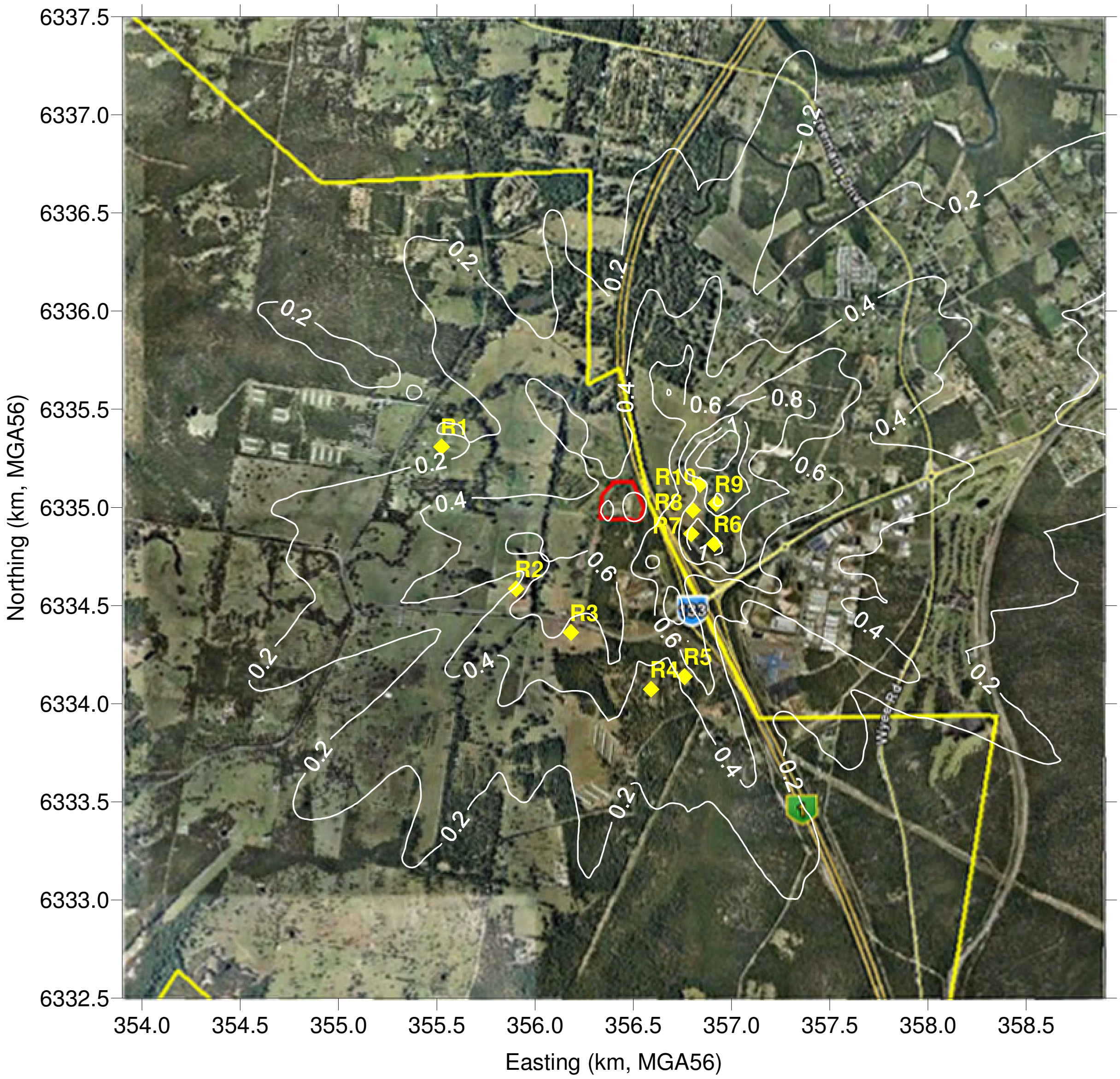
Criterion 100 mg/m^3

Appendix C, Figure C2: Case 1: Predicted Ground Level Concentrations of CO (mg/m^3 1-hr Average) – Gas Flaring



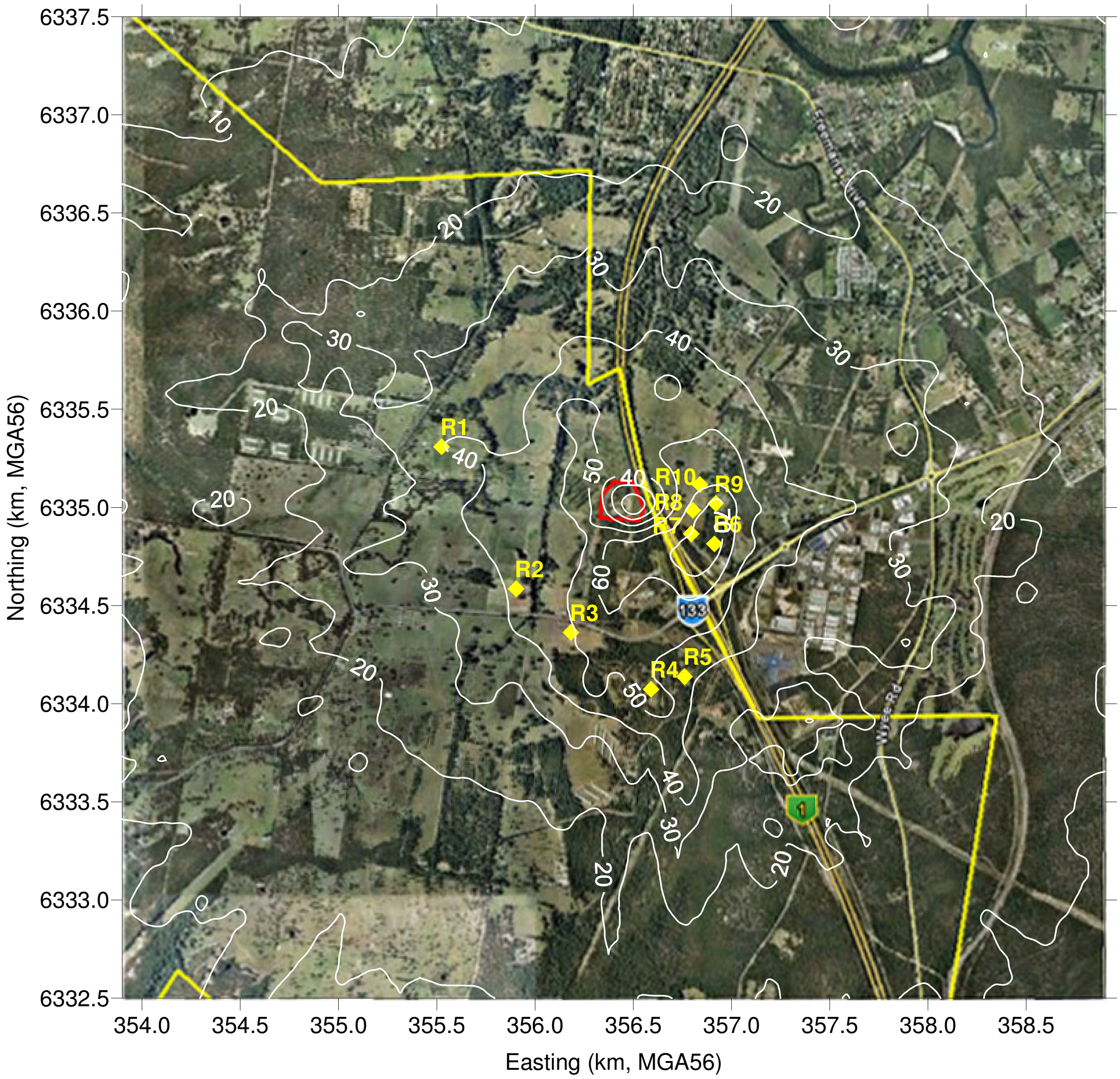
Criterion 30 mg/m^3

Appendix C, Figure C3: Case 1: Predicted Ground Level Concentrations of CO (mg/m^3 8-hr Average)



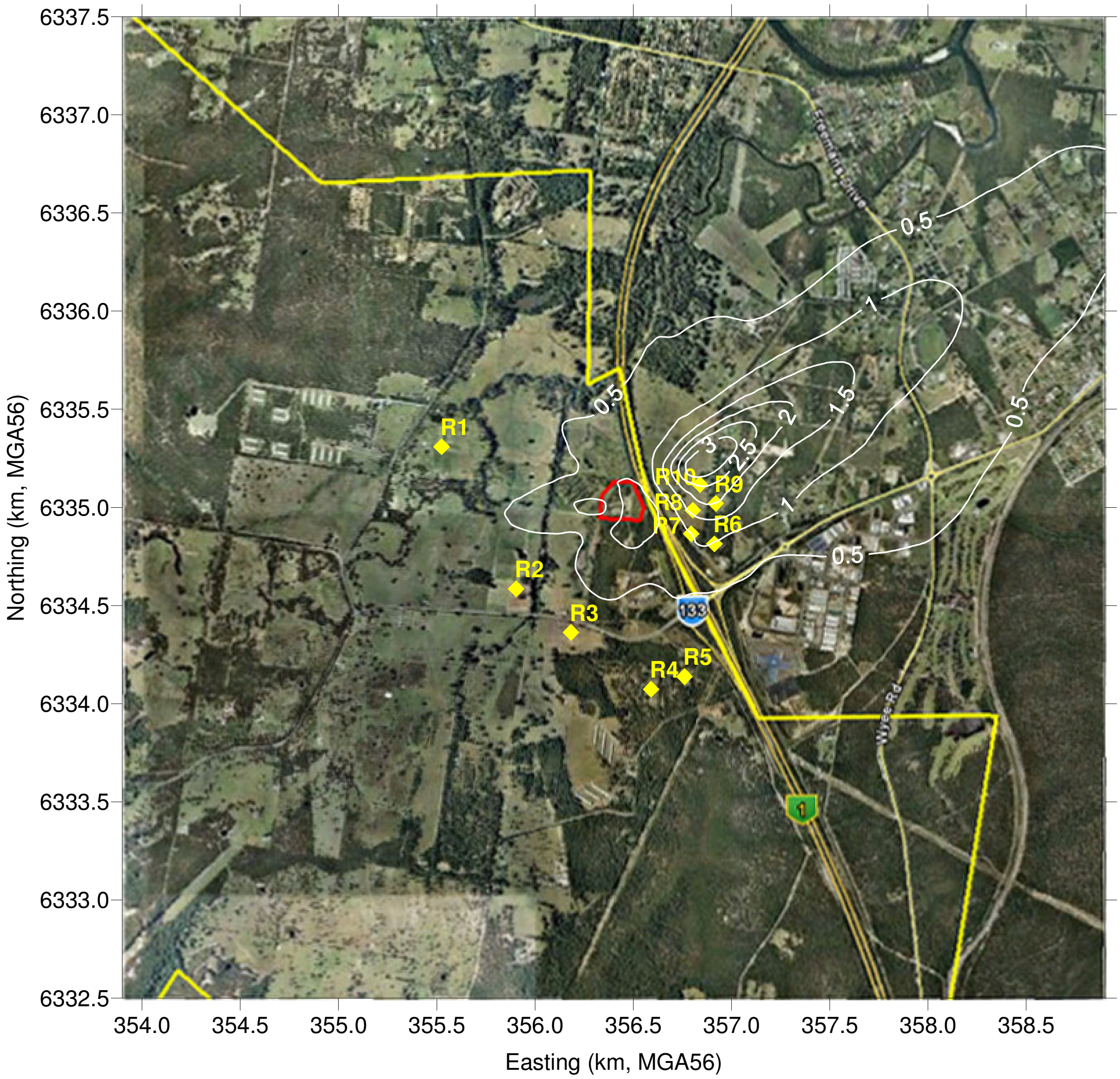
Criterion 10 mg/m^3

Appendix C, Figure C4: Case 1: Predicted Ground Level Concentrations of NO_2 (µg/m^3 1-hr Average) – Gas Flaring



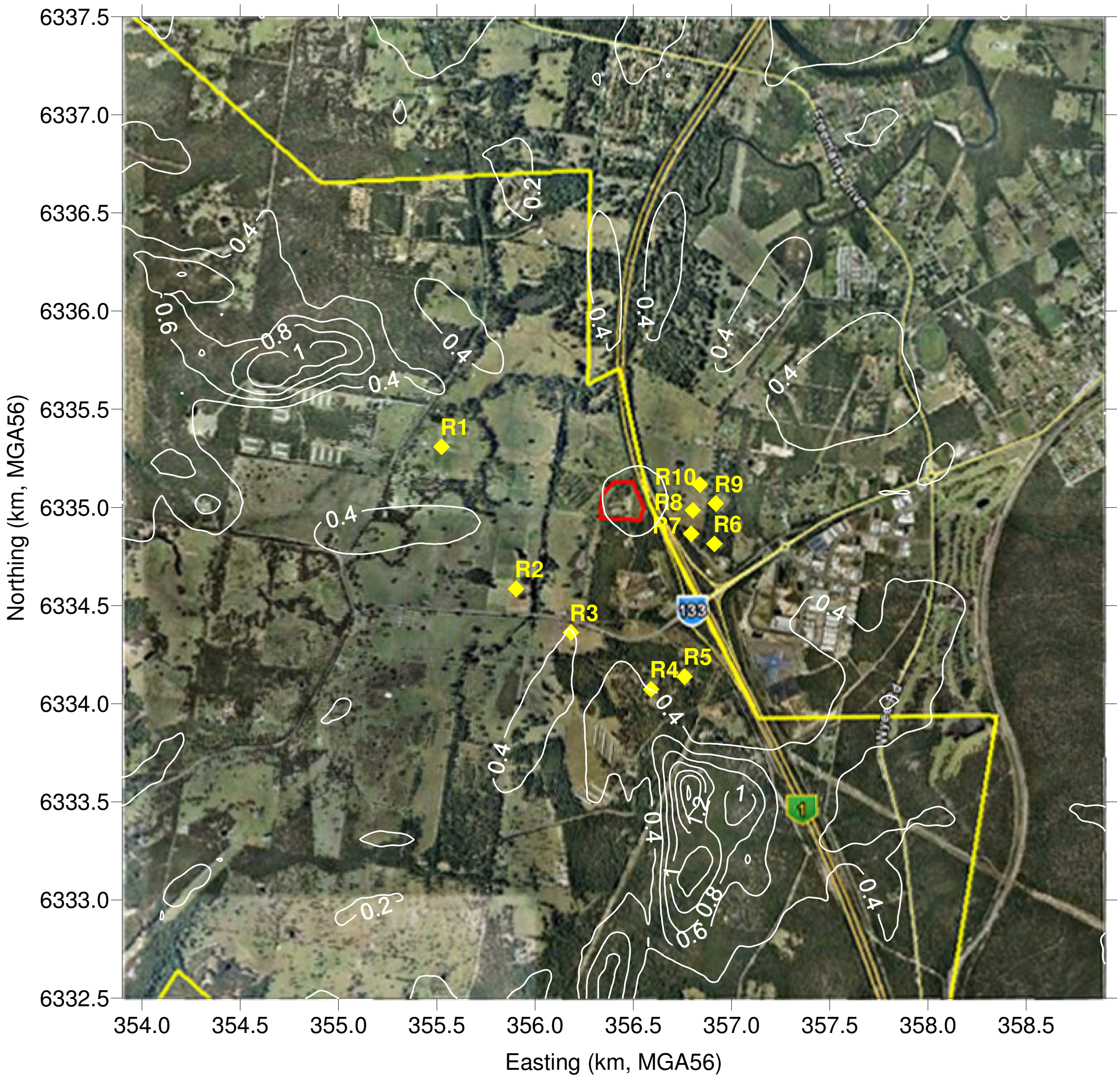
Criterion 246 µg/m^3

Appendix C, Figure C5: Case 1: Predicted Ground Level Concentrations of NO_2 (µg/m^3 Annual Average) – Gas Flaring



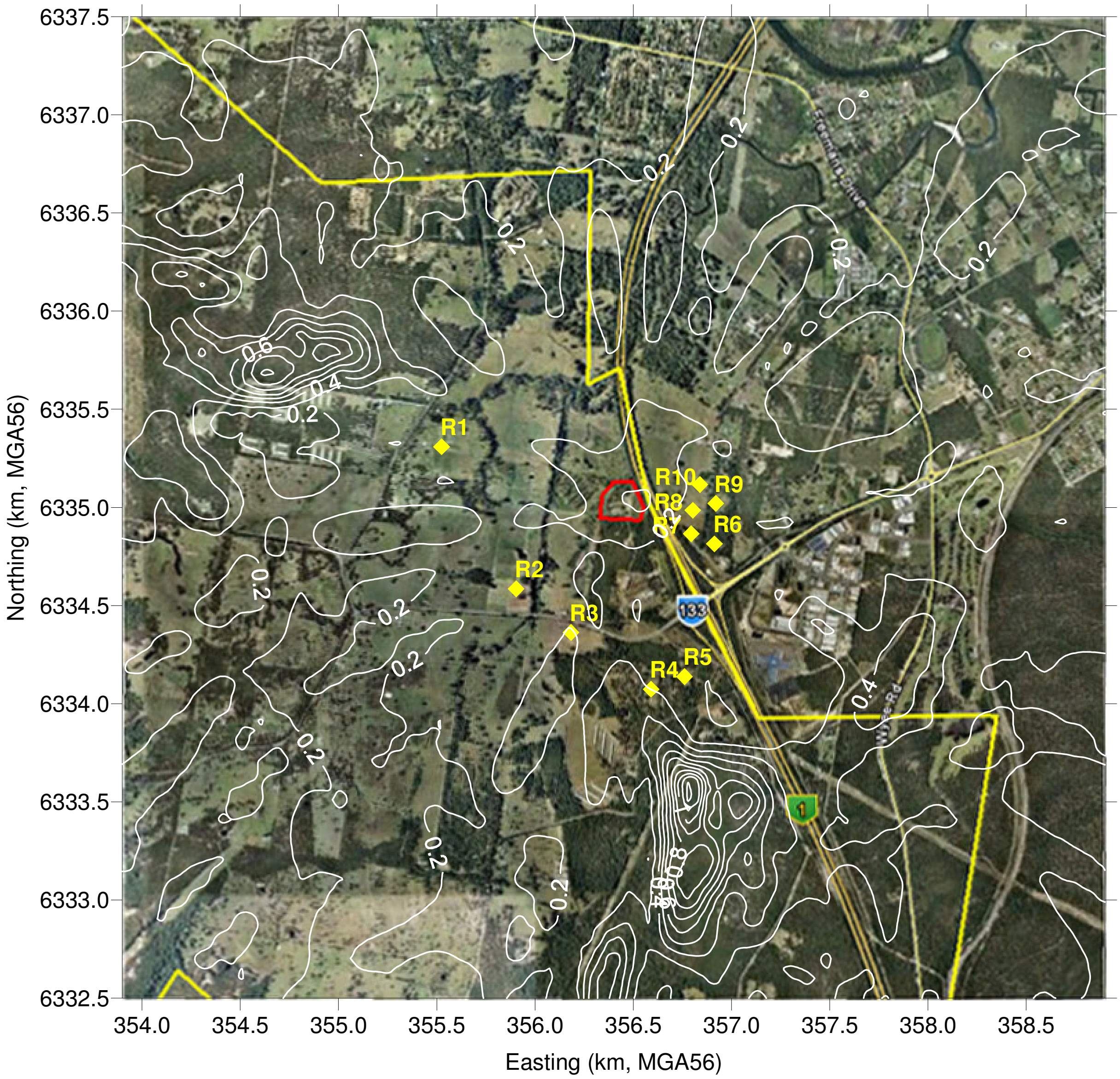
Criterion 62 µg/m^3

Appendix C, Figure C6: Case 2: Predicted Ground Level Concentrations of CO (mg/m^3 15-minute Average) – Gas Engines



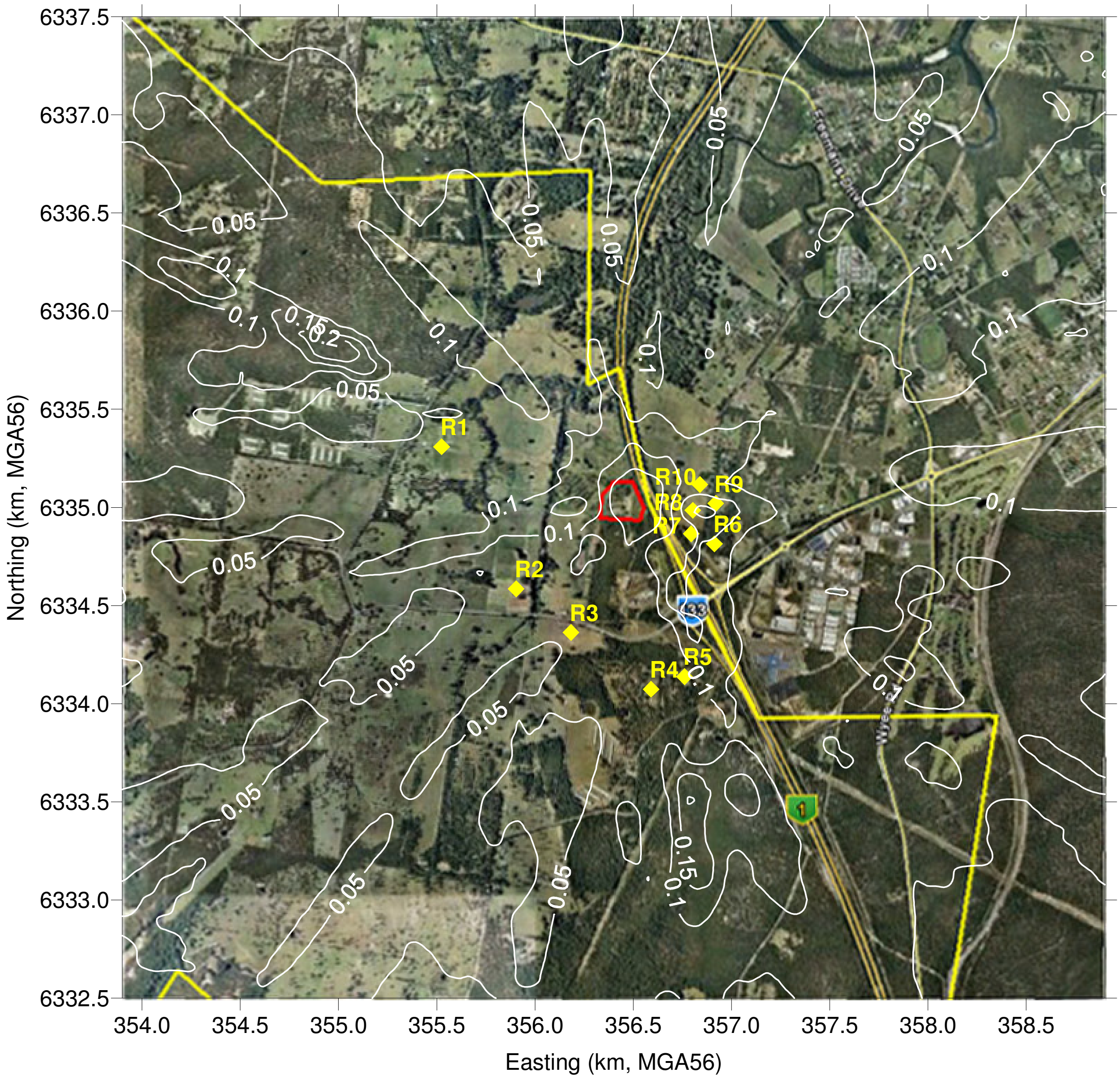
Criterion 100 mg/m^3

Appendix C, Figure C7: Case 2: Predicted Ground Level Concentrations of CO (mg/m^3 1-hour Average) – Gas Engines



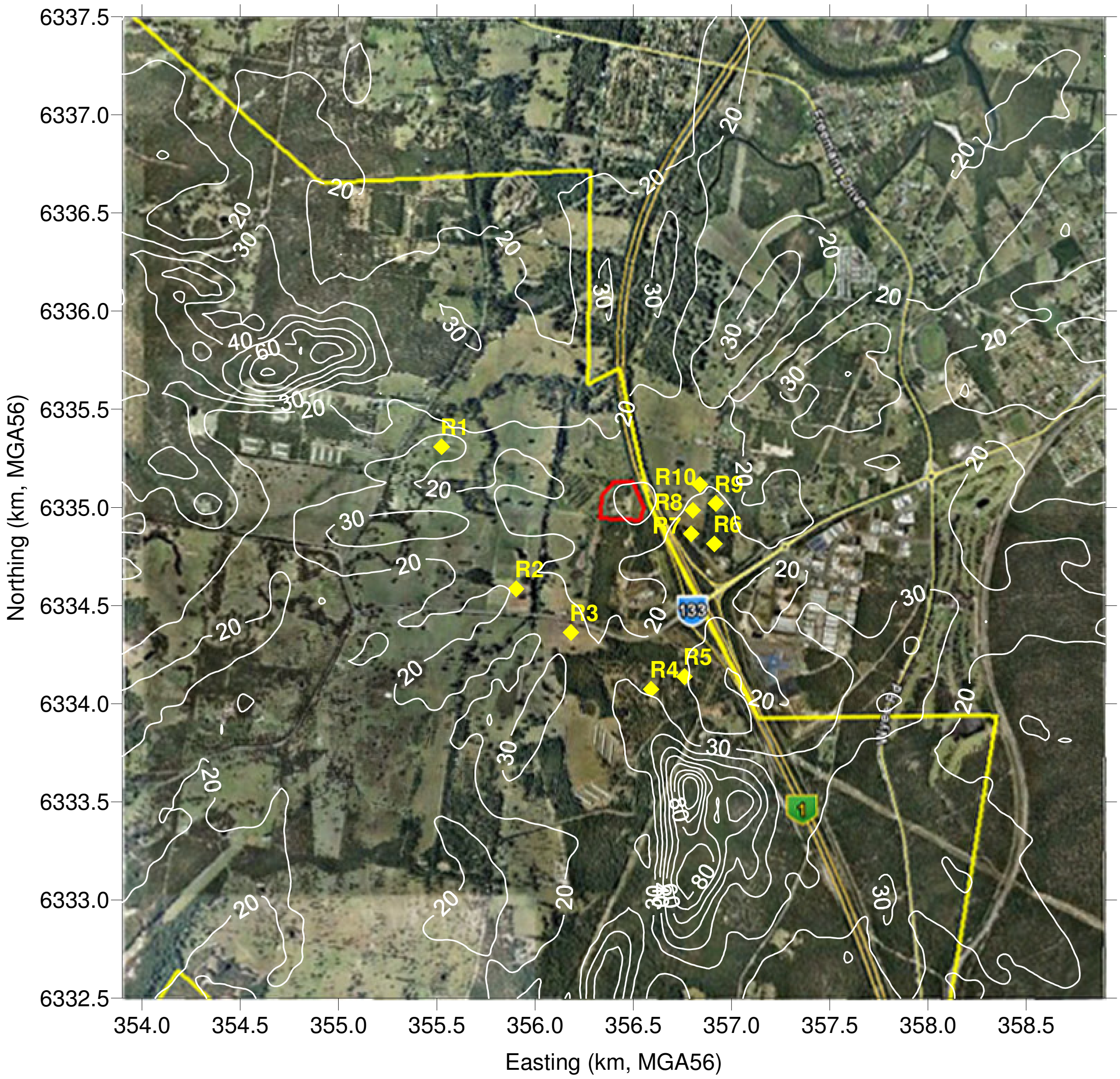
Criterion 30 mg/m^3

Appendix C, Figure C8: Case 2: Predicted Ground Level Concentrations of CO (mg/m^3 8-hour Average) – Gas Engines



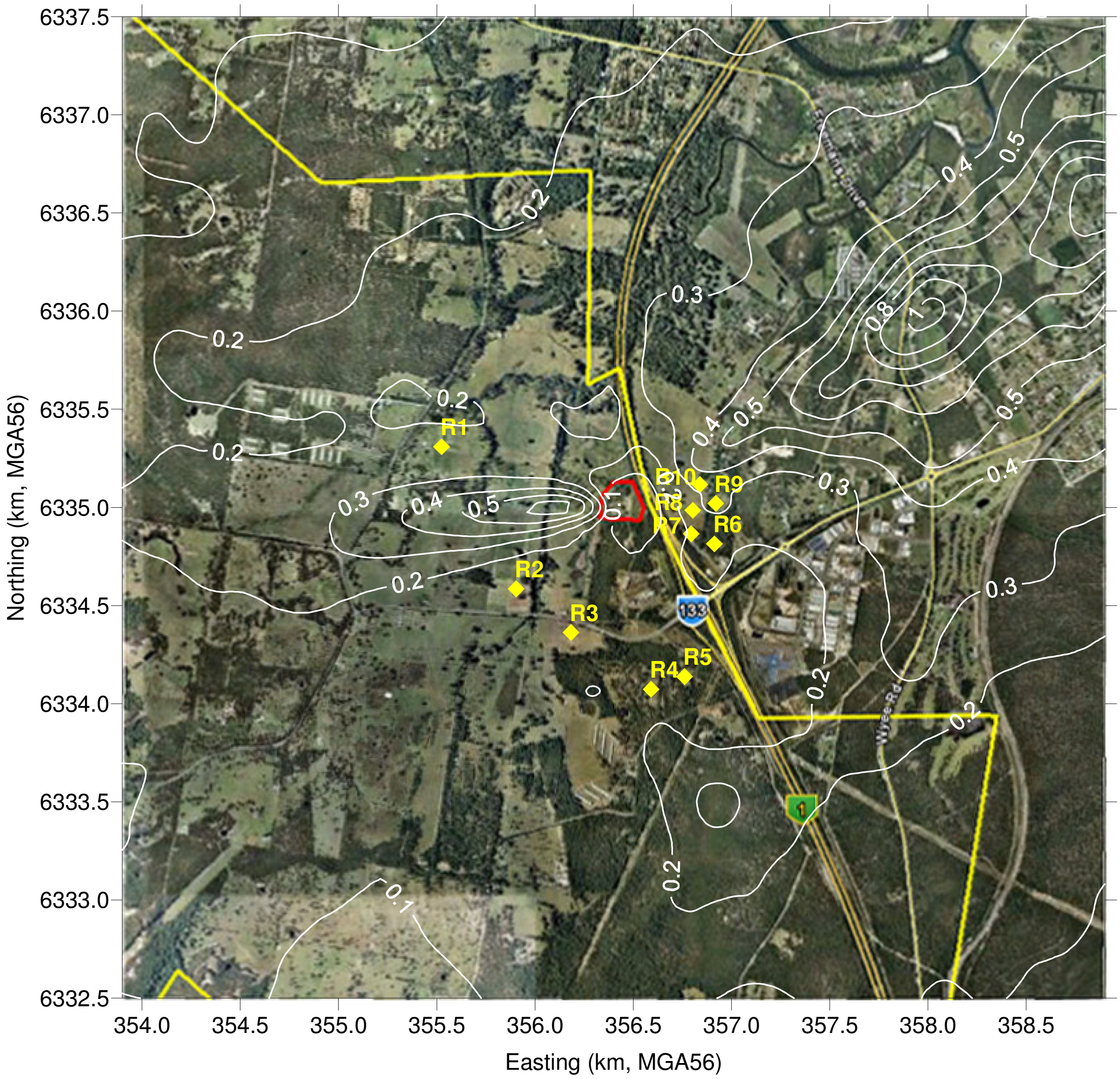
Criterion 10 mg/m^3

Appendix C, Figure C9: Case 2: Predicted Ground Level Concentrations of NO_2 (µg/m^3 1-hour Average) – Gas Engines



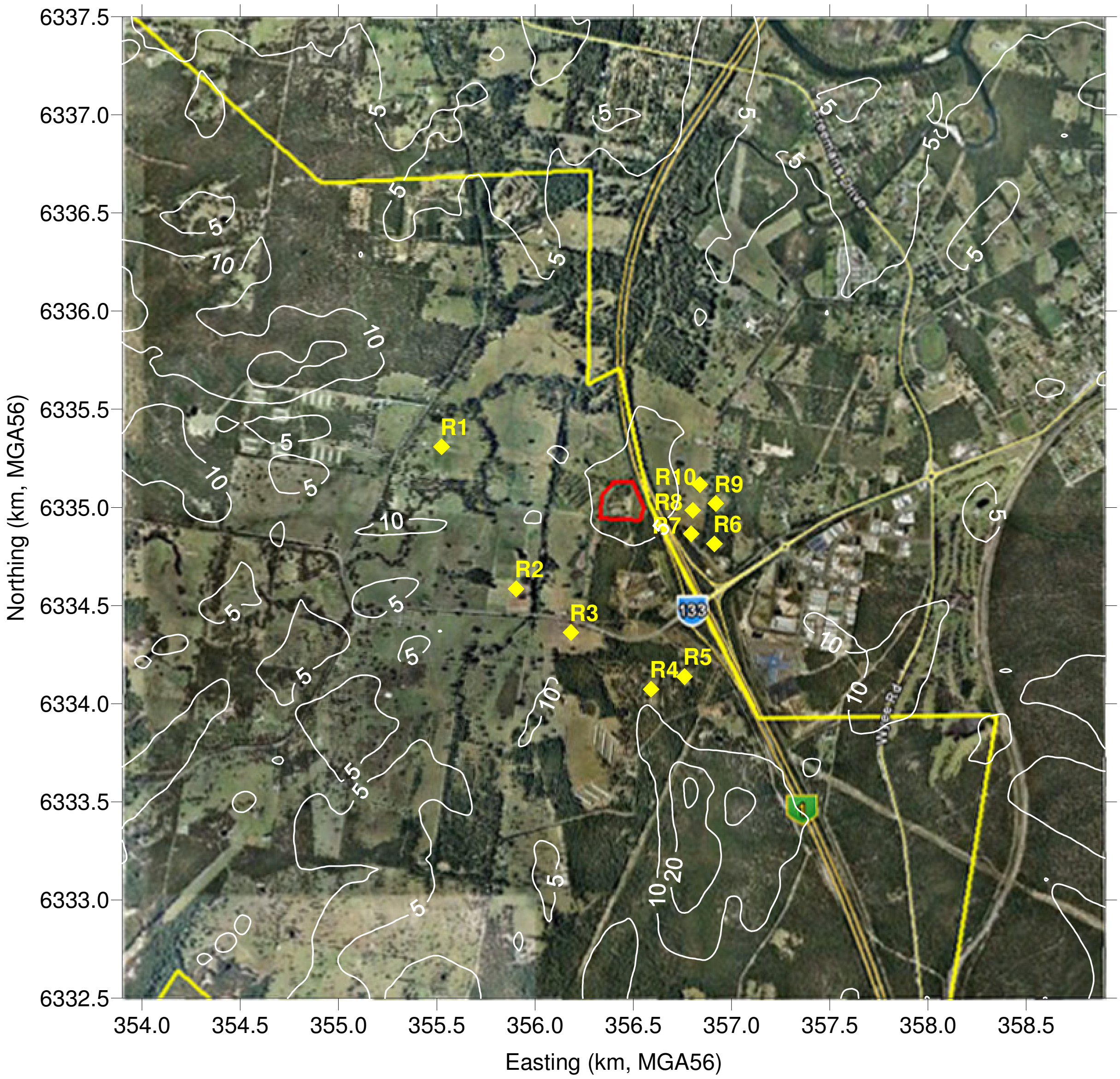
Criterion 246 µg/m^3

Appendix C, Figure C10: Case 2: Predicted Ground Level Concentrations of NO_2 (µg/m^3 Annual Average) – Gas Engines



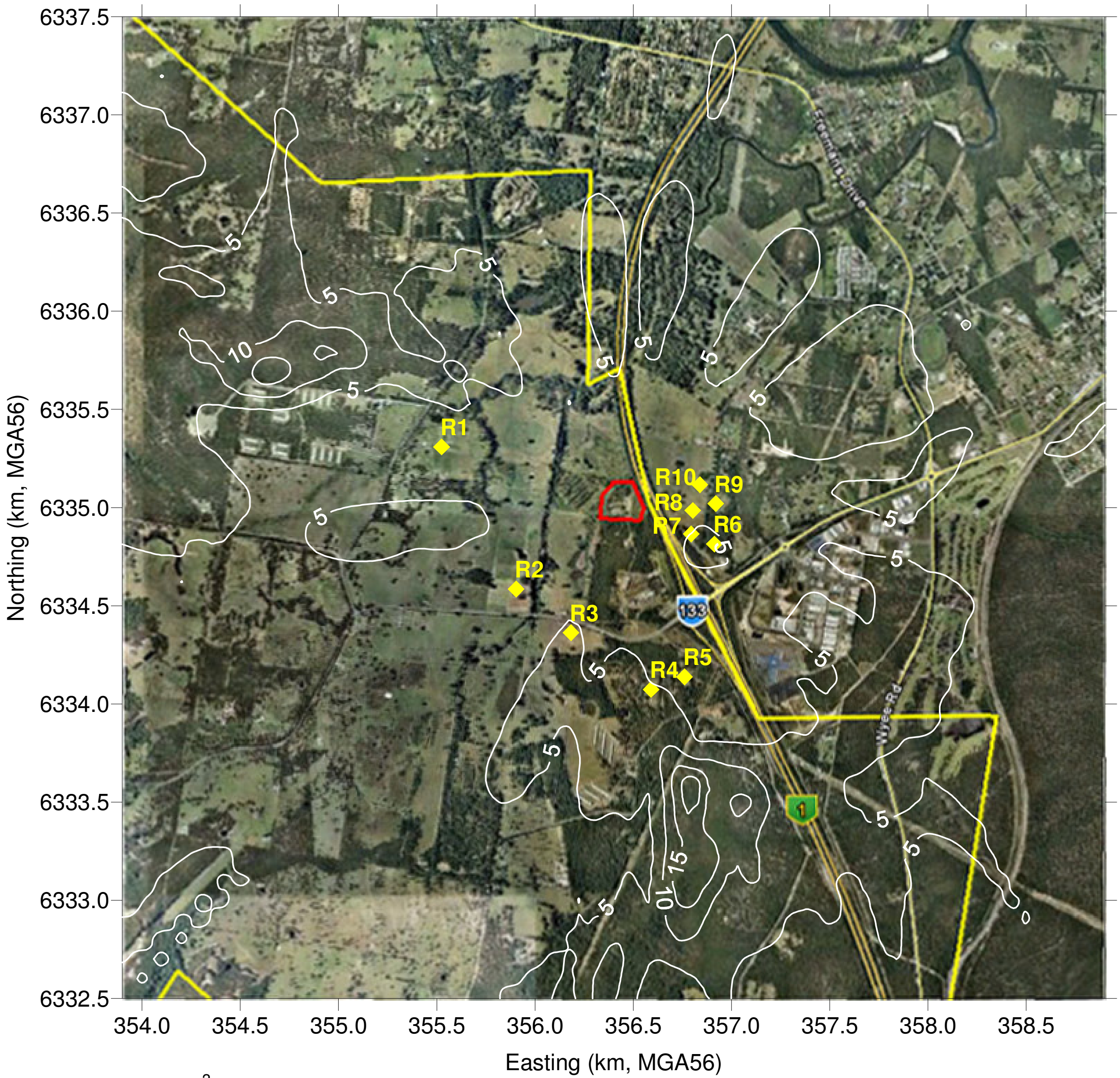
Criterion 62 µg/m^3

Appendix C, Figure C11: Case 2: Predicted Ground Level Concentrations of SO_2 (µg/m^3 10-minute Average) – Gas Engines



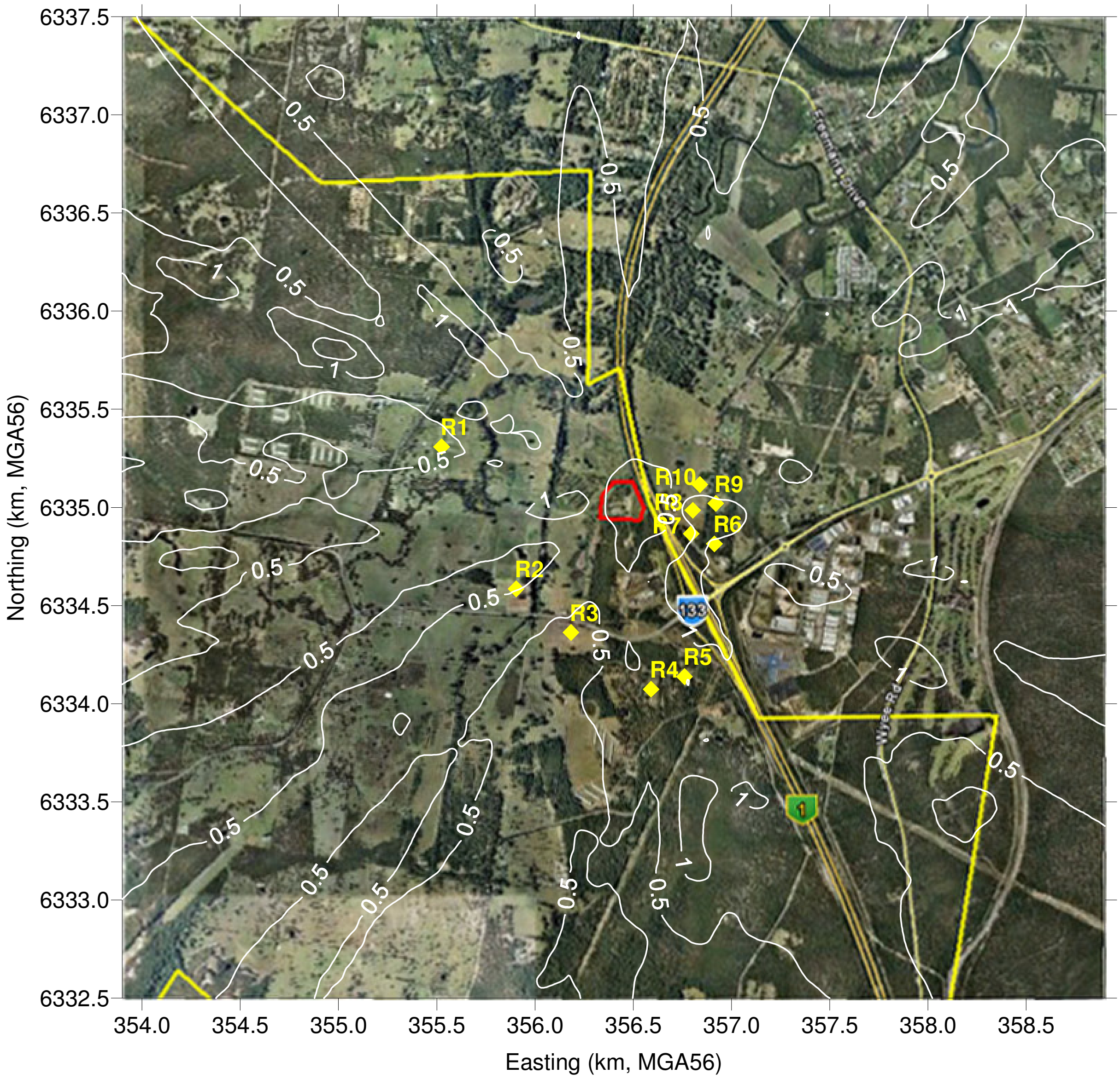
Criterion 712 µg/m^3

Appendix C, Figure C12: Case 2: Predicted Ground Level Concentrations of SO_2 (µg/m^3 1-hour Average) – Gas Engines



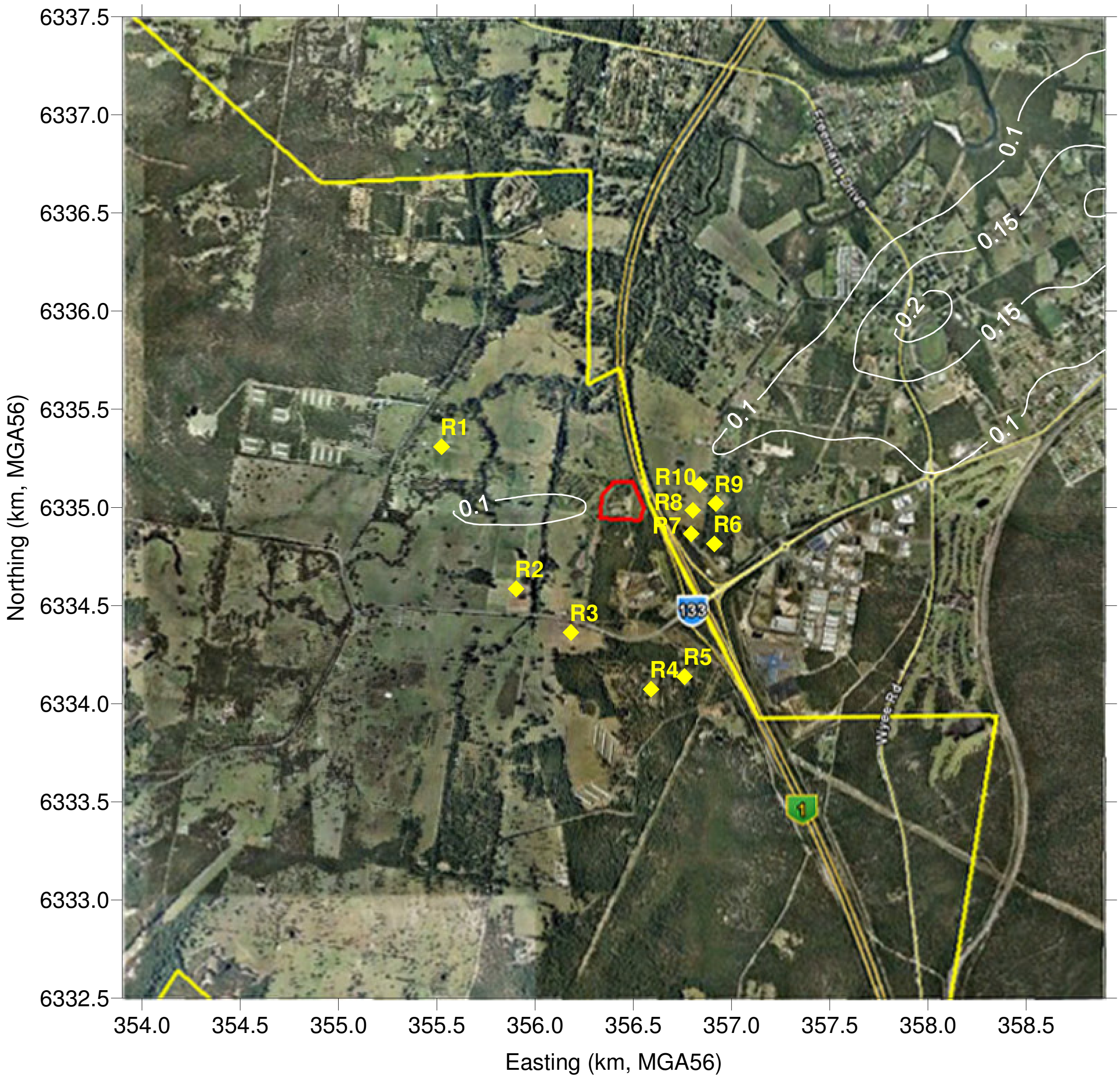
Criterion 570 µg/m^3

Appendix C, Figure C13: Case 2: Predicted Ground Level Concentrations of SO_2 (µg/m^3 24-hours Average) – Gas Engines



Criterion 228 µg/m^3

Appendix C, Figure C14: Case 2: Predicted Ground Level Concentrations of SO_2 (µg/m^3 Annual Average) – Gas Engines



Criterion 60 µg/m^3