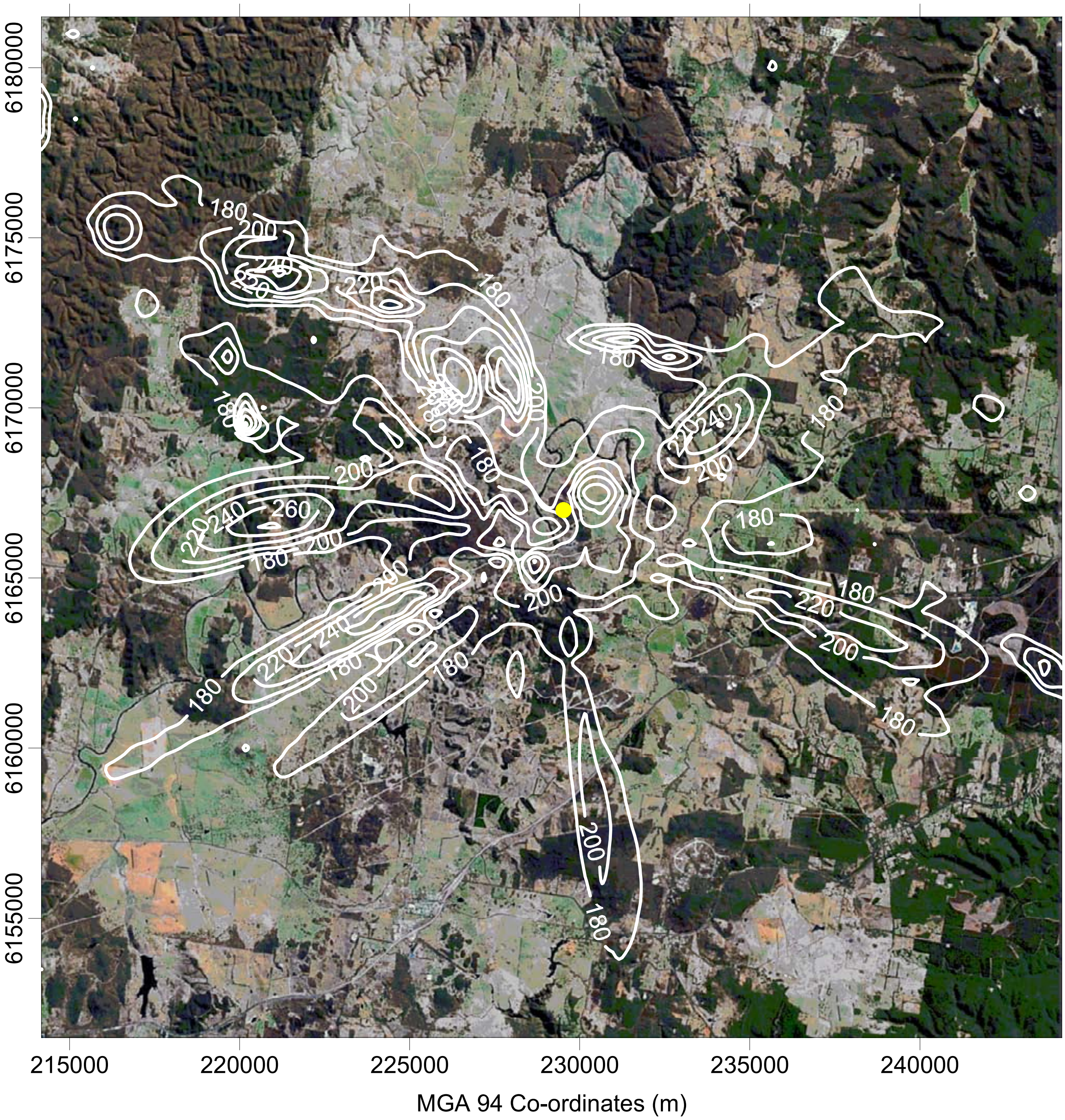
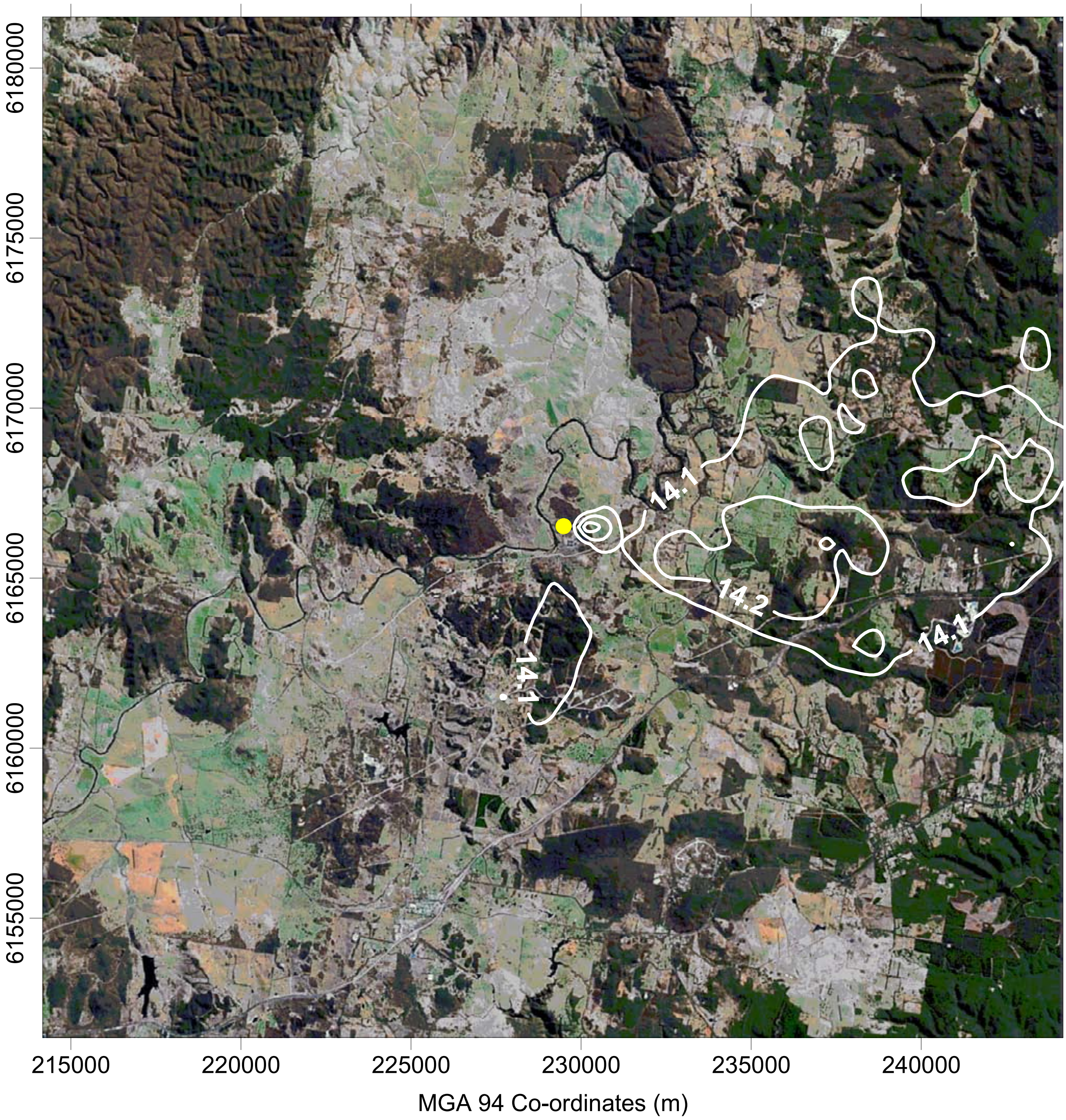


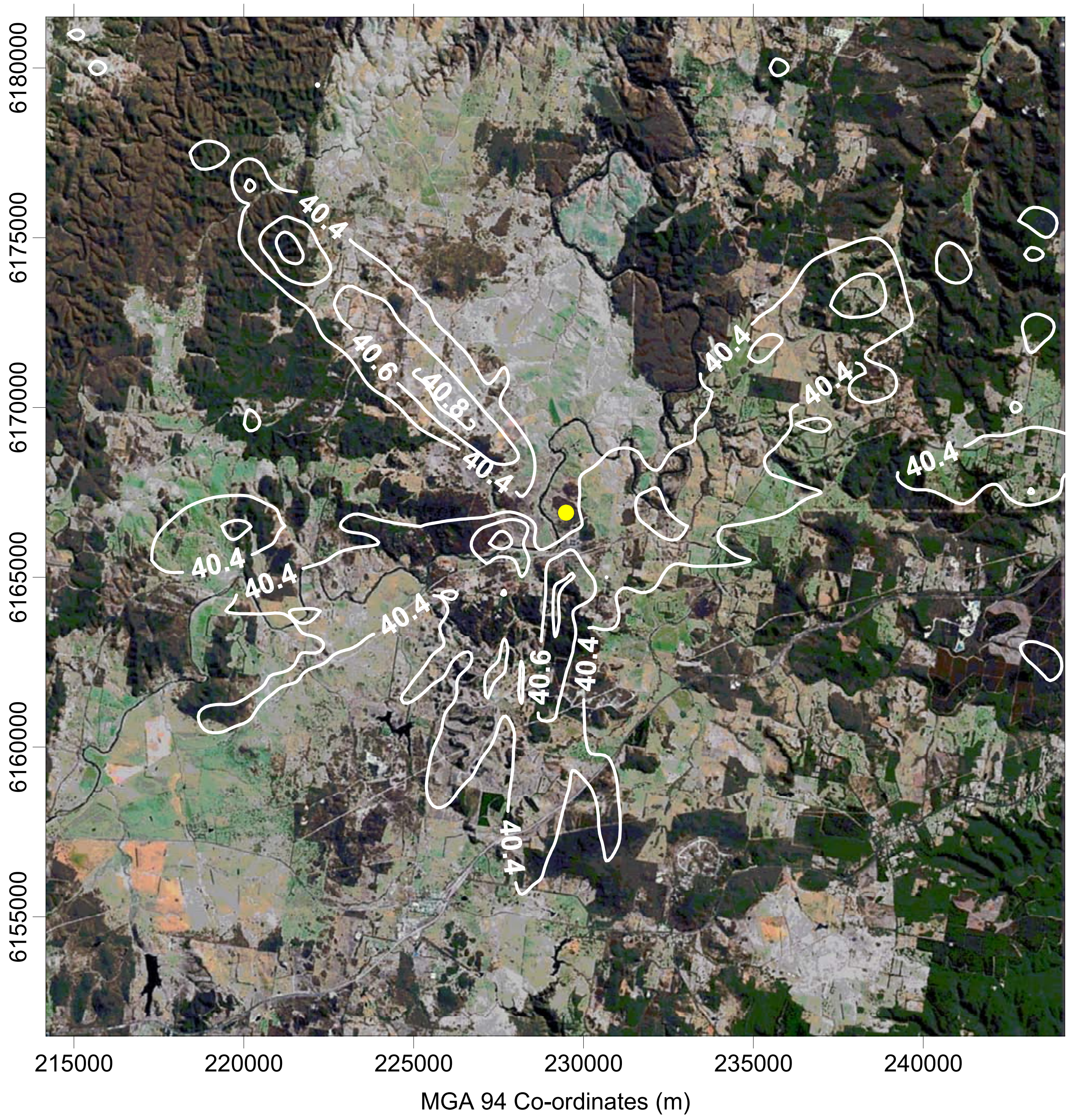
Contours in µg/m^3
Background Concentration: 116.9 µg/m^3
DECC Assessment Criteria: 246 µg/m^3
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY	Title: Combined Scenario 1: NOx 1 Hour Averaging (All NOx as NO_2) Maximum Cumulative Concentration
URS	Drawn: SWB / Approved: DRAFT / Date: March 2008	Rev: A
	Job No: 43217475 / File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 7.srf	Figure: 7 / A4



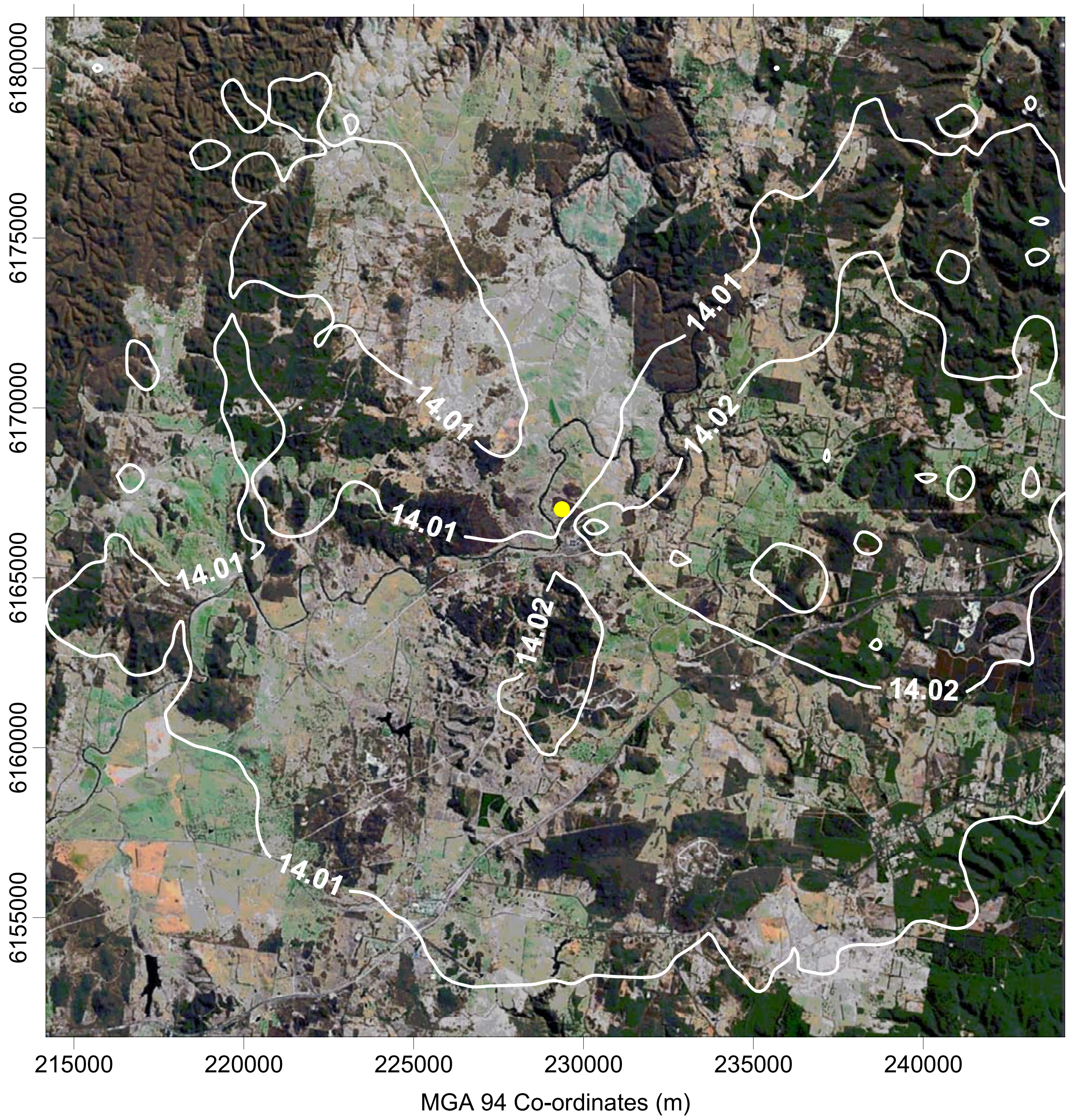
Contours in µg/m^3
Background Concentration: 13.7 µg/m^3
DECC Assessment Criteria: 62 µg/m^3
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY	Title: Combined Scenario 1: NOx Annual Averaging Cumulative Concentration
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Rev: A
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 8.srf	Figure: 8; A4



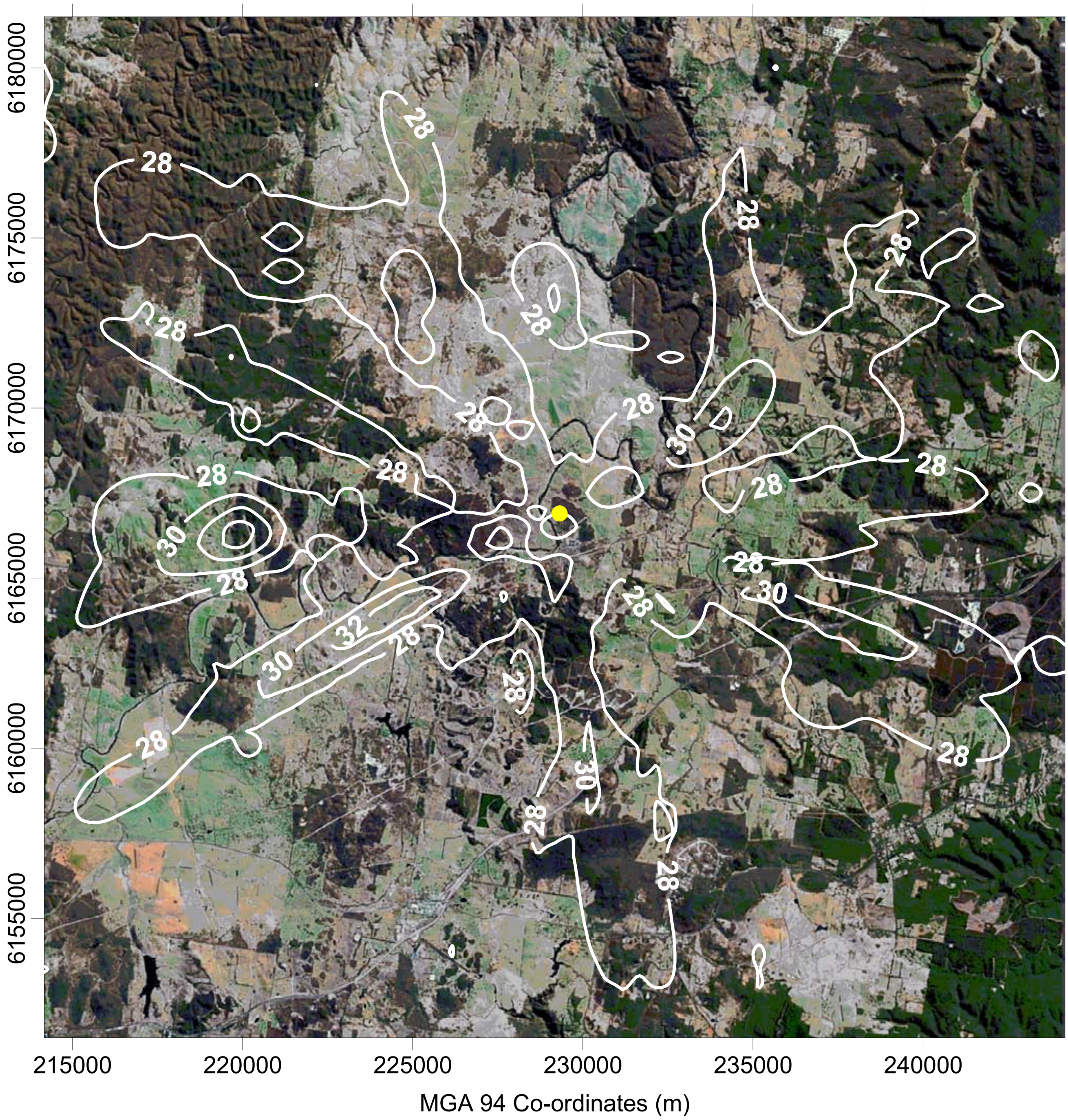
Contours in μg/m^3
Background Concentration: 40.0 μg/m^3
DECC Assessment Criteria: 50 μg/m^3
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY	Title: Combined Scenario 1: PM_{10} 24 Hour Averaging Maximum Cumulative Concentration
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008; Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 9.srf	Figure: 9; Rev: A; A4



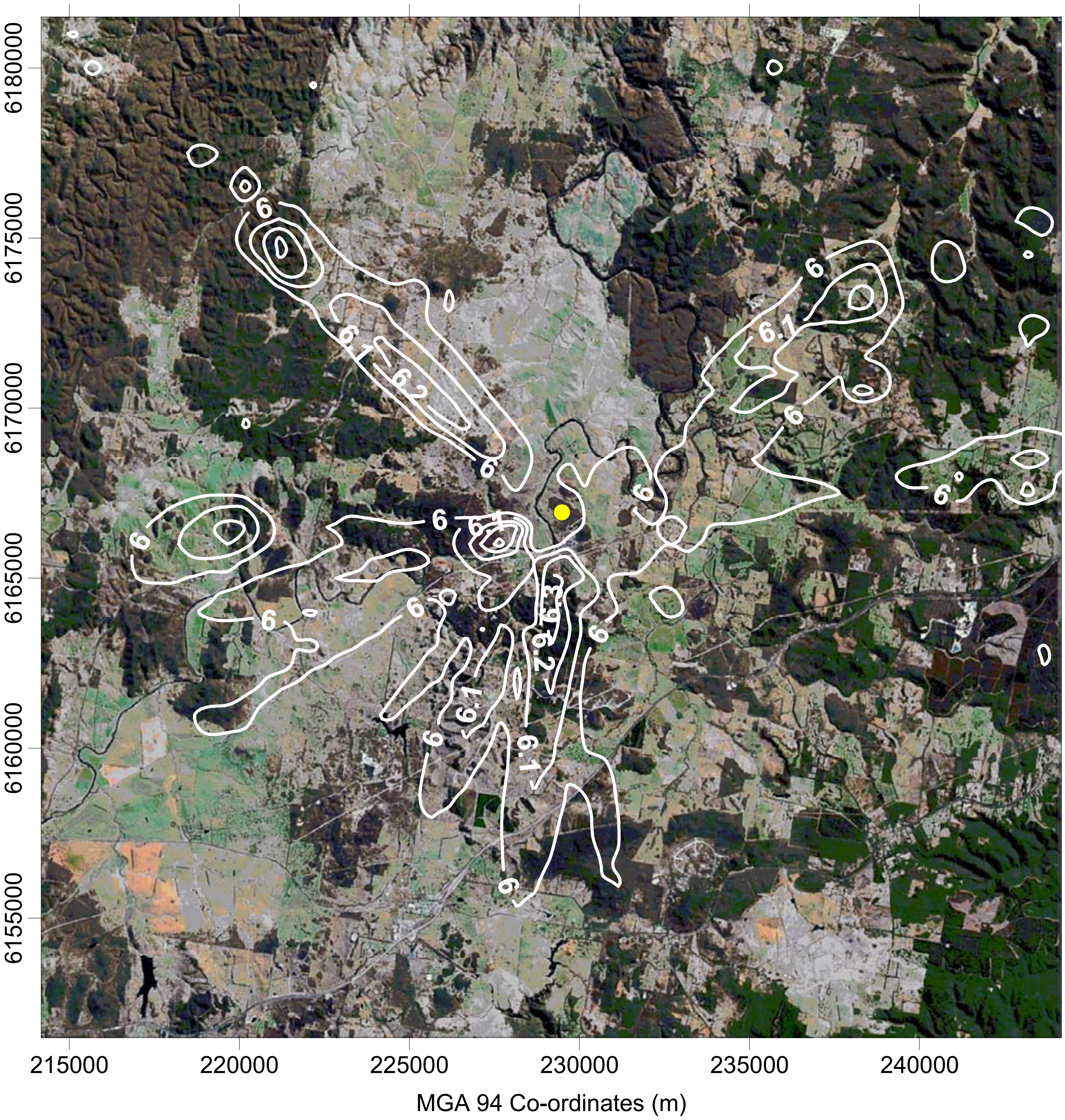
Contours in µg/m³
Background Concentration: 14.0 µg/m³
DECC Assessment Criteria: 30 µg/m³
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 1: PM_{10} Annual Averaging Cumulative Concentration**
URS	Drawn: SWB / Approved: DRAFT / Date: March 2008	Rev: A
	Job No: 43217475 / File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 10.srf	Figure: 10 / A4



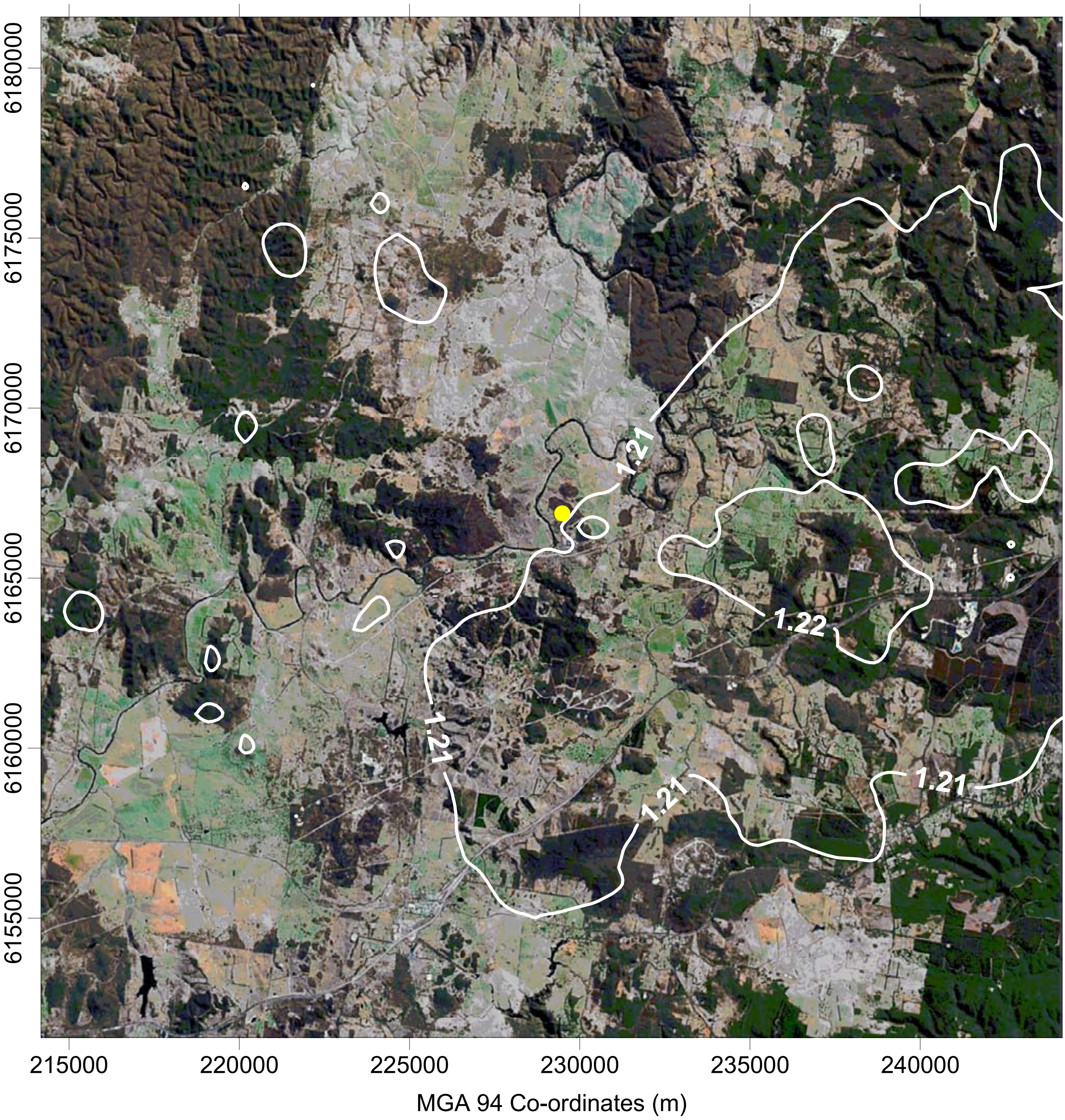
Contours in $\mu g/m^3$
Background Concentration: 25.7 $\mu g/m^3$
DECC Assessment Criteria: 570 $\mu g/m^3$
Site Location

Client: DELTA ELECTRICTY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY	Title Combined Scenario 1: SO_2 1 Hour Averaging Maximum Cumulative Concentration
URS	Drawn: SWB / Approved: DRAFT / Date: March 2008 / Job No: 43217475 / File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 11.srf	Figure: 11 / Rev: A / A4



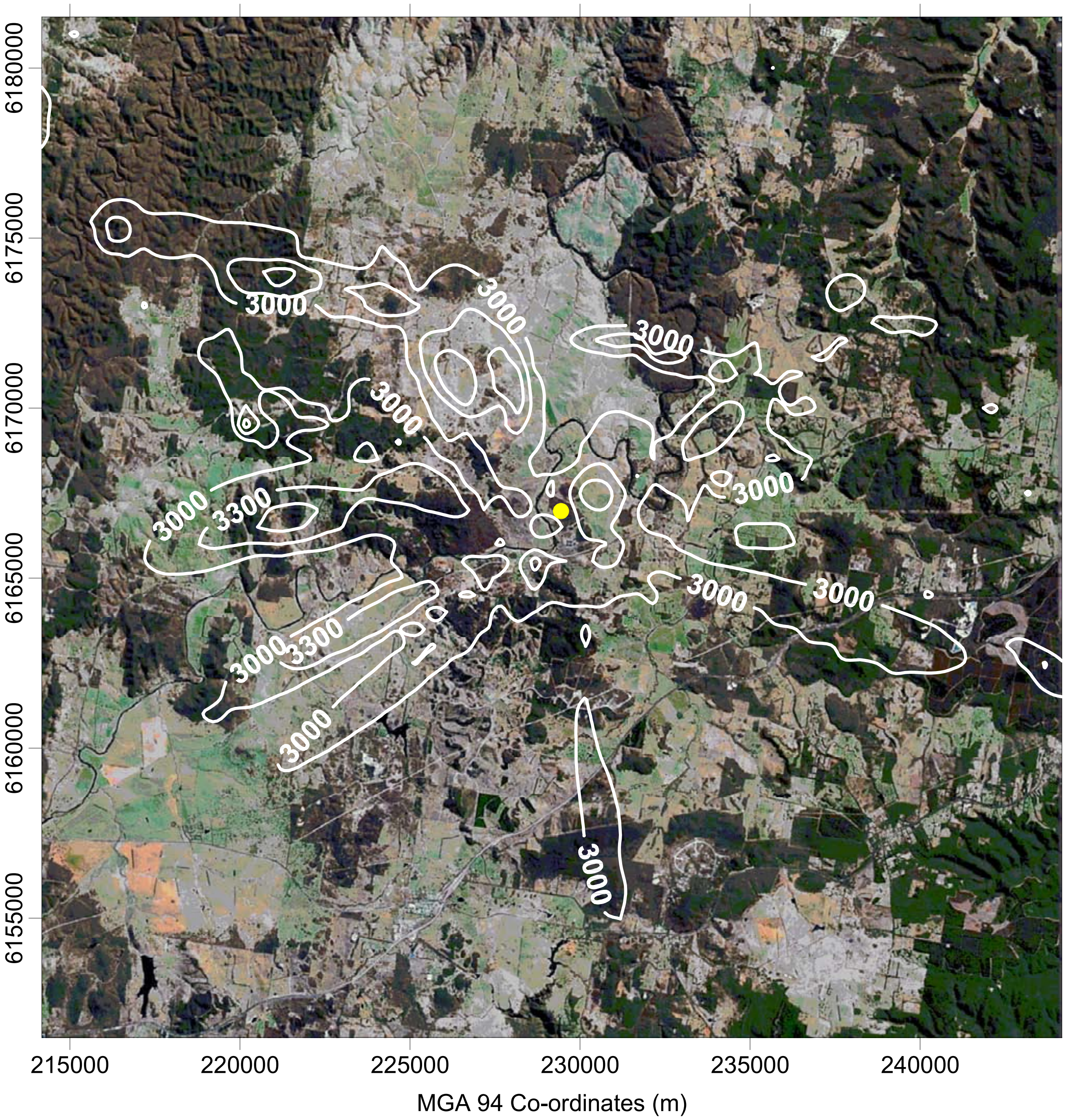
Contours in µg/m^3
Background Concentration: 5.7 µg/m^3
DECC Assessment Criteria: 228 µg/m^3
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 1: SO_2 24 Hour Averaging Maximum Cumulative Concentration**
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Figure: 12
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 12.srf	Rev: A; A4



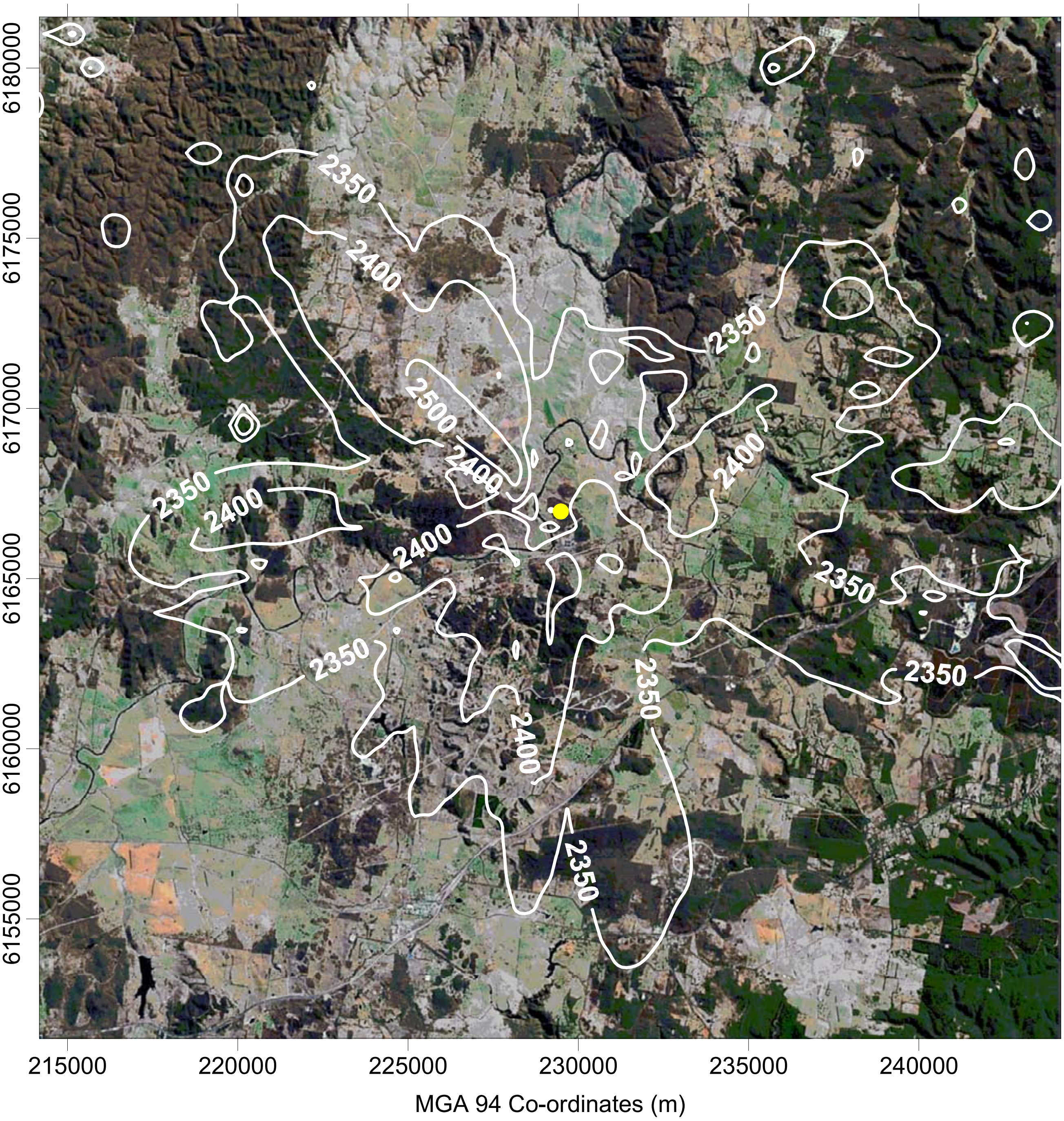
Contours in $\mu g/m^3$
Background Concentration: 1.2 $\mu g/m^3$
DECC Assessment Criteria: 60 $\mu g/m^3$
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 1: SO_2 Annual Averaging Cumulative Concentration**
URS	Drawn: SWB · Approved: DRAFT · Date: March 2008	Rev: A
	Job No: **43217475** · File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 13.srf	Figure: 13 · A4



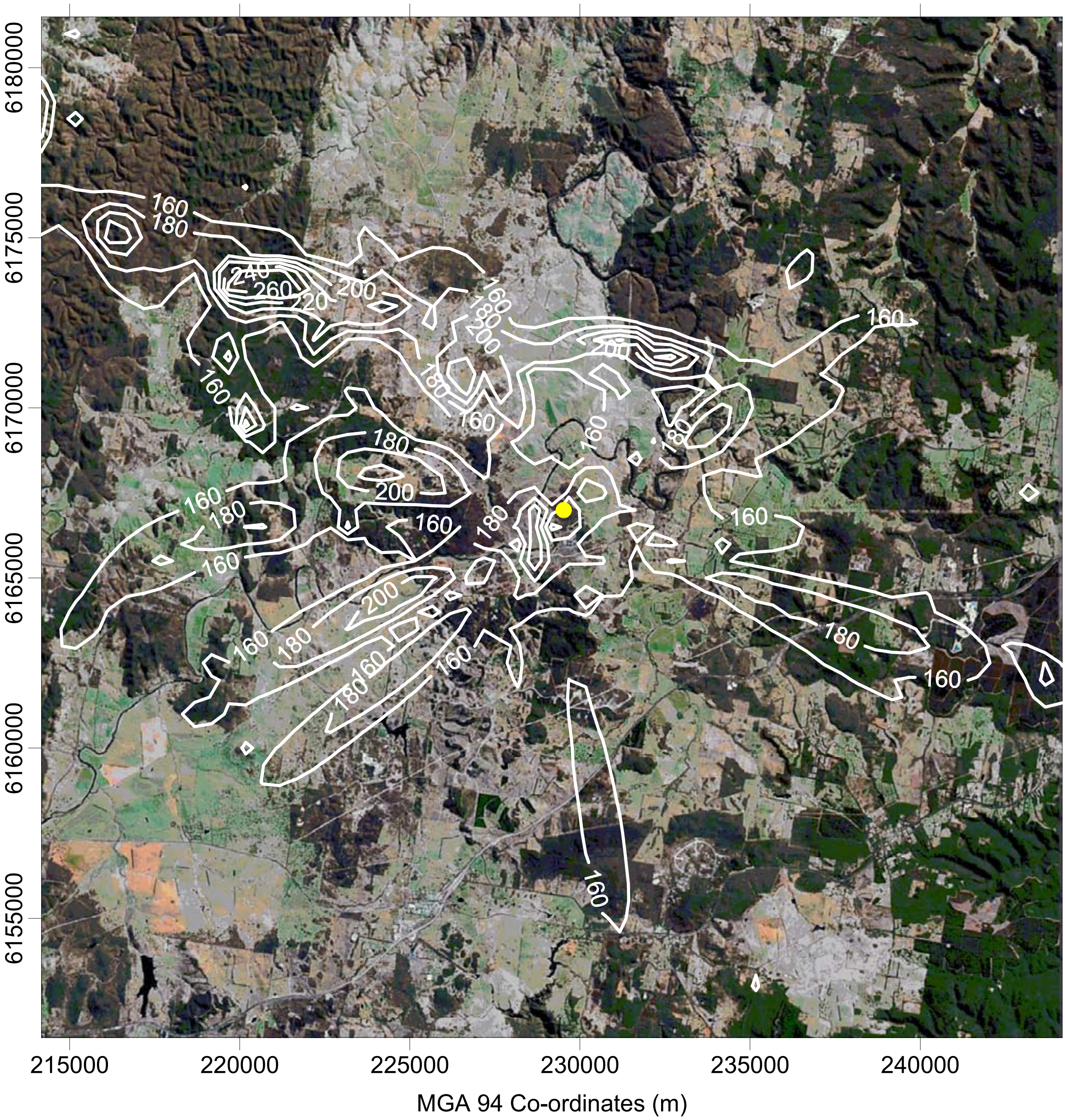
Contours in µg/m^3
Background Concentration: 2,500 µg/m^3
DECC Assessment Criteria: 30,000 µg/m^3
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY			Title: Combined Scenario 1: CO 1 Hour Averaging Maximum Cumulative Concentration	
URS	Drawn: SWB	Approved: DRAFT	Date: March 2008	Figure: 14	Rev: A
	Job No: 43217475	File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 14.srf			A4



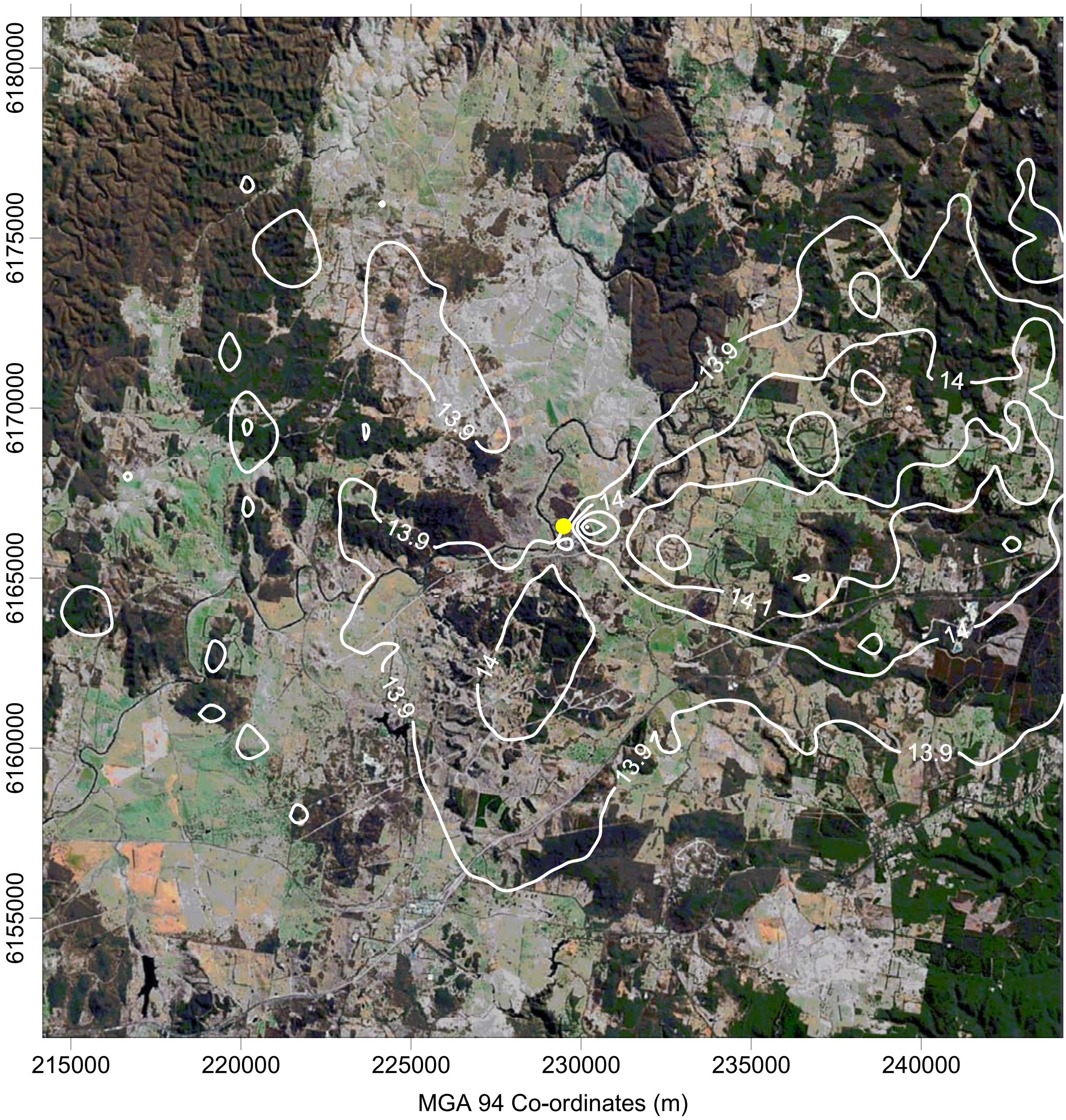
Contours in µg/m^3
Background Concentration: 2,250 µg/m^3
DECC Assessment Criteria: 10,000 µg/m^3
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 1: CO 8 Hour Averaging Maximum Cumulative Concentration**
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Rev: A
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 15.srf	Figure: 15; A4



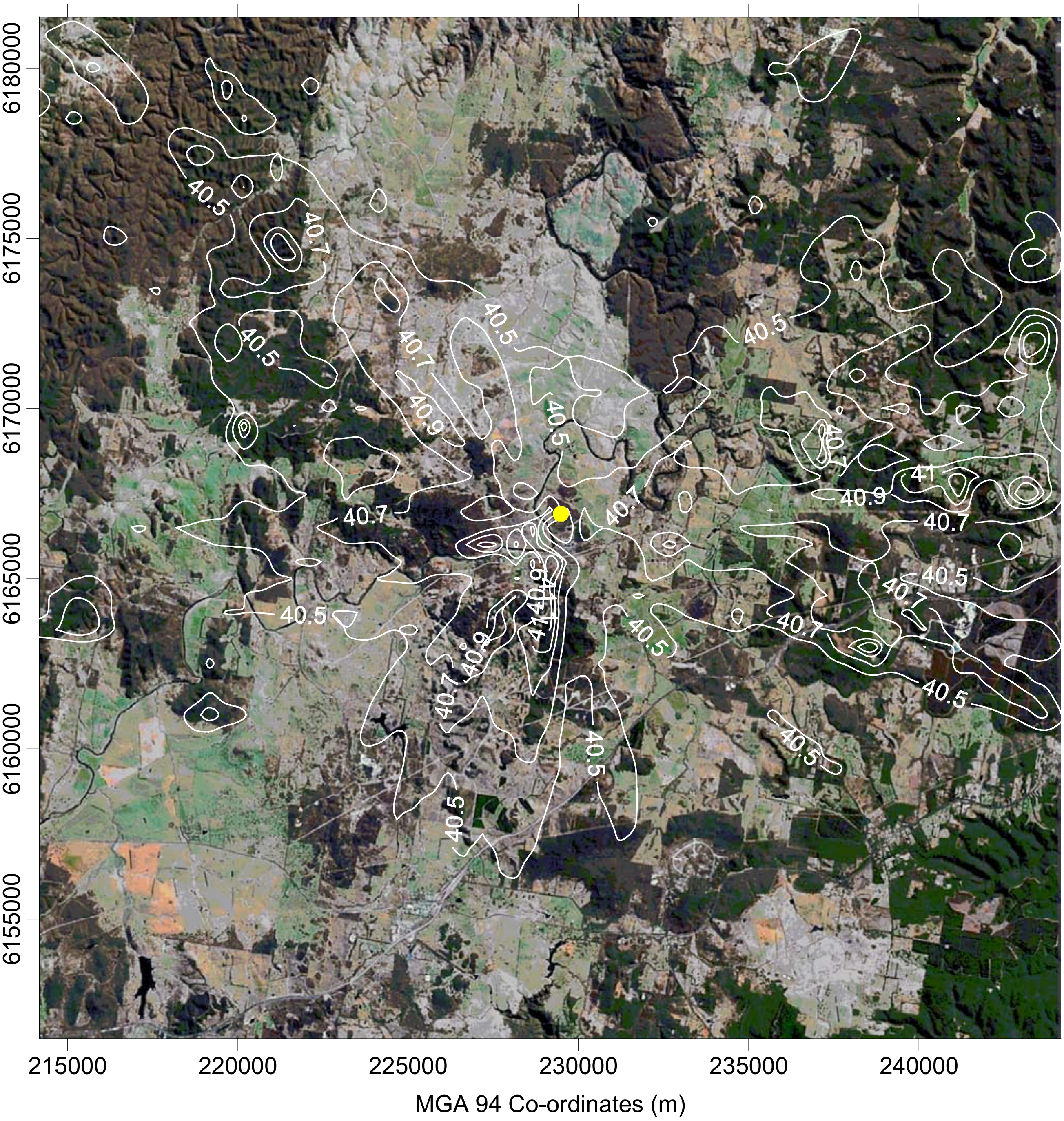
Contours in µg/m^3
Background Concentration: 116.9 µg/m^3
DECC Assessment Criteria: 246 µg/m^3
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 2: NOx 1 Hour Averaging (All NOx as NO_2) Maximum Cumulative Concentration**
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Figure: 16
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 16.srf	Rev: A; A4



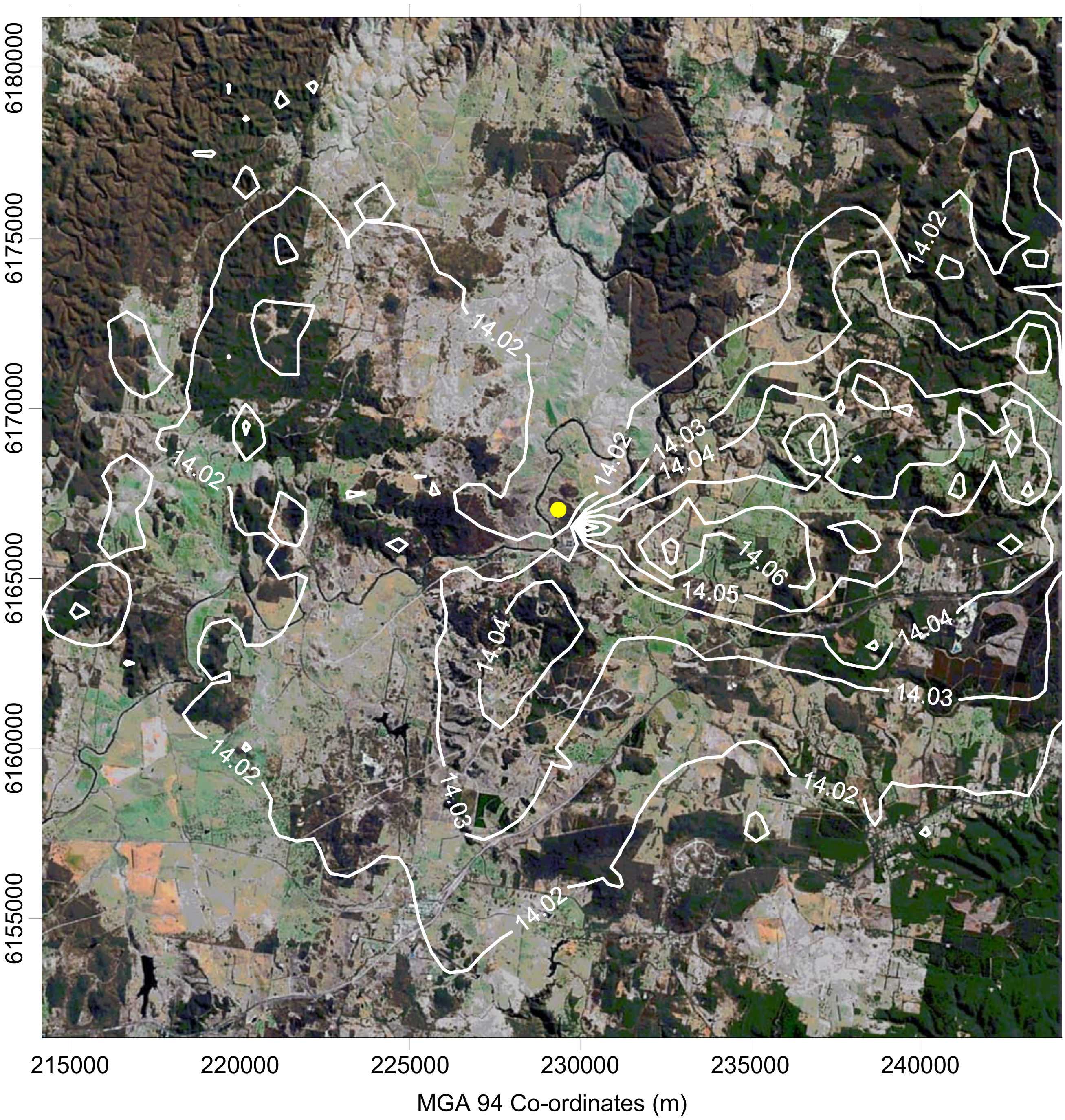
Contours in µg/m^3
Background Concentration: 13.7 µg/m^3
DECC Assessment Criteria: 62 µg/m^3
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 2: NOx Annual Averaging Cumulative Concentration**
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Rev: A
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 17.srf	Figure: 17; A4



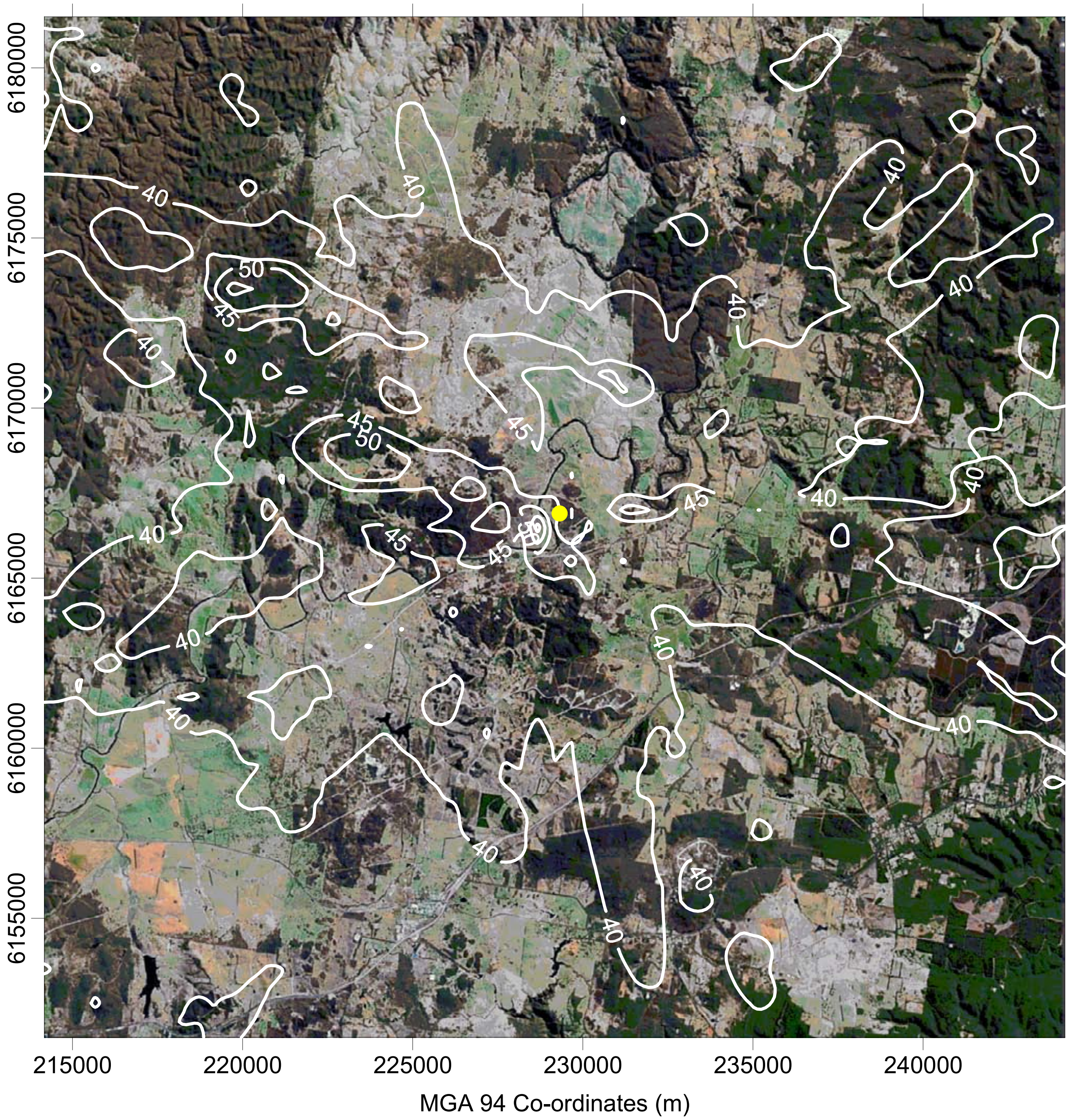
Contours in µg/m^3
Background Concentration: 40.0 µg/m^3
DECC Assessment Criteria: 50 µg/m^3
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 2: PM_{10} 24 Hour Averaging Maximum Cumulative Concentration**
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Rev: A
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 18.srf	Figure: 18; A4



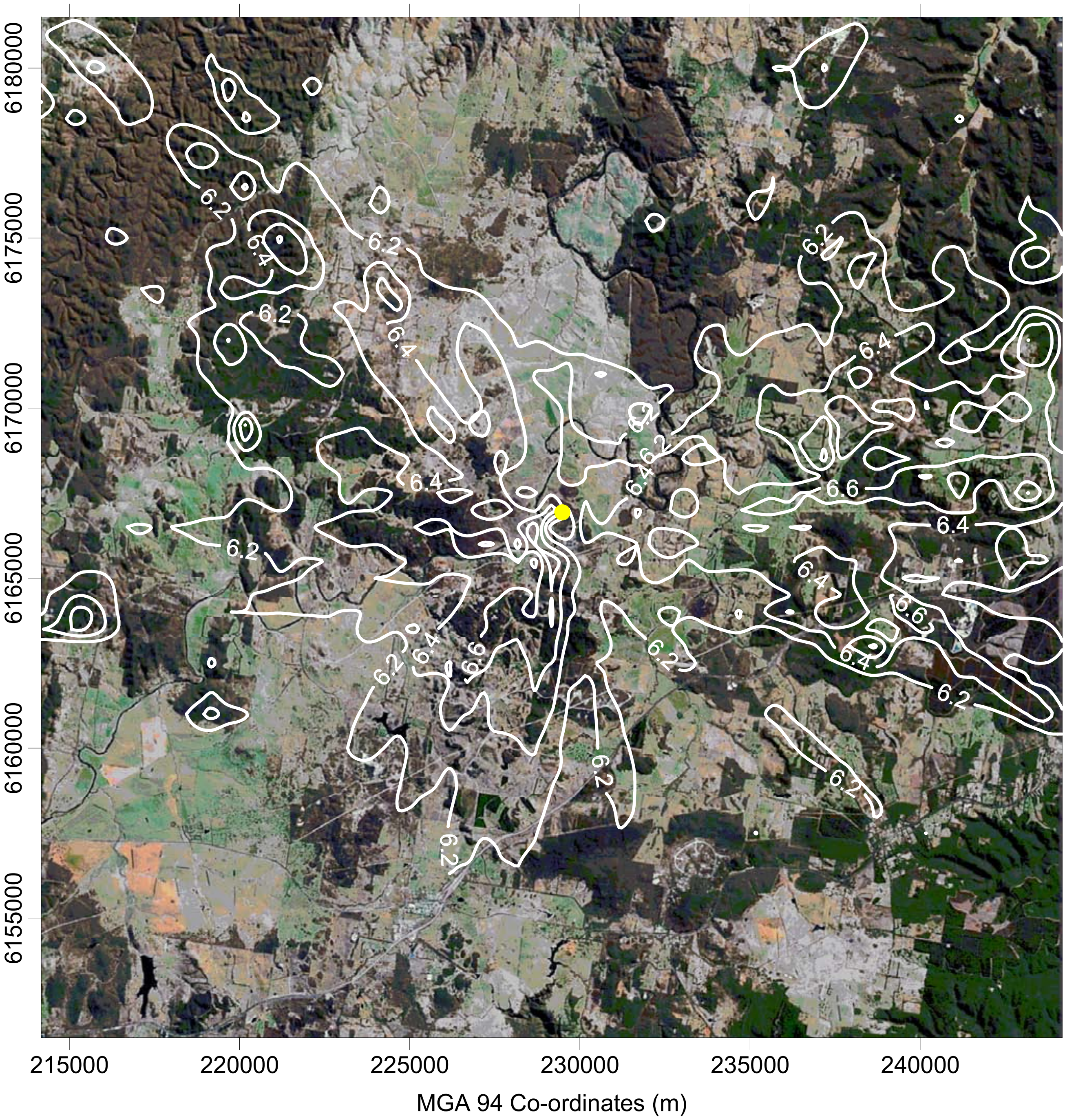
Contours in µg/m^3
Background Concentration: 14.0 µg/m^3
DECC Assessment Criteria: 30 µg/m^3
Site Location

Client: **DELTA ELECTRICITY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 2: PM_{10} Annual Averaging Cumulative Concentration**
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008; Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 19.srf	Figure: 19; Rev: A; A4



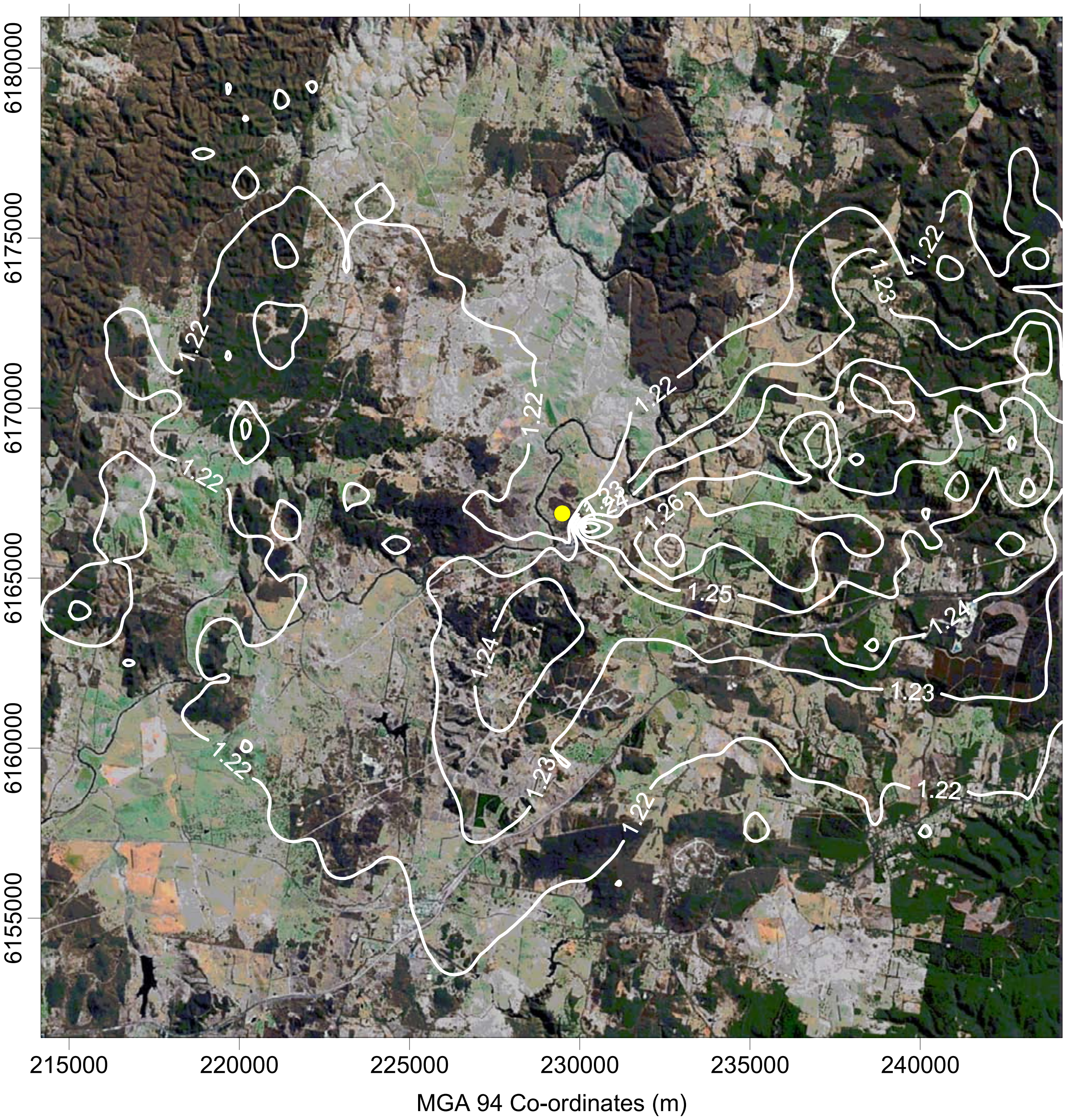
Contours in µg/m^3
Background Concentration: 25.7 µg/m^3
DECC Assessment Criteria: 570 µg/m^3
Site Location

Client: **DELTA ELECTRICTY & ENERGYAUSTRALIA**	Project: **ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY**	Title **Combined Scenario 2: SO_2 1 Hour Averaging Maximum Cumulative Concentration**
URS	Drawn: SWB / Approved: DRAFT / Date: March 2008	Rev: A
	Job No: 43217475 / File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 20.srf	Figure: 20 / A4



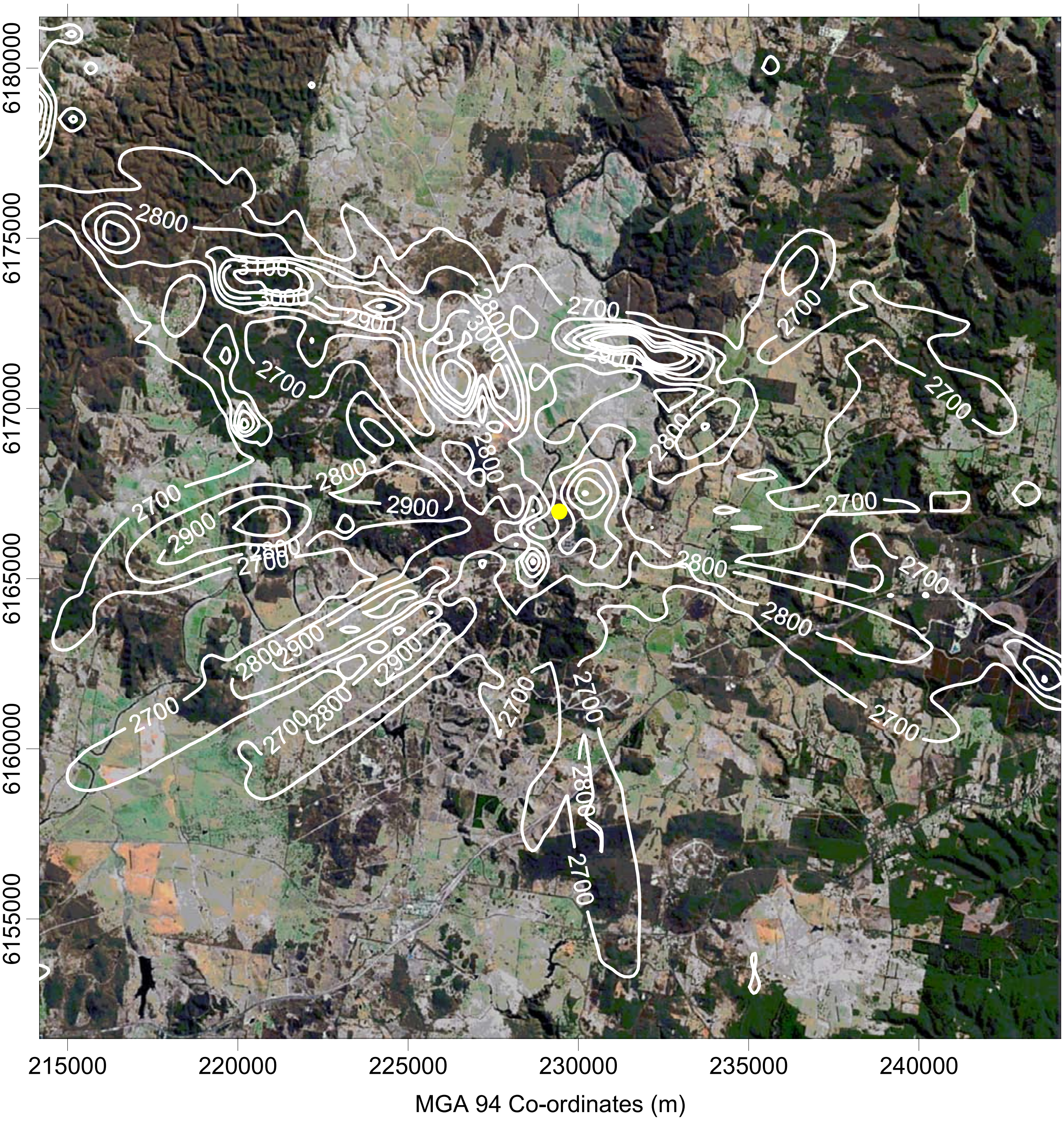
Contours in $\mu g/m^3$
Background Concentration: 5.7 $\mu g/m^3$
DECC Assessment Criteria: 228 $\mu g/m^3$
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY			Title: Combined Scenario 2: SO_2 24 Hour Averaging Maximum Cumulative Concentration	
URS	Drawn: SWB	Approved: DRAFT	Date: March 2008	Figure: 21	Rev: A
	Job No: 43217475	File: 43217475/Delta Air Quality/5000 Technical/Plots/Figure 21.srf			A4



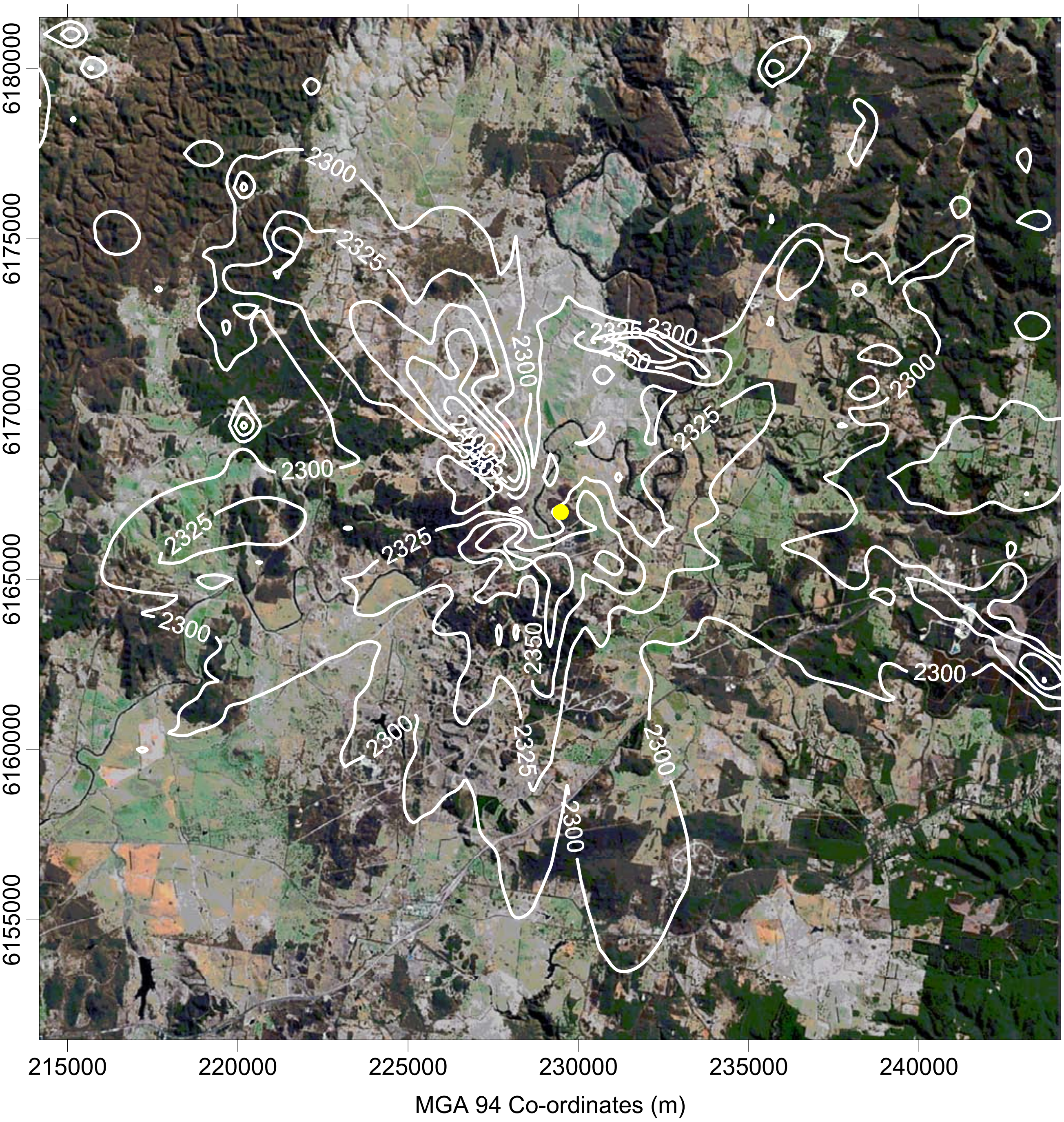
Contours in µg/m³
Background Concentration: 1.2 µg/m³
DECC Assessment Criteria: 60 µg/m³
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY	Title: Combined Scenario 2: SO_2 Annual Averaging Cumulative Concentration
URS	Drawn: SWB; Approved: DRAFT; Date: March 2008	Rev: A
	Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 22.srf	Figure: 22; A4



Contours in µg/m^3
Background Concentration: 2,500 µg/m^3
DECC Assessment Criteria: 30,000 µg/m^3
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY	Title: Combined Scenario 2: CO 1 Hour Averaging Maximum Cumulative Concentration
URS	Drawn: SWB; Approved: DRAFT; Date: January 2008; Job No: 43217475; File: 43217475/Delta Air Quality/5000 Technical/Plots/Figure 23.srf	Figure: 23; Rev: A; A4



Contours in µg/m^3
Background Concentration: 2,250 µg/m^3
DECC Assessment Criteria: 10,000 µg/m^3
Site Location

Client: DELTA ELECTRICITY & ENERGYAUSTRALIA	Project: ENVIRONMENTAL ASSESSMENT PROPOSED MARULAN GAS TURBINE FACILITY			Title: Combined Scenario 2: CO 8 Hour Averaging Maximum Cumulative Concentration	
URS	Drawn: SWB	Approved: DRAFT	Date: March 2008	Figure: 24	Rev: A
	Job No: 43217475	File: 43217475/Delta Air Quality/5000 Technical/Plots/ Figure 24.srf			A4

Appendix A Meteorological Data Discussion

Appendix A Meteorological Data Discussion

A.1 Assessment of Meteorological Data 2000-2006

The meteorological data needed for dispersion modelling is required to be site representative. As URS is not aware of meteorological data being collected within close proximity to the site, the closest automatic weather stations (AWS) were assessed. The closest Bureau of Meteorology station was found to be Goulburn Airport and data from recent years was assessed.

URS examined six years from Goulburn Airport: 2000 through to 2006, inclusive. Goulburn was used in this screening as records at the Berrima and Lynwood stations are limited to the most recent years.

This methodology is consistent with the requirements contained in DEC (2005) *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.* The Goulburn Airport wind roses for 2000–2006 are shown in **Figure 1**. Whilst the year chosen for use in the dispersion modelling must be representative of recent years, it is generally preferred to choose a recent year, given that background air pollutants are also assessed and the most recent ambient air quality data is considered to best reflect future ambient air concentrations of pollutants.

The wind roses for the individual years appear to be fairly consistent, showing winds from the west and north west to be dominant. The average wind speed showed little difference from year to year, with a range between 4.02 m/s in 2001 to 4.39 m/s in 2003. Similarly, the calms showed minor variation, ranging from 9.63% in 2003 to 15.46% in 2004. The most recent year, 2006, is consistent with other years and does not show anomalous patterns in terms of wind directions or average wind speeds. On this basis, meteorological data for 2006 considered to be appropriate for use in this assessment.

A.2 Local Meteorological Stations

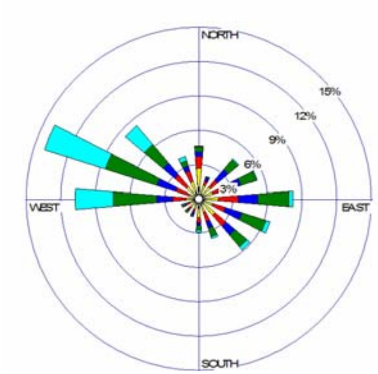
When generating site representative metrological files for use in the dispersion models, it is preferred to incorporate data from local meteorological stations, where suitable. The nearest meteorological stations, which are understood to conform to relevant Australian Standards were found to be:

1. Goulburn Airport AWS (Station 070330), operated by the Bureau of Meteorology (located approximately 37km south west of the site);
2. Lynwood AWS, operated by ReadyMix Holdings Pty Limited, located approximately 12km south south west of the site;
3. Berrima AWS, operated by Blue Circle Southern Cement Ltd, located approximately 28km east north east of the site; and
4. Moss Vale AWS (Station 068045), operated by the Bureau of Meteorology, located approximately 36km east north east of the site; and
5. South Marulan AWS, operated by Boral Resources (NSW), located approximately 19km south of the site.

The first three meteorological stations were considered appropriate for incorporation into the dispersion modelling whilst Moss Vale was considered suitable for the assessment of meteorology in the region. Both Moss Vale and South Marulan AWS's were omitted from the meteorological modelling, given that both stations are located near to, yet beyond the Berrima and Lynwood AWS's respectively, Hence these stations have limited ability to contribute significantly to those winds predicted in the region. In particular, the presence of strong local terrain features surrounding the South Marulan AWS means that wind records from the site are most likely dominated by highly localised terrain effects. Meteorological models are not able to resolve these effects with meaningful implications for broader scale meteorology.

Windroses for the sites excluding South Marulan are provided in **Figure 2**.

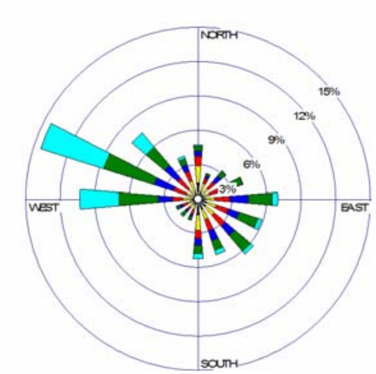
Appendix A Meteorological Data Discussion



2000

Average wind speed: 4.06 m/s

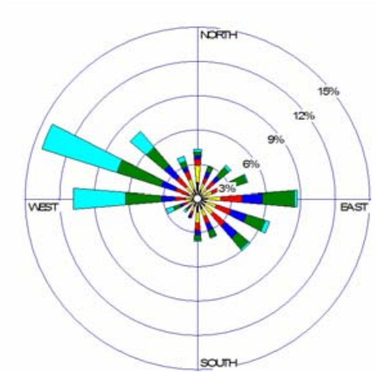
Calms: 14.26 %



2001

Average wind speed: 4.02 m/s

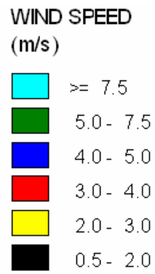
Calms: 13.83 %



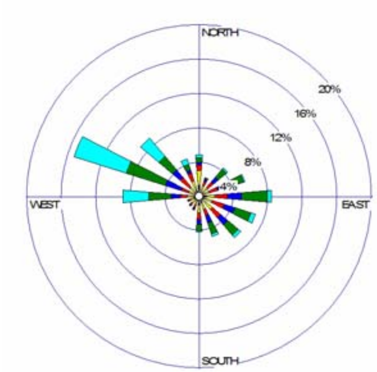
2002

Average wind speed: 4.28 m/s

Calms: 12.57 %



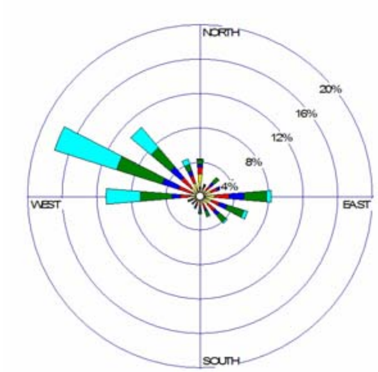
Wind Speed Legend



2003

Average wind speed: 4.39 m/s

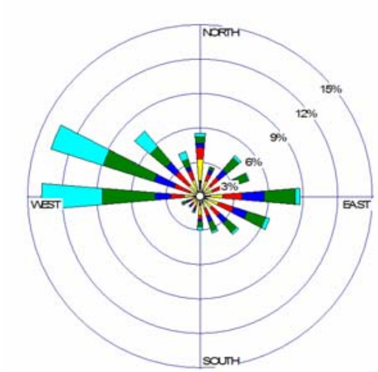
Calms: 9.63 %



2004

Average wind speed: 4.35 m/s

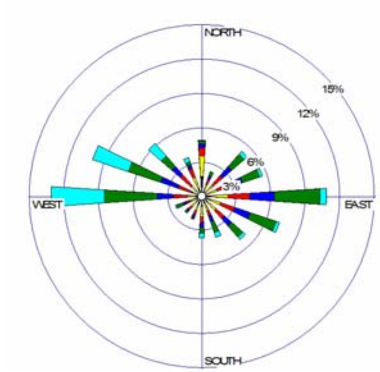
Calms: 15.46 %



2005

Average wind speed: 4.22 m/s

Calms: 13.01 %



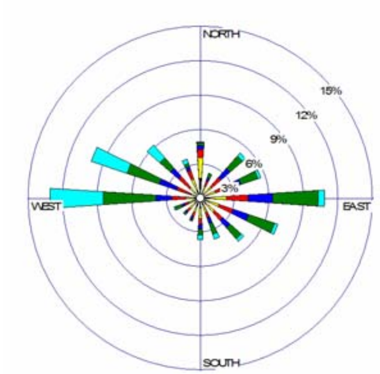
2006

Average wind speed: 4.09m/s

Calms 11.88%

Figure 1: Goulburn Airport Windroses 2000 – 2006

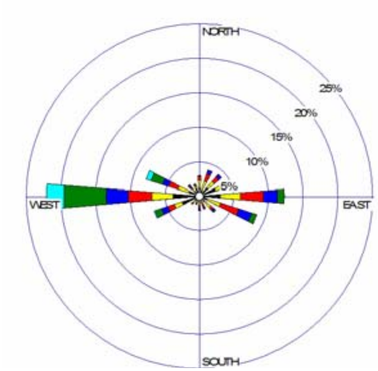
Appendix A Meteorological Data Discussion



Goulburn Airport

Average wind speed: 4.09m/s

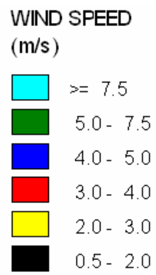
Calms 11.88%



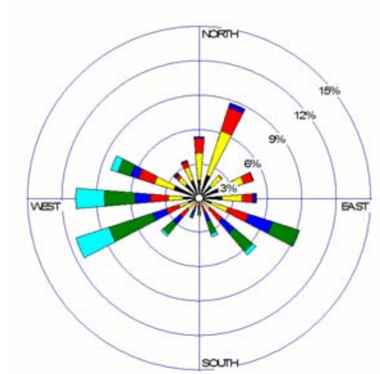
Lynwood

Average wind speed: 2.87 m/s

Calms: 11.40 %



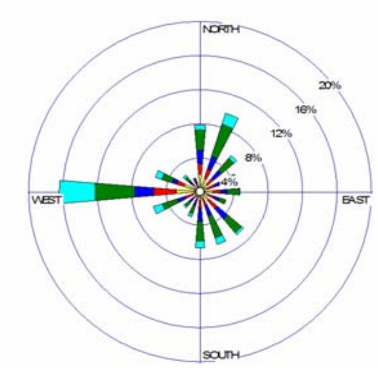
Wind Speed Legend



Berrima

Average wind speed: 3.11 m/s

Calms: 9.26 %



Moss Vale

Average wind speed: 4.44 m/s

Calms: 6.88 %

Figure 2: Comparison of 2006 windroses for various weather stations

A.3 Meteorological modelling

The meteorology used in the dispersion modelling was generated using local meteorological observations, in conjunction with both the TAPM and Calpuff modelling systems. The CSIRO's prognostic meteorological model TAPM was used to augment the surface data available from the both the Lynwood and Berrima Automatic weather stations.

TAPM was run individually at both the Lynwood and Berrima AWS sites, each with the assimilation of wind data from the respective weather stations. TAPM's output was then evaluated at these sites, in the form of complete upper air and surface station files, in the format required by Calpuff's meteorological pre-processor Calmet. These TAPM outputs were further processed to reincorporate directly the wind information from the Lynwood and Berrima AWS sites for 2006, except where AWS data is missing, in which case the TAPM data was used, or the station excluded from the modelling, (as was the case for Berrima, where wind observations were missing for December, and the majority of November).

From this point Calmet is able to perform a range of diagnostic procedures which incorporate surface heat flux and terrain effects into the calculation of hourly gridded 3-dimensional wind fields.

Utilities exist such that TAPM's output may be exported into Calmet in a gridded (CSUMM) format (developed for the Colorado State University Meteorological Model) for use in the initial guess wind field in Calmet. This is generally performed in order to incorporate synoptic variations across the modelling domain as output by prognostic models (e.g. TAPM), prior to the resolution of finer scale meteorology through the diagnostic processes in Calmet.

Given the consistency of wind data in the region, coupled with the complete reliance on TAPM for surface predictions outside of the various radii of influence of the weather stations, this option was not utilised.

A.3.1 TAPM

TAPM was run to augment the meteorological observations for both the Lynwood and Berrima weather stations. TAPM has been identified as a suitable model of choice to simulate meteorological fields in a number of situations[1].

TAPM is an incompressible, non-hydrostatic, primitive equation model with a terrain-following vertical co-ordinate for three-dimensional simulations. It includes parameterisations for cloud/rain micro-physical processes, turbulence closure, urban/vegetative canopy and soil, and radiative fluxes.

TAPM, with the use of the input databases provided by CSIRO, was used to generate a meteorological dataset for the year 2006 based on actual synoptic data. The following TAPM settings and input files were used to generate the meteorological file for the Marulan site for the year 2006. Default options were selected, except where noted otherwise below:

- Grid centre coordinates :

  Lynwood Run: –34°42’30’’ latitude, 149°59’00’’ longitude (MGA94: 773240mE, 6155248mN);

  Berrima Run: –34°31’00’’ latitude, 150°20’00’’ longitude (MGA94: 255208mE, 6177325mN);

- Meteorological grid consisting of five nests of 25 x 25 grid points at 30, 10, 3, 1km and 300m spacing, with 25 vertical grid levels from 10 to 8000 m;

- Terrain at 9 arc-second (approximately 270m) resolution from the Geoscience Australia terrain database. Land characterisation data at approximately 1km resolution, sourced from the US

[1] CSIRO, 2005. *The Air Pollution Model (TAPM) Version 3. Part 2: Summary of Some Verification Studies. CSIRO Atmospheric Research Technical Paper 72, 2005.*

geological Survey, Earth Resources Observation System (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC). Sea surface temperature data at 100 km grid intervals from the US National Centre for Atmospheric Research (NCAR);

- Six hourly synoptic scale meteorology from the BoM on a 75 to 100 km grid. This data is derived from the BoM LAPS (Limited Area Prediction System) output;
- Wind data assimilation was used in both runs, with the model configured to utilise the data to influence both the 10 and 25m levels, on a radius of influence of 15km:

  Lynwood Run - Lynwood AWS included: 773100mE, 6155400mN (MGA94);

  Berrima Run - Berrima AWS included: 255061mE, 6177719mN (MGA94);

A.3.2 Calmet

CALMET modelling was performed using the surface meteorological data from Lynwood and Berrima, whilst the upper air data for these stations was generated using TAPM, as discussed in the previous section. The meteorological grid was proportioned to incorporate both the Lynwood and Berrima sites, at a grid resolution of 500m.

- Grid Origin: 213920mE, 6146250mN (MGA94) with 97 x 79 grid cells at 500m resolution;
- 12 vertical levels with cell faces at 0, 20, 40, 60, 80, 100, 140, 180, 260, 400, 500, 1500 and 3000m;
- 3km radius of influence for step 2 objective analysis wind fields;
- 5km radius of influence for terrain effects;
- 500m terrain sourced interpolated from the 9 arc-second (~270m) TAPM database;
- Land use exported from the TAPM database

An example of a Calmet wind field is provided in **Figure 3**.

A.3.3 Windroses

The annual and seasonal windroses for the Calmet / TAPM generated meteorological data are provided in **Figure 4**. These wind roses show the dominance of winds from the west and east. Summer shows winds to be primarily from the east, with autumn and winter showing a distinct westerly component. Spring, however, shows the presence of a more uniform spread of winds, however, the dominance of westerly winds is still present.

Appendix A Meteorological Data Discussion

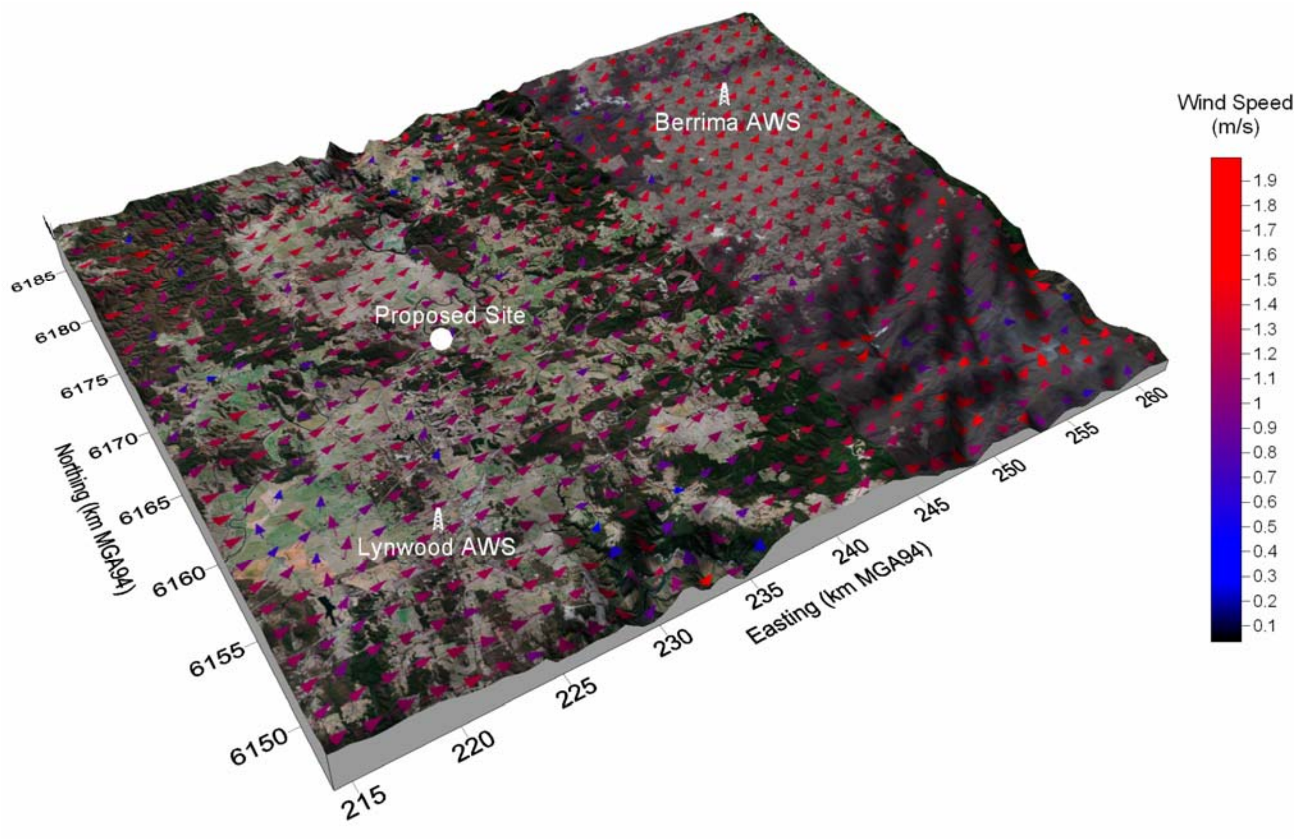
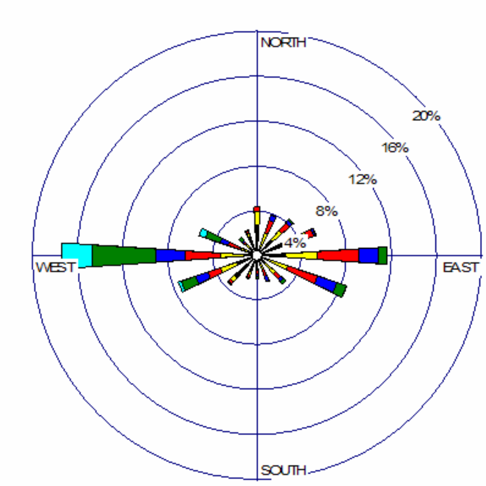


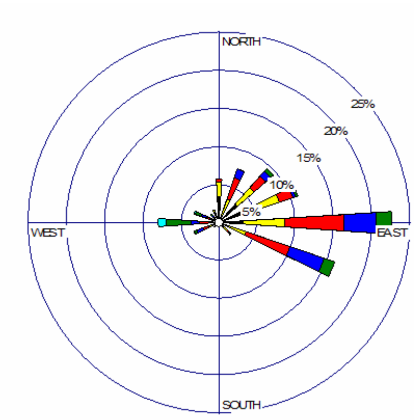
Figure 3: Example Calmet Wind Field – 20/07/06 3am

Appendix A Meteorological Data Discussion

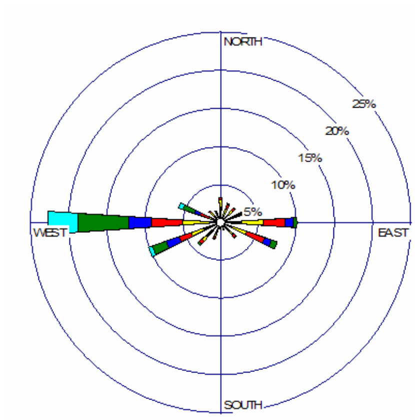


Annual Wind Rose

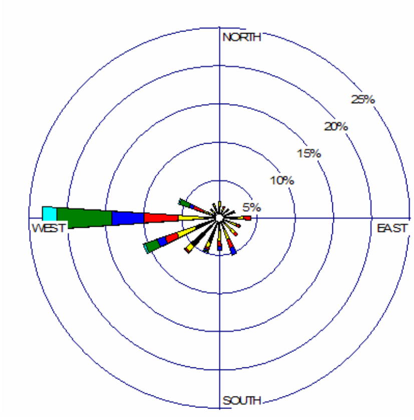
Annual Average wind speed: 2.81m/s
Annual Calms: 12.80%



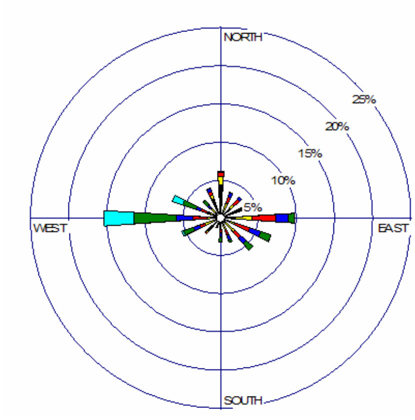
Summer



Autumn



Winter



Spring

Figure 4: Seasonal Calmet / TAPM generated wind roses for Marulan Site 2006

Appendix A Meteorological Data Discussion

The following sections discuss the atmospheric parameters for the proposed development site, as generated by Calmet/TAPM for 2006.

A.4 Mixing Height

Figure 5 shows the Mixing Height (m) vs Time of Day (Hour) for 2006. The figure shows that the predicted mixing height increases with increasing solar radiation as a function of time of day. This is consistent with general atmospheric processes that show increased vertical mixing during the daytime associated with the increasing thermal radiation. Nightime conditions are cooler, more stable and, as expected, winds are generally lighter thus vertical mixing is reduced leading to a lower mixing height.

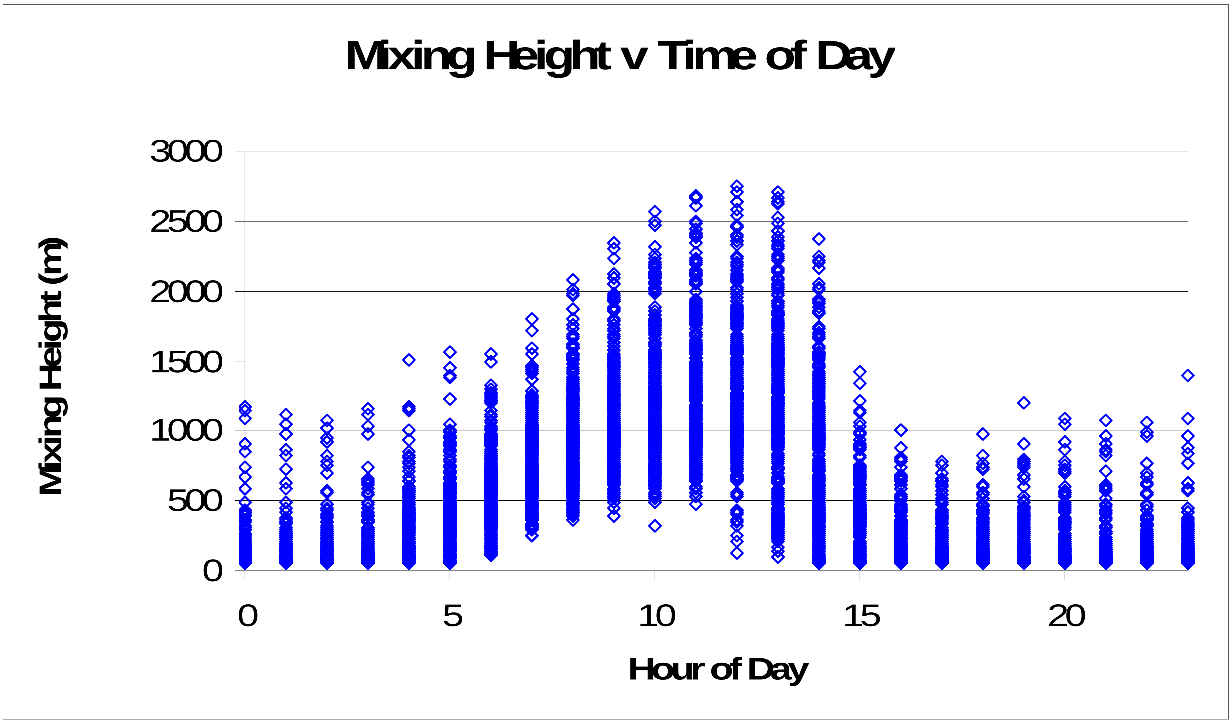


Figure 5: Mixing Height (m) vs Time of Day (Hour of Day) – generated by Calmet/TAPM for the Marulan site, 2006

A.5 Atmospheric Stability

Stability class is used as an indicator of atmospheric turbulence for use in meteorological models. The class of atmospheric stability generally used in these types of assessments is based on the Pasquill-Gifford-Turner scheme where six categories are used (A to F) which represent atmospheric stability from extremely unstable to moderately stable conditions. The stability class of the atmosphere is based on three main characteristics, these being:

- Static stability (vertical temperature profile/structure);
- Convective turbulence (caused by radiative heating of the ground); and
- Mechanical turbulence (caused by surface roughness).

The Pasquill Gifford Stability classes are provided in **Table 1**.

The stability classes for the site have been extracted from the Calmet/TAPM generated meteorological file and are shown in **Table 2**.

Appendix A Meteorological Data Discussion

Table 1: Modified Pasquill-Gifford Stability Classes (adapted from Turner, 1994[2])

Surface Wind Speed at 10m (m/s)	Insolation			Night-time cloud (Oktas)	
	Strong	Moderate	Slight	Thinly overcast of > 4/8 low cloud	< 3/8 Cloud
≤ 2	A	A-B	B	-	-
2 - 3	A-B	B	C	E	F
3 - 5	B	B-C	C	D	E
5 - 6	C	C-D	D	D	D
> 6	C	D	D	D	D

Notes:
- : Generally referred to as strongly stable conditions.

The Pasquill Gifford Stability Classes, shown in **Table 2** shows moderately stable atmospheric conditions (Stability Class D) is the most prevalent Stability Class of the area, with the Extremely Unstable conditions (Stability Class A) being the least prevalent.

Table 2: Site Representative Pasquill-Gifford Stability Classes

Stability Class	% of year
A (Extremely Unstable)	1.5%
B (Moderately Unstable)	12.0%
C (Slightly Unstable)	17.7%
D (neutral)	26.3%
E (Slightly Stable)	7.3%
F (Moderately Stable)	35.2%

[2] Turner B 1994 *Workbook of Atmospheric Dispersion Estimates: An Introduction to Dispersion Modelling*. 2nd Edition. CRC Press Inc

Appendix A Meteorological Data Discussion

In addition to their composition, Stability Classes were also predicted as a function of time of day, as shown in **Figure 6**. The Stability Classes in **Figure 6** are labelled 1 through 6 and refer to Stability Classes A (Extremely Unstable) through F (Very Stable) respectively. As expected, the Stability Classes show a tendency for the unstable classes (Stability Classes A, B and C) to occur during daytime, whilst the more stable conditions (Stability Classes D,E and F) are shown to occur primarily during night time. This is consistent with the values contained in **Table 2**.

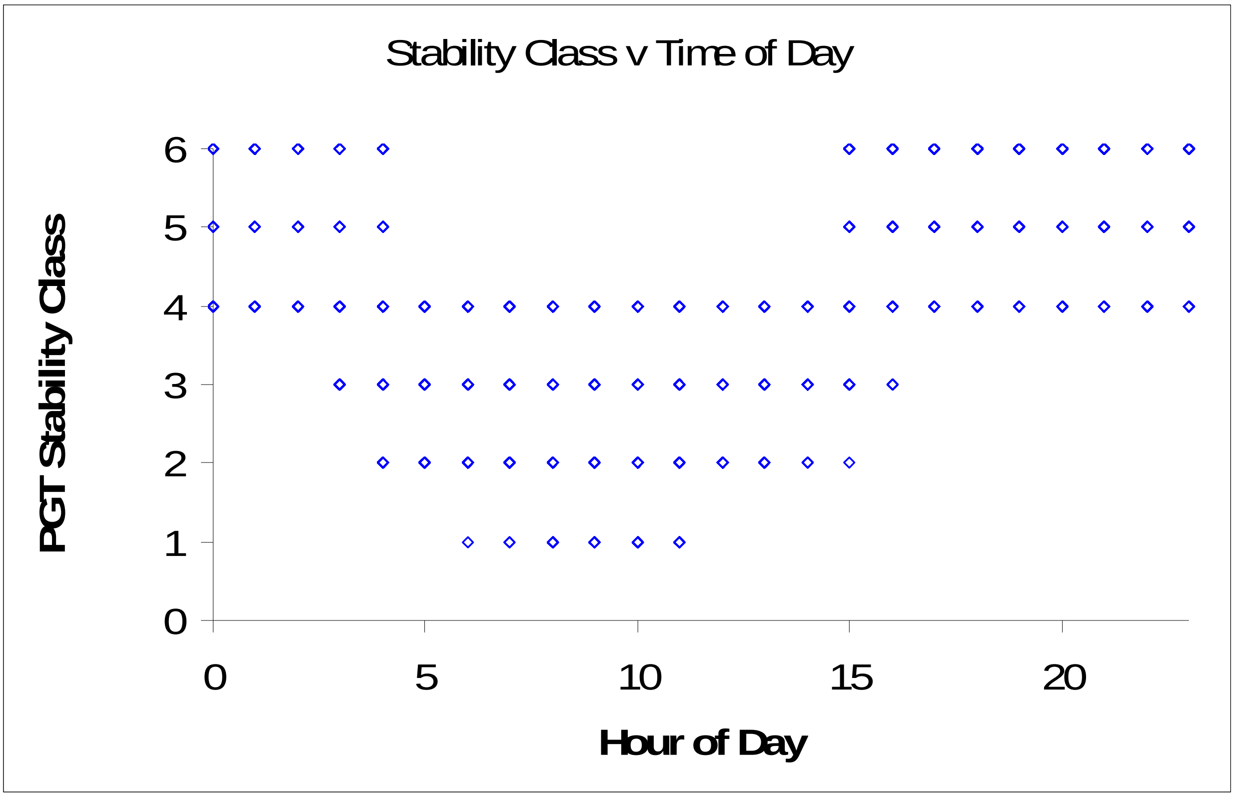


Figure 6: Stability Class vs Time of Day – generated by Calmet/TAPM predicted, for Marulan site 2006

Appendix A Meteorological Data Discussion

Stability Classes were also measured against wind speed, as shown in **Figure 7**. The Stability Classes in **Figure 7** are labelled 1 through 6 and refer to Stability Classes A through F respectively. As expected, the highest wind speeds are associated with stable or neutral stability classes (Stability Classes C and D). The more unstable conditions (Stability Classes A and B) have lower wind speeds due to vertical mixing, and the more stable conditions (Stability Classes E and F) also have low wind speeds as a result of stable night time atmospheric conditions. These data are consistent with the values contained in **Table 2.**

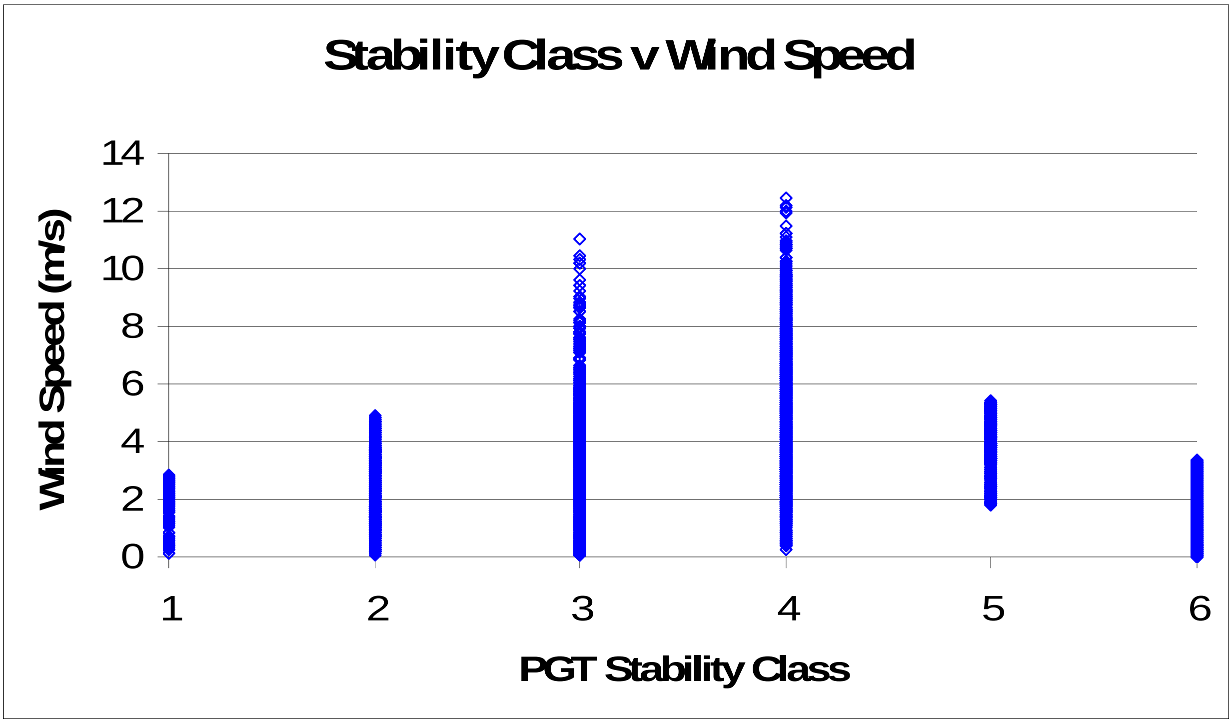


Figure 7: Stability Class vs Wind Speed – generated by Calmet/TAPM for Marulan site 2006

A.6 Conclusion

Where site specific meteorological data does not exist, as is the case for the Marulan Site, the predicted meteorological data used in the dispersion modelling is required to be representative of the surrounding area. It is accepted standard Australian practice, that in situations where adequate site-specific meteorological data does not exist, local meteorological station data can be incorporated into TAPM and Calmet to synthetically generate meteorological data. TAPM and Calmet are sophisticated, 3D meteorological models that has been extensively validated. In order to better represent the meteorology of the proposed development site, Goulburn Airport, Lynwood and Berrima data was incorporated into the predicted meteorology.

The assessment of the predicted meteorology at the Marulan site was discussed and was shown to be consistent with general atmospheric parameters. It is therefore considered that the meteorological data used in dispersion modelling is appropriate.

Appendix B Stack Emission Calculations

Appendix B Stack Emission Calculations

Table 11.5 from Parsons Brinckerhoff 2005 *Munmorah Gas Turbine Facility Environmental Impact Statement*.

Table 11.5 Emission characteristics of proposed gas turbine facility used by dispersion model

Parameter	Natural gas fired		Distillate fired	
	Normal	Start-up	Normal	Start-up
Stack easting (metres)[1]	364129	364129	364129	364129
Stack northing (metres)[1]	6324355	6324355	6324355	6324355
Stack base elevation (metres)	15	15	15	15
Stack height (metres)	35	35	35	35
Stack tip diameter (metres)	6	6	6	6
Stack temperature (degrees Celsius)	524	398	518	401
Velocity (metres per second)	43	27	44	27
Emissions (grams per second)				
CO	4.4	895.6	35.6	1711.1
NO_x (as NO_2)	81.1	117.8	112.2	162.2
SO_2	4.9	2.2	6.1	13.1
PM_{10}	4.4	4.4	9.4	9.4

Notes 1 The four emission stacks have been modelled as a single point source
Source Table 9 of Technical Paper 4

Table showing calculation of HAP Emission Rates for representative "E class" gas turbine

		"E class" gas turbine - Start Up	"E class" gas turbine - Operation
Fuel Consumption			
GJ/hr		-	1756
MMBtu/hr		-	1665
Startup			
HAP Scaling Factor Relative to Normal Operation (from ESP II LLC, 2007)		12.04	1.00
HAP Emissions	**Emissions Factor (AP-42) lb/MMBtu**	**HAP Emission Rate g/s**	**HAP Emission Rate g/s**
Acetaldehyde	4.00E-05	0.101	0.008
Acrolein	6.40E-06	0.016	0.001
Benzene	1.20E-05	0.030	0.003
Ethylbenzene	3.20E-05	0.081	0.007
Formaldehyde	7.10E-04	1.793	0.149
Total PAH	2.20E-06	0.006	0.0005
Toluene	1.30E-04	0.328	0.027
Xylene	6.40E-05	0.162	0.013

Fuel consumption taken from URS (2006).

Appendix C Plume Rise Assessment

R E P O R T

Plume Rise Assessment for Marulan Gas Turbine Facilities

Prepared for

Delta Electricity & EnergyAustralia

15 April 2008

43217475

Project Manager:

Nicole Brewer
Associate Engineer

URS Australia Pty Ltd

Level 3, 116 Miller Street
North Sydney
NSW 2060
Australia
Tel: 61 2 8925 5500
Fax: 61 2 8925 5555

Project Director:

Ian McCardle
Principal Scientist

Author:

James Grieve
Air Quality Engineer

Date: 15 April 2008
Reference: R003
Status: Final

Contents

Executive Summary

Delta Electricity and EnergyAustralia are proposing to construct and operate two separate gas turbine facilities at a site, which will be referred as *'Marulan Site'* in this report, located approximately 12 km north of Marulan, which is 25 km east of Goulburn.

Delta Electricity propose to construct and operate a Gas Turbine Facility at the Marulan Site. Subject to final plant selection, the Delta Electricity Facility will comprise two gas turbine generators and will proceed in two stages. During Stage 1, the turbines will have a total capacity of between 250 and 350MW, where the turbines will be constructed in an open cycle configuration and operate in a peaking capacity. During Stage 2 the plant will have a total capacity of between 400 and 450MW where the turbines will operate in a combined cycle configuration for base load operation.

Operation of the Delta Electricity Facility during Stage 1 is expected to be approximately 500 hours of the year per turbine. Stage 2 operation may occur for up to 90% of the year.

EnergyAustralia also propose to construct a similar gas turbine facility adjacent to the Delta Electricity Facility. The EnergyAustralia facility will be similar to the Stage 1 Delta Electricity Facility, and will comprise two turbines in the 175 MW range operating in an open cycle configuration, producing a total nominal Facility output of 350 MW. The EnergyAustralia Facility will operate in a peaking capacity for up to 10% per year. The EnergyAustralia Facility is not currently proposed to operate in combined cycle configuration.

The proposed Facilities have been assessed for their potential impacts on aviation safety. This has been performed using the CSIRO's TAPM model to predict upper air meteorology, and plume rise profiles for each hour of the year 2006, such that the critical vertical extent of the plume (height at which the plume averaged velocity slows to 4.3m/s) can be estimated.

The assessment has been conducted as a cumulative assessment to address the potential impacts of both Facilities.

The assessment has considered three scenarios:

Scenario #1: Both the Delta Electricity Facility Stage 1 and EnergyAustralia Facility (operating in open cycle mode), with the assumption that plume merging between the two Facilities does occur;

Scenario #2: Both the Delta Electricity Facility Stage 1 and EnergyAustralia Facility (operating in open cycle mode), with the assumption that plume merging between the two plants does not occur. This assumes isolation of the two plumes, hence it is also representative of a single plant operating in open cycle mode;

Scenario #3: The Delta Electricity Facility Stage 2 (exhaust stacks operating in combined cycle mode).

The distances between stacks (plumes) can have a significant influence on the buoyancy of the plumes, as plumes that are located within proximity to each other will have a greater potential to merge, resulting in greater buoyancy.

The results from Scenarios #1 and #2 were quite similar, despite the conservative assumption in Scenario #1 that all four stacks were separated by a distance of 40m (there is actually around 240m between closest two stack neighbouring Delta and Energy Australia stacks).

Further analysis of the plume radii at the critical vertical extent indicated that except in the worst case conditions, the plumes from the two plants would not merge before reaching the critical vertical velocity of 4.3 m/s. Hence results from Scenario #1 are considered conservative, whilst results for Scenario #2 are considered representative of the Delta Electricity and EnergyAustralia Facilities operating both individually, and simultaneously, except for the worst case hours, where Scenario #1 is considered more representative of simultaneous operation. Furthermore, Scenario #2 results are considered more appropriate for consideration of the plume velocities at the Obstacle Limitation Surface (OLS).

Based on this assessment, for one year (2006) of modelled open cycle operation using TAPM, the OLS is exceeded during approximately 50% of the year (for Scenarios #1 and #2), with an average critical vertical extent at 133m and 119m above ground level for Scenario #1 and #2 respectively.

Executive Summary

Furthermore, results for Scenario #3 indicate that the combined cycle Delta Electricity exhaust stacks will exceed the OLS for approximately 3% of the year, with an average critical vertical extent at 60m above ground level.

Whilst this assessment is considered conservative with respect to the modelled operating times and operating conditions, consideration should be given for the plant to be designated a potential hazard to aircraft operators in the area. The implementation of such designation is at the discretion of the Civil Aviation Safety Authority (CASA).

Further consultation with CASA will be undertaken following detailed design. It is understood that CASA will require confirmation of any changes to the design that may affect the plume rise assessment. Prior to operation of the Facilities, CASA would need to be provided with the following information:

- "as constructed" coordinates in altitude and longitude of the Facilities;
- final height (in AHD) of the exhaust stacks; and
- ground level of the site (in AHD).

Section 1 Introduction

Delta Electricity and EnergyAustralia are proposing to construct and operate two separate gas turbine facilities at a site, which will be referred as *'Marulan Site'* in this report, located approximately 12 km north of Marulan, which is 25 km east of Goulburn.

Delta Electricity propose to construct and operate a Gas Turbine Facility at the Marulan Site. Subject to final plant selection, the Delta Electricity Facility will comprise two gas turbine generators and will proceed in two stages. During Stage 1, the turbines will have a total capacity of between 250 and 350MW, where the turbines will be constructed in an open cycle configuration and operate in a peaking capacity. During Stage 2 the plant will have a total capacity of between 400 and 450MW where the turbines will operate in a combined cycle configuration for base load operation.

Operation of the Delta Electricity Facility during Stage 1 is expected to be approximately 500 hours of the year per turbine. Stage 2 operation may occur for up to 90% of the year.

EnergyAustralia also propose to construct a similar gas turbine facility adjacent to the Delta Electricity Facility. The EnergyAustralia facility will be similar to the Stage 1 Delta Electricity Facility, and will comprise two turbines in the 175 MW range operating in an open cycle configuration, producing a total output of around 350 MW. The EnergyAustralia Facility will operate in a peaking capacity for up to 10% per year. The EnergyAustralia Facility is not currently proposed to operate in combined cycle configuration.

Given the quantity, velocity and temperature of the exhaust gases emitted from the exhaust stacks, gas turbine plumes can travel at high velocities through the atmosphere. Exhaust temperatures upwards of 500 degrees Celsius and exit velocities of around 40 metres per second enhance the dispersion characteristics of the plume and reduce the ground level impacts of pollutants. However, this factor potentially presents issues for aviation safety, where the high velocity of the exhaust gases can potentially affect the handling characteristics of aircraft, with the risk of airframe damage in extreme cases.

The intent of this report is to present the information required to perform an aviation hazard analysis based on the predicted impacts of the proposed facility. The statistics have been compiled in coordination with the Civil Aviation Safety Authority's (CASA) Advisory Circular *"Guidelines for Conducting Plume Rise Assessments"* (June, 2004). This involved use of the CSIRO's The Air Pollution Model (TAPM) model which was used to create site-specific meteorological data, including meteorology for the upper atmosphere. TAPM was also used to calculate plume rise trajectories for the gas turbine emissions.

CASA considers an exhaust plume with a vertical velocity component of greater than 4.3m/s (hereafter referred to as the *critical velocity*) to be a potential hazard to aircraft stability during approach, landing, take-off and for low level manoeuvring in general. At these stages of flight the stability of the aircraft is critical, especially in situations where visibility is extremely poor, such that potentially hazardous areas cannot be identified visually, and pilots are reliant on instruments for navigation.

Such plumes also potentially create risks to the structure of the aircraft, where the transient nature of the plume has the potential to overstress the frame.

Therefore, industrial sources that may release exhaust plumes with a vertical velocity greater than 4.3m/s at the Obstacle Limitation Surface (OLS) of 110m, must undergo a hazard analysis, such that suitable measures can be taken to prevent the hazards described above.

In order to ensure the potential impacts from the proposed development are adequately assessed, the assessment has investigated the cumulative impact on aviation safety from the emissions from both the Delta and EnergyAustralia Facilities. Despite the proposed operation in open cycle mode of approximately 5 % of the year for the Delta Electricity Facility and up to 10% of the year for the EnergyAustralia Facility, this assessment has modelled operation of both Facilities during every hour of the year 2006, such that probability distributions of plume rise are representative of a range of meteorological conditions.

Section 2 Background

2.1 Proposed Facilities

Nearby Airfields

The proposed Facilities are to be located north of Marulan. The nearest major airports are Goulburn (approximately 37km to the south west), and Mittagong (approximately 45km to the east north east). There are a range of small airfields in the region, the closest of which is Highland Farm, located approximately 5km to the east. **Figure 2.1** presents the location of the proposed plant relative to nearby airfields.

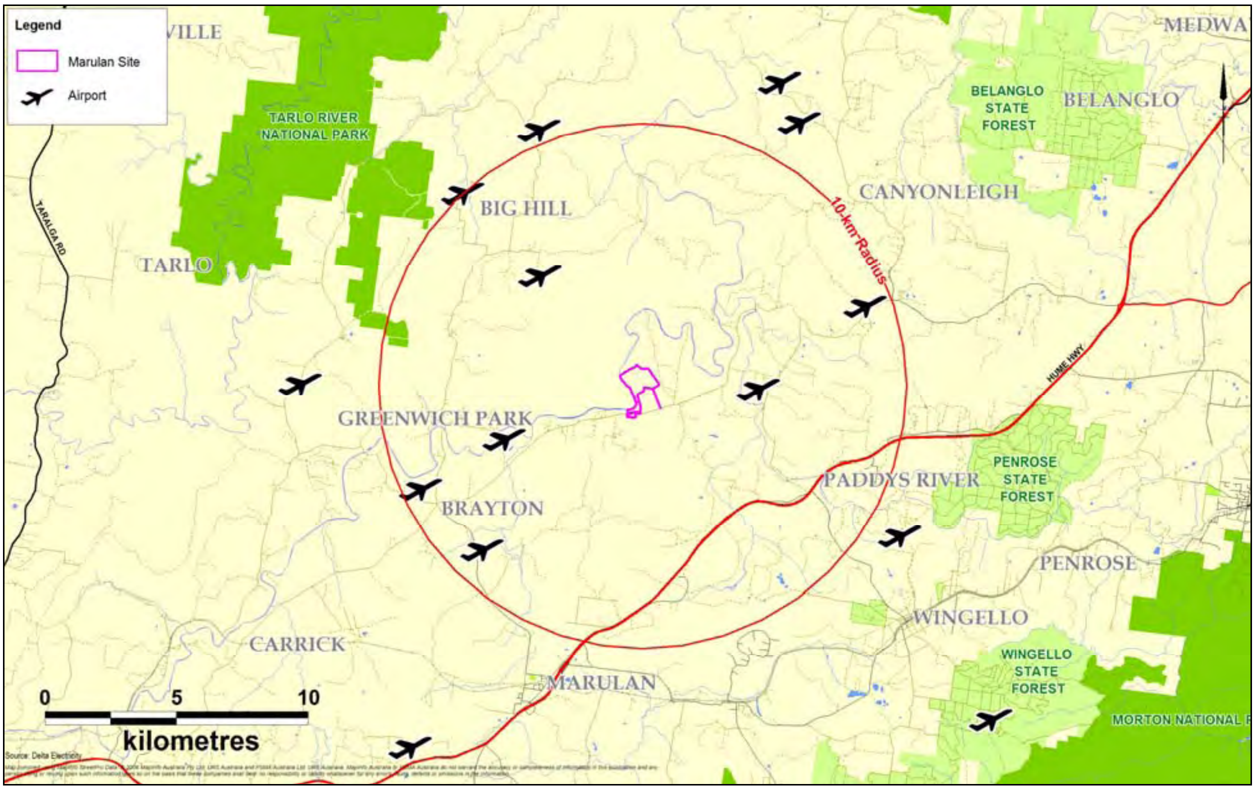


Figure 2-1 Plant Location and Nearby Airfields

Stack Locations

The indicative plant layout shows the exhaust stacks are oriented in a line from the north-west to south-east and at a base elevation of 605m Australian Height Datum (AHD). **Table 2-1** presents the locations of the four stacks used in this assessment. Further confirmation of the location of the final location will be provided to CASA following detailed design. **Figure 2-2** shows an indicative plant layout for the two facilities.

Section 2 Background

Table 2-1 Gas Turbine Stack locations

Proponent	Stack	Location (MGA94)		Base Elevation (mAHD)	Stack Height (m)
Delta	Stack 1	229384 mE	6166522 mN	605	40
	Stack 2	229424 mE	6166482 mN	605	40
EnergyAustralia	Stack 1	229144 mE	6166659 mN	605	30
	Stack 2	229171 mE	6166633 mN	605	30

As shown in the indicative plant layout the two Delta Electricity stacks have been assumed in this assessment to be separated by a distance of approximately 60m, and the two EnergyAustralia stacks by a distance of approximately 40m. The separation of the two Facilities (taken as the distance between the centres of each pair of stacks) is approximately 285m. Furthermore, the separation between closest two neighbouring Delta and EnergyAustralia stacks is 240m.

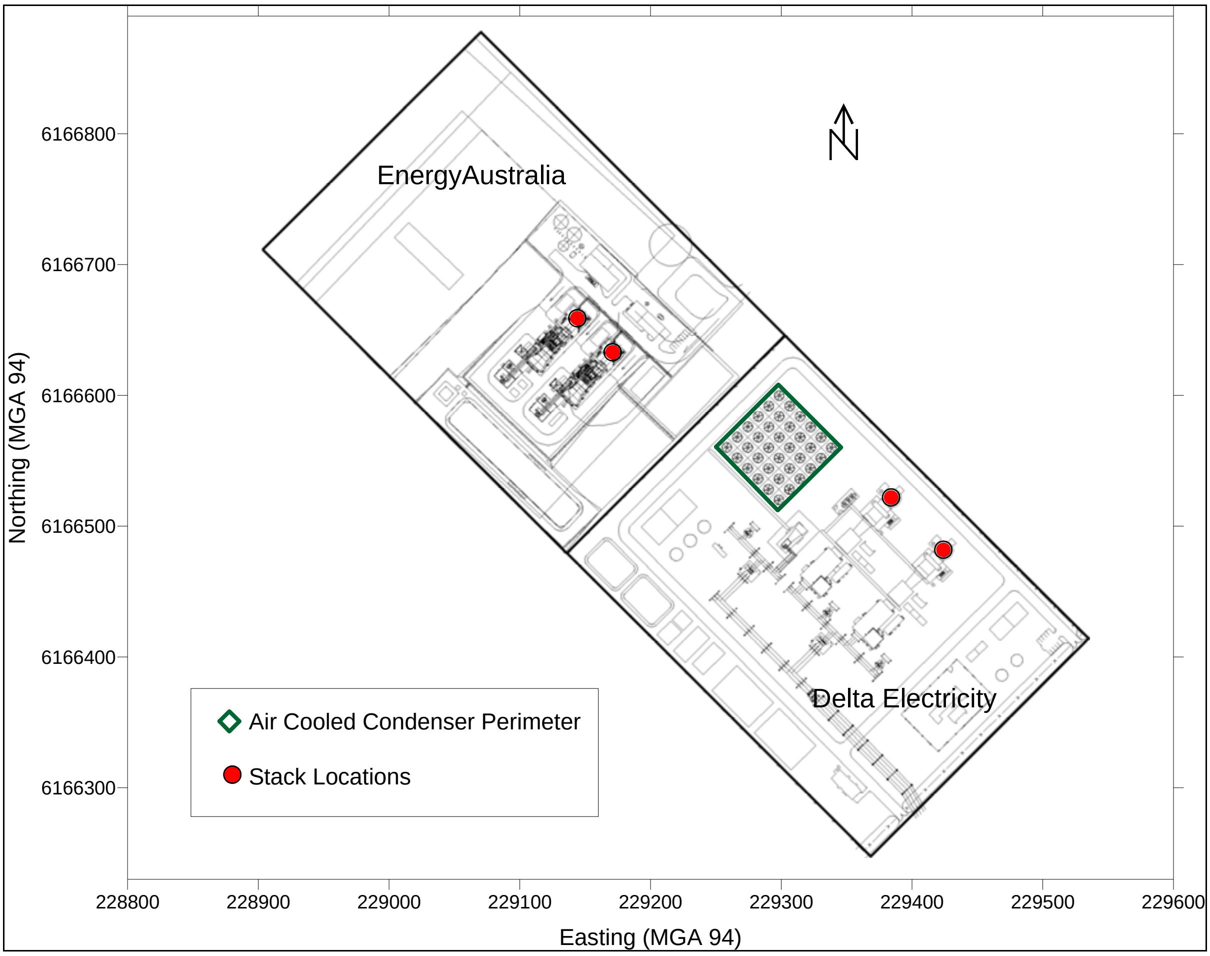


Figure 2-2 Indicative Delta Electricity and EnergyAustralia Facility Layouts

Section 2 Background

Stack Emission Parameters

Table 2-2 shows exhaust stack emission parameters for the range of operating states considered in the Air Quality Impact Assessment. Operational emission parameters are given for the turbine at full load, and are indicative of the upper limit of potential exit temperatures and exit velocities.

Table 2-2 Indicative Stack Emission Parameters

Stack Parameter	Units	Delta Electricity			EnergyAustralia	
Stack Height*	m	40			30	
Stack Diameter	m	6			6.5	
Scenario		Stage 1 - OCGT		Stage 2 - CCGT	Open Cycle	
		Start Up	Operational	Operational	Start Up	Operation
Exit Temperature	°C	398	532	125	398	532
Exit Velocity	m/s	27	40	20	23	34

*The platform height (from which the base of the stack is referenced) for the facility is 605m AHD.

Air Cooled Condenser

During Stage 2, the Delta Electricity Facility will operate in combined cycle configuration, where heat is recovered from the gas turbine exhaust to drive a steam turbine. This process necessitates a condenser, where the steam is cooled after exiting the steam turbine.

Delta Electricity propose to use an Air Cooled Condenser (ACC) for this purpose, where ambient air is ducted through a heat exchanger medium. In order to improve the performance of the cycle, the ACC is configured to operate at a low temperature differential, hence it is large in size, and emits the air at around 20 degrees above ambient temperature. The physical perimeter of the ACC is outlined in the indicative layout contained in **Figure 2-2**.

The physical structure of the unit is elevated 30m from the ground, and uses base mounted axial blowers to drive air through heat exchanger elements mounted in a series of A-frame structures, which form the top of the ACC. Preliminary designs indicate the velocity of the air as it passes through the face to be 1.8m/s. Accounting for the additional surface area associated with the A-frame configuration, the effective vertical velocity of air passing through a plane directly above the ACC is 2.8m/s.

Under low wind speed conditions, there exists the potential for the ACC plume to accelerate to beyond 4.3m/s (as a result of buoyancy effects) and exceed the OLS. There also exists the potential for the ACC plume to merge with plumes from other sources on the Marulan Site. However, given the low exit velocity, and the relatively small quantity of thermal energy (as compared to open cycle operation) emitted from the ACC, this scenario is not considered to constitute the worst case scenario beyond that detailed in this assessment. This assessment has focused on the worst case scenario of open cycle operation, and has not quantified plume rise from the ACC.

Section 3 Modelling Methodology

3.1 Model Setup

The analysis performed in this report was conducted using CSIRO's "The Air Pollution Model" (TAPM). TAPM was used in conjunction with meteorological data collected from Automatic Weather Stations (AWS's) at Goulburn Airport, Lynwood and Berrima. The meteorological data methodology is further discussed in **Appendix A** of the Air Quality Assessment reports for both Delta Electricity and EnergyAustralia.

The model was also set to produce an output of the plume rise from the exhaust stacks. This output consists of plume averaged vertical velocity, plume centreline elevation and radius of the plume. The plume elevation and radius are measured from the plume's point of release, until it stabilises in the atmosphere. TAPM produces this output in intervals ranging from 1 to 5 seconds, for each source (exhaust stack), for every hour of the modelling period. This allows interpolation of the plume elevation, at the point at which it depreciates to the critical velocity 4.3m/s.

3.1.1 TAPM Configuration

The configuration of TAPM used in this assessment was based on the guidelines included in Attachment A of the Advisory *Circular "Guidelines for Conducting Plume Rise Assessments"* (CASA –AC139-05(0) – June 2004). This is with the exception of the specified modelling period of 5 years. The year 2006 was used in this assessment. Details of the TAPM configuration are given below:

- Grid centre coordinates –34°36'30'' latitude, 150°02'30'' longitude (MGA94: 228724mE, 6166410mN);
- Meteorological grid consisting of four nests of 25 x 25 grid points at 30, 10, 3 and 1 km spacing, with 25 vertical grid levels from 10 to 8000 m;
- Terrain at 9 arc-second (approximately 270m) resolution from the Geoscience Australia terrain database. Land characterisation data at approximately 1km resolution, sourced from the US geological Survey, Earth Resources Observation System (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC). Sea surface temperature data at 100 km grid intervals from the US National Centre for Atmospheric Research (NCAR);
- Six hourly synoptic scale meteorology from the BoM on a 75 to 100 km grid. This data is derived from the BoM LAPS (Limited Area Prediction System) output; and
- Goulburn Airport, Lynwood and Berrima meteorological data for the year 2006 were assimilated into the model predictions on a radius of influence of 15km, 15km and 13km respectively.
- Eulerian dispersion was used on the outer nests, whilst Lagrangian dispersion was used on the innermost nest;
- Buoyancy enhancement from multiple stacks was calculated according to the method described in Manins et al. 1992;

3.2 Meteorological Data Assimilation

The TAPM generated wind fields were influenced by local surface wind data for 2006, from Goulburn Lynwood and Berrima. They were configured to affect the lowest two levels of TAPM generated wind fields (9.8 and 24.8m). This was performed to improve the representation local meteorological conditions. TAPM typically has difficulty representing conditions in the surface layer when it is stratified, and/or turbulence is weak or intermittent. This forms a limitation of the assessment, where synthetic meteorology has been used in the absence of on site measurements of both surface and upper air meteorology. In similar assessments, where stack heights of less than 20m have been assessed, the incorporation of local Automatic Weather Station (AWS) data at the surface has resulted in a slightly more conservative assessment, with an increase in predicted maximum and average plume extents of around 10%. Given the greater stack heights being considered at Marulan (30 – 40m), meteorological predictions at the surface are considered to be of lesser importance.

3.3 Assessment Scenarios

Given the adjacent location of the two plants, the presence of two configurations for the Delta plant (OCGT and subsequent conversion to CCGT), and both operating and start up scenarios for each plant, there exist a number of permutations of operational states available for assessment.

The plume trajectory is calculated by TAPM through a numerical solution of a system of coupled first order differential equations, each of which quantify the finite changes in buoyancy, momentum and volume flux, as the plume moves through the atmosphere. The plume is treated using a “top hat” methodology, where the plume exists within a finite boundary, and physical quantities are averaged across the plume. For this reason, all quantities reported in this assessment are plume averaged, and do not represent peak velocities within the plume. Further detail of this methodology is provided in *The Air Pollution Model (TAPM) Version 3. Part 1:Technical Description* CSIRO (2005).

Table 3-1 provides the initial conditions for Buoyancy, Momentum and Volume Flux, as derived from the stack exit parameters. For a given atmospheric profile, the value of these initial conditions are indicative of the potential of a plume to progress upwards, where higher values indicate greater plume rise potential.

Table 3-1 Initial Conditions for Source Dependent Plume Rise Parameters

Initial Condition*		Delta Electricity			EnergyAustralia	
		Stage 1 - OCGT		Stage 2 - CCGT	Open Cycle	
	Units	Start Up	Operational	Operational	Start Up	Operation
Buoyancy Flux	$m^3.s^{-3}$	1325	**2224**	444	1325	**2219**
Momentum Flux	$m^4.s^{-2}$	2914	**5331**	2695	2482	**4520**
Volume Flux	$m^3.s^{-1}$	108	**133**	135	108	**133**

*Based on an ambient temperature of 298K (25°C).
Bold values indicate worst case plume emission values for each facility.

As can be seen in the table, for each plant, the open cycle operational scenario represents the worst case scenario for potential risks to aviation safety. The marginally higher volumetric flow (volume flux) for the Delta Electricity Facility Stage 2 is most likely due to a rounding simplification in the exit parameters, and is not considered to be indicative of greater plume rise potential.

Hence, the open cycle operational scenario is of key importance with respect to high plume rise velocities.

Plume Merging

TAPM does not account for interaction between sources with regards to plume dynamics. Every source is treated separately, with its trajectory defined by its individual exit parameters and the surrounding meteorology. This is an inadequate representation for cases where, due to the presence of multiple exhaust stacks, the plumes merge and experience enhanced buoyancy. Contact between plumes results in a reduction of the entrainment of cooler static air, thus increasing the extent and rate of plume rise (relative to a single plume).

Buoyancy Enhancement Factors

In this assessment, the ‘Buoyancy Enhancement Factor’ parameter in TAPM has been used in accordance with the methodology of Manins (1992) and Hurley (2005) to account for the additional plume rise due to the merging of the plumes. This methodology takes into account the number of exhaust stacks present, their separation, as well as the exit parameters of the exhaust gas, thus arriving at a buoyancy enhancement factor for use in TAPM.

Section 3 Modelling Methodology

In TAPM this enhancement factor is used to scale the initial condition for buoyancy flux (for a given source), thus increasing the magnitude of the plume velocity throughout its rise. As the plume progresses through the atmosphere, buoyancy flux is transferred to momentum flux, as the buoyancy forces act upon the plume. Hence the modification of this initial condition is a method of incorporating the effect of the contribution to the buoyancy flux associated with entrainment of warmer gas from a neighbouring plume.

The use of the buoyancy enhancement factor to affect the initial conditions of the plume means that plume merging is incorporated into the calculation of plume velocity from the point of release, despite the fact that neighbouring plumes may not have yet made contact. Given that momentum effects are dominant (over buoyancy effects) in the early stages of plume development, for stacks with smaller separation this effect is considered to be minor and moderately conservative.

Worst Case Scenario

The methodology of Buoyancy enhancement is unable to treat sources with dissimilar separations, diameters, velocities, and exit temperatures.

Given the uneven spacing, and the differences in height and diameter between the Delta and EnergyAustralia stacks, it was necessary to consider a combination of emission parameters that represent the worst case for potential impacts upon aviation safety.

- In open cycle configuration, for the purposes of this assessment, both the Delta Electricity and EnergyAustralia plants have identical volumetric flow, and exhaust temperature. Hence stack diameter, (and the resulting impact on exit velocity) represents the only difference in stack emission parameters between the two open cycle plants. The marginally worse case of the two proposed plants is the 6.0m stack, due to the slightly higher exit velocity.
- The proposed stack heights vary between 30 and 40m, with the 40m stack representing the marginally worse case.
- The proposed stack separation varies between approximately 40 and 60 metres, where the marginally worse case of the two proposed plants is 40m, due to the theoretically higher buoyancy enhancement factor.

Hence in the worst case scenario, as considered in this assessment, it was assumed that each stack was 6.0m in diameter, 40m high, and separated by a distance of 40m**.**

The generalisation made regarding stack separation is considered suitable given that Manins' methodology is primarily sensitive to the number of sources present, with a smaller sensitivity to stack separation. The additional rows (beyond those to which scenarios have been assigned) in **Table 3-2** are included for the sole purpose of providing an indication of the low sensitivity of buoyancy enhancement factor to stack separation.

Given the larger separation between the closest neighbouring Delta and EnergyAustralia stacks (of 240m), a plume radius in the vicinity of 120m is required before the neighbouring plumes would merge. In this case the influence of the buoyancy enhancement factor prior to plume merging between plants, has been accounted for through performing a plume rise assessment of the 6.0m diameter OCGT operational stack with buoyancy enhancement factors for both four stacks and two stacks.

In order to provide an indication of whether a two stack or four stack buoyancy enhancement factor is appropriate for a given altitude, an investigation into the plume radius against the height of the critical velocity has also been made and is discussed in **Section 4.2.1**.

Section 3 Modelling Methodology

Table 3-2 shows the buoyancy enhancement factors for a range of parameters. The table gives an indication of the sensitivity of the buoyancy enhancement factor to stack separation, whilst also defining the three scenarios presented in this assessment as shown in bold text.

Table 3-2 Buoyancy Enhancement Factors (E_n) for a Range of Parameters

Scenario	Scenario Number	Number of Stacks	Temp.	Velocity	Diam--eter	Separation	E_n
4 x 6.0m Diameter OCGT stacks, 40m separation	**#1**	**4**	**532**	**40**	**6**	**40**	**1.57**
4 x 6.0m Diameter OCGT stacks, 60m separation	-	“	“	40	6	60	1.56
4 x 6.5m Diameter OCGT stacks, 40m separation	-	“	“	34	6.5	40	1.57
2 x 6.0m Diameter OCGT stacks, 40m separation	**#2**	**2**	**532**	**40**	**6**	**40**	**1.26**
2 x 6.0m Diameter OCGT stacks, 60m separation	-	“	“	40	6	60	1.26
2 x 6.5m Diameter OCGT stacks, 40m separation	-	“	“	34	6.5	40	1.26
2 x 6.0m Diameter stacks stacks 60m separation	**#3**	**2**	**125**	**20**	**6**	**60**	**1.25**

The three scenarios designated by the parameters in **Table 3-2** are considered to be representative of the following scenarios:

Scenario #1: Both the Delta Facility Stage 1 and EnergyAustralia Facility (plants operating in open cycle mode), with the assumption that merging between the two plants does occur;

Scenario #2: Both the Delta Facility Stage 1 and EnergyAustralia Facility (plants operating in open cycle mode), with the assumption that merging between the two plants does not occur. This assumes isolation of the two plumes, hence it is also representative of a single plant operating in open cycle mode;

Scenario #3: The Delta Facility Stage 2 (exhaust stacks operating in combined cycle mode).

3.4 Plume Rise Statistics

Plume rise statistics were developed using the TAPM gradual plume rise output in accompaniment with the upper air data derived from TAPM (at heights of 10 to 1400 m above ground level). This data was processed to give the statistical representation of the plume's vertical and horizontal plume extent required for the assessment.

The height at which the plume velocity decreases to 4.3m/s was calculated through linear interpolation of the TAPM gradual plume rise output. This gives the critical vertical extent of the plume for each hour of the modelling period (i.e. the height at which the vertical velocity reaches 4.3m/s).

The critical horizontal plume extent was calculated using the TAPM gradual plume rise output, in conjunction with the TAPM generated upper air data. The plume is assumed to adopt the ambient horizontal wind velocity immediately (Hurley, 2005).

i.e.

$$\frac{dx_p}{dt} = u$$

where x_p = horizontal plume velocity;

t = time;

u = horizontal component of wind speed.

For each time step of the gradual plume rise file that is output from TAPM, the upper air data was linearly interpolated to give the horizontal wind speed at that point. The horizontal translation of the plume during this time step was calculated as a product of the interpolated wind speed, and the length of the time step. These were summed for each time step until the critical vertical velocity of 4.3m/s was reached. The plume radius (Ry) at this height was then added to the total to give the horizontal distance from the source to the extremity of the plume boundary, at the point at which a vertical velocity of 4.3 m/s was reached (i.e. critical horizontal extent).

Statistics for wind speed at specific elevations were calculated through linear interpolation of the upper air data, which was given at 15 heights (between 9.3, 23.3, 46.7, 93.4, 140.1, 186.8, 233.4, 280.1, 373.5, 466.9, 560.3, 700.3, 933.8, 1167.2, 1400.6m). The error of linear interpolation is considered to be negligible, considering that the intervals between lower levels are smaller where change in wind speed with elevation is greatest. These results were then processed to give the various statistical representations required for the hazard assessment.

Section 4 Results

4.1 Local meteorology

Bureau of meteorology data from the Goulburn Airport Automatic Weather Station indicates that the region experiences light to moderate wind speeds, primarily from the west and east, with an average wind speed of 4.09 m/s, and 11.8% calms (wind speeds less than 0.5m/s) recorded for the year 2006 inclusive. Further discussion of the meteorology of the region is provided in **Appendix A** to the main Air Quality Assessment Report.

Meteorology for the proposed development site was predicted using TAPM. The TAPM predicted wind rose is provided in **Figure 4-1**. TAPM has predicted a lower percent of calms (1.3%) than those observed in the region (e.g. Berrima 11%, Goulburn 11%, Moss Vale 7%). As discussed in **Section 3.2** the stack heights at Marulan imply that wind predictions at 10m (which TAPM has most difficulty representing) are not influential in plume rise outputs.

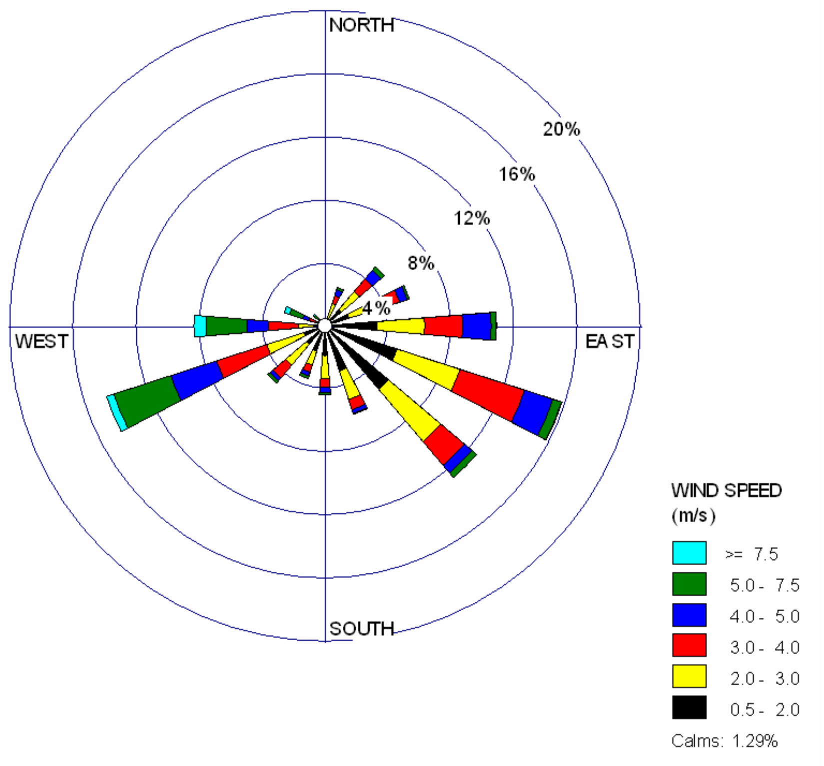


Figure 4-1 TAPM generated wind rose for Marulan 2006, all hours, 10m elevation

Figure 4-2 shows the relative cumulative frequency for wind speeds at various elevations. This figure represents the probability (at various elevations) of experiencing a wind speed less than or equal to a given value, based on the TAPM results for 2006. For example, at 40m elevation, there is approximately 80% probability that the wind speed for a given hour is less than or equal to 5m/s. The decreasing probability of low wind speeds with increasing elevation is indicated by rightward trend as elevation increases.

Section 4 Results

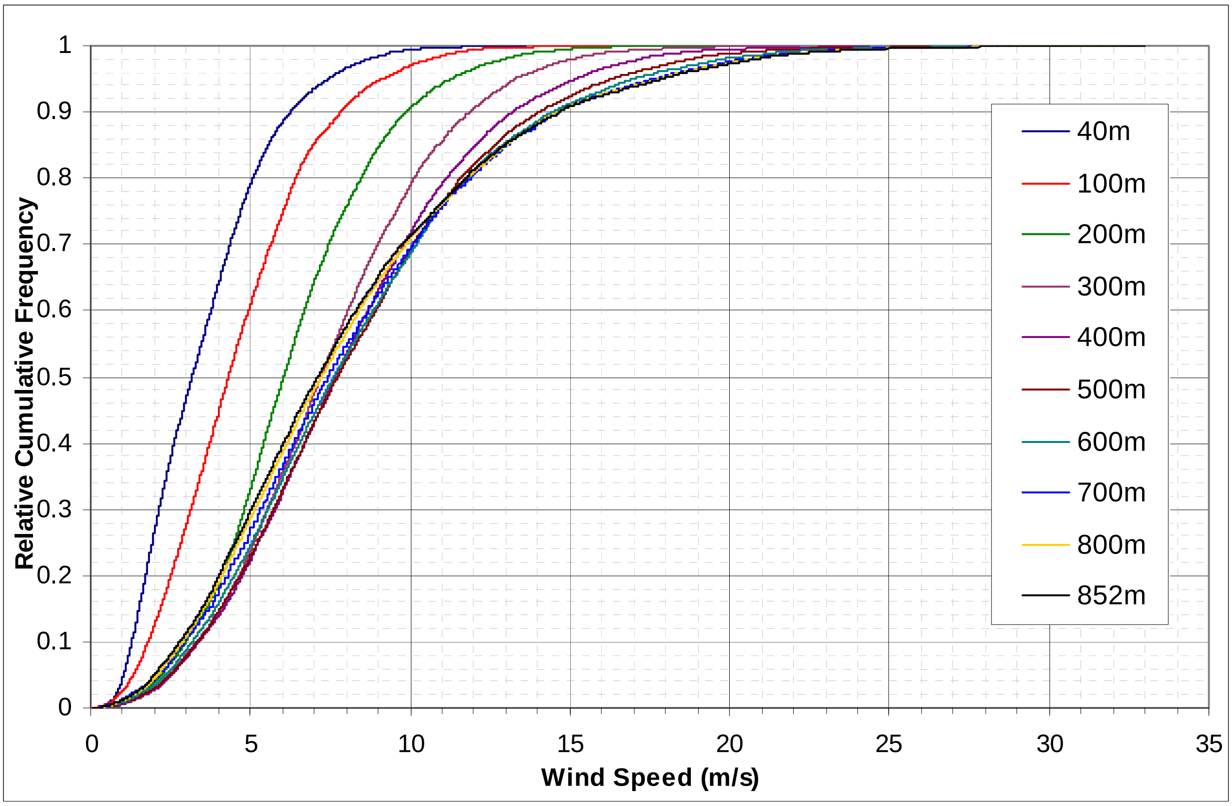


Figure 4-2 TAPM upper air wind speed relative cumulative frequency

Each row of **Table 4-1** displays the percentage of the year for which winds are less than the wind speed noted at the left of the row. The heights included range from the point of release (top of exhaust stack), to the highest point during the modelling period at which the plume velocity depreciates below 4.3m/s.

Table 4-1 Wind Speed Frequency for Various Heights

Elevation Wind Speed	40m	100m	200m	300m	400m	500m	600m	700m	800m	852m
<=0.1m/s	0.01%	0.02%	0.00%	0.02%	0.00%	0.01%	0.01%	0.00%	0.01%	0.01%
<=0.2m/s	0.05%	0.06%	0.03%	0.02%	0.02%	0.05%	0.02%	0.06%	0.01%	0.01%
<=0.3m/s	0.09%	0.21%	0.06%	0.03%	0.06%	0.05%	0.07%	0.13%	0.05%	0.03%
<=0.4m/s	0.30%	0.40%	0.14%	0.07%	0.07%	0.15%	0.10%	0.21%	0.10%	0.14%
<=0.5m/s	0.54%	0.61%	0.19%	0.09%	0.15%	0.19%	0.16%	0.37%	0.25%	0.29%
<=1.0m/s	4.5%	2.5%	0.72%	0.63%	0.58%	0.75%	0.89%	1.2%	1.1%	1.3%
<=1.5m/s	14.6%	6.7%	1.8%	1.5%	1.6%	1.7%	2.1%	2.6%	2.5%	2.6%
<=3.0m/s	47.0%	27.8%	10.1%	8.0%	7.4%	7.9%	8.8%	10.5%	10.8%	11.4%
<=5.0m/s	79.2%	60.9%	33.0%	23.7%	22.2%	22.8%	24.5%	26.5%	28.7%	29.7%

4.2 Plume Rise Statistics

The modelling results show that, as expected for an open cycle gas turbine facility, the plant will produce exhaust plumes with vertical velocities that exceed 4.3m/s above the OLS. **Table 4-2** displays the maximum, minimum and average critical plume extents.

Table 4-2 Maximum, Minimum and Average Critical Plume Extents

	Critical Plume Extent (m)					
	Scenario #1		Scenario #2		Scenario #3	
Statistic	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
Maximum	852	262	778	243	300	61
Minimum	58	37	56	30	46	11
Average	133	92	119	76	65	24

The critical vertical plume extent is the height (for a given hour modelled) at and below which, the plume averaged vertical velocity (w) exceeds 4.3m/s The critical horizontal plume extent is the sum of the total downwind translation of the plume centreline, and the plume radius at the point at which the plume averaged vertical velocity decreases to 4.3m/s. For Scenario #1 the maximum critical horizontal plume extent of 262m occurs at a height of approximately 790m (see outermost contour of **Figure 4-6** for detail of variation of maximum critical horizontal plume extent with altitude).

For Scenario #1 the maximum predicted critical vertical plume extent was 852m, which was predicted to occur on the 11/02/2006 during the 13th hour of the day. During this hour, extremely calm conditions were present in conjunction with a mostly neutral atmospheric temperature profile. Low wind speeds resulted in minimal entrainment of cooler ambient air into the plume. This allowed the plume to conserve its buoyancy to a greater degree, causing it to rise at a greater velocity, and to a greater extent. **Figure 4-3** shows ambient wind speed, ambient potential temperature and vertical plume velocity for the hour in which the maximum of 852m was predicted. The dashed red line on the right hand plot indicates the critical vertical velocity of 4.3m/s.

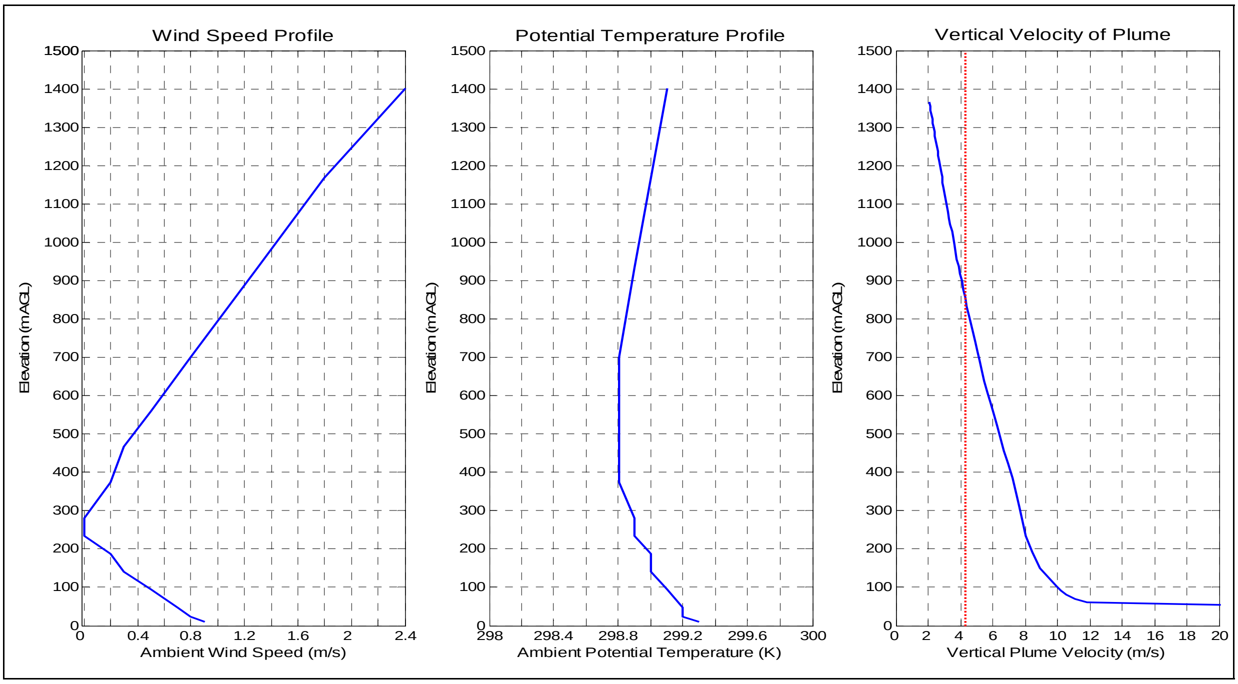


Figure 4-3 Model Predictions for Maximum Critical Vertical Extent: 11/13/2006-Hour 13

Section 4 Results

4.2.1 Plume Radii at Critical Vertical Extent

Figure 4-4 shows the horizontal plume radius at the point at which both the Delta Electricity and EnergyAustralia plumes (when each plant is assessed in absence of the other) reach the critical vertical velocity, for each hour of 2006. This has been included to provide an indication of whether the assumption of plume merging between the Facilities is appropriate for a given altitude. Given that there is approximately 240m between the closest two neighbouring Delta Electricity and EnergyAustralia stacks, the neighbouring plumes will first touch when the plume radius has grown to approximately half that of the distance between the stacks (i.e. 120m). On this basis, **Figure 4-4** indicates that except where critical extents are reached above 700m (the 5 worst hours of the year as indicated by the points to the right of the dashed green line), the plumes from the neighbouring Delta and Facilities will not merge prior to reaching the critical vertical velocity.

Hence, whilst the results for scenarios #1 and #2 are similar, it is considered that the buoyancy enhancement used for scenario #2, and the resulting statistics more appropriate, except in the very worst cases.

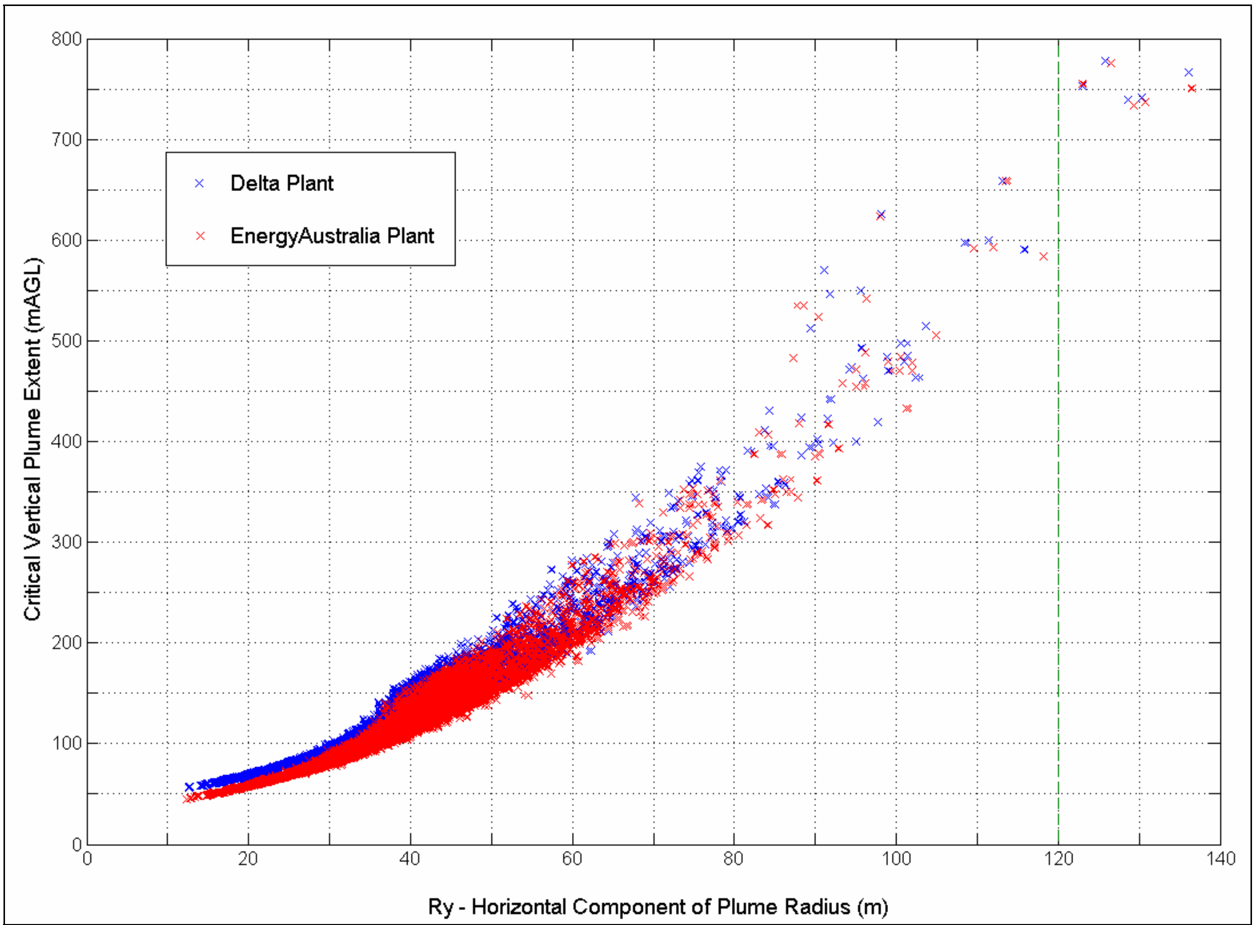


Figure 4-4 **Plume Radius Vs Critical Vertical Extent - OCGT Operation**

Section 4 Results

Table 4-3 shows the critical vertical plume extent by percentage of time, for the year 2006. The Scenario #1 result of 797m for 0.05% indicates that for 1 in every 2000 hours, the plume velocity exceeds 4.3m/s at a height greater than or equal to 797m.

For Scenario #3, the OLS of 110m is exceeded for approximately 2.5% of the year, assuming that the facility operates full time, under full load and under all possible meteorological conditions.

Table 4-3 Heights below which the vertical velocity exceeds 4.3m/s by percentage of 2006

Percentage of time, 2006	Height below which *w* >4.3m/s: (mAGL)		
	Scenario		
	#1	#2	#3
100%	58	56	47
90%	80	73	51
80%	91	82	53
70%	99	90	55
60%	107	97	57
50%	119	105	60
40%	131	117	63
30%	147	131	67
20%	166	149	74
10%	192	173	88
9%	198	176	90
8%	204	182	92
7%	213	187	95
6%	222	195	98
5%	233	205	100
4%	247	216	104
3%	271	235	108
2%	297	260	114
1%	358	306	127
0.5%	436	361	144
0.3%	544	442	154
0.2%	586	486	161
0.1%	723	597	186
0.05%	797	742	212

Section 4 Results

Figure 4-5 is another representation of the data contained in **Table 4.3** and provides the critical vertical plume extent by percentile. For example, this figure indicates that for Scenario #3, approximately 98% of the time, the vertical velocity of the plume decreases to 4.3m/s at or below 110m elevation.

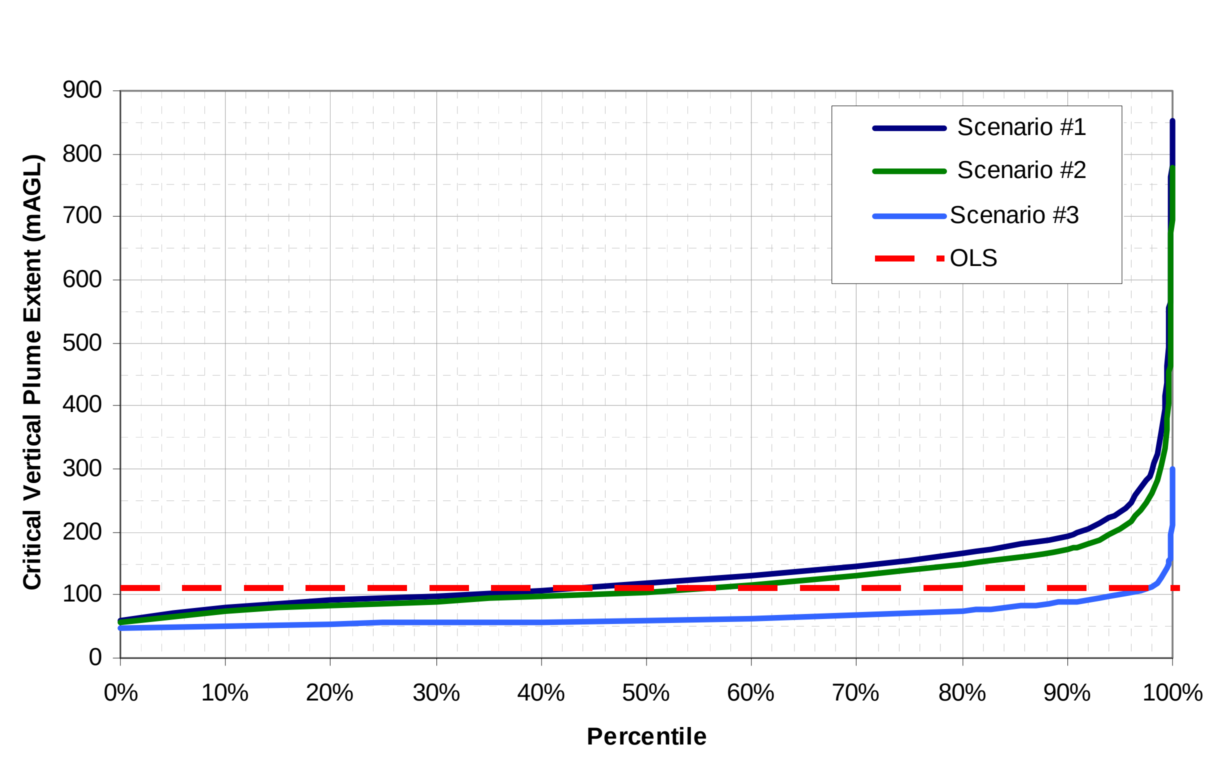


Figure 4-5 **Critical vertical plume extent by percentile**

Figures 4-6 to 4-8 illustrate the vertical and horizontal extent of the critical plume as probability density contours. These figures indicate the fraction of time that the plume vertical velocity exceeds 4.3 m/s. For example, for Scenario #1, the contour level 0.01 indicates that 1% of the time (or 87 hours per year), the plume height is approximately 360m and the corresponding total horizontal extent is 160m. It should be noted that the contour of 0.000114 is representative of the worst hour (1/8760 = 0.000114) and thus indicates entire region of space at which the vertical velocity was predicted to be greater than 4.3m/s for any hour during the year of 2006.

Figure 4-6 Scenario #1 - Probability density plot representing the region of space for which the plume averaged velocity exceeds the critical velocity of 4.3m/s.

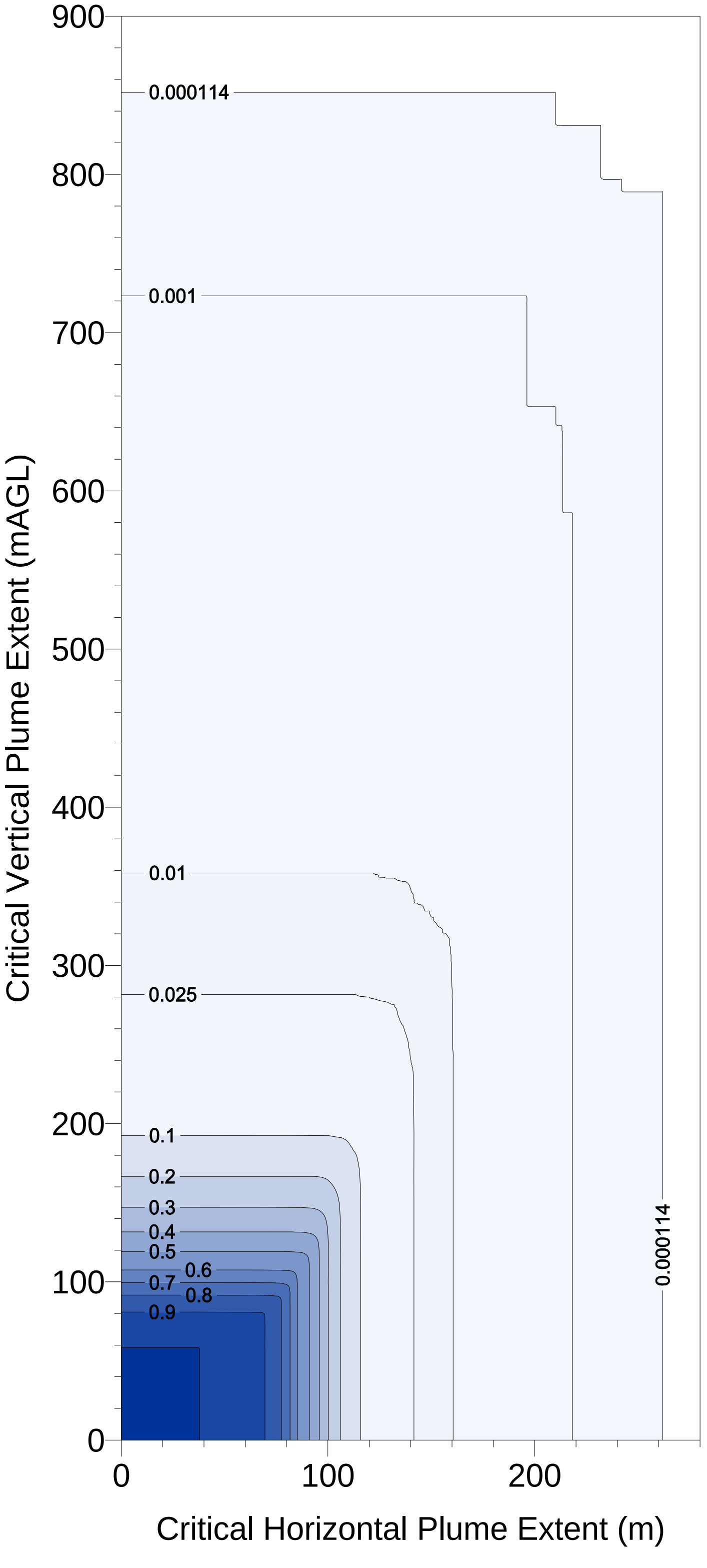


Figure 4-7 Scenario #2 - Probability density plot representing the region of space for which the plume averaged velocity exceeds the critical velocity of 4.3m/s.

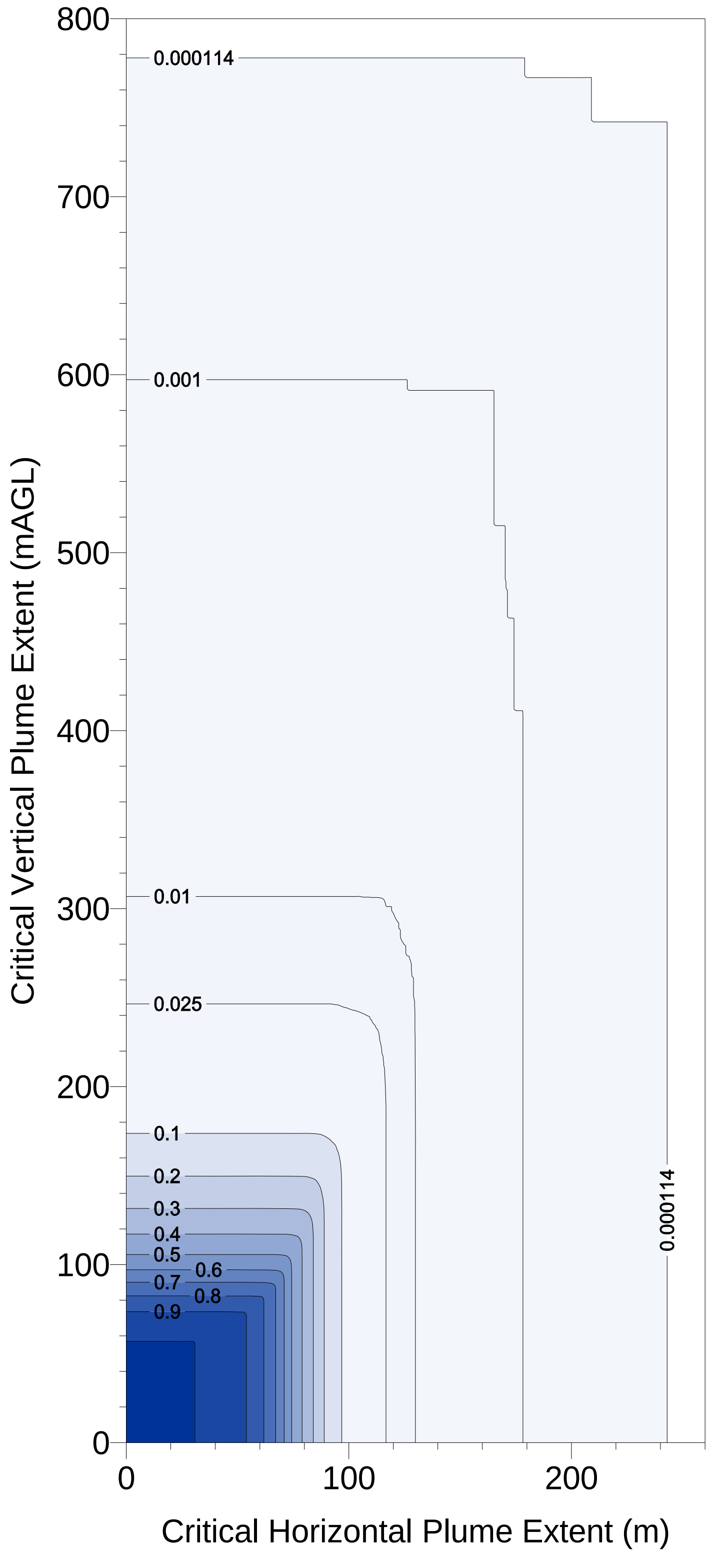
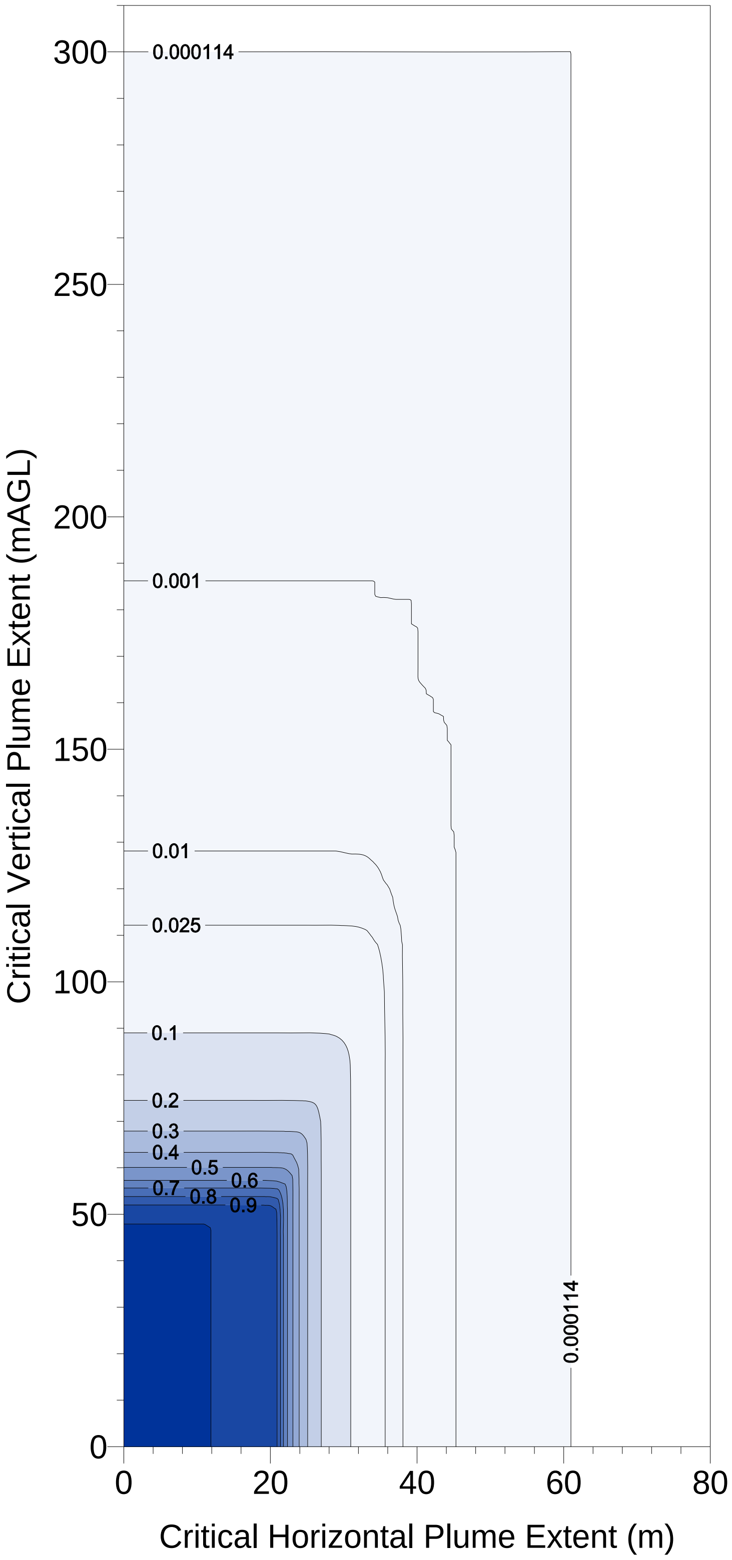


Figure 4-8 Scenario #3 - Probability density plot representing the region of space for which the plume averaged velocity exceeds the critical velocity of 4.3m/s.



Section 5 Conclusion

The proposed Gas Turbine Facilities have been assessed for their potential impacts on aviation safety. This has been performed using the CSIRO's TAPM model to predict upper air meteorology, and plume rise profiles for each hour of the year 2006, such that the critical vertical extent of the plume (height at which the plume averaged velocity slows to 4.3m/s) can be estimated.

The assessment has considered three scenarios:

Scenario #1: Both the Delta Electricity Facility Stage 1 and EnergyAustralia Facility (plants operating in open cycle mode, with the assumption that plume merging between the two plants does occur;

Scenario #2: Both the Delta Electricity Facility Stage 1 and EnergyAustralia Facility (plants operating in open cycle mode), with the assumption that merging between the two plants does not occur. This assumes isolation of the two plumes, hence it is also representative of a single plant operating in open cycle mode;

Scenario #3: The Delta Electricity Facility Stage 2 (exhaust stacks only operating in combined cycle mode).

The distances between stacks (plumes) can have a significant influence on the buoyancy of the plumes, as plumes that are located within proximity to each other will have a greater potential to merge, resulting in greater buoyancy.

The results from Scenarios #1 and #2 were quite similar, despite the conservative assumption in Scenario #1 that all four stacks were separated by a distance of 40m (indicative layouts show there is actually around 240m between closest two stack neighbouring Delta and Energy Australia stacks).

Further analysis of the plume radii at the critical vertical extent indicated that except in the worst case conditions, the plumes from the two plants would not merge before reaching the critical vertical velocity of 4.3 m/s. Hence results from Scenario #1 are considered conservative, whilst results for Scenario #2 are considered representative of the Delta Electricity and EnergyAustralia plants operating both individually, and simultaneously, except for the worst case hours, where Scenario #1 is considered more representative of simultaneous operation. Furthermore, Scenario #2 results are considered more appropriate for consideration of the plume velocities at the OLS.

Based on this assessment, for one year (2006) of modelled open cycle operation using TAPM, the OLS is exceeded during approximately 50% of the year (for Scenarios #1 and #2), with an average critical vertical extent at 133m and 119m above ground level for Scenario #1 and #2 respectively.

Furthermore, results for Scenario #3 indicate that the combined cycle Delta Electricity exhaust stacks will exceed the OLS for approximately 3% of the year, with an average critical vertical extent at 60m above ground level.

Whilst this assessment is considered conservative with respect to the modelled operating times and operating conditions, consideration should be given for the plant to be designated a potential hazard to aircraft operators in the area. The implementation of such designation is at the discretion of the Civil Aviation Safety Authority (CASA).

Further consultation with CASA will be undertaken following detailed design. It is understood that CASA will require confirmation of any changes to the design that may affect the plume rise assessment. Prior to operation of the Facilities, CASA would need to be provided with the following information:

- "as constructed" coordinates in altitude and longitude of the Facilities;
- final height (in AHD) of the exhaust stacks; and
- ground level of the site (in AHD).

Section 6 References

Hurley, Peter J, CSIRO (2005) *The Air Pollution Model (TAPM) Version 3: Technical Description;*

Manins, P C, (1992) *Plume Rise from Multiple stacks*, *Clean Air* (Australia) May 1992 Vol 26 Part2 pp 65-68;

CASA (2004) *Advisory Circular AC 139-05(0) Guidelines for conducting Plume Rise Assessments.*

Section 7 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Delta Electricity and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 14 February 2008.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between January and February 2008 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix D Scenario Assessment and TAPM Modelling Assessment

Appendix D Scenario Assessment & Model Comparison

1.1 Overview

The following assessment has been prepared in two parts, the first part being a discussion of the range of modelled scenarios and the resultant impacts, as provided in **Sections 1.2** through **1.5**. Secondly, to confirm that the model chosen for this assessment, namely Calpuff, was an appropriate model, a model validation assessment was performed using another dispersion model, namely the TAPM model. The TAPM modelling assessment is provided in **Section 2**.

1.2 Introduction and Objective

Emissions from gas turbines can vary due to a range of factors. Due to the different emission parameters during: 1) start up; 2) "peaking cycle" operation mode; and 3) "combined cycle" operation mode, a range of turbine emission combinations were assessed. The modelling scenarios undertaken are provided in **Table 1-1**. Whilst several scenarios were modelled, it was considered necessary to only present the worst case results in the main report.

The objective of this component of the report was to review the impacts from all of the modelled scenarios and ensure impacts from the standalone facilities as well as the worst case combined facility scenarios were included in the main report.

The Calpuff model was used to perform the assessment and the modelling set up is provided in **Section 6.4** of the main report.

Appendix D Scenario Assessment & Model Comparison

Table 1-1 Scenarios Modelled

Facility	Delta Stage 1		Delta Stage 2	EnergyAustralia	
	Start Up	General Operation	General Operation	Start Up	General Operation
Delta	✓	-	-	-	-
Delta	-	✓	-	-	-
Delta	-	-	✓	-	-
Combined	✓	-	-	✓	-
Combined	-	✓	-	✓	-
Combined	✓	-	-	-	✓
Combined	-	-	✓	✓	-
Combined	-	✓	-	-	✓
Combined	-	-	✓	-	✓
EnergyAustralia	-	-	-	-	✓
EnergyAustralia	-	-	-	✓	-

1.3 Methodology

The assessment methodology for these scenarios is discussed in Section 6 of the main report.

1.4 Results

The results for the scenarios listed in **Table 1-1** are provided in **Table 1-2**, and show the maximum predicted ground level concentrations for each scenario.

Appendix D

Scenario Assessment & Model Comparison

Table 1-2 Modelling results for all scenarios (ug/m³)

Species	Averaging Period	Delta Stage 1 Start Up	Delta Stage 1 Operation	Delta Stage 2 Operation	Delta Stage 1 Start Up	Delta Stage 1 Operation	Delta Stage 1 Start Up	Delta Stage 2 Operation	Delta Stage 1 Operation	Delta Stage 2 Operation	Delta -	Delta -
		EA -	EA -	EA -	EA Start Up	EA Start Up	EA Operation	EA Start Up	EA Operation	EA Operation	EA Start Up	EA Operation
NO_2 (all NO_X as NO_2)	1 hour maximum	105.1	28.2	97.8	182.0	124.8	105.1	162.0	54.4	98.7	122.1	27.7
	Annual average	0.3	0.1	0.3	0.7	0.4	0.4	0.6	0.1	0.3	0.3	0.1
PM_{10}	24 hour maximum	0.5	0.5	1.1	0.9	0.9	0.9	1.3	0.9	1.2	0.5	0.5
	Annual average	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
SO_2	10 minute maximum	6.5	10.3	35.5	12.7	16.0	16.0	36.0	19.8	35.8	6.75	10.05
	1 hour maximum	4.5	7.2	24.8	8.9	11.2	11.2	25.1	13.8	25.1	4.72	7.03
	24 hour maximum	0.4	0.5	1.2	0.7	0.9	0.9	1.3	1.0	1.3	0.36	0.502
	Annual average	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.01	0.015
CO	15 minute maximum	1054	9	31	1795	1218	1054	1218	17	31	1217	9
	1 hour maximum	799	7	23	1361	923	799	923	13	24	922	7
	8 hour maximum	181	1	3	330	166	182	166	3	4	166	1
Acetaldehyde	1 hour average	0.026	0.012	0.043	0.563	0.028	0.027	0.034	0.005	0.012	0.317	0.026
Acrolein	1 hour average	0.004	0.002	0.007	0.090	0.005	0.004	0.006	0.001	0.002	0.051	0.004
Benzene	1 hour average	0.008	0.004	0.013	0.169	0.008	0.008	0.010	0.001	0.003	0.095	0.008
Ethyl benzene	1 hour average	0.021	0.010	0.034	0.450	0.023	0.022	0.028	0.004	0.009	0.254	0.021
Formaldehyde	1 hour average	0.464	0.218	0.755	9.990	0.501	0.481	0.610	0.087	0.206	5.634	0.468
Toluene	1 hour average	0.085	0.040	0.138	1.829	0.092	0.088	0.112	0.016	0.038	1.031	0.086
Total (PAH)	1 hour average	0.001	0.001	0.002	0.031	0.002	0.001	0.002	0.000	0.001	0.017	0.001
Xylenes	1 hour average	0.042	0.020	0.068	0.901	0.045	0.043	0.055	0.008	0.019	0.508	0.042

Worst case concentrations are shaded.

Appendix D Scenario Assessment & Model Comparison

The maximum predicted ground level concentrations for all scenarios, presented in **Table 1-2,** were added to background concentrations and compared to criteria, as shown in **Table 1-3**.

Table 1-3 Summary of Worst Case Impacts

Species	Averaging Period	Maximum Background (ug/m^3)	Maximum Predicted Ground Level Concentration (ug/m^3)	Scenario of Maximum Predicted Ground Level Concentration		Maximum Cumulative (ug/m^3)	Air Quality Criteria (ug/m^3)
				Delta	EnergyAustralia		
NO_2	1 hour maximum	116.9	182.0	Stage 1 Start Up	Start Up	229.9 (298.9 A)	246
	Annual average	13.7	0.7	Stage 1 Start Up	Start Up	14.4	62
PM_{10}	24 hour maximum	40	1.3	Stage 2 Operation	Start Up	41.3	50
	Annual average	14	0.1	Stage 2 Operation	Start Up	14.1	30
SO_2	10 minute maximum	36.8	36.0	Stage 2 Operation	Start Up	72.8	712
	1 hour maximum	25.7	25.1	Stage 2 Operation	Start Up	50.8	570
	24 hour maximum	5.7	1.3	Stage 2 Operation	Start Up	7.0	228
	Annual average	1.2	0.1	Stage 2 Operation	Start Up	1.3	60
CO	15 minute maximum	3299	1795	Stage 1 Start Up	Start Up	5094	100,000
	1 hour maximum	2500	1361	Stage 1 Start Up	Start Up	3861	30,000
	8 hour maximum	2250	330	Stage 1 Start Up	Start Up	2580	10,000
Acetaldehyde	1 hour average	0	0.563	Stage 1 Start Up	Start Up	0.563	42
Acrolein	1 hour average	0	0.090	Stage 1 Start Up	Start Up	0.090	0.42
Benzene	1 hour average	0	0.169	Stage 1 Start Up	Start Up	0.169	290
Ethyl benzene	1 hour average	0	0.450	Stage 1 Start Up	Start Up	0.450	8000
Formaldehyde	1 hour average	0	9.990	Stage 1 Start Up	Start Up	9.990	20
Toluene	1 hour average	0	1.829	Stage 1 Start Up	Start Up	1.829	360
Total (PAH)	1 hour average	0	0.031	Stage 1 Start Up	Start Up	0.031	0.4
Xylenes	1 hour average	0	0.901	Stage 1 Start Up	Start Up	0.901	190

Note:
A: Presumes all NOx is present as NO_2. Conversion of the predicted NO_X concentration to NO_2, using the Janssen equation, as discussed in Section 6.4.5 of the main report results in a cumulative concentration of 194.5 $\mu g/m^3$.

1.5 Discussion

As shown in **Tables 1-2** and **1-3**, the worst case scenarios are the *Delta Stage 1 Start Up with EnergyAustralia Start Up* and *Delta Stage 2 General Operation with EnergyAustralia Start Up*. This is consistent with general plume behaviour and pollutant emission from these plants, as combined *Start Up* emissions would generally give rise to the release of the greatest mass of NO_2, CO and hazardous air pollutants leading to elevated ground level concentrations of these species. However, the relatively cooler and less buoyant, stack emissions associated with *Delta Stage 2 General Operation with Energy Australia Start Up* result in elevated ground level concentrations of SO_2 and PM_{10}. Consequently, the

Appendix D Scenario Assessment & Model Comparison

presentation in the main report of the impacts from the individual facilities and the worst case combined scenarios listed above is considered appropriate.

It should also be noted that the compounds modelled were generally well below the air quality criteria, with the exception of NO_2, where ground level concentrations were shown to be approaching criteria.

Appendix D Scenario Assessment & Model Comparison

2.1 Introduction and Objective

Different atmospheric dispersion models incorporate different dispersion methodologies and generally provide different results. The objective of the TAPM modelling assessment was to verify the modelling results generated using Calpuff and to confirm that the primary pollutant, namely NO_2, did not exceed regulatory criteria using the TAPM model. This was performed by modelling several scenarios using the TAPM dispersion model and results were compared against the Calpuff results.

2.2 Method

The two chosen models to undertake the assessment were Calpuff and TAPM. Both models are approved by the NSW EPA as appropriate for dispersion modelling of this type of facility.

Given that NO_2 was shown to be the primary compound approaching criteria (see **Table 1-3**), NO_2 was chosen as the preferred pollutant to be assessed.

2.2.1 Calpuff Model Set-up

The Calpuff model set up is provided in **Section 6.4** of the main report.

2.2.2 TAPM Model Set-up

Details of the TAPM configuration are given below:

- The model was configured to run from December 25, 2005, to December 31, 2006. The model was started prior to the beginning of the year, as in preliminary runs, annual peak 1 hour impacts were found to occur approximately 4 hours into the modelling run. Given the importance of run-up time in establishing atmospheric dynamics within the model, the model was re-configured to commence on 25th December 2005.
- Grid centre coordinates –34°36'30'' latitude, 150°02'30'' longitude (MGA94: 228724mE, 6166410mN);
- Meteorological grid consisting of four nests of 31 x 31 grid points at 30, 10, 3 and 1 km spacing, with 25 vertical grid levels from 10 to 8000 m;
- Terrain at 9 arc-second (approximately 270m) resolution from the Geoscience Australia terrain database. Land characterisation data at approximately 1km resolution, sourced from the US geological Survey, Earth Resources Observation System (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC). Sea surface temperature data at 100 km grid intervals from the US National Centre for Atmospheric Research (NCAR);
- Six hourly synoptic scale meteorology from the BoM on a 75 to 100 km grid. This data is derived from the BoM LAPS (Limited Area Prediction System) output;
- Goulburn Airport, Lynwood and Berrima meteorological data for the year 2006 were assimilated into the model predictions on a radius of influence of 15km, 15km and 13km respectively. More detailed information on the automatic weather stations used to generate the meteorological data is provided in **Appendix A** of the main report;
- Eulerian dispersion was used on the outer nests, whilst Lagrangian dispersion was used on the innermost nest; and

- Buoyancy enhancement from multiple stacks was calculated according to the method described in Manins et al. 1992[1]. This incorporated merging between neighbouring stacks within each plant. No buoyancy enhancement due to plume merging between separate plants (Delta and EnergyAustralia) was assumed to occur. Plume merging is further discussed in **Appendix C** of the main report.

2.3 Results

The results comparing the worst case (100% frequency) NO_2 results using TAPM and Calpuff are provided in **Table 2-1**. It should be noted that the concentrations presented in **Table 2-1** conservatively show NO_2 concentrations, presuming all NO_X is present as NO_2, however actual concentrations of NO_2 are likely to be lower.

Table 2-1 Comparison of worst case NO_2 results (µg/m^3) using TAPM and Calpuff^A

	TAPM 1 Hour Average	Calpuff 1 Hour Average	TAPM Annual Average	Calpuff Annual Average
Standalone Scenarios				
Delta Stage 1 Operation	34.5	28.2	0.2	0.1
Delta Stage 2 Operation	139.9	97.8	0.8	0.3
Delta Stage 1 Start Up	183.0	105.1	0.9	0.3
EnergyAustralia Operation	36.1	27.7	0.2	0.1
EnergyAustralia Start Up	188.9	122.1	0.9	0.3
Combined Scenarios				
Delta Stage 2 Operation EnergyAustralia Start Up	328.7	162.0	1.6	0.6
Delta Stage 1 Start Up EnergyAustralia Start Up	355.8	182.0	1.7	0.7

Notes:
A: Presumes all NO_X is present as NO_2,

Data for other species are available upon request.

As stated, the NO_2 concentrations presented in **Table 2-1** presume all NO_X is present as NO_2. The relationship between NO_X and NO_2 is further discussed in Section 7.4.5 of the main report. Using the peak 1 Hour NO_2 background concentration of 116.9 µg/m^3, certain scenarios shown in **Table 2-1** would produce concentrations of NO_2 (presuming all NO_X is NO_2) that may exceed the NSW EPA regulatory criteria of 246 µg/m^3. To ensure more realistic NO_2 concentrations are represented, the Janssen equation has been applied to scenarios were elevated concentrations of NO_2 occurred, which is the same approach adopted in the main report. These scenarios are provided in **Table 2-2**. It should be noted that

[1] Manins, P C, (1992) *Plume Rise from Multiple stacks*, *Clean Air* (Australia) May 1992 Vol 26 Part2 pp 65-68;

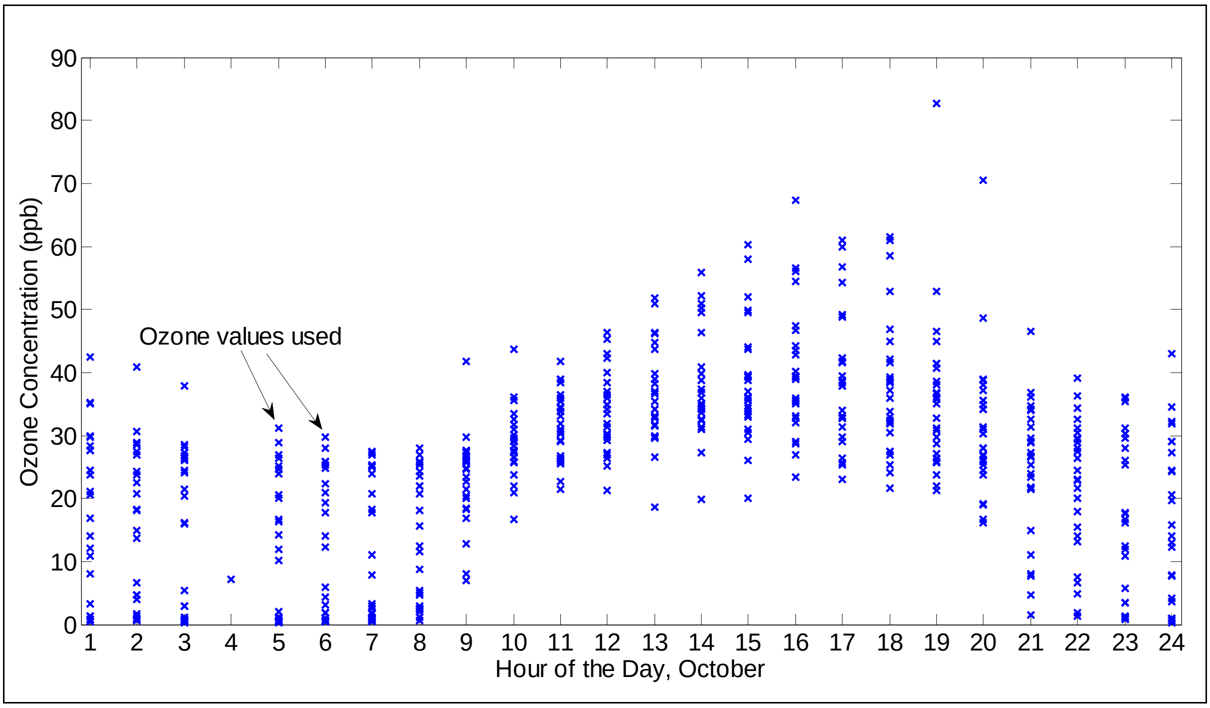
the Janssen Method requires the input of other atmospheric parameters, such as background ozone concentrations, which were sourced from the NSW EPA Bargo Monitoring station.

The Janssen Method was adopted for several scenarios, and where data were missing, the peak ozone range was assumed (as prescribed in the Janssen methodology).

The Scenario *Delta Stage 1 Start Up and EnergyAustralia Start Up* resulted in the highest NO_2 predictions, some of which were found to occur in the absence of hourly background ozone data. In this case, the assumption of the peak ozone range was found to be too conservative. Hence, for the two highest peaks a single hour was missing, and the ozone data for these hours were linearly interpolated, thus eliminating these predictions as peaks.

The next two highest peaks occurred during 5th and 6th hours of the 24th October 2006. In October, the Bargo monitoring station missed three days of data, which encompassed these two peak NO_2 predictions. On this basis, the peak ozone measurements for the 5th and 6th hours of all the days in the month of October were used (as indicated in **Figure 2-1**). This resulted in an NO_2 prediction of 119.9 µg/m^3.

Figure 2-1 October Hourly Ozone Data



Appendix D Scenario Assessment & Model Comparison

Table 2-2 Comparison of worst case NO_2 results (µg/m^3) using TAPM and Calpuff to NSW EPA NO_2 Regulatory Criteria^A

	TAPM	Calpuff	TAPM	Calpuff
	1 Hour Average Cumulative concentration ^{C}	1 Hour Average Cumulative Concentration ^{C}	Annual Average Cumulative concentration ^{C}	Annual Average Cumulative Concentration ^{C}
Standalone Scenarios				
Delta Stage 1 Operation	151.4	145.1	13.9	13.8
Delta Stage 2 Operation	256.8 (187.2 ^{B})	214.7	14.5	14
Delta Stage 1 Start Up	299.9 (185.5 ^{B})	222.0	14.6	14
EnergyAustralia Operation	153.0	144.6	13.9	13.8
EnergyAustralia Start Up	305.8 (186.0 ^{B})	239.0	14.6	14
Combined Scenarios				
Delta Stage 2 Operation EnergyAustralia Start Up	445.6 (224.7 ^{B})	278.9 (188.1 ^{B})	15.3	14.3
Delta Stage 1 Start Up EnergyAustralia Start Up	472.7 (236.8 ^{B})	298.9 (229.9 ^{B})	15.4	14.4
NSW EPA Air Quality Criteria (µg/m^3)	246	246	62	62

Notes:
A: Conservatively presumes all NO_x is present as NO_2, unless value is provided in brackets.
B: Value in brackets is the sum of the peak background NO_2 concentration and the plant NO_2, as derived using the Janssen Method
C: 1 hour averaged cumulative concentrations include a background concentration of 116.9µg/m^3 whilst annual averaged cumulative concentrations include a background concentration of 13.7µg/m^3.

To allow comparison against the Calpuff modelling contour figures provided in the main report, the TAPM contour modelling figures for the Combined Scenarios presented in **Table 2-2** in are provided in the Figures section of this Appendix.

2.4 Discussion

The 1 hour averaged results provided in **Table 2-1** show the 100% frequency i.e. the most extreme results of the modelled year, hence some variation between models is expected. Overall, the TAPM results indicate broadly higher concentrations, with results for the “Operation Scenarios” generally similar and “Start Up Scenarios” demonstrating some variation.

The annual average results show low concentrations in all scenarios and are generally similar.

Predicted ground level concentrations from different dispersion models are expected to show varying results, and this was demonstrated in this assessment using TAPM and Calpuff. However, the maximum cumulative NO_2 results, shown in **Table 2-2** for both TAPM and Calpuff were shown to be below regulatory criteria and were generally comparable. Thus the results do not suggest that the Calpuff predictions were anomalous or erroneous, hence the use of Calpuff in this assessment is considered valid.

2.5 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Delta Electricity and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 14 February 2008.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared during February 2008 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.