



Appendix C
Revised Air Quality and Plume Rise
Assessment



HEGGIES

REPORT 10-4044-R3

Revision 1

**Proposed Gas Turbine Power Station
Bamarang, NSW
Air Quality Impact Assessment
Stage 2 Operations**

PREPARED FOR

GHD Pty Ltd
10 Bond Street
SYDNEY NSW 2000

27 MARCH 2008

HEGGIES PTY LTD
ABN 29 001 584 612

Incorporating

New Environment

Graeme E. Harding & Associates

Eric Taylor Acoustics



Proposed Gas Turbine Power Station Bamarang, NSW Air Quality Impact Assessment Stage 2 Operations

PREPARED BY:

Heggies Pty Ltd
2 Lincoln Street Lane Cove NSW 2066 Australia
(PO Box 176 Lane Cove NSW 1595 Australia)
Telephone 61 2 9427 8100 Facsimile 61 2 9427 8200
Email sydney@heggies.com Web www.heggies.com

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EXECUTIVE SUMMARY

Introduction

Delta Electricity (DE) propose to construct a gas turbine power station, and associated infrastructure, including transmission connections at Bamarang, approximately 7 km south-west of Nowra, NSW. The proposal is planned to be developed in two stages:

- Stage 1: Open cycle gas turbines for peaking periods.
- Stage 2: Conversion to combined cycle for base load capabilities.

Heggies Pty Ltd (Heggies) was commissioned by GHD Pty Ltd (GHD) on behalf of DE to undertake an Air Quality Impact Assessment (AQIA) as part of the Environmental Impact Statement (EIS) for a proposed gas turbine power facility, which was completed in December 2005 (Heggies Report 10-4044R1R1). The proposed power facility was based on a water cooling system (cooling towers) for the plant, noting that water cooling is required as part of the Stage 2 operations.

DE are proposing replacement of the Stage 2 water cooling system with an air cooled system to inter alia reduce the operational water requirements for the facility. Heggies has been commissioned by GHD on behalf of DE to assess the resulting air quality implications of replacing water cooling system with an air cooled system.

Atmospheric Emissions

The primary pollutants from gas turbine engines are oxides of nitrogen (NO_x); formed by the high temperatures generated in the combustor; carbon monoxide (CO) and volatile organic compounds (VOC); which are formed predominately by the incomplete combustion of fuel. Particulate matter less than 10 microns in aerodynamic diameter (PM₁₀) and sulphur dioxide (SO₂) are emitted in trace to low amounts from gas turbine operations.

The greenhouse gases carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₄) are all produced during gas turbine operation (USEPA, 1995). CO₂ and N₂O are produced during the combustion process, while CH₄ is present in the exhaust gas as unburnt fuel when the fuel is natural gas.

Existing Air Quality Environment

An estimation of background air quality has been made through a combination of monitoring data from an air quality and weather monitoring station at the Nowra Water Treatment Plant and the Department of Environment and Climate Change (DECC) air quality monitoring station at Albion Park South, located approximately 43 km north-east of the proposed site.

Air Quality Goals and Relevant Approvals

The NSW DECC has established ground level air quality criteria for key air pollutants to achieve appropriate environmental outcomes and to minimise associated risks to human health. The criteria specified by DEC, as expressed in their document "*Approved Methods and Guidance for Modelling and Assessment of Air Pollutants in New South Wales*" 2005, have been adopted as the ambient air quality goals for this assessment.

In addition to demonstrating that the ground level concentration (glc) criteria are being met, a Combined Cycle Gas Turbine (CCGT) power facility is required to obtain an environmental protection license under the *Protection of the "Environment Operations (POEO) Act 1997"* and satisfy the associated "*Clean Air (Plant and Equipment) Regulation 1997*" ("The CAPER").



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Site Meteorology

Meteorological data from the Nowra Water Treatment Plant monitoring station was used to obtain a representation of local conditions at the Project Site. Data from the nearest Bureau of Meteorology (BoM) monitoring station, located within the Nowra Royal Australian Navy (RAN) Air station, located 4 km to the southwest of the site., was also utilised in this assessment. Climatic averages are available since records began in 1942.

The Air Pollution Model (TAPM) software, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to simulate the meteorology of the proposed site. For this assessment, TAPM was used to generate a complete 2006 meteorological data set for the Project Site, incorporating hourly observations recorded by both the Nowra Water Treatment Plant and Nowra RAN Air Station BoM monitoring stations.

Dispersion Modelling

TAPM (v3.0) is a prognostic model which may be used to predict three-dimensional meteorology and air pollution concentrations with no local meteorological data inputs required.

Such a complex and computationally intensive model is required to simulate chemical transformation of stack emissions and influences of relatively complex terrain that would not be accounted for using a conventional Gaussian model (such as Ausplume).

The TAPM model has been run in chemistry mode, and as such accounts for the photochemistry that will drive the formation / destruction of oxides of nitrogen.

Atmospheric dispersion modelling has been used to assess the impacts of revised Stage 2 operations.

Stack emission parameters are dependant upon the ambient temperature during the period of operation. To simulate “worst-case” release parameters, stack exit parameters corresponding to an ambient temperature of 273 K (0°C) have been used in dispersion modelling.

Stack emission rates for key atmospheric pollutants (NO_x, CO and unburnt hydrocarbons (UHC)) for project stages were provided by the technical design team.

Air Quality Assessment

Modelling of PM₁₀, NO₂, SO₂, and regional photochemistry was undertaken using the TAPM (v3.0) Dispersion Model software. The results of atmospheric dispersion modelling undertaken within this assessment indicate that for Stage 2 operations, the project air quality goals are predicted to be satisfied, for both full-load and start-up/shut-down operations.

While it is anticipated that construction-phase particulate emissions may largely be controlled using technical means, control strategies should be detailed in a Construction Phase Air Quality Management Plan, and should include:

- Additional watering of exposed surfaces.
- Minimisation of exposed surfaces.
- Rehabilitation of available areas of disturbance (eg. topsoil, subsoil, spoil stockpiles).
- Minimising the drop heights between front end loader buckets and trucks carrying excavated materials.
- Dust screening between construction activities and residential receptors.



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- Installation of water sprays along the unsealed access ways.
- Routine use of a water truck.
- Limiting of high dust-generating activities during adverse wind conditions, ie winds blowing directly towards the nearest sensitive receptors.

Greenhouse Gas Assessment

The proposed power facility at Bamarang has the potential to produce greenhouse gases, with the primary source being the two gas turbines during electricity generation operations.

The proposed power facility at Bamarang is anticipated to have an annual gas demand of 24.0 PJ over 8,300 hours of actual operation for Stage 2 Base Load operations.

The annual emissions of carbon dioxide and other greenhouse gases from this source have been estimated using the Australian Greenhouse Office (AGO) document “*Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002 – Energy (Stationary Sources)*”.

The CO₂-equivalent emissions associated with the proposed power facility’s operations as a percentage of the total emissions from electricity generation operations in Australia compared with 1990 and 2002 levels are anticipated to be 0.97% and 0.68% respectively for Stage 2 operations.

Mitigation Measures and Safeguards

The gas turbine combustors would be of the (dry) low NO_x design for gas fuel. Dry low NO_x combustors represent the best practicable option for emission control when used with natural gas as they do not need any fluid injection to maintain emissions at acceptable levels over a wide operational range. Low NO_x combustors are considered effective and reliable, and as they may be more fuel efficient, they may pay for themselves when considering whole-of-life costs.

Given the results of atmospheric dispersion modelling, it is anticipated that no additional post-combustion mitigation measures from an air quality perspective (such as selective catalytic reduction) will be required under the current design.

Conclusion

The results of atmospheric dispersion modelling undertaken within this assessment indicate that for revised Stage 2 operations, the project air quality goals are predicted to be satisfied.

Compliance with air quality goals is anticipated to be governed principally by NO₂ emissions.

As a result of the “worst-case scenario” being modelled, all predictions should be viewed as conservatively high, with levels expected to be significantly lower than those modelled during standard operation.



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1 INTRODUCTION

1.1 Introduction

Delta Electricity (DE) propose to construct a gas turbine power station and associated infrastructure, including transmission connections at Bamarang, approximately 7 km south-west of Nowra, NSW. The proposal is planned to be developed in two stages:

- Stage 1: installation of two open cycle gas turbines (OCGT) for a peaking facility;
- Stage 2: conversion to a combined cycle gas turbine (CCGT) power facility to meet intermediate/base load demands. The conversion essentially consists of the addition of a heat recovery steam generator to each gas generator and the addition of steam generators to form the CCGT.

Heggies Pty Ltd (Heggies) was commissioned by GHD Pty Ltd (GHD) on behalf of DE to undertake an Air Quality Impact Assessment (AQIA) as part of the Environmental Impact Statement (EIS) for a proposed gas turbine power facility, which was completed in December 2005 (Heggies Report 10-4044R1R1). The proposed power facility was based on a water cooling system (cooling towers) for the plant, noting that water cooling is required as part of the Stage 2 operations.

DE are proposing replacement of the Stage 2 water cooling system with an air cooled condenser system (ACC) to inter alia reduce the operational water requirements for the facility. Heggies has been commissioned by GHD on behalf of DE to assess the resulting air quality implications of replacing water cooling system with an ACC system. Given that the air released from the ACC may enhance the plume released by the turbine stacks, the study incorporates both a vertical plume rise assessment and revised atmospheric pollutant dispersion modelling.

1.2 Site Location

The site is located at Bamarang, approximately 8km south-west of Nowra on the NSW south coast and falls within the Shoalhaven Local Government Area. The site has frontage to Yalwal Road (number 681), which links Nowra to Yalwal. **Figure 1** shows the location of the proposed site and the surrounding area.

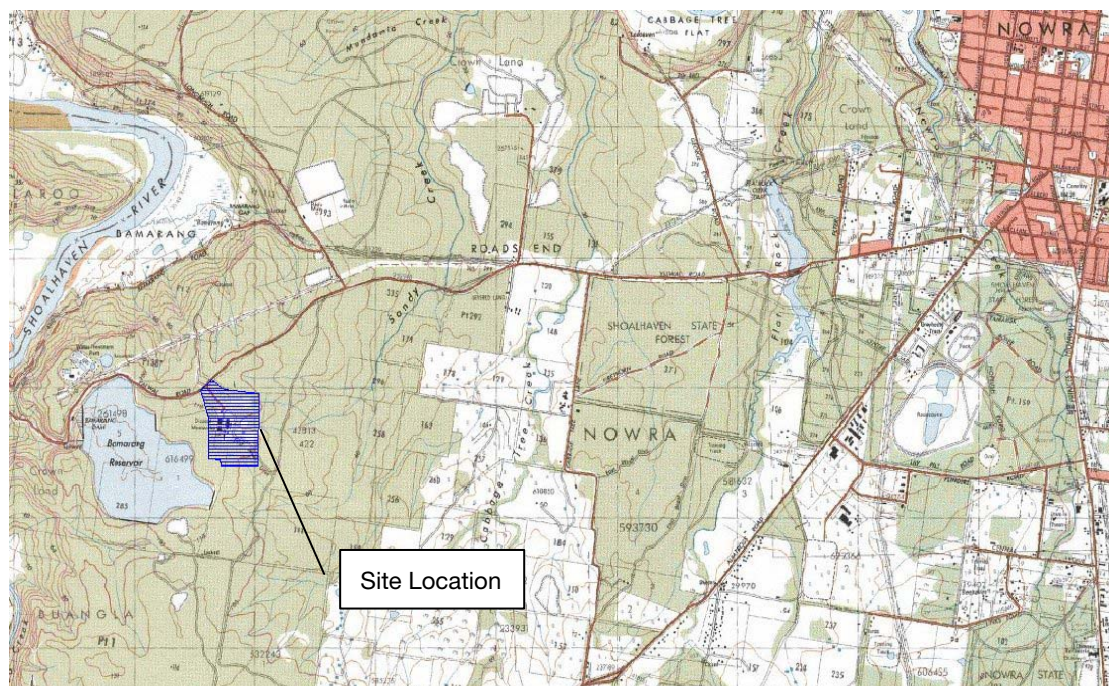
The site is approximately 20 hectares, of which 5 hectares would be required for the gas turbine plant and 2 hectares would be required for a switchyard. The site is bounded by Bamarang Nature Reserve to the North and Crown Land elsewhere. Bamarang Dam, which supplies Nowra's water, is located 300 m to the west.

The central portion of the site was previously cleared and developed as an abattoir, although the facility was never operated. Some regrowth has occurred since the site was cleared for the abattoir development, which may need to be removed. The remainder of the site contains bushland that extends into the adjoining properties owned by the Crown and Council. This bushland is part of a larger parcel that is of high conservation value and includes the Bamarang Nature Reserve, Triplarina Nature Reserve, Wogamia Nature Reserve and the Colymea State Conservation Area.

There are a number of existing buildings on the site, constructed during the abattoir development, which include stockyards, an amenities building, processing building and storage shed, all of which will be demolished as part of the construction of the proposal.



Figure 1 Site Location



1.3 Project Summary

DE is currently considering increasing its generation capacity through the development of a gas turbine power facility at the Project Site near Bamarang.

To ensure that DE is able to respond to increased energy demands with time, the project is planned in two stages as follows:

Stage 1: Open Cycle Gas Turbines for Peaking Periods

Stage 1 would involve the use of two gas turbine generators operating in an open cycle configuration. An open cycle, or simple cycle gas turbine (OCGT) is the most basic operating cycle for gas turbines, where the heat content of the exhaust gases exiting the turbine is discarded. This stage of the project would ensure that the power facility is able to meet demands during peak periods on the national electricity grid, and would therefore be limited to operating during peak demand. This stage of operation is expected to generate between 240 and 300 MW of net power output.

It is noted that OCGTs are ideal for meeting peak demands, as they can provide a large amount of capacity from cold standby. They have thermal efficiencies of the order of 34%, expressed on a Lower Heating Value (LHV) basis. As such, they are relatively inefficient, and are therefore not suitable for meeting base load demands.

Stage 2: Conversion to combined cycle for base load capabilities

Stage 2 of the project involves the conversion of the power facility to a combined cycle gas turbine (CCGT) through the addition of one heat recovery steam generator (HRSG) per gas turbine, and one steam turbine generator, to service both HRSGs. This conversion will increase the power facility's electricity generation capacity to 400 MW.



CCGTs have a high thermal efficiency (typically 50% or more, expressed on a LHV basis), and as such are appropriate for longer operational hours, including a base load application.

1.4 Study Focus

This study focuses on the resultant air quality impacts of the proposed Stage 2 operations, utilising an ACC system, on the surrounding environment. **Figure 2** illustrates the layout of the Project Site, with the inclusion of the ACC structure. **Table 1** presents the specifications of the ACC structure.

While there are no pollutant emissions to air associated with the ACC system, there is still the potential for the released air to provide enhancement to the release plume of the turbine stacks. Plume enhancement can result in a longer plume life, which can alter local pollution dispersion and vertical plume growth. Consequently, this study will incorporate atmospheric pollution dispersion modelling and vertical plume rise assessment of Stage 2 operations, accounting for the influence of the ACC system.

Figure 2 Revised Layout of Project Site - with Air Cooled Condenser System

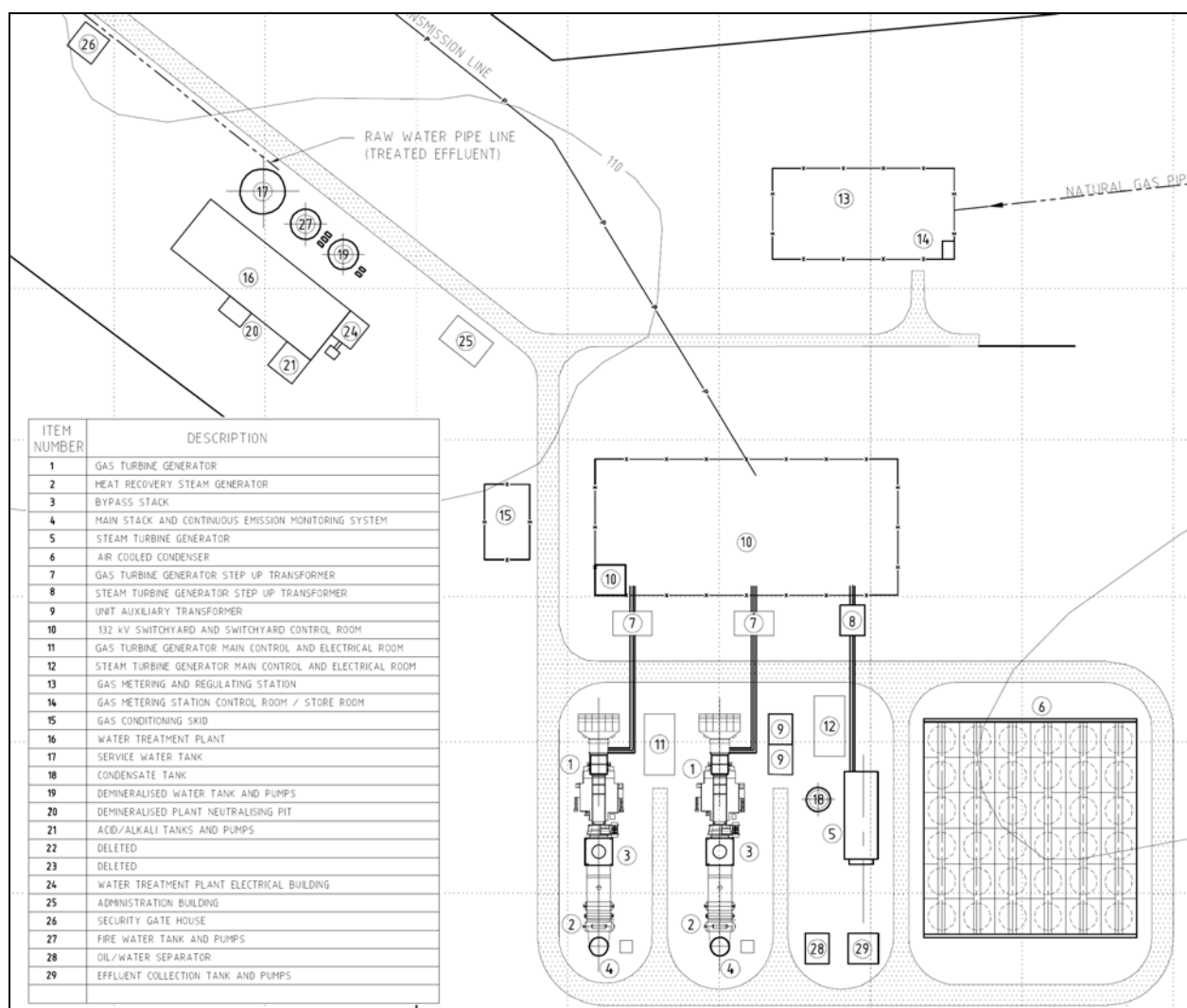




Table 1 Air Cooled Condenser Structure Parameters

Parameter	Value
Number of Release Points	36
Exit Velocity (m/s)	6.14
Exit Diameter (m)	9.14
Exit Temperature (°K)	315.15
Exit Flow Density (kg/m ³)	1.16
Total Area of Structure (m ²)	4900
Centre of Structure (m AMG)	273958 E, 6134892 N



2 PLANT OPERATION

A summary of the main plant proposed for the power facility is given below.

2.1 Gas Turbines

Gas turbines for the proposed project will be fuelled by natural gas. The three primary components of a gas turbine are a compressor, a combustor and a power turbine. The basic process of a gas turbine begins with ambient air being drawn and compressed to higher pressure before admitted into the combustor. In the combustor fuel is injected and combustion occurs at very high temperatures. The resulting mixture of hot gas is admitted into the gas turbine where it expands, converting heat energy from the hot gases into work. The exhaust hot gas is vented into the atmosphere at a suitable height. Some of the work developed by the turbine is used to drive the compressor, while the remaining is available for useful work, which is converted into electricity by the generator coupled to the gas turbine. Typically, more than 50% of the work developed by the turbine section is used to power the compressor.

The gas turbines used for this power facility will be of the stationary type, heavy-duty industrial design, with direct driven generators suitable for use in both open cycle and combined cycle systems (Stage 1 and 2 respectively).

Auxiliary equipment for the gas turbines will be installed onsite. Auxiliary equipment includes inlet air filters and silencers, inlet air evaporative coolers, gas fuel packages, lube oil systems and stacks. The unit and auxiliary equipment would be supplied with a free-standing noise enclosure and silencers.

The gas turbines will use natural gas from the Eastern Gas Pipeline as the fuel source.

To control operational emissions, the gas turbine combustors will use Dry Low Nitrogen Oxide (NO_x) burners. In the event of distillate oil fuelling, the added practice of demineralised water injection into the combustor would be implemented to assist with NO_x emission control. Combustor design is mindful of heat efficiency, which in turn will assist in the reduction of emissions of both Carbon Monoxide (CO) and Volatile Organic Compounds (VOCs).

2.2 Heat Recovery Steam Generators

As part of the progression to Stage 2 of this project, a HRSG will be coupled to each OCGT. The HRSG systems used for this project are natural circulation dual pressure non-reheat units which are compatible with a steam turbine generator.

Exhaust gas from the gas turbine will be routed to the HRSG through insulated ductwork. Heat from the exhaust gas will convert incoming feedwater to steam, which is then piped through to an adjoining steam turbine generator. The exhaust gas is then discharged to atmosphere through the HRSG exhaust stack.

At present no duct firing is included in the design. However, it is assumed that duct firing, if included, will not have a significant impact on the mass emission rates of criteria pollutants discharged through the HRSG exhaust stacks (GHD, 2005). It is noted that installation of HRSG systems will yield a reduction in exhaust stack temperatures and exit velocities. This will have a corresponding effect on atmospheric dispersion of mass emissions from the HRSG exhaust stacks.

2.3 Steam Turbine Generator System

The steam turbine used for this power facility will be of the stationary type, heavy-duty industrial design, with a direct driven generator suitable for the frequent starting and stopping use likely to occur during completed Stage 2 operations.



Steam produced by the HRSG would be directed to the steam turbine via the High Pressure and Low Pressure steam systems. The steam turbine converts thermal energy of steam into shaft work for transformation into electrical energy by the generator. Waste steam would be exhausted to the ACC system.

2.4 Air Cooled Condenser System

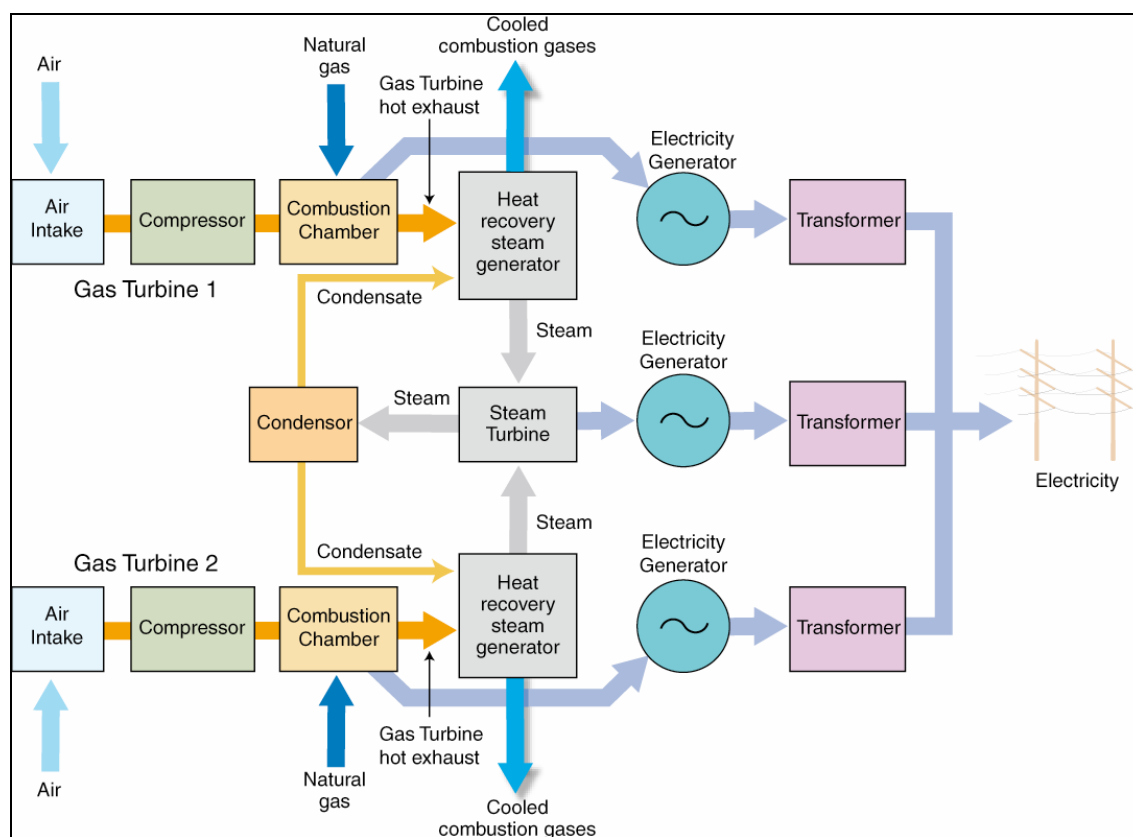
The ACC system is used to condense steam from the turbine exhaust. The ACC does not consume water for cooling. The ACC would be one of the largest structures in the plant, and requires a large footprint to complement its height. The ACC is required to be located closer to the steam turbine building to minimise the steam duct length.

Some of the key advantages of an ACC are that it eliminates the need for a cooling tower, cooling tower make up water, circulating water pumps and piping, cooling water treatment and blowdown treatment/disposal.

2.5 Process Schematic

A summary of the proposed CCGT system, incorporating air cooling, is shown in the schematic detailed in **Figure 3**.

Figure 3 Combined Cycle Gas Turbine Process Schematic



Source: GHD, 2008



2.6 Fuel Supply

2.6.1 Natural Gas

Natural gas has been chosen as the primary source of fuel for the power facility. It will be sourced from the Eastern Gas Pipeline, located approximately 2 km to the east of the site, and will be connected via an underground pipeline.

An onsite gas compound will house a Fuel Gas System that will receive, filter, pre-heat, regulate and supply natural gas to the Gas turbines and HRSG duct burners, if installed, as the main fuel.

The entire Fuel Gas System will be sized based on the maximum continuous gas consumption of the facility. The Fuel Gas System would incorporate an emergency shutdown valve in the gas compound to shut off the fuel supply to the gas turbine in case of fire.

2.6.2 Distillate Oil

While the gas turbines have the potential for use of distillate oil as a secondary fuel, the use of distillate is not considered within the current design layout. Accordingly, air quality impacts attributable to the use of distillate oil as a fuel source have not been addressed further within this document. Any variation from the use of natural gas as the fuel source would therefore require additional assessment.

2.7 Water Supply

Water for the power facility is to be provided by treated effluent supplied from the existing Nowra effluent treatment plant through a dedicated water pipeline. It is anticipated that Reverse Osmosis (RO) would be used to remove dissolved solids from the raw water. Pre filtration would be employed upstream of the RO plant.

RO plant output would be fed into an ion exchange plant and the resultant demineralised water would be used primarily as feedwater for the steam cycle.

2.8 Atmospheric Emissions

The primary pollutants from gas turbine engines are oxides of nitrogen (NO_x) formed by the high temperatures generated in the combustor, carbon monoxide (CO) and volatile organic compounds (VOC) which are formed predominately by the incomplete combustion of fuel. Particulate matter less than 10 microns in aerodynamic diameter (PM_{10}) and sulphur dioxide (SO_2) are emitted in trace to low amounts from gas turbine operations.

Greenhouse gases carbon dioxide (CO_2) nitrous oxide (N_2O) and methane (CH_4) are all produced during gas turbine operation (USEPA, 1995). CO_2 and N_2O are produced during the combustion process, while CH_4 is present in the exhaust gas as unburnt fuel when the fuel is natural gas.

Stack discharges are detailed in **Section 6.4**.

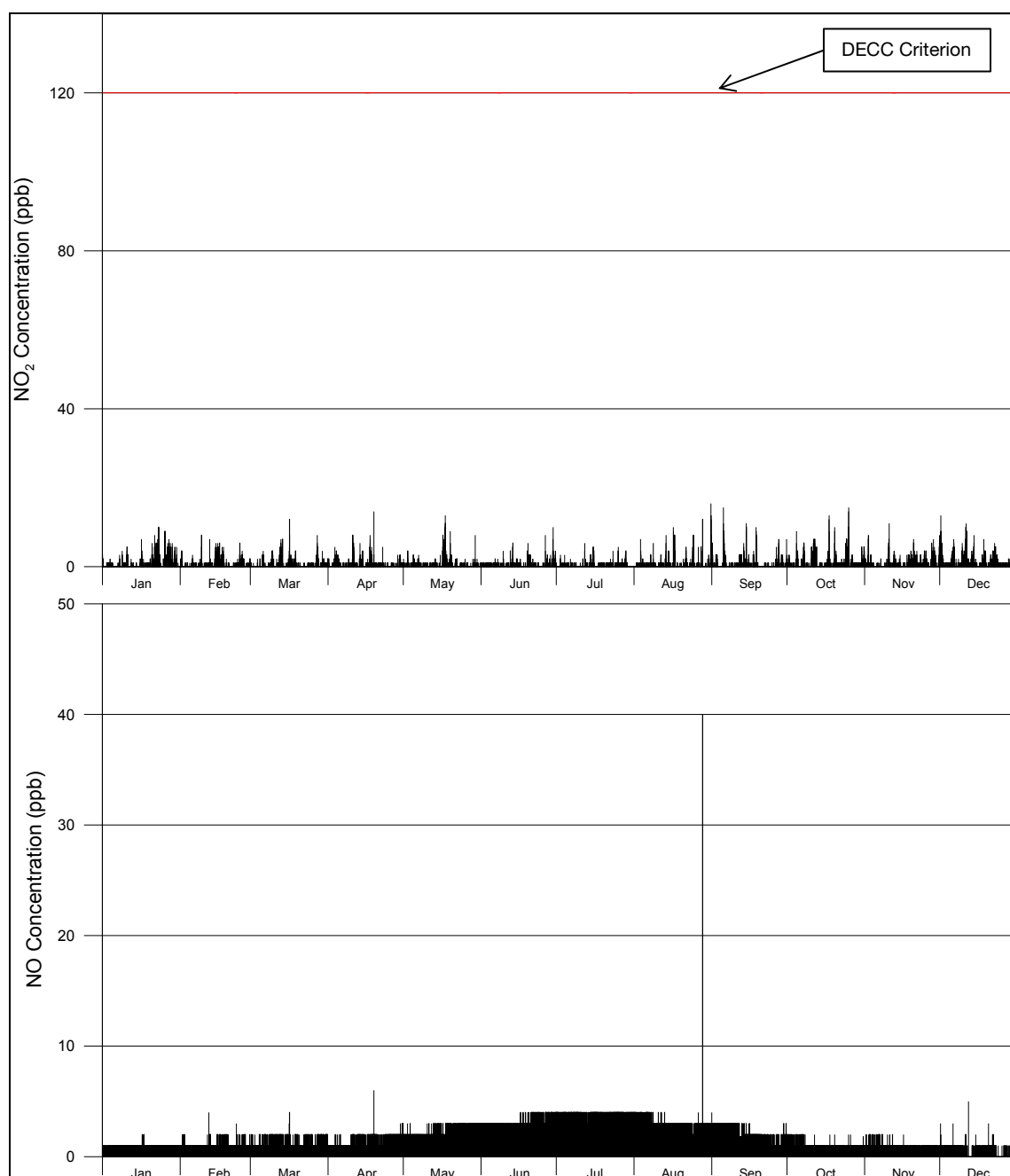


3 EXISTING AIR QUALITY ENVIRONMENT

3.1 Local Monitoring Station Data

An air quality and weather monitoring station was established within the vicinity of the Project Site in 2005 at the Nowra Water Treatment Plant, approximately 1 km to the northwest. The station records ambient concentrations of oxides of nitrogen (NO , NO_2 & NO_x) and a range of weather parameters (wind speed, wind direction, temperature, etc). The monitoring data for nitrogen dioxide (NO_2) and nitrogen oxides (NO_x) recorded during 2006 is presented in **Figure 4**.

Figure 4 1-hour Average NO_2 and NO_x Concentrations - Nowra Water Treatment Plant, 2006





As illustrated in **Figure 4**, the recorded 1-hour average NO₂ concentrations at the Nowra Water Treatment Plant do not exceed the DECC's goal of 120 ppb (246 µg/m³) at any time during 2006. The highest observed concentration was 16 ppb (30.8 µg/m³) which occurred on the 21 November 2006. The annual average NO₂ concentration for 2006 is 0.8 ppb (1.6 µg/m³).

The relationship between NO₂ and NO at the Nowra Water Treatment Plant is illustrated in **Figure 4**. The recorded maximum 1-hour average recorded concentration of NO at the Project Site throughout 2006 was 40 ppb (49.2 µg/m³), occurring on 28 August 2006. The annual average NO concentration during 2006 is 1.8 ppb (2.2 µg/m³).

Analysis of the ratio of NO₂ to NO concentrations at the Nowra Water Treatment Plant was undertaken for all hours in 2006 where concentrations of both pollutants had been recorded. Findings from this analysis are detailed in **Table 2**. It can be seen that on average during 2006, NO concentrations are 1.4 times greater than NO₂ concentrations at the Nowra Water Treatment Plant. This finding is significant since in the dispersion simulations undertaken, measured NO_x concentrations were taken as being representative of background NO₂ levels. From the information provided in **Table 2** it is evident that this would result in a conservative estimate of cumulative NO₂ concentrations occurring as a result of the proposed facility's emissions.

Table 2 Monitored NO₂ - NO_x Relationship - Nowra Water Treatment Plant, 2006

Measure	NO/NO ₂ Ratio
Maximum	5
Average	1.4
Median	1
Minimum	0.1

3.2 NSW Department of Environment and Climate Change Data

The NSW Department of Environment and Climate Change (hereafter, "DECC"), maintains an air quality monitoring station at Albion Park South, located approximately 43 km north-east of the Project Site. The monitoring station is located within Terry Reserve on Hughes Drive, Albion Park and was commissioned in December 2005.

The following air pollutants are measured at the Albion Park South monitoring station:

- Fine particles (PM₁₀);
- Ozone (O₃);
- Oxides of nitrogen (NO, NO₂ & NO_x); and
- Sulphur dioxide (SO₂).

All gravimetric concentrations quoted within this section have been derived based on 25 °C and 1 atmosphere pressure.

3.2.1 Particulate Matter Less than 10 Microns (PM₁₀)

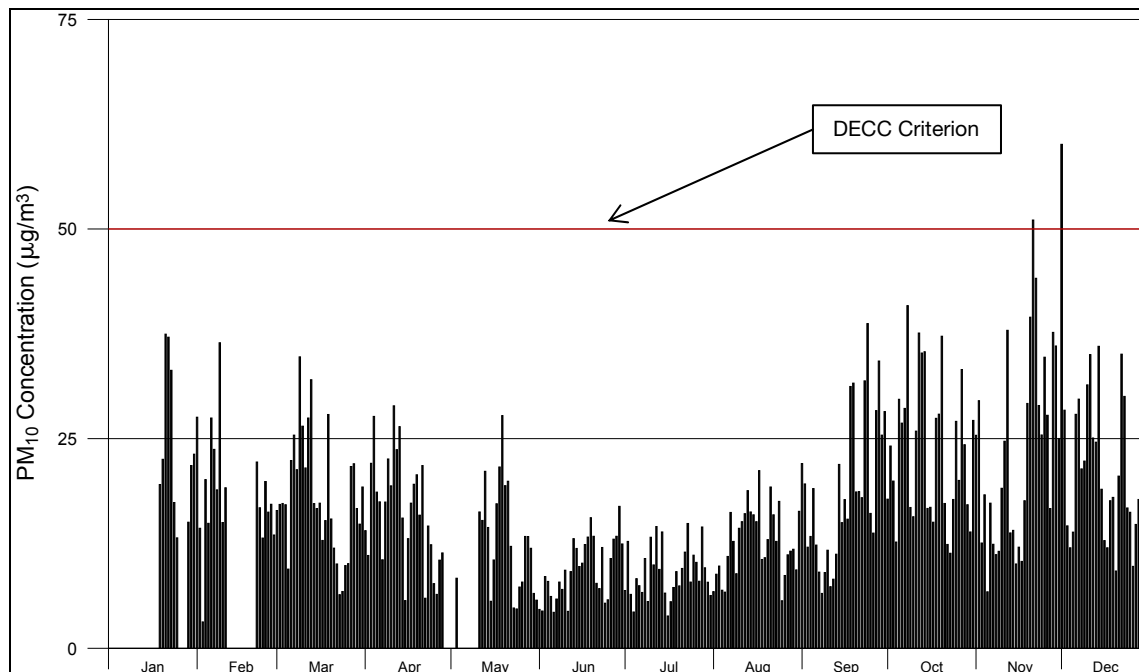
The term "particulate matter" refers to a category of airborne particles typically less than 50 microns (µm) in aerodynamic diameter and ranging down to 0.1 µm in size. Particles less than 10 µm are referred to in this report as PM₁₀.



Ambient concentrations of PM₁₀ are recorded at Albion Park South using a Tapered Element Oscillating Microbalance (TEOM) instrument. This instrument gives real-time recordings of ambient particulate matter, detected by observing changes to the loading on a filter mounted within the unit.

The verified data for 2006, showing 24-hour average PM₁₀ concentrations at the Albion Park South monitoring site, are presented in **Figure 5**.

Figure 5 24-Hour Average PM₁₀ Concentrations - Albion Park South, 2006



As illustrated in **Figure 5**, the recorded 24-hour average PM₁₀ concentrations at Albion Park South exceeded the DECC's goal of 50 µg/m³ twice during 2006. The highest observed concentration was 60.1 µg/m³, occurring on 1 December 2006. A further exceedance (51.1 µg/m³) occurred on 21 November 2006. The highest concentration below the DECC's 24-hour average goal is 44.1 µg/m³, which occurred on 22 November 2006.

It is likely that these exceedances were as a result of an anomalous local or regional event such as a dust storm or bushfire. However, in accordance with the DECC Approved Methods (DECC, 2005), these values have been included in the assessment as it is appropriate to demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of operations at the Project Site.

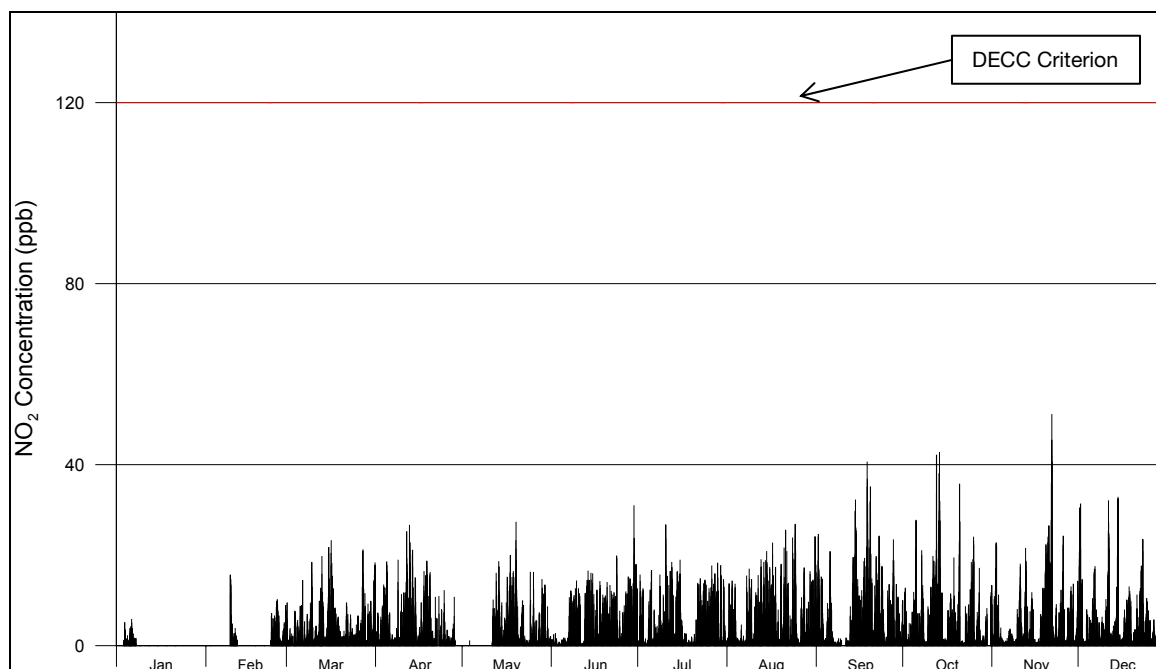
The annual average PM₁₀ concentration for 2006, recorded at the DECC's Albion Park South monitoring site was 17.2 µg/m³.

3.2.2 Nitrogen Dioxide

The 1-hour average concentrations of NO₂ measured at Albion Park South in 2006 are presented in **Figure 6**.



Figure 6 1-hour Average NO₂ Concentrations - Albion Park South, 2006



As illustrated in **Figure 6**, the recorded 1-hour average NO₂ concentrations at Albion Park South did not exceed the DECC's goal of 120 ppb (246 µg/m³) at any time during 2006. The highest observed concentration was 51.2 ppb (96.3 µg/m³) which occurred on the 21 November 2006. The annual average NO₂ concentration for 2006 is 4.8 ppb (9.0 µg/m³) see **Table 3** in **Section 3.5**.

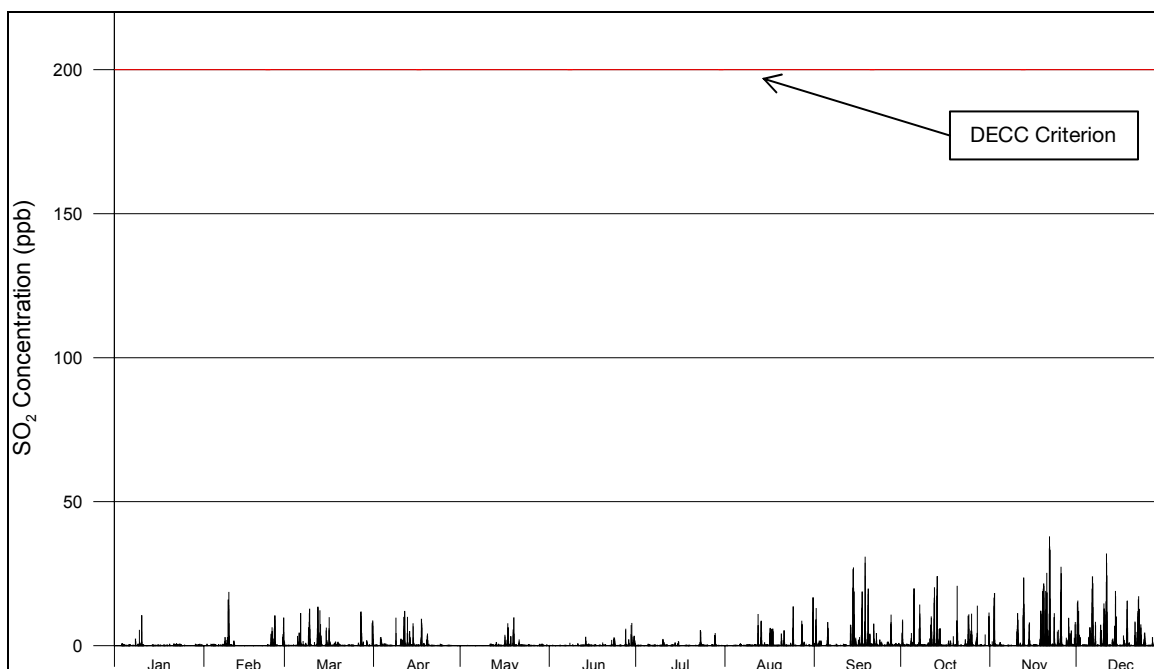
It can be seen that the recorded concentrations of NO₂ at Albion Park South are considerably higher than those recorded at the Nowra Water Treatment Plant (**Figure 4**) during 2006. This would highlight differences between the local airsheds of the two locations and emphasise that any monitoring data adopted from the Albion Park South station is highly conservative in representing the existing air quality environment at the Nowra Water Treatment Plant.

3.2.3 Sulphur Dioxide

The 1-hour average concentrations of SO₂ measured at Albion Park South in 2006 are presented in **Figure 7**.



Figure 7 1-hour Average SO₂ Concentrations - Albion Park South, 2006



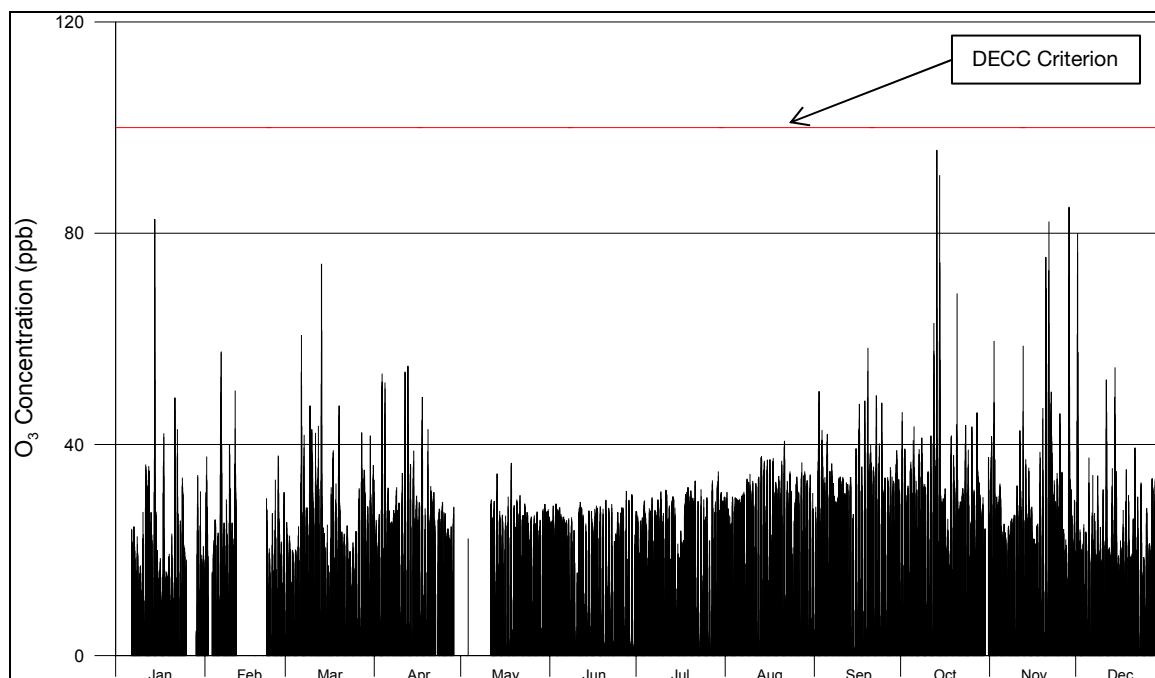
As illustrated in **Figure 7**, the recorded 1-hour average SO₂ concentrations recorded at Albion Park South did not exceed the DECC's goal of 200 ppb (570 µg/m³) at any time during 2006. The highest observed concentration was 34.3 ppb (89.9 µg/m³) which occurred on 21 November 2006. The highest observed 24-hour average concentration was 9.9 ppb (25.9 µg/m³). The annual average SO₂ concentration for 2006 is 0.85 ppb (2.2 µg/m³).

3.2.4 Ozone

The 1-hour average concentrations of O₃ measured at Albion Park in 2006 are presented in **Figure 8**.



Figure 8 1-hour Average O₃ Concentrations, Albion Park South, 2006



As illustrated in **Figure 8**, the recorded 1-hourly average O₃ concentrations recorded at Albion Park did not exceed the DECC's criterion of 100 ppb (196 µg/m³) at anytime throughout 2006. The maximum concentration is 95.7 ppb (188 µg/m³), occurring on 13 October 2006. The annual average O₃ concentration for 2006 is 17.3 ppb (33.9 µg/m³).

3.3 Carbon Monoxide

The closest DECC monitoring station for Carbon Monoxide is located in Wollongong, approximately 63 km from the Project Site. The Wollongong air quality monitoring site is located in the Australian Army Depot on Gipps Street. It is situated in a residential area close to the commercial centre of Wollongong and is at an elevation of 15 metres.

The maximum 1-hour and 8-hour concentrations of CO recorded at Wollongong for 2006 were 2.7 ppm (3.1 mg/m³) and 1.5 ppm (1.7 mg/m³) respectively.

CO in ambient air is usually attributed to vehicular emissions in urban environments. CO is only significant close to source, and is quickly oxidised to carbon dioxide.

Given the semi-rural location of the project site, adopting background concentrations of this pollutant using data from Wollongong may be viewed as highly conservative.

3.4 Inter-Regional Transport of Pollutants

The Metropolitan Air Quality Study (MAQS, 1997), commissioned by the DECC (then NSW EPA) identified that ozone events in the Illawarra region were influenced by aged emissions, consistent with transport of pollutants from Sydney.

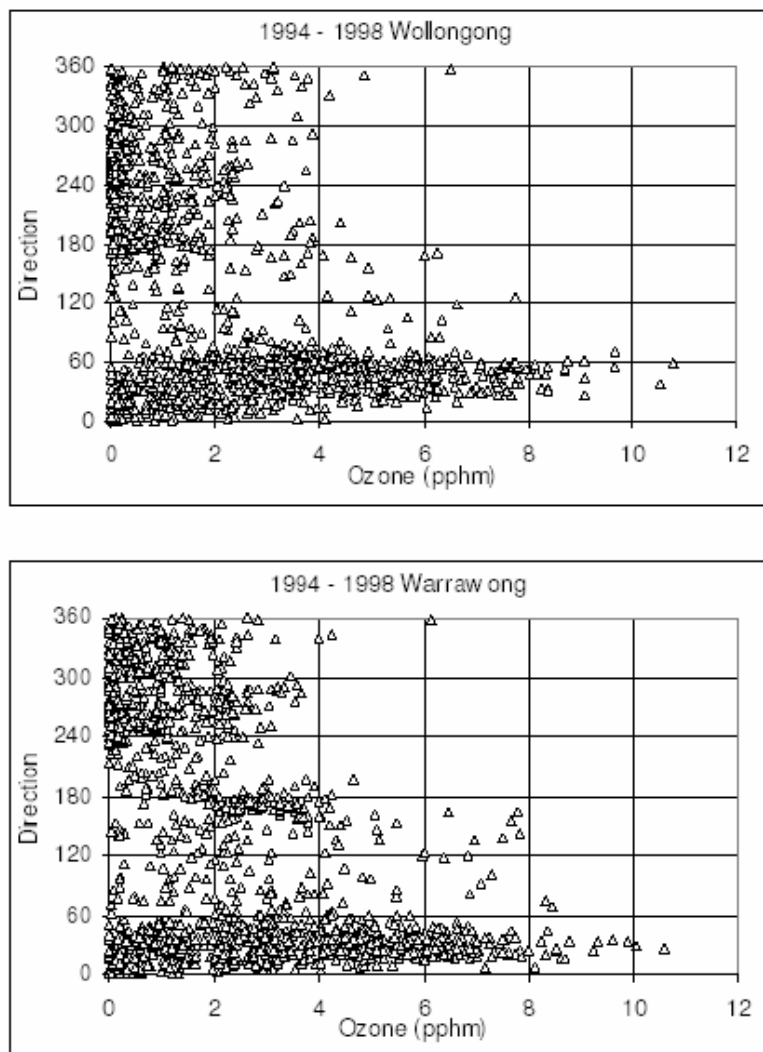
Inter-regional transport between Sydney and the Illawarra can potentially occur as a result of early morning westerly drainage flow transporting emissions offshore from Sydney and subsequently the air parcels moving down the coast towards the Illawarra.



This conclusion has been illustrated through airshed modelling techniques, and verified observationally, as many photochemical smog events in the Illawarra occur under northerly sector gradient winds, indicating that the transport of pollutants from Sydney plays an important role in the air quality to the south.

The relationship between ozone concentration and wind direction observed at both the Wollongong and Warrawong DECC monitoring stations has been investigated (Hyde et al, 2002) and is shown in **Figure 9**.

Figure 9 Variation of Ozone Concentration and Wind Direction at Wollongong and Warrawong, 1994 - 1998



Source: Hyde R, Azzi M and Cope M, (2003). "Simulating Environmental Chamber Experiments with Photochemical Models", Proceedings of the 16th International Clean Air Conference & Environment Conference, Christchurch 2002.

Figure 9 indicates that the majority of elevated ozone events (those above 40 ppb) are clustered around northeasterly / north-northeasterly wind directions. Results of this investigation are thus consistent with aged photochemical smog being transported into the area from source regions in the north.



The impact of inter-regional transport of photochemical precursors from the Sydney airshed to the project site is addressed further in **Section 7.5**.

Finally, it is noted that the MAQS study concluded that inter-regional transport of pollutants may also occur from the southern regions (Illawarra) to the Sydney airshed when gradient winds have a southerly component.

However, this should be put in context, as emissions of photochemical smog precursors (VOC and NO_x) are an order of magnitude higher within the Sydney region (MAQS, 1997) than in the Illawarra.

Accordingly, and in view of the anticipated high level of atmospheric dispersion during inter-regional transport to the north, impacts of the proposed power facility on the Sydney airshed have not been considered further.

3.5 Background Air Quality for Assessment Purposes

Section 5.1.3 of the NSW DECC document, “Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales”, August 2005 (hereafter, “the Approved Methods”) notes that in some locations, existing ambient air pollutant concentrations may exceed the impact assessment criteria from time to time.

In this instance (applicable to **Section 3.2.1**– PM₁₀), an impact assessment should demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of the proposed activity.

In view of the foregoing, the background air quality levels adopted for this assessment of the Bamarang site are summarised in **Table 3**.

Table 3 Background Air Quality Environment for Assessment Purposes

Air Quality Parameter	Averaging Period	Maximum Background Concentration ¹	Monitoring Data Location
PM ₁₀	24-Hour	44.1 µg/m ³	Albion Park South
	Annual	17.2 µg/m ³	
NO ₂	1-Hour	16 ppb (30.1 µg/m ³)	Nowra Water Treatment Plant
	Annual	0.8 ppb (1.6 µg/m ³)	
SO ₂	1-Hour	38 ppb (99.6 µg/m ³)	Albion Park South
	24-Hour	9.6 ppb (25.1 µg/m ³)	
	Annual	0.8 ppb (2.2 µg/m ³)	
Photochemical Oxidants (as O ₃)	1-Hour	95.7 ppb (188 µg/m ³)	Albion Park South
	Annual	17.3 ppb (33.9 µg/m ³)	
CO	1-Hour	2.7 ppm (3.1 mg/m ³)	Albion Park South
	8-Hour	1.5 ppm (1.7 mg/m ³)	

Note 1: All gravimetric concentrations quoted within this section have been derived based on 25 °C and 1 atmosphere pressure

3.5.1 Parameterisation of R_{smog}

The photolytic rate at which new smog will be produced is determined by sunlight intensity and the value of R_{smog}, a photolytic rate coefficient. Values of R_{smog} for ambient air are related to the emissions of VOC.

Typical values of R_{smog} used in other assessments of photochemistry using the TAPM model are summarised in **Table 4**.



Table 4 Typical values of R_{smog} used in TAPM Photochemistry Assessments

Project	R_{smog} Value Selected (ppb)	Comment
Urban Airshed Modelling in Melbourne, Hurley et al, 2002	0.7	Modelling representative of an urban environment dominated by vehicle emissions
Verification Study: Air Pollution Modelling in the Pilbara, Hurley 2005	0.2	Modelling representative of coastal towns in WA, combined with heavy industry (power facility and LNG plant)
AirTrak Monitoring in Rocklea, SE QLD, (50 th percentile value), QLD EPA, 2003	0.7	Monitored value representative of air quality influenced by arterial roads in Greater Brisbane.
Burrup Peninsula, Physick et al. (2002)	0.1	Modelling representative of sources emitting into an almost pristine background environment. Anthropogenic area sources are associated with a few hundred people.
TAPM simulations for Brisbane, Ischtwan, 2002	0.8	Modelling representative of the airshed of Australia's third largest city, representative of higher ambient temperatures.

Table 4 implies that the appropriate value for background R_{smog} in a TAPM simulation is proportional to the population in the modelled region.

In the absence of local/regional VOC monitoring data, the NO_2 modelling within this assessment has been conducted using an ambient value R_{smog} value of 0.5 ppb. This value was selected as a conservative value, and has been derived from analyses of airmass reactivity in the Illawarra (Hyde et al, 2002) and is consistent with the information within **Table 4**.



4 AIR QUALITY GOALS AND RELEVANT APPROVALS

As discussed in **Section 2**, the air quality parameters of interest in this Assessment are NO_x (as NO₂), SO₂, CO, and particulates (expressed as PM₁₀ and dust deposition - construction phase only).

This section outlines the criteria applicable to these pollutants and the relevant (air quality) approvals required for the proposal. **Appendix A** details the potential health impacts associated with the relevant air pollution parameters.

4.1 NSW DECC Air Quality Impact Assessment Criteria

The NSW DECC has established ground level air quality criteria for key air pollutants to achieve appropriate environmental outcomes and to minimise associated risks to human health. The criteria specified by DECC, as expressed in the Approved Methods, for NO₂, SO₂, O₃ and CO are outlined in **Table 5**.

Table 5 DECC Air Quality Criteria - NO₂, SO₂, O₃ and CO

Pollutant	Averaging Time	Maximum Concentration	
		Gravimetric	Volumetric
Nitrogen dioxide (NO ₂)	1 hour	246 µg/m ³	120 ppb
	Annual	62 µg/m ³	30 ppb
Sulphur Dioxide (SO ₂)	10 minutes	712 µg/m ³	250 ppb
	1 hour	570 µg/m ³	200 ppb
	24 hours	228 µg/m ³	80 ppb
	Annual	60 µg/m ³	20 ppb
Photochemical oxidants (as ozone - O ₃)	1 hour	214 µg/m ³	100 ppb
	4 hours	171 µg/m ³	80 ppb
Carbon Monoxide (CO)	15 minutes	100 mg/m ³	87 ppm
	1 hour	30 mg/m ³	25 ppm
	8 hours	10 mg/m ³	9 ppm

4.2 National Environment Protection Measure

In June 1998, the National Environment Protection Council (NEPC) of Environment Ministers agreed to set uniform health standards for ambient air quality to apply to all States and Territories. These standards are contained in the National Environment Protection Measure (NEPM) for ambient air quality. These NEPM goals were developed by the NEPC to be achieved within 10 years of commencement.

NEPM standards for pollutants relevant to the project area are summarised in **Table 6**.



Table 6 National Environment Protection Measure (NEPM) Ambient Air Quality Goals

Pollutant	Averaging Time	Maximum Concentration		Maximum Allowable Exceedances
Nitrogen dioxide (NO ₂)	1 Hour	230 µg/m ³	0.12 ppm	1 day per year
	Annual	60 µg/m ³	0.03 ppm	None
Sulphur Dioxide (SO ₂)	1 Hour	520 µg/m ³	0.2 ppm	1 day per year
	24 Hours	210 µg/m ³	0.08 ppm	1 day per year
	Annual	50 µg/m ³	0.02 ppm	None
PM ₁₀	24 Hours	50 µg/m ³		5 days per year
CO	8 Hours		9.0 ppm	1 day per year

It is noted that the NEPM goals have been developed with the intention of assessing regional air quality and accordingly are not intended as impact assessment criteria.

4.3 Criteria Applicable to Particulate Matter Less than 10 Microns (PM₁₀)

Emissions of PM₁₀ are considered important pollutants in terms of impact due to their ability to penetrate into the respiratory system. Recent health research has shown that this penetration can occur deep into the lungs. Potential adverse health impacts associated with exposure to PM₁₀ include increased mortality from cardiovascular and respiratory diseases, chronic obstructive pulmonary disease and heart disease, and reduced lung capacity in asthmatic children.

One of the difficulties in dealing with air quality criteria governing fine particles such as PM₁₀ is that the medical community has not been able to establish a threshold value below which there are no adverse health impacts.

The NSW DECC PM₁₀ impact assessment criteria, as expressed in the Approved Methods, are:

- A 24-hour maximum of 50 µg/m³.
- An annual average of 30 µg/m³.

The 24-hour PM₁₀ reporting standard of 50 µg/m³ is numerically identical to the equivalent NEPM reporting standard except that the NEPM reporting standard allows for five exceedances per year.

4.4 Criterion Applicable to Total Suspended Particulate (TSP)

The annual goal for Total Suspended Particulate (or TSP) is given as 90 µg/m³, as recommended by the National Health and Medical Research Council (NHMRC) at their 92nd session in October 1981. It was developed before the more recent results of epidemiological studies suggested a relationship between health impacts and exposure to PM₁₀ concentrations.

Since in areas where vehicle traffic is not the dominant source of particulate the PM₁₀ particle size fraction is typically of the order of 50% of the TSP mass, the goal is consistent with an annual PM₁₀ goal of approximately 45 µg/m³. Thus, the historical NHMRC goal may be regarded as not as stringent as the newer PM₁₀ goal of 30 µg/m³ expressed as an annual average.

Therefore, as the annual TSP goal is seen to be achieved if the annual PM₁₀ goal is satisfied, TSP has not been considered further in this report.



4.5 Nuisance Impacts of Fugitive Emissions

The preceding sections are concerned with the health impacts of particulate matter. Nuisance impacts also need to be considered, mainly in relation to dust. In NSW, accepted practice regarding the nuisance impact of dust is that dust-related nuisance can be expected to impact on residential areas when annual average dust deposition levels exceed 4 g/m²/month.

Table 7 presents the NSW DECC impact assessment criteria for dust fallout, showing the allowable increase in dust deposition level over the ambient (background) level which would be acceptable so that dust nuisance could be avoided.

Table 7 DECC Criteria for Allowable Dust Deposition

Averaging Period	Maximum Increase in Deposited Dust Level	Maximum Total Deposited Dust Level
Annual	2 g/m ² /month	4 g/m ² /month

Source: NSW DECC, "Approved Methods & Guidance for the Modelling and Assessment of Air Pollutants in NSW", August 2005.

4.6 Project Air Quality Goals

In view of the foregoing, the air quality goals adopted for this assessment, which conform to current DECC air quality targets and other relevant air quality criteria, are summarised in **Table 8**.

Table 8 Project Air Quality Goals

Pollutant	Averaging Time	Maximum Concentration		Reference
		Gravimetric	Volumetric	
Nitrogen dioxide (NO ₂)	1 hour	246 µg/m ³	120 ppb	DECC
	Annual	62 µg/m ³	30 ppb	
Sulphur Dioxide (SO ₂)	10 minutes	712 µg/m ³	250 ppb	DECC
	1 hour	570 µg/m ³	200 ppb	
	24 hours	228 µg/m ³	80 ppb	
	Annual	60 µg/m ³	20 ppb	
Photochemical oxidants (as ozone - O ₃)	1 hour	214 µg/m ³	100 ppb	DECC
	4 hours	171 µg/m ³	80 ppb	
Carbon Monoxide (CO)	15 minutes	100 mg/m ³	87 ppm	DECC
	1 hour	30 mg/m ³	25 ppm	
	8 hours	10 mg/m ³	9 ppm	
PM ₁₀	24 hours	50 µg/m ³	N/A	DECC/NEPM
	Annual	30 µg/m ³		
Dust Deposition	Annual	4 g/m ² /month #	N/A	DECC

Note: # Assumes background dust deposition of the order of 2 g/m²/month.

4.7 Relevant Approvals

In addition to ground level concentration criteria detailed above, additional criteria apply to maximum in-stack concentrations as set out under the "Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2005" (the "Regulation"). This regulation is made under the Protection of the Environment Operations Act 1997 (POEO Act).



The Regulation sets emission-based limits to control the impact of industry on ambient air quality. These limits apply at the point of discharge (ie at the top of the stack) and apply to all large industries as listed in Schedule 1 of the *Protection of the Environment (Operations) Act 1997 (POEO)*.

Schedule 1 of the POEO Act defines scheduled activities and states a scheduled activity to be:

“Electricity generating works (including associated water storage, ash and waste management facilities) that:

(1) supply or are capable of supplying more than 30 megawatts of electrical power from energy sources (including coal, gas, bio-material or hydro-electric stations), but not including from solar powered generators, or

(2) are within the metropolitan area of Sydney, Newcastle and Wollongong (being the area bounded by and including the local government areas of Newcastle, Maitland, Singleton, Hawkesbury, Blue Mountains, Wollondilly, Wollongong, Shellharbour and Kiama) and incorporate electricity generating plant (other than emergency standby plant that operates for less than 200 hours per year) and are based on or use:

(a) gas turbines, which burn or are capable of burning, in the aggregate, fuel at a rate of more than 20 megawatts on a net thermal energy basis, or

(b) internal combustion piston engines, which burn or are capable of burning, in the aggregate, fuel at a rate of more than 3 megawatts on a net thermal energy basis”.

As the activity would operate after 1 September 2005, it belongs in Group 6 of scheduled activities.

The Regulation standards for pollutants relevant to the proposed facility are summarised in **Table 9**

Table 9 POEO (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2005 Maximum in-stack Pollutant Concentrations

Pollutant	Maximum in-stack concentration
NO ₂	70 mg/m ³

In stack concentrations are designed to comply with these Regulation guidelines, and are addressed in **Section 7.7**.



5 SITE METEOROLOGY

5.1 Climate Averages

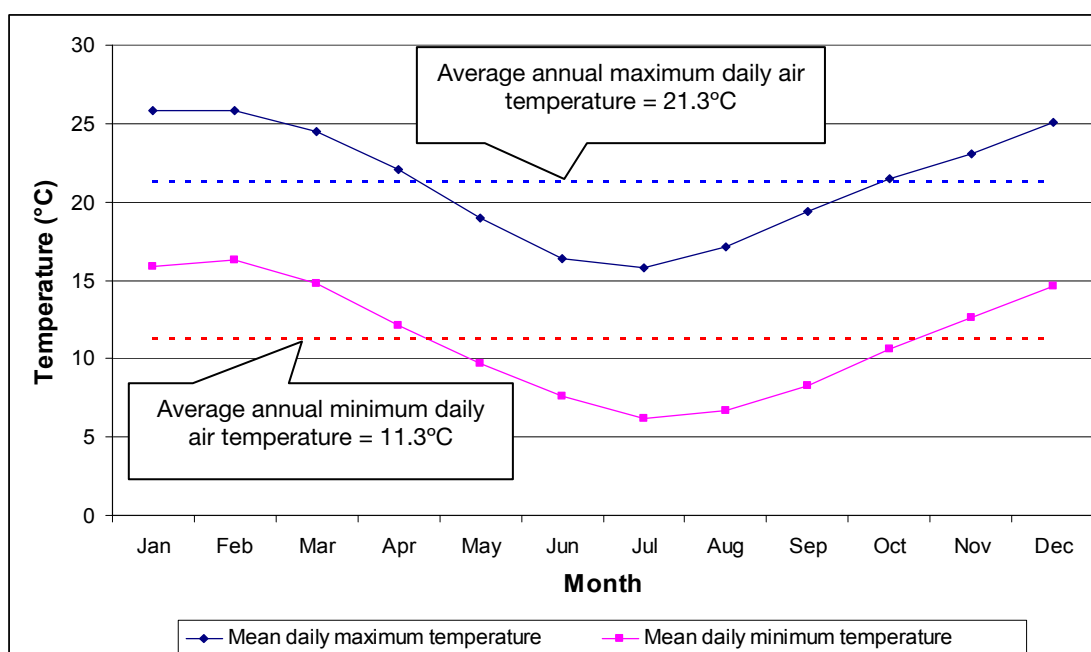
The nearest Bureau of Meteorology (BoM) monitoring site to the project site is located within the Nowra Royal Australian Navy (RAN) Air station, located 4 km to the southwest of the site. Climatic averages are available since records began in 1942 until 2000.

A detailed summary of the climatic average observations for this monitoring site is presented in **Appendix B**.

5.1.1 Air Temperature

A graph displaying the monthly fluctuations in mean daily minimum and mean daily maximum temperatures at Nowra RAN Air station is shown in **Figure 10**.

Figure 10 Mean Daily Air Temperature Measurements, Nowra RAN Air Station



It can be seen from **Figure 10** that the temperature in the vicinity of the site may be described as mild in nature.

Air temperatures during the day tend to be cool to mild, varying from 15.8 °C-17.1 °C in winter, to 25.1 °C-25.8 °C in summer. Air temperatures during the night tend to be cool to mild, varying from 6.2 °C-7.6 °C in winter to 14.6 °C-16.3 °C in summer.

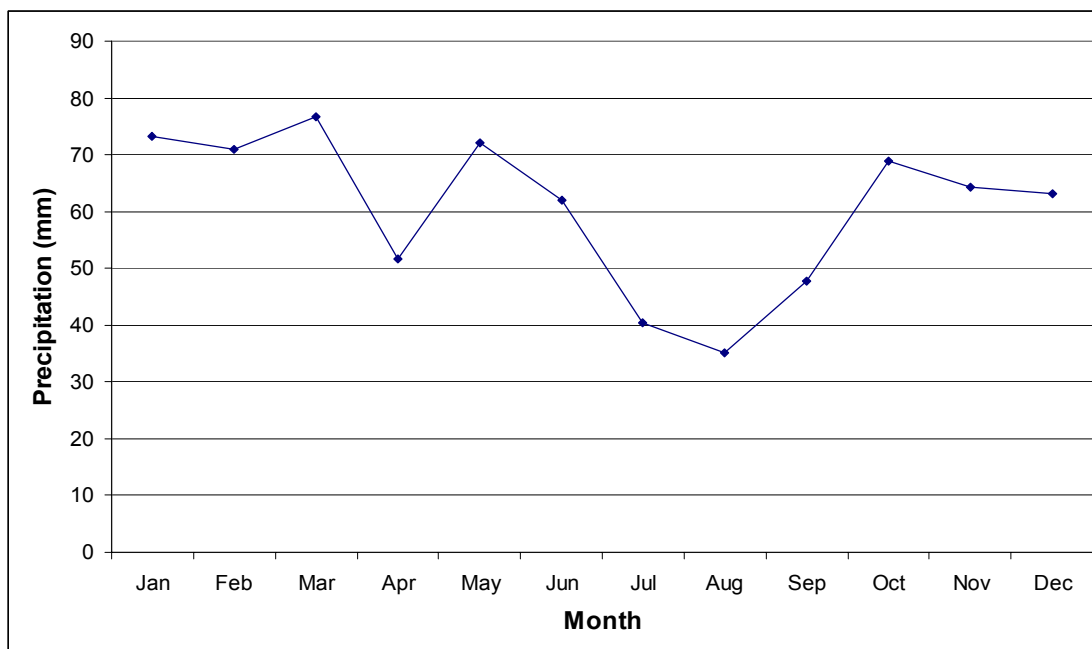
The average annual maximum daily air temperature is 21.3 °C, and the average annual minimum daily air temperature is 11.3 °C.



5.1.2 Rainfall

A graph displaying the median (5th decile) monthly rainfall at Nowra RAN Air Station is shown in **Figure 11**.

Figure 11 Median (5th decile) Monthly Rainfall Measurements, Nowra RAN Air Station



The rainfall experienced at Nowra RAN Air Station can be described as moderate, with the area receiving, on average, approximately 1093 mm per annum. Rainfall at Nowra RAN Air Station is relatively uniform in nature, with a slight decrease in rainfall during winter.

Rainfall has a significant effect on the way in which particles behave in the atmosphere, and hence the way in which pollution is dispersed. When rainfall occurs, pollutants are flushed out of the atmosphere quickly, thus reducing potential nuisance impacts, as well as those on health and visibility.

5.1.3 Relative Humidity

The relative humidity of Nowra RAN Air Station can be described as medium to high. The mean 9am and 3pm relative humidity is 70% and 58% respectively, with little variation occurring between seasons.

5.2 Prevailing Dispersion Meteorology

5.2.1 Wind Regime

As detailed in **Section 3.1**, an air quality and weather monitoring station has been established nearby to the Project Site at the Nowra Water Treatment Plant. Additionally, the closest BoM station is situated at the Nowra RAN Air station, located 4 km to the southwest of the site.



Summaries of the 2006 annual wind behaviour for the project site area as wind roses are included in **Appendix B**. These wind roses are representative of the meteorological input files used in the atmospheric dispersion modelling, and display occurrences of winds from all quadrants. The annual and seasonal wind roses for the Nowra RAN Air Station are also included in **Appendix B** for comparison with the locally recorded data.

The prevailing annual wind directions and average wind speeds for each monitoring station is summarised in **Table 10**.

Table 10 Summary of Annual Wind Behaviour about Project Site by Station

	Nowra Water Treatment Plant	Nowra RAN BoM
Dominant Wind Direction	SW-W	W-WNW and S
Average Wind Speed (m/s)	1.2	3.4
Frequency of Calms (%)	20.7	4.9

5.2.2 TAPM-Generated Meteorology

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

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

The TAPM model also allows for the assimilation of wind observations to be optionally included in a model simulation. The wind speed and direction observations are used to “nudge” the predicted solution towards the observation values.

For this assessment, TAPM was used to generate a complete 2006 meteorological data set for the project site, incorporating hourly observations recorded at both the Nowra Water Treatment Plant weather station and the Nowra RAN Air Station BoM monitoring site. The 2006 data set is consistent with the background air quality data compiled for the assessment.

5.2.3 TAPM-Generated Meteorology – Atmospheric Stability and Mixing Depth

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth’s surface, either through the retardation of flow due to the frictional drag of the earth’s surface, or as result of the heat and moisture exchanges that take place at the surface (Stull, 1997; Oke, 2003). During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth’s surface and the extension of the mixing layer to the lowest elevated subsidence inversion. Elevated inversions may occur for a variety of reasons including anticyclonic subsidence and the passage of frontal systems.

Radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential. The mixed layer thus ranges in depth from a few metres (i.e. stable or neutral layers) during night-times to the base of the lowest-level elevated subsidence inversion during unstable, daytime conditions.



For elevated releases, the highest ground level concentrations frequently occur during unstable, daytime conditions when the plume is “brought to ground”. In contrast, the highest concentrations for ground level non-wind dependent releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Turner assignment scheme identifies six Stability Classes, “A” to “F”, to categorise the degree of atmospheric stability. These classes indicate the characteristics of the prevailing meteorological conditions and are used as input into various air dispersion models (**Table 11**).

Table 11 Description of atmospheric stability classes

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

The frequency of each stability class at the Bamarang site is presented in **Figure 12**. The seasonal stability class distributions are included in **Appendix B**.

The results indicate a high frequency of conditions typical to Stability Class “D” throughout the year at the Bamarang site. Stability Class “D” is indicative of neutral conditions, which neither enhance nor inhibit plume dispersion.

The second highest frequency of occurrence is for Stability Class “F” conditions. Such highly stable conditions provide a low potential for atmospheric dispersion of pollutants due to a low level of vertical mixing.

Diurnal variations in maximum and average mixing depths forecast by TAPM at the Project Site during 2006 is illustrated in Figure 13. It can be seen that an increase in the mixing depth during the morning, arising due to the onset of vertical mixing following sunrise, is apparent with maximum mixing heights occurring in the mid to late afternoon, due to the dissipation of ground-based temperature inversions and the growth of the convective mixing layer.



Figure 12 TAPM-Predicted Annual Stability Class Distributions for Bamarang site, 2006

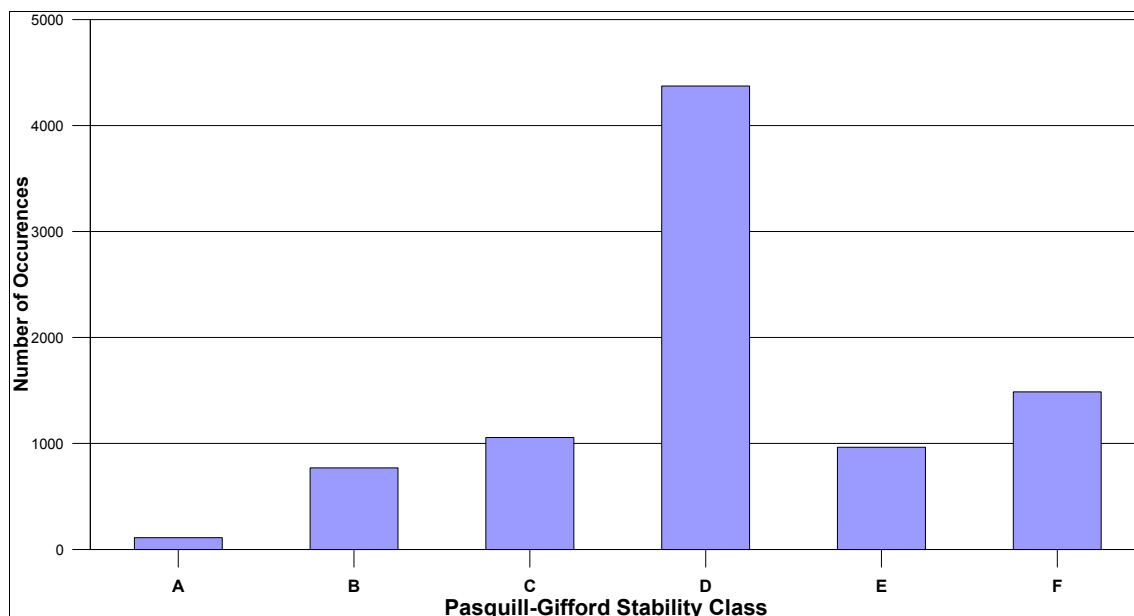
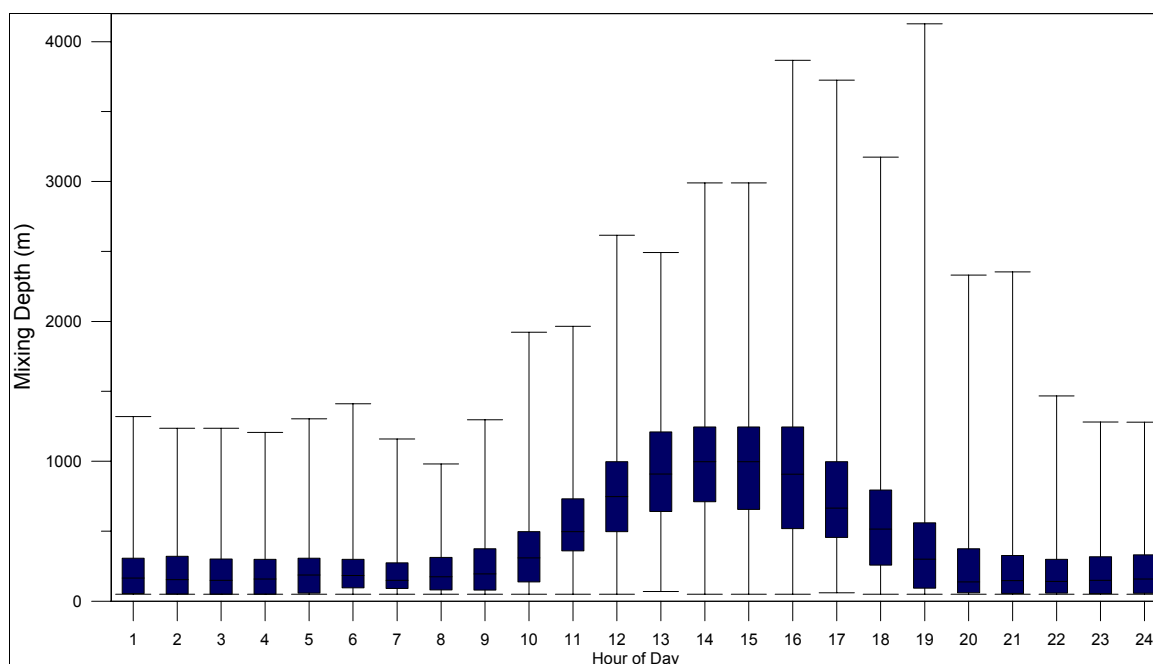


Figure 13 TAPM-Predicted Diurnal Variation in Mixing Depth at the Project Site, 2006





6 DISPERSION MODELLING

6.1 Methodology

TAPM (v3.0) is a prognostic model which may be used to predict three-dimensional meteorology and air pollution concentrations with no local meteorological data inputs required.

Such a complex and computationally intensive model is required to simulate chemical transformation of stack emissions and influences of relatively complex terrain that would not be accounted for using a conventional Gaussian model (such as Ausplume).

Given that the location of the proposed site is approximately 20 km inland, coastal recirculation is not anticipated to play a major role in atmospheric dispersion of pollutants from the proposed power facility. However, TAPM is known to accurately account for any such influences.

TAPM reflects local topographical influences by drawing on terrain databases and is thus able to simulate the impacts of local topography on atmospheric dispersion.

The TAPM model has been run in chemistry mode, and as such accounts for the photochemistry that will drive the formation / destruction of nitrogen dioxide. In chemistry mode, gas-phase photochemistry is based on the semi-empirical mechanism called the Generic Reaction Set of Azzi et al. (1992), with a hydrogen peroxide modification (Hurley, 2005).

The following parameters were used in the TAPM model for stack emissions associated the operation of the proposed power facility.

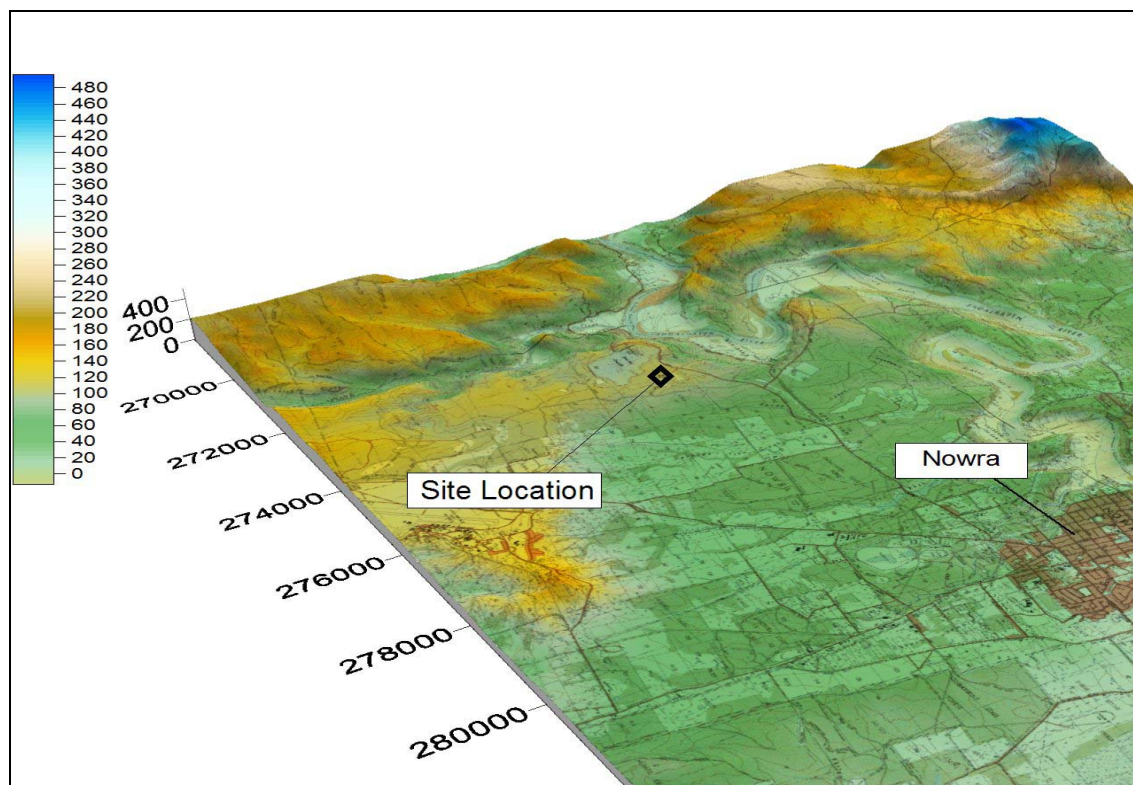
- TAPM was used in a nested mode, consisting of 20 × 20 × 20 grid points, and 30 km, 10 km, 3 km, 1 km and 300m spaced horizontal grids for meteorology, and with 41 × 41 × 25 grid points and 15 km, 5 km, 1.5 km and 0.5 km spaced horizontal grids for pollution. Note that the area covered by each pollution grid is slightly less than the area of the corresponding meteorological grid. In this way, the pollution grids avoid the boundary regions of the nested meteorological grids, where spurious vertical velocities can sometimes occur.
- The Pollution Input of the TAPM software has been run using the Lagrangian Particle Module (LPM), to conservatively assess ground level concentrations at near field receptors. While it is noted that this mode is computationally intensive, this is theoretically the most accurate approach for predicting near-source maximum ground level concentrations (Hurley, 2005).
- An hourly varying background concentration file, incorporating measured concentrations of NO_x (from Nowra Water Treatment Plant air quality station), PM₁₀, O₃ and SO₂ (from Albion Park South DECC station) has been used as input into TAPM during chemistry mode in order to accurately simulate the transformation of NO_x to NO₂. It is noted that the background file is used by TAPM as boundary inflow at the outermost grid of the computations. Additionally, it should be noted that modelling has assumed a high level of photochemical reactivity for the region (background R_{smog} equal to 0.5 ppb).

6.2 Topography and Land Use

The Bamarang site is located on relatively flat terrain, with a slight gradient present running along the site's north-northwest to south-southeast axis. The site lies at an elevation of between 100m and 110m AHD. **Figure 14** shows the topography of the region surrounding the Project Site.



Figure 14 Regional Topography Surrounding the Project Site -
Vertical exaggeration of 2



As discussed in **Section 1.2**, the proposed site at Bamarang is bounded by Bamarang Nature Reserve and Crown Land, both of which represent a majority land cover type of mid-density forest.

TAPM v3.0 enables the user to edit the preset land cover type for any grided area to increase the accuracy of the meteorological modelling. Following a site inspection and analysis of regional aerial photographs, the land cover type at 300m model grid resolution was altered to reflect mid-density forest to the south of the site, and to include the Bamarang Dam water body to the west of the site.

6.3 Nearest Sensitive Receptors

The NSW DECC defines a sensitive receptor as a location where people are likely to work or reside, including dwellings, schools, hospitals, offices or public recreational areas (the Approved Methods, 2005).

The proposed site at Bamarang is located 8 km to the south-west of Nowra, a regional centre of the Shoalhaven Local Government Area. The nearest potentially affected residential properties are summarised in **Table 12** including property name, dwelling locations and coordinates.



Table 12 Nearest Potentially Affected Residential Dwellings and other Property types

Receptor ID	Property Name	Description	AMG Dwelling Coordinates	
			East (m)	North (m)
R1	“Bundanon”	2.6 km north east of proposed site	271728	6136340
R2	Water Treatment Plant	1.3 km west north-west of proposed site	272710	6135389
R3	Bamarang Bush Cabins	1.2 km north north-east of proposed site	273436	6136080
R4	“Katalives”	1.8 km north of proposed site	274343	6136620
R5	“Mundamia” Properties	2.3km west north-west of proposed site	275993	6135903
R6	“Lot 7” Gannet Road	1.8 km south west of proposed site	275018	6133615

The “Lot 7” Gannet Road property has been selected as representative of the residences of Gannet Road and Stringybark Road, the two closest streets to south west of the Project Site.

In the same way, the Bamarang Bush Cabins have been selected as the representative property for the residential dwellings located along Bamarang Road.

6.4 Stack Exit Parameters and Pollutant Emission Rates

Atmospheric dispersion modelling has been used to assess the impacts of proposed Stage 2 activities on the surrounding environment. Stack emission parameters are dependant upon the ambient temperature during the period of operation.

It is noted that the Stage 2 stack parameters, particularly with regard to stack release area and velocity, have altered since the original AQIA report conducted by Heggies in 2005. A summary of the full-load exit parameters are given in **Table 13**.

Table 13 Full Load Stack Exit Parameters

Stack Parameter	East and West HRSO Exhaust Stacks			
Description	Exhaust stack servicing the Eastern Gas Turbine, operating in Combined Cycle mode. Combustion gases passed through the Heat Recovery Steam Generator prior to exhaust			
Location (Easting, Northing)	273812		273851	
	6134875		6134869	
Height (m)	40		40	
Diameter (m)	6.7		6.7	
Area (m ²)	35.3		35.3	
Exit Temperature (K)	398		398	
	Ambient Temperature			
	273	288	298	313
Exit Temperature (K)	398	422	416	406
Flow Rate (Nm ³ /s)	392	372	360	339
Flow Rate (Am ³ /s)	572	575	548	503
Exit Velocity (m/s)	16.0	16.2	15.5	14.2



Considering the information above, to simulate “worst-case” release parameters, stack exit parameters corresponding to an ambient temperature of 273 K (0°C) have been used in dispersion modelling.

Stack emission rates for key atmospheric pollutants (NO_x, CO and unburnt hydrocarbons (UHC)) for project stages were provided by the technical design team (Pers. Comm. GHD). As with the stack parameters, these emission rates are temperature dependant and are presented in **Table 13**.

Information from the technical design team indicates that operational emissions of SO₂ and PM₁₀ are anticipated to be negligible.

However, to predict “worst-case” conditions, an emission rate for SO₂ has been derived based on sulphur content limits for natural gas of 50 mg/Nm³. An emission rate for particulate has been derived based on vendor maximum of 10 kg/hour for a gas fired turbine (URS, 2001). Both of these emission rates may be regarded as conservatively high.

Table 14 Variable Stack Emission Rates with Ambient Temperature

Atmospheric Pollutant	Ambient Temperature			
	273	288	298	313
Particulate Matter ¹ (g/s)	2.8	-	-	-
Sulphur Dioxide (g/s)	0.5	-	-	-
Oxides of Nitrogen (g/s)	18.3	17.2	16.7	15.6
Carbon Monoxide (g/s)	4.4	4.2	4.2	3.9
Unburnt Hydrocarbons (g/s)	1.7	1.7	1.7	1.4

Note 1 Particulate Matter refers to Total Particulate, and not the PM₁₀ size fraction in this instance. For modelling purposes, however, all Particulate Matter has been assumed to be PM₁₀.

It is noted that emission rates are greatest corresponding to an ambient temperature of 273 K (0°C). As with the stack exit parameters, these values have therefore been used in dispersion modelling to present a “worst case” operational scenario.

6.5 Building Wake Effects

Plumes trapped in building wakes can either be recirculated in the cavity region immediately downwind of a building or subjected to plume downwash and enhanced horizontal or vertical spreading due to the turbulent zone that exists further downwind.

Buildings generate downwind wake effects up to 5 times the lesser of the building height or projected building width. If there are stacks less than approximately 2.5 times the building height within this zone, then the effect of building wakes should be considered.

Due to the size and proximity of the ACC system to the exhaust stacks (see **Figure 2**), the above criteria for building wakes effects are met. Consequently, the dimensions of this structure have been inserted within TAPM to allow for potential interaction with predicted dispersion.

6.6 Buoyancy Enhancement

According to Hibbard et al. (2005), buoyant plumes, or plumes of a greater stack temperature than the ambient temperature, emitted from closely-spaced stacks tend to merge after their release. The merging of buoyant plumes will result in an overall greater plume rise, resulting in lower ground level concentrations of pollutants.



During Stage 2 of the Project, the two stacks are located 40 metres apart, as listed in **Table 13**. Furthermore, the proximity of the ACC system to the exhaust stacks, approximately 75 m at a minimum, presents the potential for plume enhancement through merging of released air.

Consequently, it is necessary to assess the impact of plume merging and subsequent buoyancy enhancement.

Manins et al. (1992) identifies that for a number of stacks with the same emission geometries and exit conditions, as is the case with this Project, then the buoyancy enhancement factor (N_E) is defined as:

$$N_E = \left[\frac{n + S}{1 + S} \right]$$

Where n is the number of stacks and S is the dimensionless separation factor, defined as:

$$S = 6 \cdot \left[\frac{(n-1) \cdot \Delta s}{n^{1/3} \cdot \Delta z} \right]^{3/2}$$

Where Δs is the stack separation and Δz is the rise of an individual plume.

The plume rise enhancement factor is then determined by the following:

$$E_N = N_E^{1/3} < N^{1/3}$$

To determine the individual plume rise value, single stack scenarios representing the exhaust stacks and ACC system were modelled with TAPM using the stack parameters detailed in **Section 6.4**. An hourly-varying plume rise enhancement factor for each stack type was derived based on the single stack final plume rise for each hour of the modelling period, accounting for varying ambient conditions.

Additionally, the potential plume rise enhancement that the ACC system plumes may provide the exhaust stack plumes required calculation. Anfossi et al (Zanetti et al, 2003) developed a methodology in 1978 that allows for the calculation of final plume rise from multiple sources of differing buoyancy and stack heights (ΔH^N) by first deriving the point of plume merging (H_i), as follows:

$$\Delta H^N = H_i + C \sum_{j=1}^N \left\{ F_j^{1/3} - \left[\frac{(H_i - H_j)}{C} \right]^3 \right\}^{1/3}$$

in which

$$H_i = H_{MAX} + \frac{\Delta H_{MIN} - (H_{MAX} - H_{MIN})}{1 + [\Delta H_{MIN} - (H_{MAX} - H_{MIN})] / D}$$

is the merging point, ΔH_{MIN} is the maximum single plume rise from the lowest stack H_{MIN} , $C = \Delta H_{MIN} / F_{MIN}^{1/3}$ and $D = (n-1)\Delta s$. F_{MIN} is the buoyancy flux parameter, F_B , for the lowest stack defined by Anfossi et al (Zanetti et al, 2003):



$$F_b = U_{SC} R^2 g \left[\frac{(\rho_a - \rho_s)}{\rho_a} \right]$$

where U_{SC} is the plume centreline velocity, R is the plume radius, g is the acceleration due to gravity and ρ_a and ρ_s are the density of the air and plume respectively. Ambient air density is assumed to be 1.2 kg/m^3 while the plume density for the exhaust stacks and ACC system are 0.87 kg/m^3 and 1.16 kg/m^3 respectively (personal correspondence, GHD, 2007).

In order to calculate the distance between the ACC system and each individual exhaust stack, the closest ACC system release point (AMG Coordinates 273924E, 6134867N) has been adopted as the marker point.

The hourly final plume rise height for each exhaust stack-ACC system merging event was then substituted back into the buoyancy enhancement factor (Manins, 1992) to derive an hourly-varying buoyancy enhancement factor that accounts for the potential plume rise enhancement influence that the ACC system may provide to the exhaust stacks.

Finally, the hourly exhaust stack-ACC system plume rise enhancement factor was multiplied with the hourly plume rise enhancement factor accounting for the relationship between the two exhaust stacks to return a combined plume rise enhancement factor. This final factor, varying both hourly and by exhaust stack source, was then applied against the exit velocity of each exhaust stack and inserted into TAPM through an hourly varying emissions file.

The above equations were used in the assessment of potential impacts of the stack exhaust plume from the proposed power facility on regional aviation safety, as documented in **Appendix C**.



7 AIR QUALITY ASSESSMENT

7.1 Operational PM₁₀

Table 15 shows the TAPM v3.0 predictions for maximum 24-hour average PM₁₀ concentration. It has been assumed (refer **Section 3.5**) that background levels of PM₁₀ are at the 24-hour maximum concentration (44.1 µg/m³) of the Albion Park South 2006 dataset (excluding the two exceedance days).

Table 15 Predicted Worst Case 24 Hour Average PM₁₀ Concentrations at the Nearest Sensitive Receptors

Receptor	PM ₁₀ Concentration - Maximum 24 Hour Average - µg/m ³			
	Maximum Increment	Maximum Background	Background + Increment	Project Goal
R1	0.51	44.1	44.61	50
R2	0.37	44.1	44.47	50
R3	0.29	44.1	44.39	50
R4	0.80	44.1	44.90	50
R5	0.92	44.1	45.02	50
R6	1.38	44.1	45.48	50

Table 15 indicates that at the all nearest sensitive receptors, the maximum 24-hour average incremental concentration of PM₁₀ associated with Stage 2 operations of the proposed power facility are predicted to be less than 1.4 µg/m³. When combined with the maximum 24-hour PM₁₀ concentration from the Albion Park South 2006 dataset (excluding the two exceedance days), maximum concentrations are predicted to satisfy the project goal of 50 µg/m³ (and will therefore not be responsible for an increment in exceedance days).

Contour plots of the maximum incremental 24-hour average PM₁₀ concentrations from Stage 2 operations are presented in **Appendix D**.

It is noted that the background PM₁₀ concentration, adopted in this assessment from the Albion Park South station, is highly conservative. Furthermore, as the assumption that all emitted particulate matter from the facility is PM₁₀ has been made, the predicted PM₁₀ increments presented in **Table 15** are also highly conservative. The predicted increments are more than an order of magnitude below the adopted background value. As such, it is anticipated that the day-to-day impacts of the proposed plant on PM₁₀ concentrations at the nearest sensitive receptors will be negligible.

An investigation of predicted annual average PM₁₀ concentrations experienced at the nearest sensitive receptors has also been undertaken. It has been assumed (refer **Section 3.5**) that background levels of PM₁₀ are of the order of 17.2 µg/m³ (annual average).

Dispersion modelling indicates that the predicted increase in the annual concentration of PM₁₀ associated with the proposed power facility may yield an increase of up to 0.1 µg/m³ (annual average) during Stage 2 operations, assuming worst-case emissions and continuous operation. Consequently, it is anticipated that the annual concentration of PM₁₀ (background plus increment) will be well below the project air quality goal of 30 µg/m³ at all sensitive receptors.



7.2 Nitrogen Dioxide

Table 16 shows the TAPM v3.0 predictions for NO₂ concentrations experienced both at the nearest sensitive receptors and across the entire modelling domain surrounding the Project Site.

Table 16 Predicted Worst-Case 1-Hour Average NO₂ Concentrations at the Nearest Sensitive Receptors

Receptor	Averaging Time	NO ₂ Concentrations - ppb	
		Maximum Predicted NO ₂ (Background + Increment)(a)	Project Goal
R1	1-hour	11.26	120
	Annual	1.09	30
R2	1-hour	11.53	120
	Annual	1.10	30
R3	1-hour	11.28	120
	Annual	1.10	30
R4	1-hour	11.75	120
	Annual	1.11	30
R5	1-hour	11.27	120
	Annual	1.16	30
R6	1-hour	14.65	120
	Annual	1.18	30

(a) Measured NO_x concentrations from the Nowra Water Treatment Plant Station were input in the TAPM simulations to quantify baseline NO₂ concentrations as specified in the TAPM methodology. TAPM uses the background NO_x concentrations to characterise the pollutant influx at the boundary of the study airshed. Due to meteorological characteristics and chemical transformations simulated within the airshed, the predicted peak cumulative NO₂ concentrations were predicted by the model at the discrete sensitive receptor sites to be lower than the measured peak NO_x concentrations.

Table 16 indicates that at the nearest sensitive receptors, the maximum cumulative 1-hour average and annual average concentrations of NO₂ associated with the proposed gas fired power facility is predicted to satisfy the project goals of 120 ppb (1-hour average) and of 30 ppb (annual average) for Stage 2 operations.

Contour plots of the maximum modelled 1-hour average NO₂ concentrations obtained around the project site under Stage 2 operations are presented as **Appendix D**.

As stated in **Section 6.1**, an hourly varying background concentration file including ambient measurements of NO_x and O₃ has been used as input into TAPM's chemistry mode calculations.

Due to the complex atmospheric chemistry processes that are simulated by TAPM, it is not instructive to report the maximum predicted 1-hour average NO₂ concentration at each sensitive receptor location against the maximum predicted background recorded for the corresponding hour to find the incremental impact of the facility. Rather, it is more useful to compare the peak predicted 1-hour average concentration across the entire modelling domain with the maximum recorded concentration from the Nowra Water Treatment Plant station.

Comparison between the maximum predicted 1-hour average NO₂ concentration across the entire modelling domain and the peak 1-hour average recorded concentration is presented in **Table 17**.

**Table 17 1-hour Average NO₂ Comparison – Peak Predicted vs Peak Measured**

	1-hour Average NO ₂ Concentration - ppb
Maximum Predicted	27.4
Peak Monitored	16

It can be seen in **Table 17** that over the modelling period for 2006, the Stage 2 operations of the proposed facility presents a maximum increase of 71.4% at any point over the modelled domain (6 km x 6 km) on the maximum recorded 1-hour average background concentrations from the Nowra Water Treatment Plant Station.

7.3 Carbon Monoxide

Table 18 shows the TAPM v3.0 predictions for CO concentrations experienced at the nearest sensitive receptors to the project site. It has been assumed (**Section 3.5**) that background levels of CO are of the order of 3.2 ppm (1-hour average) and 2.1 ppm (8-hour average).

Table 18 Predicted Worst-Case 1-Hour and 8-Hour Average CO Concentrations at the Nearest Sensitive Receptors

Receptor	Averaging Times	CO Concentrations – ppm			
		Maximum Increment	Background	Background + Increment	Project Goal
R1	1-hour	0.004	2.7	2.7	25
	8-hour	0.001	1.5	1.5	9
R2	1-hour	0.004	2.7	2.7	25
	8-hour	0.001	1.5	1.5	9
R3	1-hour	0.003	2.7	2.7	25
	8-hour	0.001	1.5	1.5	9
R4	1-hour	0.005	2.7	2.7	25
	8-hour	0.003	1.5	1.5	9
R5	1-hour	0.005	2.7	2.7	25
	8-hour	0.002	1.5	1.5	9
R6	1-hour	0.015	2.7	2.7	25
	8-hour	0.005	1.5	1.5	9

Table 18 indicates that at the nearest sensitive receptors, the maximum predicted 1-hour and 8-hour average concentrations of CO (background plus increment) associated with the proposed gas fired power facility is predicted to satisfy the project goals of 25 ppm (1-hour average) and 9ppm (8-hour average) during Stage 2 operations.

Contour plots of the maximum modelled 1-hour average CO incremental concentrations obtained around the project site for Stage 2 operations are presented in **Appendix D**.

It is well established in literature, that observed annual peak ground level concentrations for averaging times ranging from minutes to hours, can be related through a power law expression (CSIRO, 2005). Applying such a relationship, under conservative assumptions, the peak 15-minute average ground level concentration is expected to be less than twice the maximum 1-hour predicted ground level concentration.



Accordingly, the maximum 15-minute average CO concentration is also anticipated to be negligible and the corresponding project goal of 87 ppm is expected to be satisfied.

7.4 Sulphur Dioxide

Table 19 shows the TAPM v3.0 predictions for SO₂ concentrations experienced at the nearest sensitive receptors to the project site. It has been assumed (**Section 3.5**) that background levels of SO₂ are of the order of 38 ppb (1-hour average), 9.6 ppb (8-hour average) and 0.85 ppb (annual average).

Table 19 Predicted Worst-Case 1-Hour, 24-Hour and Annual Average SO₂ Concentrations at the Nearest Sensitive Receptors

Receptor	Averaging Times	SO ₂ Concentrations – ppb			Project Goal
		Maximum Increment	Background	Background + Increment	
R1	1-hour	0.20	38	38.20	200
	24-hour	0.03	9.6	9.63	80
	Annual	0.002	0.85	0.85	20
R2	1-hour	0.18	38	38.18	200
	24-hour	0.025	9.6	9.63	80
	Annual	0.001	0.85	0.85	20
R3	1-hour	0.17	38	38.17	200
	24-hour	0.02	9.6	9.62	80
	Annual	0.001	0.85	0.85	20
R4	1-hour	0.23	38	38.23	200
	24-hour	0.05	9.6	9.65	80
	Annual	0.002	0.85	0.85	20
R5	1-hour	0.24	38	38.24	200
	24-hour	0.06	9.6	9.66	80
	Annual	0.003	0.85	0.85	20
R6	1-hour	0.72	38	38.72	200
	24-hour	0.09	9.6	9.69	80
	Annual	0.003	0.85	0.85	20

Table 19 indicates that at the nearest sensitive receptors, the maximum predicted 1-hour, 24-hour and annual average SO₂ concentrations (background plus increment) associated with the proposed gas fired power facility will satisfy their corresponding air quality goal.

Contour plots of the maximum predicted 1-hour average incremental SO₂ concentrations obtained around the project site during Stage 2 operations are presented in **Appendix D**.

The power law expression discussed in **Section 7.3** may be used to relate annual peak ground level concentrations for averaging times ranging from minutes to hours. Applying such a relationship, under conservative assumptions, the peak 10-minute average ground level concentration is expected to be of the order of two times the maximum 1-hour predicted ground level concentration.

Accordingly, the maximum 10-minute average SO₂ air quality goal (250 ppb) is expected to be satisfied.



7.5 Photochemistry Impact

The original AQIA (Heggies Report “10-4044R1R1”, 2005) addressed the potential photochemical impact of the proposed power facility on the surrounding region. As stated in the original AQIA, photochemical pollution is generated when chemical reactions occur with oxides of nitrogen (NO_x), hydrocarbons and atmospheric oxygen in the presence of ultraviolet radiation. Ozone (O₃) is classed as a secondary pollutant as it is a product of these chemical reactions. Detailed analysis of photochemistry may be found in **Section 7.5** of the original AQIA.

Findings from the original AQIA indicated that emissions from the proposed power facility would not significantly influence the ability of the receiving airshed to generate adverse photochemical reactions.

Indeed, it is noted that NO_x within the power facility plume are generally expected to be released under light-limited conditions, and hence will effectively reduce ambient O₃ concentrations in the near-field by titration with NO generated by the facility.

The original AQIA report additionally notes that a detailed analysis of ambient air quality in the Illawarra conducive to ozone production from a gas fired power facility source between 1993 and 1996 has been conducted historically (Azzi et al, 1998). The conclusions of this assessment were that at Albion Park (the closest DECC air quality monitoring station to the project site), there are less than 30 hours per year with suitable ambient air quality conditions for ozone generation to proceed within a power facility plume. Many of these potential hours have ambient ozone concentrations well below 80 ppm (1-hour ozone air quality goal is 100 ppm).

As the original pollutant emission rates are not expected to change for revised operations, combined with the low level of predicted pollutant concentration change shown in **Section 7**, it can be assumed that the resultant air quality impact from revised Stage 2 operations will not differ significantly from that predicted in the original AQIA. Consequently, it can be assumed that the potential photochemistry impact of the proposed power facility’s revised operating conditions would not differ significantly from the original findings.

Therefore, it is not anticipated that the revised stack parameters will adversely alter the conclusions of the original AQIA with regards to regional photochemical impacts from the proposed power facility.

7.6 Start-Up and Shut-Down Emissions

Information provided by GHD on in-stack concentrations during full load, start-up and shut-down conditions is presented in **Table 20**.

Table 20 In-stack Concentrations during Full Load, Start-Up and Shut-Down

Operational Scenario	In-Stack Concentration @ 15% O ₂ Reference Level (ppm, dry)		
	NO _x	CO	UHC
Full Load Operations	25	10	7
Start-Up and Shut-Down	75	4500	6500

Table 20 indicates that a potential 3-fold increase in NO_x emissions may occur during start-up/shut-down. Additionally, increases in CO and hydrocarbon emissions may be 450 and 1,000 times their respective emissions during full-load operations.

Start-up / shut-down conditions will occur much more frequently during Stage 1 operations, when the power facility is anticipated to run to service peak demand.



Start-up duration will depend upon the specific gas turbine selected, however a period of up to 4 hours may apply when start-up is conducted under cold ambient conditions. Start-up during Stage 2 operations will be the most protracted, as it is necessary to warm the steam cycle components in a controlled manner.

Even in view of a 4-hour start-up period, and accounting for the emissions increases implied in **Table 20**, ground level air quality goals are anticipated to be satisfied. This is based on extrapolation of maximum ground level concentrations established in **Section 7.2** and **Section 7.3**.

Unburnt hydrocarbons (UHC) will be predominantly methane, derived from the fuel source, and accordingly does not have a corresponding ground level air quality goal.

Finally, it is noted that power facility operators are typically granted a time window in their emissions limits to allow for plant start-up.

7.7 Performance Against the Regulation Emission Limits

Predicted stack concentrations of criteria pollutants compared to the maximum in-stack concentrations set out in the “*Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2005*” (the “Regulation”) are documented in **Table 21**.

Table 21 Stack Concentrations Compared with the Regulation Emission Limits

Atmospheric Pollutant	Ambient Temperature			
	273	288	298	313
Predicted Stack Concentration				
Particulate Matter (mg/Nm ³)	7.1	-	-	-
Sulphur Dioxide (mg/Nm ³)	1.4	-	-	-
Oxides of Nitrogen (mg/Nm ³)	46.8	46.3	46.3	45.9
Carbon Monoxide (mg/Nm ³)	11.3	11.2	11.6	11.5
Unburnt Hydrocarbons (mg/Nm ³)	4.3	4.5	4.6	4.1
Regulation Emission Limit				
Particulate Matter (mg/Nm ³)	N/A	N/A	N/A	N/A
Sulphur Dioxide (mg/Nm ³)	N/A	N/A	N/A	N/A
Oxides of Nitrogen (mg/Nm ³)	70.0	70.0	70.0	70.0
Carbon Monoxide (mg/Nm ³)	N/A	N/A	N/A	N/A
Unburnt Hydrocarbons (mg/Nm ³)	N/A	N/A	N/A	N/A

Note: The results are based on an in-stack reference O₂ concentration of 15 percent.



Table 21 indicates that predicted stack concentrations will satisfy the Regulation emission-based limits.

7.8 Greenhouse Gas Assessment

The proposed power facility at Bamarang has the potential to produce greenhouse gases, with the primary source being the two gas turbines during electricity generation operations.

Carbon dioxide (CO₂) is produced during fuel combustion as a result of the oxidation of the fuel carbon content. CO₂ is likely to make the largest contribution to greenhouse gas emissions from fuel combustion as approximately 99.5% of natural gas fuel is oxidised during the combustion process (Australian Greenhouse Office, 2002).

Other greenhouse gases emitted as a result of the proposed operations at the Bamarang site may include CO, CH₄, NO_x and non-methane volatile organic compounds (NMVOCs). These are produced by incomplete fuel combustion, reactions between air and fuel constituents during fuel combustion, and post-combustion reactions. Fugitive emissions of NMVOCs may also be expected due to fuel evaporation.

For comparative purposes, non-CO₂ greenhouse gases are awarded a “CO₂-equivalence” based on their contribution to the enhancement of the greenhouse effect. The CO₂-equivalence of a gas is calculated using an index called the Global Warming Potential (GWP). The GWPs for a variety of non-CO₂ greenhouse gases are contained within the Intergovernmental Panel on Climate Change (IPCC) document “*Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*”. The GWPs of relevance to this assessment are:

- **Methane:** GWP of 21 (21 times more effective as a greenhouse gas than CO₂).
- **Nitrous Oxide:** GWP of 310 (310 times more effective as a greenhouse gas than CO₂).

The short-lived gases such as CO, NO₂, and NMVOCs vary spatially and it is consequently difficult to quantify their global radiative forcing impacts. For this reason, GWP values are generally not attributed to these gases nor have they been considered further as part of this assessment.

The proposed power facility at Bamarang is anticipated to have an estimated annual gas demand of 24.0 PJ over 8,300 hours of actual operation for Stage 2 Base Load operations.

The annual emissions of carbon dioxide and other greenhouse gases from this source have been estimated using the Australian Greenhouse Office (AGO) document “*Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002 – Energy (Stationary Sources)*”.

A summary of the predicted net increase in emissions from this source for Stage 2 is provided in **Table 22**. The CO₂-equivalent emissions are also detailed as a percentage of the total emissions from electricity generation operations in Australia during 1990 and 2002 (129 and 182 Mt/year respectively, (AGO, 2004)).

Table 22 Predicted Emissions of Greenhouse Gases Natural Gas-fired Turbine Engines, Stage 2 operations

Compound	CO ₂	N ₂ O	CH ₄	Total Emissions
Stage 2 Operations				
Predicted Emissions (tonnes/year)	1,240,800	2.4	192	1,240,994.4
CO ₂ -Equivalent (tonnes/year)	1,240,800	744	4032	1,245,576
% of CO ₂ emissions of	0.96%	0.00058%	0.00313%	0.97%



Australian electricity generation, 1990				
% of CO ₂ emissions of Australian electricity generation, 2002	0.68%	0.00041%	0.00222%	0.68%

7.9 Construction Air Quality Impacts

The construction phase of the proposed plant and associated infrastructure will result in the generation of particulate matter (dust deposition, TSP and PM₁₀). Significant particulate generating activities associated with the proposal will include:

- Earthworks associated with installation of the natural gas pipeline.
- Demolition of existing buildings and structures.
- Exposure of surfaces resulting from vegetation removal.
- Wheel-generated dust (by machinery and transport vehicles).

Given the separation distance between proposed construction works and the nearest sensitive receptors, significant fugitive particulate impacts at these locations are not expected. To ensure this outcome, a comprehensive dust control strategy should be implemented throughout the construction phase.

While it is anticipated that construction-phase particulate emissions may largely be controlled using technical means, control strategies should be detailed in a Construction Phase Air Quality Management Plan, and should include:

- Additional watering of exposed surfaces.
- Minimisation of exposed surfaces.
- Rehabilitation of available areas of disturbance (eg. topsoil, subsoil, spoil stockpiles).
- Minimising the drop heights between front end loader buckets and trucks carrying excavated materials.
- Dust screening between construction activities and residential receptors.
- Installation of water sprays along the unsealed access ways.
- Routine use of a water truck.
- Limiting of high dust-generating activities during adverse wind conditions, ie winds blowing directly towards the nearest sensitive receptors.

It is noted that asbestos has been identified in the existing site amenities building, due for demolition. As such, all asbestos removal and waste disposal should be carried out in accordance with *"The Code of Practice for the Safe Removal of Asbestos, Second Edition {NOHSC: 2002(2005)}"*, *"NSW EPA Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes"* (1999), any other relevant State and Federal legislation.



8 MITIGATION MEASURES AND SAFEGUARDS

The gas turbine combustors would be of the (dry) low NO_x design for gas fuel.

Low NO_x combustors operate by promoting combustion conditions conducive to lower flame temperatures, primarily by decreasing the amount of available oxygen in the zones critical for NO_x creation.

Dry low NO_x combustors represent the best practicable option for emission control as when used with natural gas, they do not need any fluid injection to maintain emissions at acceptable levels over a wide operational range.

Use of water injection as a means of NO_x control is not desirable as this would increase the operating and maintenance costs of the power facility, and reduces fuel efficiency. It does not represent a desirable environmental outcome as water used cannot be recycled as it is injected into the combustion system would exit via the turbine exhaust stacks.

There are a range of low NO_x combustor designs (such as internally staged and externally staged configurations), and this technology has been used for some time in power generation.

Low NO_x combustors are considered effective and reliable, and as they may be more fuel efficient, they may pay for themselves when considering whole-of-life costs.

The initial cost of low NO_x combustors is model-specific, and is reported as being from 15% to 100% more expensive than a conventional equivalent, with maintenance costs being about 40% higher than gas turbines not fitted with low NO_x combustors (PAE, 2005).

Given the results of atmospheric dispersion modelling, it is anticipated that no additional post-combustion mitigation measures from an air quality perspective (such as selective catalytic reduction) will be required under the current design.



9 CONCLUSION

Heggies Pty Ltd has been commissioned by GHD Pty Ltd (GHD) on behalf of Delta Electricity (DE) to conduct an Air Quality Impact Assessment (AQIA) as part of the Environmental Impact Statement (EIS) for a proposed gas turbine power facility at Bamarang, NSW.

This report examines the impact of the revised Stage 2 operations, which now incorporate an ACC structure. Modelling of PM₁₀, NO₂, CO, SO₂, and regional photochemistry was undertaken using the TAPM (v3.0) Dispersion Model software developed by the CSIRO. An assessment of greenhouse gases emitted from the proposed plant was also undertaken.

The results of atmospheric dispersion modelling undertaken within this assessment indicate that for revised Stage 2 operations, the project air quality goals are predicted to be satisfied. Thus, the impact assessment demonstrates that no additional exceedances of the NSW DECC impact assessment criteria will occur as a result of the proposed activity.

Atmospheric pollutant isopleths (contours), as detailed in **Appendix D**, indicate that neither the recreational amenity nor the water quality of the nearby Bamarang Dam is anticipated to be impacted by emissions from the proposed facility.

Compliance with air quality goals is anticipated to be governed principally by NO₂ emissions.

While it is anticipated that construction-phase particulate emissions may largely be controlled using technical means, control strategies should be detailed in a Construction Phase Air Quality Management Plan, and should include methods detailed within this report.

As a result of the “worst-case scenario” being modelled, all predictions should be viewed as conservatively high, with levels expected to be significantly lower than those modelled during standard operation.



10 REFERENCES

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11 GLOSSARY OF TERMS

ACC	Air Cooled Condenser
AQIA	Air Quality Impact Assessment
AS	Australian Standard
AWS	Automatic Weather Station
CCGT	Combined Cycle Gas Turbine
CH ₄	Methane
CO	Carbon monoxide
CAPER	Clean Air (Plant and Equipment) Regulation 1997
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DE	Delta Electricity Pty Ltd
DECC	NSW Department of the Environment and Climate Change
glc	Ground level concentration
GT	Gas Turbine
Heggies	Heggies Pty Ltd
HRSR	Heat Recovery Steam Generator
LHV	Lower Heating Value
mg	Milligram (g x 10 ⁻³)
µg	Microgram (g x 10 ⁻⁶)
µm	Micrometre or micron (metre x 10 ⁻⁶)
m ³	Cubic metre
MAQS	Metropolitan Air Quality Study
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO ₂	Nitrogen dioxide
NO	Nitric oxide
NO _x	Oxides of nitrogen
OCGT	Open Cycle Gas Turbine
PM ₁₀	Particulate matter less than 10 microns in aerodynamic diameter
PM _{2.5}	Particulate matter less than 2.5 microns in aerodynamic diameter
ppb	Parts per billion (volumetric concentration)
pphm	Parts per hundred million (volumetric concentration)
ppm	Parts per million (volumetric concentration)
SO ₂	Sulphur dioxide
TAPM	"The Air Pollution Model"
TEOM	Tapered Element Oscillating Microbalance
TSP	Total Suspended Particulate
UHC	Unburnt Hydrocarbons
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organisation