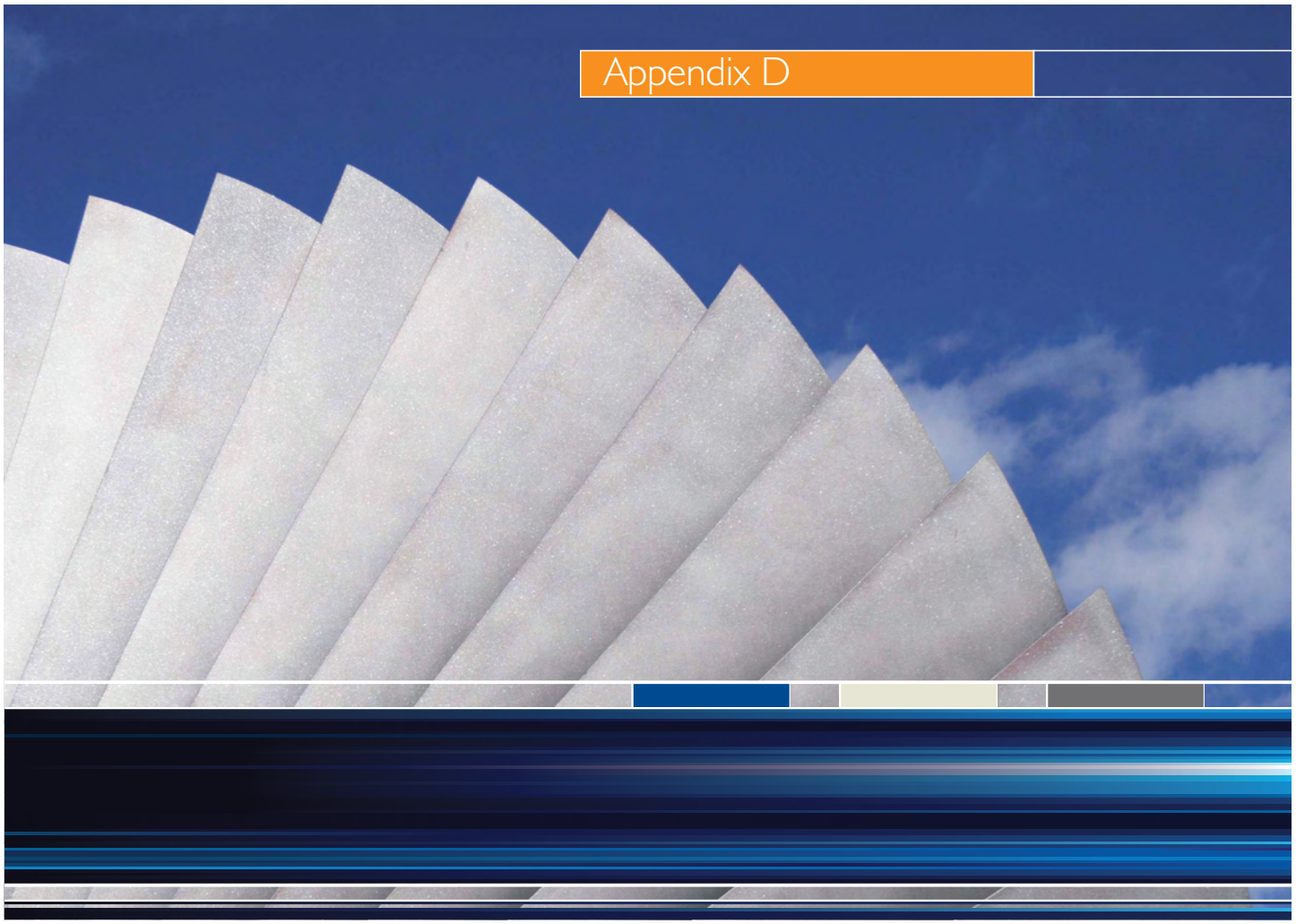

Air Quality Assessment

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED BAYSWATER B POWER STATION PROJECT

Prepared for

MACQUARIE GENERATION

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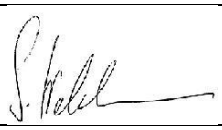
Final 1.0	17/09/09	Simon Welchman	

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Glossary

Term	Definition
µg/m^3	micrograms per cubic metre
µm	microns
°C	degrees Celsius
km	kilometre
km/h	kilometre per hour
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mg	milligram
t	tonnes
tpa	tonnes per annum
MW	Megawatt
Pa	Pascals
MPa	Megapascals
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
SO_2	Sulfur dioxide
PM	Particulate matter (fine dust)
PM_{10}	Particulate matter less than 10 microns
$PM_{2.5}$	Particulate matter less than 2.5 microns
TSP	Total suspended particles
CO	Carbon monoxide
CO_2	Carbon dioxide
F	Fluoride
Pb	Lead
VOC	Volatile organic compounds
PAH	Polycyclic aromatic hydrocarbons
HAP	Hazardous air pollutants
RHC	Robust Highest Concentration
LDL	Lower Detection Limit
TAPM	The Air Pollution Model
LPM	Lagrangian Particle Module
EGM	Eulerian Grid Module
HRSG	Heat Recovery Steam Generator

Executive Summary

Katestone Environmental has been commissioned by Macquarie Generation (MacGen) to undertake an Air Quality Impact Assessment as part of the Environmental Impact Statement (EIS) for the proposed Bayswater B Power Station Project. The development proposal provides two options for the generation and supply of an additional 2000 MW of base load electricity to the national grid, they are:

1. *Coal-fired power station comprising two Ultra Super Critical Pulverised Coal-fired units (2 x 1000 MW)*
2. *Gas-fired power station comprising five combined cycle gas turbine units with heat recovery steam generation (HRSG) (5 x 400 MW)*

The objective of the assessment is to investigate the degree to which air emissions associated with the combustion of carbon-based fuels in either the coal- or gas-fired power station options may affect the air environment. Air pollutants to be assessed for the coal-fired plant option have been identified from Part 4 of the Protection of the Environment Operations (Clean Air) Regulation (2002): Emission of Air Impurities from Activities and Plant, and from the air pollutants assessed as part of the National Pollutant Inventory (NPI) reporting for Bayswater and Liddell Power Stations. For the gas-fired plant option, air pollutants have been identified from the Clean Air Regulation (2002) and the USEPA AP-42, Chapter 3.1 – Stationary Gas Turbines document.

Emissions associated with the Bayswater B Project have been calculated in several ways. Emissions of pollutants regulated under the Clean Air Regulation (2002) are the product of source design characteristics for flow rate and the emission concentration limits specified in the Regulation. Emissions of pollutants not regulated under the Clean Air Regulation (2002) are the product of source design characteristics for flow rate and the in-stack concentration based on several sources including USEPA AP-42 emissions factors, and Load Based Licensing and NPI handbooks. Details of emission source characteristics have been provided by MacGen.

The assessment has been carried out in accordance with the methods outlined in the NSW Department of Environment and Climate Change's Approved methods for the modelling and assessment of air pollutants in NSW (2005). Impact assessment criteria have been primarily drawn from the Approved Methods (2005). However, for air pollutants not represented in the Approved Methods (2005), air quality criteria from other jurisdictions have been referenced, including the Texas Commission on Environmental Quality's Effects Screening Levels (2009) and the Ontario Ministry of the Environment (2008).

The assessment of criteria pollutants has been carried out by comparing the maximum (100^{th} percentile) cumulative ground-level concentrations associated with modelled predictions for Bayswater B plus contemporaneous background concentrations from the network of monitoring stations operated by MacGen at Singleton, Ravensworth, Liddell, Mount Arthur North and Muswellbrook. The assessment of non-criteria pollutants has been carried out by comparing the ninth highest (99.9^{th} percentile) ground-level concentrations associated with modelled predictions for Bayswater B in isolation.

The existing environment in the Upper Hunter Valley was summarised and an analysis was carried out in terms of the local climate, inter-annual climate variability, local meteorology, terrain and land use, identification of sensitive land uses and receptors, air pollutants emitted by other industrial sources and the existing air quality based on observations at MacGen's monitoring locations for the period 1994 to 2009. The study found that there was little significant variability in the climate and local meteorological factors that influence plume dispersion other than a slight drying of the climate during the severe drought years 2006-2007. A further statistical analysis was carried out to select three years for the dispersion modelling study, based on any identifiable variability in the wind field distributions. In addition to the study of wind field variability, a correlation analysis was carried out on air quality monitoring observations during the same fifteen year period to identify any variation in air quality impacts. The statistical analyses for the variability in wind field distributions and air quality impacts were then combined to select two typical years and one atypical year for the dispersion modelling. The typical years selected were March 1999 – February 2000 and March 2000 – February 2001, while the atypical year was March 2007 – February 2008.

Dispersion modelling was performed using TAPM version 4. The TAPM dispersion model was selected over CALMET/CALPUFF as the preferred model during a previous model evaluation study by Katestone Environmental (2005b). In the time since this study, two further versions of TAPM have been released. Consequently, an evaluation of the performance of TAPM to predict ground-level concentrations of sulfur dioxide and to simulate the meteorological factors important to dispersion in the region was carried out. This evaluation found that TAPM performed well in the prediction of the maximum (100th percentile) ground-level concentrations and reasonably well in the prediction of the ninth highest (99.9th percentile) values. TAPM also performed well in the simulation of both wind speed and direction at all sites evaluated at both the surface and upper air levels and the prediction of air temperature. The study concluded that TAPM was suitable for use in the prediction of air quality impacts for the study.

The air quality impact assessment study included a stack height sensitivity analysis to optimise plume dispersion and minimise predicted ground-level concentrations. Two stack heights were assessed, 250 and 300 metres, with the taller 300 metre option optimising plume dispersion and minimising ground-level concentrations of SO_2. The 300 metre design option has been chosen by MacGen for the Bayswater B coal fired option.

For the assessment of sulfur dioxide, emissions have been based on the design flow rate and a mass balance and stochastic modelling approach to calculate the in-stack concentration of sulfur dioxide associated on the mass of coal consumed per unit time and the distribution of sulfur in the coal. The assessment has then been based on predicted ground-level concentrations of sulfur dioxide for a range of coal sulfur contents. The range of predictions presented are for the average (0.53 wt% sulfur in coal) and maximum (0.67% wt% sulfur in coal). Further investigation was carried out using a Monte Carlo simulation technique to quantify the probability of any additional exceedances of the 1-hour average impact assessment criterion due to the operation of the proposed Bayswater B Project in combination with the existing Bayswater and Liddell Power Stations.

For the assessment of nitrogen dioxide, the rate of conversion of oxides of nitrogen emitted from the proposed Bayswater B Project to nitrogen dioxide has been calculated using the Janssen et al. (1988) method. The method incorporates the rates of the chemical reactions involving nitric oxide, nitrogen dioxide and ozone, the time it takes for the plume to reach the receptor (providing for the length of time the plume is exposed to solar radiation) and the ambient concentration of ozone. Ambient ozone is not monitored in the Upper Hunter Valley and, consequently, a range of ozone concentrations (35 ppb and 120 ppb) representing the average and maximum likely concentration were used to assess the conversion of oxides of nitrogen to nitrogen dioxide.

In regard to air quality impacts associated with emissions from the proposed Bayswater B Coal-fired Power Station, the air quality impact assessment has found that the proposed power station would cause a relatively minor change to ambient air quality. The most important air pollutant is sulfur dioxide. Ground-level concentrations of sulfur dioxide can be managed and minimised with the use of low sulfur coal. The specific outcomes of the assessment are detailed below for each air pollutant:

For sulfur dioxide -

- *Based on the stochastic modelling of the distribution of coal sulfur content, one additional exceedance of the impact assessment criterion of 570 µg/m^3 is predicted due to the operation of the proposed Bayswater B Power Station. The additional exceedance is predicted for the 2007-2008 modelled period, which was selected as an atypical year for wind speed and direction.*

- *The predicted maximum 24-hour average for Bayswater B with background at all sensitive receptor locations is below 200 µg/m^3. The impact assessment criterion is 228 µg/m^3.*

- *The predicted annual average for Bayswater B with background at all sensitive receptor locations is below 25 µg/m^3. The impact assessment criterion is 60 µg/m^3.*

For nitrogen dioxide -

- *The predicted maximum 1-hour average for Bayswater B with background at all sensitive receptor locations is below 202 µg/m^3 for all modelled years. The impact assessment criterion is 246 µg/m^3.*

- *The predicted maximum annual average for Bayswater B with background at all sensitive receptor locations is 22 µg/m^3 for all modelled years. The impact assessment criterion is 62 µg/m^3.*

For carbon monoxide -

- *The maximum 15-minute, 1-hour and 8-hour averages for Bayswater B in isolation are predicted to be well below the impact assessment criterion of 100,000 µg/m^3, 30,000 µg/m^3 and10,000 µg/m^3, respectively.*

For hydrogen fluoride -

- *The results indicate that the impact assessment criterion for specialised vegetation for the 24-hour average is exceeded at all sensitive receptor locations, while the general land use criterion is only exceeded at receptors R7, R8 and R9. However, the only receptor location with a specialised vegetative land use is the Arrowfield Winery, where the predicted maximum 24-hour average is 2.88 µg/m^3, which is 191% of the criterion.*

- *There are no predicted exceedances of the 7-day average impact assessment criterion for specialised vegetation of 0.8 µg/m^3 at any sensitive receptor locations for all modelled years.*

- *An exceedance of the short-term 24-hour average criterion of HF is unlikely to significantly affect the cultivation of grapevines due to the rate of plant growth. The most reliable indicator of the potential for adverse impact of HF on specialised vegetation is the longer 30-day and 90-day averages, which provide for the assessment of air quality in relation to the growing season. It is more likely an adverse affect will be sustained in vegetation if HF levels are elevated throughout the growth cycle, primarily between November and grapevine harvest time in February.*

- *There are no predicted exceedances of the 30-day average impact assessment criterion for general land use of 0.84 µg/m^3 at any sensitive receptor locations for all modelled years. While the 30-day average impact assessment criterion for specialised vegetation of 0.4 µg/m^3 is predicted to be exceeded at Mount Arthur North, R4, R5, R6, R7, Liddell and Ravensworth, no specialised vegetation such as viticulture has been identified there. Consequently, the applicable criterion is for the general land use. At the only receptor location with a specialised vegetative land use, the Arrowfield Winery, the predicted maximum 30-day average is 0.31 µg/m^3.*

- *There are no predicted exceedances of the 90-day average impact assessment criterion for general land use of 0.5 µg/m^3 at any sensitive receptor locations for all modelled years. While the 90-day average impact assessment criterion for specialised vegetation of 0.25 µg/m^3 is predicted to be exceeded at Mitchell Line Road, Mount Arthur North, R4, and Ravensworth, no specialised vegetation such as viticulture has been identified there. Consequently, the applicable criterion is for the general land use. At the only receptor location with a specialised vegetative land use, the Arrowfield Winery, the predicted maximum 90-day average is 0.24 µg/m^3.*

For PM_{10} -

- *The predicted maximum 24-hour and annual averages for Bayswater B in isolation are a very small proportion of the background levels of these pollutants and of the criterion.*

- *Impacts associated with the emission of fine particles from the Bayswater B coal-fired option in conjunction with Bayswater and Liddell Power Stations are not likely to significantly contribute to the ground-level concentrations of fine particles in the region. They comprise a small proportion of the background dust levels.*

For individual air toxics –

- *There are no predicted exceedances of the impact assessment criterion for any air toxics at any sensitive receptor location for all modelled periods. Predicted maximums (99.9th percentiles) are all well below the criterion.*

For metals and metalloids –

- *There are no predicted exceedances of the impact assessment criterion for any metals and metalloids at any sensitive receptor location for all modelled periods. Predicted maximums (99.9th percentiles) are all well below the criterion.*

In regard to air quality assessment of the proposed Bayswater B Gas-fired Power Station, the air quality impact assessment has found that the proposed power station would cause a relatively minor impact on ambient air quality. The most important air pollutant is nitrogen dioxide. Ground-level concentrations of nitrogen dioxide can be managed and minimised with the proposed use of low emissions technology. The specific outcomes of the assessment are detailed below for each air pollutant:

For nitrogen dioxide -

- *The predicted maximum 1-hour average for Bayswater B with background at all sensitive receptor locations is below 202 µg/m^3 for all modelled years. The impact assessment criterion is 246 µg/m^3.*

- *The predicted maximum annual average for Bayswater B with background at all sensitive receptor locations is 22 µg/m^3 for all modelled years. The impact assessment criterion is 62 µg/m^3.*

For carbon monoxide -

- *The maximum 15-minute, 1-hour and 8-hour averages for Bayswater B in isolation are predicted to be well below the impact assessment criterion of 100,000 µg/m^3, 30,000 µg/m^3 and 10,000 µg/m^3, respectively.*

For PM_{10} -

- *The predicted maximum 24-hour and annual averages for Bayswater B in isolation are a very small proportion of the background levels of these pollutants and of the criterion.*

- *Impacts associated with the emission of fine particles from the Bayswater B gas-fired plant option, in conjunction with Bayswater and Liddell Power Stations, are not likely to significantly contribute to the ground-level concentrations of fine particles in the region. They comprise a small proportion of the background dust levels.*

For individual air toxics –

- *There are no predicted exceedances of the impact assessment criterion for any air toxics at any sensitive receptor location for all modelled periods. Predicted maximums (99.9th percentiles) are all well below the criterion.*

1. Introduction

Katestone Environmental has been commissioned by Macquarie Generation (MacGen) to undertake an Air Quality Impact Assessment as part of the Environmental Impact Statement (EIS) for the proposed Bayswater B Power Station Project. The development proposal provides two options for the generation and supply of an additional 2000 MW of base load electricity to the national grid, they are:

3. Coal-fired power station comprising two Ultra Super Critical Pulverised Coal-fired units (2 x 1000 MW)
4. Gas-fired power station comprising five combined cycle gas turbine units with heat recovery steam generation (HRSG) (5 x 400 MW)

The objective of the assessment is to investigate the degree to which air emissions associated with the combustion of carbon-based fuels in either the coal- or gas-fired power station options may affect the air environment. The investigation aimed at quantifying the affect on air quality under all possible conditions, including variable:

- Meteorology
- Power station operating loads
- Coal sulfur content

For the proposed coal-fired power station option, emissions will be released from a single, 300 metre tall, twin flue stack (one flue per boiler unit). The following air pollutants have been assessed:

- Oxides of nitrogen (NO_X), as nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Solid particles (PM) as PM_{10}
- Carbon monoxide (CO)
- Fluoride (F)
- Volatile Organic Compounds (VOC)
- Polycyclic Aromatic Hydrocarbons (PAH)
- Persistent Organic Pollutants (Dioxins & Furans)
- Metals and metalloids
- Acid gases

For the gas-fired power station option, emissions will be released from five, 55 metre tall, single flue stacks (one stack per gas turbine unit). The following air pollutants have been assessed:

- Oxides of nitrogen, as nitrogen dioxide
- Solid particles as PM_{10}
- Carbon monoxide
- Volatile Organic Compounds
- Polycyclic Aromatic Hydrocarbons

The assessment has been carried out in accordance with the DECC Approved Methods (2005) and uses the CSIRO's TAPM (The Air Pollution Model) version 4 prognostic meteorological model and dispersion model to predict ground-level concentrations of air contaminants at sensitive receptor locations. All air pollutants listed above have been assessed for Bayswater B in isolation, by comparing predicted ground-level concentrations with the ambient air quality objectives outlined for the assessment. The assessment of cumulative impacts for criteria pollutants such as NO_2, SO_2, and PM_{10}, at each receptor location, has been carried out by contemporaneously adding the background measured at the closest MacGen monitoring station. For the criteria pollutants that are not continuously monitored, CO, F and lead (Pb), emissions of each associated with the existing Bayswater and Liddell Power Stations were modelled and ground-level concentrations were predicted at each receptor location to represent the background levels.

In order to support the findings of the air quality impact assessment, several studies were conducted to ensure that:

- The assessment was made using the range of likely meteorological conditions including worst case meteorological conditions
- The assessment was made using emissions associated with the maximum load profiles
- The variability and range in coal sulfur content was accounted for
- The predicted ground-level concentrations were consistent with measurements

At present, MacGen operate two coal-fired power stations, Bayswater and Liddell, that are located either side of the New England Highway in the area adjacent to Lake Liddell. MacGen has monitored the ambient air quality in the region since 1986. Ten-minute average measurements, covering the past fifteen years at five monitoring locations, have been incorporated into this study. The monitoring stations are located at Singleton, Muswellbrook (the largest towns in the local region), Lake Liddell, Ravensworth and Mount Arthur North/Mitchell Line Road. Air pollutants monitored at these locations include $NO_X/NO_2/NO$, SO_2 and PM_{10}.

A key feature of the air quality study therefore, is the use of monitoring information to evaluate the performance of the air dispersion model to predict ground-level concentrations, and to provide background concentrations of air contaminants at sensitive receptor locations for the assessment of cumulative impacts. The large data set of monitoring information also provided for the long term analysis of the existing environment.

In addition to the air quality monitoring network, wind speed and direction are also measured at Liddell, Ravensworth and Mount Arthur North. The meteorological data was used to analyse trends in the long term wind speed and direction distributions. This analysis was then coupled with the analysis of observed ground-level concentrations of SO_2 and NO_2 at the monitoring stations. The aim of the analysis was to identify the years where the average ground-level concentrations of SO_2 and NO_2 had been the highest and to categorise the wind fields during these years. Three years were then selected for the assessment to represent the typical wind fields during the fifteen year period and the worst case background air quality.

Coal sulfur sampling data was analysed to provide a probability distribution for coal sulfur content. Ground-level concentrations of SO_2 were then predicted for the emission rates associated with the mean and maximum percentages of sulfur in the coal consumed. This provided a range of outcomes for ground-level concentrations. To determine the probability of exceeding the air quality objective for the convolution of varying emission rates based on the coal sulfur distribution and hourly varying meteorological conditions, a stochastic modelling technique was used.

The performance of the TAPM (version 4) dispersion model was also evaluated using statistical techniques for a year when detailed hourly emissions data were available from Bayswater and Liddell Power Stations by:

- Correlating the observed ground-level concentrations of SO_2 at the five monitoring locations with model predictions
- Correlating the observed wind speed, wind direction and temperature at three monitoring locations with model predictions including surface and upper level measurements

This report presents the aims, methodology, results and conclusions of the air quality impact assessment for the proposed Bayswater B Power Station in conjunction with emissions from the existing sources of air pollutants in the local region including the existing coal-fired power generating facilities owned and operated by MacGen. The report includes a detailed discussion of the following:

- Processes and infrastructure at the proposed Bayswater B Power Station, for the coal- and gas-fired options, in relation to air emissions
- Emission rates of air contaminants from the coal- and gas-fired plants
- Discussion of existing air quality, climate and local meteorological conditions
- Evaluation of the performance of the TAPM air dispersion model for wind fields and the prediction of ground-level concentrations
- Methodology for the TAPM dispersion modelling impact assessment
- Methodology used in the stochastic modelling to determine the range in SO_2 emissions associated with the variability in coal sulfur content and statistical probability of exceeding air quality criteria
- A discussion of background sources and method for including existing emission sources in the assessment of cumulative air pollutant concentrations
- Description of the method of conversion of NO_X to NO_2
- Predicted ground-level concentrations of all air pollutants for various averaging periods and comparison with air quality impact assessment criteria

2. Overview of the Assessment Methodology

The air quality impact assessment for the proposed Bayswater B Project has been undertaken in accordance the methodology prescribed in the DECC's Approved Methods (2005) document. In accordance with the Approved Methods, a Level 2 impact assessment has been carried out using site-specific emissions and meteorological information. This section outlines the impact assessment methodology adopted for the study.

The air pollutants to be assessed were selected by:

- For the coal-fired power station, air pollutants to be assessed were selected from -
  - *Part 4* of the *Protection of the Environment Operations (Clean Air) Regulation (2002)* – electricity generating plant producing greater than 30 MW of energy using solid fuels
  - The National Pollutant Inventory (NPI) and Load Based Licensing (LBL) Handbooks for coal-fired power stations.

- For the gas-fired power station, air pollutants to be assessed were selected from –
  - *Part 4* of the *Protection of the Environment Operations (Clean Air) Regulation (2002)* – electricity generating plant producing greater than 30 MW of energy using gaseous fuels
  - USEPA AP-42 Emission Factors, Chapter 3.1, Stationary Gas Turbines

The method for the calculation of emission rates included:

- For the coal-fired power station -
  - The product of the source design flow rate and the emission concentration
  - Use of coal properties, design coal consumption data, particulate matter control effectiveness, fuel energy consumption information for the proposed power station in conjunction with the Liddell Power Station NPI and LBL calculation procedures
  - Emissions of SO_2 considered the distribution of sulfur in the coal fuel to be used for Bayswater B based on sampling analysis from the coal source

- For the gas-fired power station -
  - The product of the source design flow rate and the emission concentration standard prescribed in the Clean Air Regulation (2002)
  - The USEPA AP-42 Emission Factors based on mass of pollutant per unit energy consumed per unit time

The existing environment in the local region has been described in terms of:

- Climate, including temperature, solar radiation, relative humidity, rainfall and atmospheric pressure
- Meteorology, including wind speed and direction
- Inter-annual climate variability, including temperature, relative humidity and rainfall
- Terrain and land use
- Sensitive receptors
- Emissions associated with the existing local industries
- Ambient air quality, including NO_2, SO_2 and PM_{10}

The impact assessment criteria were adopted from the following sources:

- *Approved methods for the modelling and assessment of air pollutants in NSW (2005)*
- For air pollutants not contained in the Approved Methods, Texas Commission on Environmental Quality (2009)

The approach adopted for the atmospheric dispersion modelling included:

- An air dispersion model selection study that found TAPM to be the most suitable model
- An evaluation of the performance of TAPM version 4 to simulate local meteorological conditions and predict ground-level concentrations
- Selection of three representative years to be modelled based on -
    - A statistical analysis of the inter-annual variability in meteorological conditions (for wind speed and direction) based on fifteen years of data at two meteorological stations
    - A statistical analysis of the inter-annual variability in ambient air quality (for SO_2 and NO_2) based on fifteen years of data at five monitoring stations
- The optimisation of the TAPM configuration, including –
    - 900 second Lagrangian Particle Module time-step before conversion to the Eulerian Grid Module
    - Terrain enhancement using Geoscience Australia 9 second Digital Elevation Model (DEM) data

The assessment of air quality impacts considered the following:

- Assessment of criteria pollutants (including NO_2, SO_2, PM, CO, HF and Pb) by comparison of the maximum (100^{th} percentile) cumulative ground-level concentration (incremental plus background) at sensitive receptor locations with the impact assessment criteria. Where the predicted concentration is insignificant compared with the impact assessment criteria, cumulative impact assessment has not been conducted.
- Calculation of the total cumulative ground-level concentration of criteria pollutants at a receptor, for pollutants monitored by MacGen (NO_2, SO_2), by adding the measured background concentration at the nearest monitoring station to model predictions contemporaneously hour by hour
- Calculation of the total cumulative ground-level concentration of fluoride at a receptor by modelling the emissions from the existing Bayswater and Liddell Power Stations with the emissions from Bayswater B
- Assessment of all other hazardous air pollutants by comparison of the ninth highest (99.9^{th} percentile) incremental ground-level concentration at, and beyond, the site boundary with the impact assessment criteria
- Conversion of in-plume NO_X to NO_2 at receptor locations using the method described by Janssen *et al.* (1988), in accordance with the Approved Methods (2005)
- Assessment of ground-level concentrations of SO_2 based on average and maximum coal sulfur content
- Assessment of the probability of exceeding the impact assessment criteria for SO_2 based on a variable SO_2 emission rate, by applying a stochastic modelling technique to the distribution of sulfur in the coal fuel and the distribution of ground-level concentrations at a receptor

3. Project Background and Previous Studies

Katestone Environmental has been involved extensively over the past five years with air quality studies for MacGen, and in particular, with impact assessment studies for various plant design options for the proposed Bayswater B Power Station. Studies undertaken and commissioned to assess the impact of the proposed Bayswater B Power Station on the atmospheric environment are listed below:

1. Major air quality (NO_2 and SO_2) constraints for the proposed power station expansion considering baseline air quality monitoring data (Katestone, 2005a)
2. Ground-level concentrations of NO_2 and SO_2 due to the proposed power station expansion in conjunction with the existing power stations. Validation of modelling techniques (Katestone, 2005b)
3. Potential for elevated concentrations of SO_2 using refined dispersion modelling techniques and a realistic characterisation of future SO_2 emissions based on stochastic emissions modelling techniques (Katestone, 2006a)
4. Potential for emissions from the expanded power station to be transported into the greater metropolitan region of Sydney, Newcastle and Wollongong and enhancement of photochemical activity (Katestone, 2006b)
5. Computational fluid dynamics (CFD) modelling was undertaken by Maunsell Australia to investigate the Heller cooling tower design option as well as the conventional multi-flue stack option. The simulation of the CFD modelling was undertaken to demonstrate how the stack-in-tower emissions would disperse within the cooling tower plume and the plume rise of both options (Maunsell, 2006)
6. MEL Consultants using the Monash University wind tunnel conducted wind tunnel modelling (Lorie et al, 2006). Wind tunnel modelling provides an accurate description of how the plumes behave under specific meteorological conditions. The wind tunnel was used to better determine the interaction of wakes generated by the towers themselves on the plume dispersion.
7. Modification of the dispersion model using the findings of the wind tunnel modelling so that the dispersion model can be used to accurately characterise the dispersion of the Heller plume. Work undertaken by CSIRO and findings presented in Hibberd (2007).

A brief summary of these studies undertaken for MacGen was issued by Katestone Environmental (2007) and is presented here as Appendix A.

4. Project Infrastructure and Processes

MacGen is investigating two options for the additional power generating capacity of 2000 MW of base load electricity for the Bayswater B project. Development approval is sought for two possible fuel alternatives:

- Ultra Supercritical Pulverised Coal-Fired Plant
- Combined Cycle Gas Turbine

The following sections describe the infrastructure and processes associated with both options in relation to their emission of air contaminants.

4.1 Ultra Supercritical Pulverised Coal-fired Power Station Option

The preferred option for the coal-fired power station is an Ultra Supercritical Pulverised Coal Fired (USCPC) plant with a Post Combustion Carbon Capture (PCCC) ready design. USCPC technology is commercially viable and offers high thermal efficiency and lower greenhouse emissions than current coal-fired plant in NSW. The proposed USCPC power plant would operate continuously 365 days a year.

The proposed USCPC plant will comprise the following processes and infrastructure (AECOM, 2009):

- Transport of coal fuel to site via rail and conveyor with delivery to the coal storage area.
- Coal pulverising mills that grind supplied coal into a fine powder.
- Boilers (boiler furnaces), to which pulverised coal is directed. Combustion of fuel occurs with the addition of air, heating water that flows through pipes near the perimeter of the boilers, converting the water into superheated steam.
- Turbine house (containing steam turbine generators), where the superheated steam expands on passing through turbine blades at successively lower pressures, rotating the turbine shaft which in turn powers a generator, creating electricity
- Steam exhausts from the turbine and enters an air cooled condenser (ACC), where it is cooled and condensed back into water. The water is re-used as feedwater for the boiler furnaces.
- Ash handling and disposal plant, which collects and disposes of dense mineral matter rejected by the pulverising mills, course ash from the furnaces, and fine flue ash (fly ash) that is collected by fabric filters. Ash would then be conditioned and disposed of in open-cut mine voids in the vicinity of the site.
- Stack, from which exhaust flue gases would be discharged after filtration.

4.1.1 Infrastructure and processes and their associated emissions to air

4.1.1.1 Coal Handling

The annual consumption of coal by the proposed Bayswater B project is estimated to be approximately 6.2 million tonnes per year. Coal will be supplied by rail from remote open cut coal mines. Coal trains will deliver approximately 9,000 tonnes of coal each to the existing Antiene Rail Coal Unloader (ARCU), for 365 days per year.

Coal will then be conveyed to the Bayswater B Power Station bunkers at a rate of 4,000 tonnes per hour. The Bayswater B coal storage stockpile will remain dry and fully covered with a redundancy built in for up to ten days coal supply (188,000 tonnes). This stockpile will comprise an area of approximately 2.5 hectares, and include fully mechanised formation and reclamation by means of a long-travelling stacker and a long-travelling reclaimer. An additional uncovered, low stacking, four hectare stockpile will also be constructed to increase the capacity of the coal storage yard for a further ten days of coal supply.

Dust emissions associated with coal handling, transport and storage prior to combustion in the boiler furnaces is beyond the scope of this air quality impact assessment study. The management of dust emissions from coal handling activities will be addressed in the Environmental Management Plan. Dust mitigation and control techniques will be applied to minimise the emission of dust.

4.1.1.2 Coal Pulverising Mills

Coal feeders would transfer coal at a controlled rate from the coal bunkers into the pulverising mills, where table mills and rollers grind the coal into a fine powder. The coal mills have a total rated design capacity of 800 tonnes per hour. This pulverised coal powder would subsequently be piped into the boiler houses. The pulverising mill classifiers sort pulverised material and reject any dense mineral matter within the supplied coal (such as pyrite / iron sulfide), which is collected and transported to the ash plant.

4.1.1.3 Boilers

The once-through ultra supercritical boilers would be designed to supply main steam at 28.5 MPa and 600°C with reheat steam at 620°C.

Two boiler furnaces, each of approximately 64 metres wide, 80 metres long and 175 metres in height, would be ignited by a fuel oil firing system. Pulverised coal powder is directed into furnace chambers along with heated air from the draught plant systems. Use of low NO_X burners in the furnaces serves to control emissions of NO_X. Rapid combustion of the coal occurs within each furnace, resulting in thermal radiation which heats water flowing through tubes which form the furnace walls, creating steam. This steam is superheated (ultra supercritical steam generation) before being piped to steam turbines.

Coarse furnace ash and fine fly ash generated during coal combustion would each be collected by different components of the ash handling and disposal plant and removed for storage. Fly ash and fine particles will be controlled using a fabric filtration system.

4.1.1.4 Turbine House

The turbine house would be approximately 40 metres wide, 200 metres long and 40 metres in height. It would contain two steam turbine generators, each made up of a series of interconnected turbines that operate at successively lower pressures, attached to a generator on a common shaft.

The superheated steam (28.5MPa, 600°C) first enters the high pressure (HP) steam turbine and progressively expands as it passes through the cylinder. From the HP turbine, steam is then reheated in the boiler (to 620°C) before passing through the double flow intermediate pressure (IP) turbine and then two double flow low pressure (LP) turbines. As the steam expands through each turbine it imparts a force on the rotor blades thereby rotating the turbine shaft, which is coupled to the generator rotor in which electrical energy is generated,

typically at 23,000 volts. After passing through the steam turbine generator, the steam exits to the air cooled condensers before it is recirculated.

There are no emissions of air contaminants associated with the Turbine House.

4.1.1.5 Air-cooled Condensers

Low energy steam exhausted from the low pressure turbines is directed to air cooled condensers (ACC), where it is cooled and condensed back into water. The condensed water is pumped back through feedwater heaters to be re-used in the boiler furnace.

Each ACC unit would comprise of some 81 cells with overall dimensions 110m x 110m x 38m high. Two dry cooling options are as follows:

A dry ACC uses direct heat transfer to the atmosphere to cool and condense the steam. Steam at 30°C to 70°C is ducted directly to the large heat exchanger elements, which are cooled by ambient air pushed past the finned tubes by large fans. As the heat transfer mechanism is by convection, the performance of the ACC depends on ambient dry bulb temperatures. During hot periods the effectiveness of the ACC decreases and performance of the plant declines. To help counter this effect, water sprays cool the incoming air and provide some evaporative cooling on the external surfaces of the heat exchanger elements. This provides plant performance improvements on hot days by allowing more heat to be dissipated.

The water output from the ACC (condensate) has impurities removed by the polishing plant before being heated by the regenerative feedwater heaters, which utilise bled steam from the turbines to improve plant thermal efficiency. The heated water then returns to the boiler. This completes the Steam/Water Cycle which begins with water being converted to steam in the boiler, followed by steam passing through the turbines before being exhausted to the ACC where it is converted back to water, which is then treated in the polishing plant and heated by the feedwater heaters, before returning to the boiler.

4.1.1.6 Ash Handling and Disposal Plant

The ash plant involves a number of different components, including the Pulveriser Rejects Handling Plant, Furnace Ash Collection and Handling Plant, Flue Gas Cleaning Plant, Fly Ash Handling Plant, Ash Conditioning Plant, and Ash Disposal Plant. Each of these is addressed below.

Pulveriser Rejects Handling Plant
The coal pulverising mills generate rejects (including dense mineral matter) which are collected and transported via a wet jet pump system, then dewatered and sent for disposal with the furnace ash.

Furnace Ash Collection and Handling Plant
Coarse furnace ash (bottom ash) makes up approximately 15-20% of the ash generated by the furnace. After combustion of coal, the coarser furnace ash collects in the furnace hopper and is removed by a wet submerged scraper conveyor system. The furnace ash along with the pulveriser rejects are then dewatered and conditioned if required prior to being transported to the ash disposal site by truck.

Flue Gas Cleaning Plant
The remaining 80-85% of ash generated by the furnace is in the form of fine fly ash (dust), which is transported with flue gases through the boiler. The fly ash is removed from the flue gases prior to emitting the gases to the atmosphere. The flue gas dust collecting plant would involve fabric filter baghouses, which are highly efficient particulate removal devices.

Fabric filter baghouses (four per boiler furnace, eight in total) will be approximately 50 metres wide, 42 metres long and 30 metres in height. Fly ash collected in the fabric filters is dislodged by pulse jet into hoppers and then transferred to the fly ash handling plant.

Fly Ash Handling Plant
A fly ash handling plant is required to remove and transport fly ash from the fabric filter hoppers to the Ash Conditioning Plant prior to disposal.

Ash Conditioning Plant
Ash conditioning would be required to improve handling and control dust from ash, however the type and extent of conditioning required is dependent on the condition of the ash and other products received together with the system selected for disposal. Ash would be conditioned with recycled wastewater from the site before being transferred to the Ash Disposal Plant.

Ash Disposal Plant
Ash disposal is proposed to occur in existing void/s created as a result of past open cut coal mining operations located within a 10km radius of the site. The conditioned fly ash would be transported by enclosed conveyor, while furnace ash and pulveriser rejects would be transported by truck via a purpose-built private ash haulage road to the ash disposal site. The ash conveyor and ash haulage road are proposed to be built side-by-side.

4.1.1.7 Stack

The flue exhaust gases from burning of fuel in the furnace are discharged via the chimney stack after filtration. A single twin flue stack would be provided at Bayswater B, having a height of 300 metres and a diameter of 8.17 metres for each flue.

4.1.2 Emissions Control and Sustainability

4.1.2.1 USCPC technology

MacGen has adopted USCPC technology to maximise plant thermal efficiency and minimise greenhouse emissions.

4.1.2.2 Sulfur Emissions Minimisation

The domestic grade coal proposed to be used by MacGen to fire the proposed Bayswater B project has inherently low sulphur content by international standards (typically around 0.5%). As a consequence the base plant proposal would have uncontrolled sulfur emissions and employ fabric filter plant for particulate removal.

The air quality impact assessment study has included a stack height optimisation study, predicting ground-level concentrations of SO_2, based on the average and maximum coal sulfur content, for the 250 metre and 300 metre options. The study found that a stack height of 300 metres optimised plume dispersion and minimised ground-level concentrations of SO_2. The 300 metre stack design has been selected by MacGen for the Bayswater B coal fired power station option.

Low NO_X Burners
Low NO_X burners optimise fuel and air mixing at each burner in order to create large flames with less available air in order to reduce peak flame temperature and thermal NO_X formation. Low NO_X burners typically have three stages: combustion, reduction and burnout. In the first stage, combustion occurs in a fuel rich, oxygen deficient zone where the majority of thermal NO_X is formed. The reducing atmosphere follows, where hydrocarbons are formed which react with the already formed NO_X. In the third stage, additional air staging completes the combustion process although some additional NO_X formation may occur.

Fabric Filter Technology
Bayswater B will use fabric filter plant to minimise particulate emissions. Fabric filter bags can achieve overall collection efficiencies of 99.9 % of primary particulates.

The fabric filter plant uses woven or felted cotton, synthetic, or glass-fibre material bags to filter the fly ash from the flue gas. All the flue gas enters from the bottom of the fabric filer plant casing and flows from the outside to inside of the bags. A metal cage prevents collapse of the bag, as the fly ash forms a cake on the surfaces of the bags. The fabric bag primarily provides a surface on which fly ash collects, with the build up of fly ash enhancing the collection efficiency.

The build up of fly ash cake on the filter bags eventually increases the resistance to flue gas flow and necessitates periodic cleaning. The pulse jet cleaning system cleans the bags by injecting a short burst of compressed air through a common manifold over a row of bags. The jet pulse causes the bag surfaces to flex, dislodging the fly ash which falls into a storage hopper below.

4.1.2.3 Ash Handling and Disposal

Sustainability options considered in regard to ash handling and disposal, include:

- Removal and handling of ash from the furnace and other locations in the boiler to ensure efficient operation and reduce the amount of ash contained in boiler gases
- Dry ash disposal to reduce environmental effects of wastewater and leachate

4.1.2.4 Carbon Capture Readiness

Carbon capture readiness employing Post Combustion Carbon Capture (PCCC) ready design would be incorporated at Bayswater B. An area of 4ha would be allocated on the site to allow for PCCC if and when it becomes available.

PCCC implementation is likely to require connection to flue gas ducts, additional cooling, additional auxiliary power usage and potentially use of steam as part of the PCCC process. Depending upon the technology adopted, other components of plant may be required. PCCC is likely to involve compressed captured carbon which is subsequently piped to a suitable storage site.

Advances in the development of PCCC technology are being made and it is possible that the technology may become feasible within the operational life of Bayswater B. Manufacturers are able to make generators PCCC ready in their designs to enable retrofitting of the technology when it becomes proven and commercially viable.

It is unknown at this stage which PCCC option/s may become available or suitable as technology develops. The proponent would continue to monitor and investigate developing PCCC technologies.

4.2 Gas-fired Power Station Option

The preferred option for the gas-fired power station is a Combined Cycle Gas Turbine (CCGT) plant design. CCGT technology is commercially viable and is suited to providing for base load requirements, with high efficiency due to the combination of a gas turbine and a steam turbine in each unit. The proposed CCGT power plant would operate up to 365 days a year.

The proposed CCGT plant will comprise the following processes and infrastructure (AECOM, 2009):

- Gas supply involving transport of natural gas via pipeline directly to the site.
- Process units for each of the five proposed CCGT units would include:
    - Gas turbine, which firstly compresses air that is used for the combustion of gas, with the resultant hot gases rotating the shaft of the power turbine, producing mechanical energy to drive the electrical generator (and the air compressor)
    - The Heat Recovery Steam Generator (HRSG) then takes in the hot gases exhausted from the gas turbine, using this to heat water flowing through tubes, converting the water into superheated steam.
    - Generator, driven by both the gas turbine and the steam turbine.
    - Air cooled condensers (ACC), where steam exhaust from the turbine is cooled and condensed back into water, which is re-used as feedwater for the HRSG.
    - Stacks, from which exhaust gases from the HRSG and waste heat from the ACC would be discharged.

4.2.1 Infrastructure and processes and their associated emissions to air

4.2.1.1 Gas Supply

Gas would be supplied to Bayswater B via a spur pipeline of approximately 20km from the approved Queensland to Hunter Gas Pipeline (QHGP), which is situated to the northeast of the Bayswater B site. The spur pipeline is proposed to run from the power station site to the northeast towards the Antiene Rail Loop, and then continue north-northeast before connecting with the QHGP near Beggary Creek Road.

Gas would be delivered to the proposed project site 365 days per year. A gas power station at Bayswater B would require approximately 340 TJ per day or 112 PJ per year of natural gas.

Gas would be piped to a common metering, regulating and conditioning station. The gas then enters the compressor station before being supplied to each gas turbine. As gas would be delivered directly into the process units, no storage of gas will be required on site.

4.2.1.2 Main Plant Process Units

Each of the five combined cycle gas turbine units would include a gas turbine – steam turbine – generator enclosure with air inlet filters (40m x 8m x 18m high), heat recovery steam generator (45m x 14m x 22m high) and air cooled condenser (51m x 51m x 27m high). Stacks and various other items of plant are also required for operation of a CCGT power station. Each of these components is discussed below.

Gas Turbine
The gas turbine comprises compressor, combustion and turbine stages. On receival, gas would be compressed in the compressor station, while ambient air is also drawn in to increase the air pressure. Gas and high pressure air are then supplied to the gas turbines low NO_X burners in the combustion chamber. Combustion of fuel gas occurs, resulting in hot gases that pass through the turbine stage of the gas turbine, rotating the shaft of the turbine, producing mechanical energy to drive the electrical generator

The rotation of the gas turbine shaft also continues to drive the air cooler and compressor. In order to offset performance degradation of gas turbines during hot periods, spray systems for cooling the intake air cooling system may also be installed.

The primary pollutants from gas turbine engines are nitrogen oxides (NO_X), carbon monoxide (CO), and to a lesser extent, volatile organic compounds (VOC). As an emissions control measure to control the formation of NO_X, low NO_X combustion burners would be employed.

Heat Recovery Steam Generator
The exhaust from gas turbines has significant heat energy, which is recovered by HRSG. The HRSG takes in the hot gases exhausted from the gas turbine, using the hot gas to heat water flowing through tubes via heat exchange, which converts the water into superheated steam.

HRSGs consist of three major components – the economizer, evaporator and superheater. The economizer is a heat exchange device that captures the waste heat and transfers it to the water. The steam drum and evaporator then convert the heated water into steam. This steam then passes through the superheater to raise the temperature and pressure past the saturation point, converting saturated steam into dry steam used for use in the steam turbines.

A triple pressure HRSG is planned for Bayswater B that would consist of three sections: a LP (low pressure) section, a reheat/IP (intermediate pressure) section, and an HP (high pressure) section. Each section has an evaporator and superheater.

After passing through the HRSG, the cooled gases are discharged to the atmosphere via the stack, while the steam is used to drive the condensing steam turbine and add to the drive of the electrical generator.

Steam Turbine Generator
The steam turbines extract thermal energy from the pressurized steam and convert it into rotary motion. The superheated steam is passed through the steam turbine generator, where the steam rotates a turbine, creating mechanical energy. The steam turbines drive the generators via direct coupling (i.e. a direct drive system), which adds to the mechanical energy already provided to the generator by the gas turbines, creating additional electricity.
After passing through the steam turbines, the steam exits to the air cooled condensers. The generated electricity is transferred to the transmission infrastructure.

Air Cooled Condensers
Low energy steam exhausting from the steam turbines is directed to air cooled condensers (ACC), where it is cooled and condensed back into water. The condensed water is pumped back through feedwater heaters to be re-used in the HRSG.

As for the coal-fired power station scenario, a dry ACC with spray cooling dry cooling is the preferred option. The use of water sprays for additional cooling ameliorates high temperature performance issues.

4.2.1.3 Stacks

The cooled exhaust gases from the HRSG along with waste heat from the ACC would be discharged via five wake-free stacks.

Each combined cycle unit would have a stack some 55 metres high with a diameter of approximately 6.8 metres. The stacks would be the highest part of the power station infrastructure.

4.2.2 Emissions Control and Sustainability

4.2.2.1 CCGT technology

MacGen has adopted CCGT technology utilising F Class Gas Turbines to maximise plant thermal efficiency and minimise greenhouse emissions per unit of energy produced. The benefit of CCGT is that the maximum energy is derived from the gas fuel source due to the amalgamation of a gas turbine and a heat recovery steam generator combined with a steam turbine in each unit.

Low NO_X burners in the gas turbine combustion chambers will deliver a significantly lower emission concentration than the limit regulated under the NSW Clean Air Regulation (2002).

4.2.2.2 Carbon Capture Readiness

Carbon capture readiness employing PCCC ready design will be incorporated for the Bayswater B CCGT option in a similar manner to the design for the USCPC option.

5. Emissions

This section provides details of the source characteristics and the emission rate of air pollutants being released to atmosphere that have been considered in the air quality impact assessment for the Bayswater B project. The coal- and gas-fired power station options are discussed separately.

Emissions from other existing sources of air pollutants in the region that contribute to background concentrations observed at the MacGen ambient air quality monitoring network, and have been included as part of the cumulative air quality assessment, are discussed in Section 7.6.

5.1 Ultra Super Critical Coal-fired Power Station Option

5.1.1 Best Practice Emission Concentration Limits

In accordance with *Section 128* of the *Protection of the Environment Operations Act (1997)*, licensed premises are required to comply with any air emissions standards prescribed by the regulations. These air emission standards are provided as emission concentration limits, and are presented in *Part 4* of the *Protection of the Environment Operations (Clean Air) Regulation (2002)*.

The standards are in-stack emission limits and are the maximum emissions permissible for an industrial source anywhere in NSW. Even where the Regulation does not prescribe standards for a particular air impurity, occupiers must still take all practicable means to prevent or minimise air pollution (DECC, 2009).

Table 1 presents the emission concentration limits for the relevant air contaminants released from coal-fired energy generating plant, as specified in the Clean Air Regulation (2002).

Table 1 Emission concentration limits from electricity generating plant, as specified in the Clean Air Regulation (2002)

Air impurity	Coal-fired standard of concentration (mg/m^3)
Oxides of nitrogen (as NO_2)	500
Solid particles	50
Fluorine (as HF)	50
Cadmium and mercury individually	0.2
Volatile organic compounds, as propane equivalent or Carbon monoxide	40 125
Type 1 and Type 2 substances	1
Table note: Reference conditions for Group 6 Activities All air impurities for coal burning – Dry, 273 K. 101.3 kPa, 7% O_2	

5.1.2 Source Characteristics and Emissions

The USCPC plant will comprise two boiler units, with both boiler exhaust gas streams being ducted to a single, tall, wake-free, twin flue stack. Table 2 presents a summary of the stack characteristics for the proposed coal-fired power station that have been used in the atmospheric dispersion modelling assessment. In order to account for the buoyancy dynamics of the stack top merging of the plumes emitted from the twin flues, a combined effective stack diameter has been configured in the model.

Table 2 Emission source characteristics for the proposed Bayswater B USCPC Coal-fired Power Station

Parameter	Units	Value
Number of stacks	--	1
Number of flues per stack	--	2
Stack Coordinates - Easting, Northing	MGA Zone 56 (metres)	302821, 6412652
Stack height[1]	m	250 / 300
Stack top flue diameter (each flue)	m	8.17
Stack top cross sectional area (each flue)	m^2	52.42
Effective stack top cross-sectional area (both flues combined)[2]	m^2	104.85
Effective stack top flue diameter (both flues combined)[2]	m	11.55
Stack exit velocity	m/s	24.8
Exhaust gas temperature	^oC	142.30
Actual exhaust gas volume flow (per flue)	Am^3/s	1,300.13
Normalised exhaust gas volume flow (per flue)	Nm^3/s	854.81

Table note:
[1] Two stack height options (250 metre and 300 metre) have been assessed to determine the optimum performance in relation to the minimisation of ground-level concentrations
[2] For dispersion modelling purposes, the twin flues have been combined to model the characteristics of a single effective flue.

Table 3 presents the concentration and mass emission rates of criteria air pollutants released from the proposed coal-fired power station option.

Table 3 Emission concentrations and rates of criteria air pollutants for the proposed Bayswater B USCPC Coal-fired Power Station based on total emission from twin flue stack

Pollutant	Standard of concentration[1] (mg/m^3)	Actual concentration[2] (mg/m^3)	Total emission rate[3] (g/s)
Oxides of nitrogen (as NO_2)	500	349	906
Sulfur dioxide (SO_2) average coal S	-	-	2,003
Sulfur dioxide (SO_2) maximum coal S	-	-	2,532
Solid particles (assume all PM_{10})	50	35	90.6
Carbon monoxide	125	87	226.6
Fluorine	50	35	90.6
Chloride	200	139	363
Hydrogen chloride	100	70	181
Volatile organic compounds (as propane equivalent)	40	28	72.5
Dioxins and furans	0.1 ng/m³	0.098 µg/m³	0.254 µg/s

Table note:
[1] Reference conditions for Group 6 Activities in accordance with NSW Clean Air Regulation – Dry, 273 K. 101.3 kPa, 7% O_2. Dioxins and furans referenced to 11% O_2.
[2] Actual stack conditions for coal-fired power station – 415 K. 101.3 kPa, 4.86% O_2, 8.02% moisture content
[3] Total stack mass emission rate for two flues combined
[4] The emission rate for sulfur dioxide has been assessed on the basis of the average and maximum sulfur contents of the coal fuel to provide a range of ground-level concentrations.

The emission rates of speciated organic compounds, metals and metalloids have been calculated based on Bayswater B coal properties, coal usage and energy usage, trace element concentrations from Liddell Power Station coal sampling and the power station LBL and NPI handbooks. The emission factor equations are reproduced in Table 4 and Table 5.

Table 4 Emission factor equations for organic compounds based on LBL and NPI handbooks for coal-fired power stations

Pollutant	Emission factor equation
Benzene	3.4kg/PJ coal
Cumene	$2.7x10^{-6}$ kg/tonne coal
Cyclohexane	$3.4x10^{-5}$ kg/tonne coal
Ethylbenzene	$4.7x10^{-5}$ kg/tonne coal
n-Hexane	$3.4x10^{-5}$ kg/tonne coal
Polychlorinated dioxins & furans	$8.8x10^{-10}$ kg/tonne coal
Sulfuric acid (factor and S%)	0.2xS kg/tonne coal; (S = % sulfur; S = 0.53)
Toluenes	$1.2x10^{-4}$ kg/tonne coal
Total VOCs	0.03 kg/tonne coal
Xylenes	$1.9x10^{-5}$ kg/tonne coal

Table 5 Emission factor equations for metals and metalloids based on LBL and NPI handbooks for coal-fired power stations

Pollutant	Average concentration in coal (ppm)	Emission factor equation
Antimony	0.65	$0.675x[C/AxPM]^{0.63}$ kg/PJ coal
Arsenic & compounds	3.36	$2.73x[C/AxPM]^{0.85}$ kg/PJ coal
Beryllium & compounds	1.66	$1.31x[C/AxPM]^{1.1}$ kg/PJ coal
Boron & compounds	24.5	$Cx10^{-3}x0.5$ kg/tonne coal
Cadmium & compounds	0.08	$2.17x[C/AxPM]^{0.5}$ kg/PJ coal
Chromium (III) compounds	14.6	$0.95x2.6x[C/AxPM]^{0.58}$ kg/PJ coal
Chromium (VI) compounds	14.6	$0.05x2.6x(C/AxPM)^{0.58}$ kg/PJ coal
Cobalt & compounds	7.2	$1.31x[C/AxPM]^{0.69}$ kg/PJ coal
Copper & compounds	19.5	$1.31x[C/AxPM]^{1.1}$ kg/PJ coal
Lead & compounds	9.8	$2.87x[C/AxPM]^{0.8}$ kg/PJ coal
Manganese & compounds	164.7	$2.71x[C/AxPM]^{0.6}$ kg/PJ coal
Mercury & compounds	0.06	$Cx1.7x10^{-4}$ kg/tonne coal
Nickel & compounds	11.4	$2.84x[C/AxPM]^{0.48}$ kg/PJ coal
Selenium & compound	0.94	$6.5x10^{-4}$ kg/tonne coal
Zinc & compounds	32.9	$2.84x[C/AxPM]^{0.48}$ kg/PJ coal

Table note:
C= Concentration of metal in the coal part per million by mass or mg/kg (as received basis)
A= Weight fraction of ash in the coal (10% ash is 0.1 ash fraction)
PM= facility specific emission factor for total emitted particulate matter (kg/GJ) ie particulate matter emitted per GJ heat input

Emission rates of organic compounds, metals and metalloids are shown in Table 6.

Table 6 Emission rates of organic compounds, metals and metalloids for the proposed Bayswater B USCPC Coal-fired Power Station as total emission from twin flue stack

Pollutant	Total emission rate (g/s)
Antimony	0.0005
Arsenic & compounds	0.004
Benzene	0.016
Beryllium & compounds	0.0006
Boron & compounds	2.6
Cadmium & compounds	0.0008
Chromium (III) compounds	0.012
Chromium (VI) compounds	0.0007
Cobalt & compounds	0.004
Copper & compounds	0.01
Cumene	0.0006
Cyclohexane	0.007
Ethylbenzene	0.01
n-Hexane	0.007
Lead & compounds	0.01
Manganese & compounds	0.06
Mercury & compounds	0.002
Nickel & compounds	0.013
Polycyclic aromatic hydrocarbons (as BaP)	0.002
Selenium &compound	0.14
Sulfuric acid (factor and S%)	22.7
Toluenes	0.03
Xylenes	0.004
Zinc & compounds	0.02

5.1.2.1 Sulfur Dioxide Emissions Variability

Sulfur dioxide emissions associated with the coal-fired power station have been estimated based on the rate of consumption of coal fuel in the boilers and the sulfur content of the coal. When fuels containing sulfur are combusted, most of the organic sulfur is oxidised to gaseous SO_2, and is released to atmosphere via the stack.

The sulfur content of the coal to be received by the proposed Bayswater B Coal-fired Power Station has been determined to be in the range of 0.44 – 0.67 wt%. Consequently, SO_2 emissions are expected to vary according to the distribution of sulfur in the coal. Notwithstanding this variability, blending and mixing of the coal resources at the mine to meet a particular coal quality specification will have the effect of smoothing out the peaks in the sulfur content of the coal received by the power station.

The probability density function of the coal sulfur distribution is presented in Figure 1.

This distribution of coal sulfur content and the consequent variable emission rate of SO_2 has been used to calculate the probability of an exceedance of the impact assessment criteria using a stochastic modelling technique, and is described in Section 8.6.3.

5.2 Combined Cycle Gas Turbine Power Station Option

5.2.1 Best Practice Emission Concentration Limits

The Clean Air Regulation (2002) prescribes the emission concentration limits for the relevant air contaminants released from gas-fired energy generating plant. The standards of concentration are presented in Table 7.

Table 7 Emission concentration limits from electricity generating plant, as specified in the Clean Air Regulation (2002)

Air impurity	Gas-fired standard of concentration (mg/m^3)
Oxides of nitrogen (as NO_2)	70
Volatile organic compounds, as propane equivalent or Carbon monoxide	40 125
Table note: Reference conditions for Group 6 Activities All air impurities for gas burning – Dry, 273 K. 101.3 kPa, 15% O_2	

5.2.2 Source Characteristics and Emissions

The CCGT plant will comprise five gas turbine units, with each turbine exhaust gas stream being ducted a tall, wake-free stack, after passing through an HRSG. The HRSG will have the effect of reducing the temperature of the exhaust gases. Table 8 presents a summary of the stack characteristics for the proposed gas-fired power station, used in the atmospheric dispersion modelling assessment. Each stack is located approximately forty-five metres apart and has been explicitly represented in the model.

Table 8 Emission source characteristics for the proposed Bayswater B CCGT gas-fired Power Station

Parameter	Units	Value
Number of stacks	--	5
Number of flues per stack	--	1
Stack Coordinates - Easting, Northing	MGA Zone 56 (metres)	302741, 6412727 302787, 6412705 302838, 6412682 302889, 6412660 302940, 6412637
Stack height	m	54.80
Stack top flue diameter (each flue)	m	6.80
Stack top cross sectional area (each flue)	m^2	36.32
Stack exit velocity	m/s	20.4
Exhaust gas temperature	^oC	102.40
Actual exhaust gas volume flow (per flue)	Am^3/s	740.86
Normalised exhaust gas volume flow (per flue)	Nm^3/s	704.39

The emission rates of speciated organic compounds have been calculated based on Bayswater B emission specification for VOCs and the AP-42 VOC speciation for gas turbines (Table 9).

Table 9 Emission factor equations for organic compounds based on AP-42 for gas-turbines

Speciated VOCs	Emission factor (lb/MMBtu)
1,3-butadiene	4.30E-07
Acetaldehyde	4.00E-05
Acrolein	6.40E-06
Benzene	1.20E-05
Ethylbenzene	3.20E-05
Formaldehyde	7.10E-04
Naphthalene	1.30E-06
Polycyclic Aromatic Hydrocarbon (assume as BaP)	2.20E-06
Propylene Oxide	2.90E-05
Toluene	1.30E-04
Xylene	6.40E-05

Estimated emission rates of VOCs from the gas-turbines are shown in Table 10.

Table 10 Emission rates of organic compounds for the proposed Bayswater B CCGT gas-fired Power Station based on the AP-42 emission factors for gas turbines

Speciated VOCs	Emission rate per stack (g/s)
1,3-butadiene	0.00014
Acetaldehyde	0.013
Acrolein	0.002
Benzene	0.004
Ethylbenzene	0.011
Formaldehyde	0.234
Naphthalene	0.00043
Polycyclic Aromatic Hydrocarbon (as BaP)	0.00073
Propylene Oxide	0.010
Toluene	0.043
Xylene	0.021

6. Air Quality Assessment Criteria

6.1 Relevant Environmental Statutory Requirements

In accordance with *Part 4 of the Protection of the Environment Operations (Clean Air) Regulation (2002): Emission of Air Impurities from Activities and Plant*, the statutory methods that are to be used to model and assess emissions of air pollutants from stationary sources are outlined in the *Approved methods for the modelling and assessment of air pollutants in NSW (2005) (Approved Methods)*. These methods are also specified in the Director-General's requirements for the Bayswater B Power Station project.

The Approved Methods provides guidance in the following areas that are relevant to this study (DECC, 2005):

- Preparation of emissions inventory data
- Preparation of meteorological data
- Methods for accounting for background concentrations and dealing with elevated background concentrations
- Dispersion modelling methodology
- Interpretation of dispersion modelling results
- Impact assessment criteria -
    - Sulfur dioxide (SO_2)
    - Nitrogen dioxide (NO_2)
    - Ozone (O_3)
    - Lead (Pb)
    - PM_{10}
    - Total suspended particulates (TSP)
    - Carbon monoxide (CO)
    - Hydrogen fluoride (HF)
- Individual and complex mixtures of toxic air pollutants
    - Volatile organic compounds
    - Polycyclic aromatic hydrocarbons
    - Metals
    - Metalloids
    - Persistent organic pollutants (Dioxins and Furans)

6.2 Ambient Air Quality Guidelines

6.2.1 Criteria air pollutants

Table 11 presents the relevant air quality impact assessment criteria for criteria pollutants adopted for this assessment.

Table 11 Relevant air quality impact assessment criteria for criteria air pollutants

Pollutant	Averaging period	Criteria[1] (µg/m³)	
Nitrogen dioxide	1-hour	246	
	Annual	62	
Carbon monoxide	15-minute	100,000	
	1-hour	30,000	
	8-hour	10,000	
Particles as PM_{10}	24-hour	50	
	Annual	30	
Sulfur dioxide	10-minute	712	
	1-hour	570	
	24-hour	228	
	Annual	60	
Hydrogen fluoride	24-hour	2.9[2]	1.5[3]
	7 day	1.7[2]	0.8[3]
	30 day	0.84[2]	0.4[3]
	90 day	0.5[2]	0.25[3]
Lead	Annual	0.5	

Note:
[1] Impact assessment criteria at 0°C
[2]General land use, which includes all areas other than specialised land use
[3]Specialised land use, which includes all areas with vegetation sensitive to fluoride, such as grape vines and stone fruits

6.2.2 Total, gaseous or particulate fluoride

The values for fluoride are derived from the ANZECC (1990) Air Quality Goals for Fluoride, which were expressed in terms of concentrations of hydrogen fluoride in the atmosphere, and were intended to apply to the gaseous component of fluoride emissions. Where there are multiple sources of fluoride, the ambient impact assessment criteria would apply to the total exposure. It may be noted in passing that a specific air quality impact assessment criteria for conservation areas has been established for gaseous fluoride, but not for any other air contaminant.

In circumstances where both gaseous and particulate emissions occur, it is generally considered that the particulate component has relatively little effect as compared with the gaseous component (Weinstein 1977, 1983; Doley 1986a). The greater impact of gaseous fluoride is due to its ability to diffuse into plant leaves and its high solubility in comparison with particulate fluoride compounds. The Approved Methods (2005) does not specify the physical phase in which fluoride should be assessed against the impact assessment criteria (i.e., gaseous, liquid or solid – adsorbed to solid particles), but the derivation of the ANZECC (1990) goal for fluoride in air, and its apparent adoption by the DECC, leads to the proposition that it relates to the gaseous component, and not to total fluoride.

6.2.3 Individual toxic air pollutants

In addition to the criteria air pollutants detailed above, the combustion of coal in the coal-fired power station is also likely to produce small quantities of other hazardous air pollutants (HAPs) including VOCs, PAHs, metals, acid gases and dioxins and furans, while the gas-fired plant is likely to produce small quantities of HAPS such as VOCs and PAHs. For air quality impact assessments, it is common practice to consider, and where appropriate adopt, impact assessment criterion for a specific substance from another jurisdiction if information is not available in the Approved Methods (2005). As a result, impact assessment criteria from the following guidelines and standards have been adopted where the Approved Methods (2005) does not provide any assessment criteria for the hydrocarbons identified in this study:

- Texas Commission on Environmental Quality Effects Screening Levels 2009 (TCEQ, 2009)
- Ontario Ministry of the Environment, Ambient Air Quality Criteria, 2008 (MOE, 2008)

Table 12 presents the relevant air quality impact assessment criteria for individual toxic air pollutants adopted from the Approved Methods (2005) for this assessment.

Table 12 Relevant air quality impact assessment criteria for individual toxic air pollutants (Approved Methods, 2005)

Substance	Averaging period	Impact assessment criteria (µg/m³)
1,3-butadiene	1-hour	40
Acetaldehyde	1-hour	42
Acrolein	1-hour	0.42
Benzene	1-hour	29
Chlorine	1-hour	50
Cyclohexane	1-hour	19,000
Ethylbenzene	1-hour	8,000
Formaldehyde	1-hour	20
Naphthalene	1-hour	440[1]
n-Hexane	1-hour	3,200
Hydrogen chloride	1-hour	140
Dioxins and furans	1-hour	2.00E-06
Polycyclic aromatic hydrocarbons (as benzo[a]pyrene)	1-hour	0.4
Propylene Oxide	1-hour	90
Sulphuric Acid	1-hour	18
Toluenes	1-hour	360
Xylenes	1-hour	190

[1] TCEQ (2009)

Table 13 presents the relevant air quality impact assessment criteria for metals and metalloids adopted from the Approved Methods (2005), OME (2008) and TCEQ (2009) for this assessment.

Table 13 Relevant air quality impact assessment criteria for individual metals

Indicator	Averaging period	Impact assessment criteria (µg/m³)
Antimony and compounds	1-hour	9
Arsenic and compounds	1-hour	0.09
Beryllium and compounds	1-hour	0.004
Boron	24-hour	120[1]
	1-hour	50[2]
	Annual	5[2]
Cadmium and compounds	1-hour	0.018
Chromium (III) compounds	1-hour	9
Chromium (VI) compounds	1-hour	0.09
Cobalt	24-hour	0.1[1]
	1-hour	0.2[2]
	Annual	0.02[2]
Copper dusts and mists	1-hour	18
Manganese and compounds	1-hour	18
Mercury organic	1-hour	0.18
Mercury inorganic	1-hour	1.8
Nickel and compounds	1-hour	0.18
Selenium and compounds	24-hour	10[1]
	1-hour	2[2]
	Annual	0.2[2]
Zinc oxide fumes	1-hour	90

Note:
[1] OME (2008)
[2] TCEQ (2009)

7. Existing Environment

7.1 Surrounding Terrain and Land Use

The proposed Bayswater B Power Station is situated approximately four and a half kilometres to the southwest of the existing Bayswater Power Station, with the Liddell Power Station is located a further three kilometres to the northeast on the western edge of Lake Liddell. There are two main population centres in the local region, Singleton and Muswellbrook, while several smaller towns are also situated within a thirty kilometre radius of the proposed site. Table 14 lists the towns identified in the local region, their distance and direction from the proposed Bayswater B site.

Table 14 Towns located in the local region and their direction and distance from the proposed Bayswater B site (in km)

Town	Direction from MacGen to town	Distance from MacGen (km)
Singleton	Southeast	28.0
Ravensworth	Southeast	14.6
Muswellbrook	North-northwest	13.5
Liddell	Northeast	10.6
Dalswinton	West	19.1
Denman	West	20.3
Mangoola	Northwest	18.3
Roxburgh	North-northwest	18.0
Bengalla	North-northwest	14.7
Edinglassie	North-northwest	13.4
Balmoral Corner	North-northwest	12.6
Flower Gardens Flat	North	14.6
Muscle Creek	North-northeast	17.1
Grasstree	North-northeast	14.1
Hebden	East-northeast	15.2
Newdell Junction	East	13.4
Camberwell	Southeast	19.1
Howick	South	8.6
Jerrys Plains	South	9.7

Notwithstanding the abovementioned towns, the region primarily comprises a mixture of open cut coal mines and rural, pastoral land use. To the southwest of the proposed Bayswater B Power Station also lies the Arrowfield Winery. While grape growing for wine making is a feature of the Hunter Valley, vineyards are less prevalent in the local region within twenty kilometres of the proposed site, and tend to be located to the south of Singleton and the north of Muswellbrook.

The terrain in the local region can generally be described as rolling rural, with the Hunter River traversing the landscape and meandering through its broad floodplain. Figure 2 presents a topographical contour map of the region and is representative of the terrain input to the air dispersion model.

7.2 Location of Sensitive Receptors

Figure 3 presents an aerial image of the local region surrounding the existing and proposed power stations, and shows the locations of potential receptors. Many of the buildings identified as potential receptors are associated with local industry including coal mining activities and, consequently, have not been considered as sensitive receptor locations for the purpose of the air quality assessment. With the exception of the monitoring station locations and the Arrowfield Winery, towns outside a ten kilometre radius of the Bayswater B site have not been assessed as sensitive receptor locations. The sensitive receptor locations assessed in the dispersion modelling study are presented in Table 15.

Table 15 Sensitive receptor locations considered in the air quality impact assessment

Receptor		Location	
ID	**Description**	**X coordinate (MGA)**	**Y coordinate (MGA)**
R1	Muswellbrook	302604	6426232
R2	Mitchell Line Road	299821	6424713
R3	Mount Arthur North	299949	6424208
R4	Mitchell Family	300497	6423831
R5	Group of residencies (Perram, Jackson, Newton, Jacobsen, Mitchell Hill, Rivett and Vineburg)	305090	6423878
R6	Hendrik, De Boer and De Boer residence	305845	6422078
R7	Wayne David Smith residence	310491	6419820
R8	Liddell	311481	6419007
R9	Ravensworth	317193	6409808
R10	Jerrys Plains	303155	6403071
R11	Singleton	325986	6396963
R12	Arrowfield Winery	296467	6407848

7.3 Overview of the Local Climate

This section provides an overview of the local climate and meteorology in the Upper Hunter Valley region surrounding the proposed Bayswater B Power Station. The climate summary is based on long term temperature, solar radiation, surface pressure, rainfall and relative humidity observations collected at four monitoring locations by the Bureau of Meteorology (BoM) and wind speed and direction measurements collected at a further three monitoring locations by MacGen, (in accordance with the Environment Protection Licence for Bayswater Power Station). A list of the monitoring sites, parameters measured, and the period of monitoring data available is presented in Table 16. The location of the monitoring stations and the Liddell, Bayswater and Bayswater B power stations are shown in Figure 4.

It should be noted that the analysis of annual climate statistics has been carried out by arranging the months from March through to February the following year in order to combine seasons of sequential months. This has also been done for the purposes of the background air quality analyses and the dispersion modelling.

Table 16 Details of monitoring station operations used in the summary of the local climate and meteorology

Site	Operator	Location	Start date	End date	Parameters recorded
Singleton Sewage Treatment Plant (STP)	Bureau of Meteorology	32.57 latitude 151.16 longitude	November 2002	July 2009	Temperature, rainfall, dew point, cloud cover, wind speed, wind direction
Singleton Water Board	Bureau of Meteorology	32.57 latitude 151.16 longitude	1991	November 2002	Temperature, rainfall, dew point, cloud cover, wind speed, wind direction, solar radiation and relative humidity
Jerrys Plains Post Office (PO)	Bureau of Meteorology	32.50 latitude 150.91 longitude	1884	July 2009	Evaporation, temperature, wind run, rainfall, dew point, cloud cover, wind speed, wind direction, solar radiation and relative humidity
Cessnock Airport	Bureau of Meteorology	32.79 latitude 151.34 longitude	1968	July 2009	Evaporation, temperature, maximum wind gust speed, wind run, rainfall, dew point, pressure, cloud cover, wind speed, wind direction and relative humidity
Mount Arthur North	Macquarie Generation	32.30 latitude 150.88 longitude	January 1995	May 2009	Wind speed, wind direction
Lake Liddell	Macquarie Generation	32.37 latitude 150.96 longitude	December 1994	May 2009	Wind speed, wind direction, rainfall, temperature, relative humidity, net radiation
Ravensworth	Macquarie Generation	32.43 latitude 151.06 longitude	January 1995	May 2009	Wind speed, wind direction

The overall climate tends to be warm temperate/sub-tropical and is indicative of the latitude of the region. The climate is also influenced by its elevation in the Great Dividing Range (approximately 150 metres above sea level) and proximity to the Australian east coast, 100 kilometres northwest of Newcastle and 150 kilometres due west of Smiths Lake. This results in relatively warm, dry summers and cooler, wetter winters. This location provides for the occasional sub-zero minimum daily winter temperatures, while maximum daily summer temperatures can exceed 40°C.

7.3.1 Temperature and solar radiation

The local temperature variability and extremes for the region have been summarised using meteorological data recorded by monitoring stations operated by the BoM at Singleton, Jerrys Plains and Cessnock. The closest of the three monitoring sites to the Bayswater B Power Station is the station at Jerrys Plains, located approximately 12 kilometres south-southwest of the proposed site.

A summary of the seasonal mean and maximum temperatures at the three BoM monitoring sites is presented in Table 17. The average maximum daily temperature at Jerrys Plains ranges from 18.3°C during winter (June to August) to 31.3°C during summer (December to February). The average minimum daily temperature at this site ranges from 16.6°C during summer down to 4.5°C during winter. A time-series of the average daily maximum and minimum temperatures for the three BoM monitoring sites is presented in Figure 5. Table 17 and Figure 5 indicate that maximum and minimum temperatures are very similar at the Jerrys Plains and Singleton sites, with temperatures slightly cooler at the Cessnock site.

Table 17 Seasonal temperature (°C) summary for Singleton, Jerrys Plains and Cessnock

Season	Average daily maximum temperature			Average daily minimum temperature		
	Singleton [1]	Jerrys Plains [2]	Cessnock [3]	Singleton [1]	Jerrys Plains [2]	Cessnock [3]
Summer	31.0	31.3	29.2	16.9	16.6	15.9
Autumn	24.7	25.2	23.9	10.6	11.1	10.7
Winter	18.7	18.3	18.2	4.7	4.5	4.6
Spring	26.2	26.1	24.6	10.7	10.1	9.7
Season	**Maximum temperature**			**Minimum temperature**		
	Singleton [1]	Jerrys Plains [2]	Cessnock [3]	Singleton [1]	Jerrys Plains [2]	Cessnock [3]
Summer	45.9	45.6	44.0	4.5	5.0	2.8
Autumn	38.5	42.8	38.4	-1.2	-1.8	-3.8
Winter	27.8	31.0	30.0	-4.0	-4.5	-6.7
Spring	44.1	44.9	42.5	-1.2	-0.6	-2.8

Table note:
[1] Data period November 2002 to July 2009
[2] Data period 1957 to July 2009
[3] Data period 1968 to July 2009

The average daily solar radiation (MJ/m²) for the region surrounding the proposed Bayswater B Power Station has been summarised using data recorded by the BoM monitoring stations at Singleton (1990 to 2009) and Jerrys Plains (1990 to 2009). Figure 6 presents the mean daily solar exposure (in MJ/m²) recorded at Singleton and Jerrys Plains during 1990 to 2009. This figure illustrates the typical monthly pattern of solar exposure, with the annual solar exposure 2.5 times greater during the summer than the winter. The Singleton and Jerrys Plains sites record similar levels of daily solar exposure, however, the Jerrys Plains site records marginally higher solar exposure during the summer months (October through to March).

7.3.2 Relative Humidity

The relative humidity in the region surrounding the proposed Bayswater B Power Station has been summarised using data from the BoM monitoring sites at Singleton (WB) (1990 to 2002), Jerrys Plains (1990 to 2009) and Cessnock (1994 to 2009).

The monthly averaged relative humidity at 9am and 3pm at the BoM sites at Singleton and Jerrys Plains are presented in Figure 7. This figure shows that the spring and summer months (August to January) tend to be less humid, ranging from 66% to 76% relative humidity at 9am at Singleton and from 59% to 71% at Jerrys Plains. A higher relative humidity was measured during the months of February through to July with measurements at 9am ranging from 82% to 85% at Singleton and from 72% to 80% at Jerrys Plains.

The data also shows that, on average, the relative humidity at Singleton is 56% higher at 9am than at 3pm, while the relative humidity at Jerrys Plains is 47% higher at 9am than at 3pm. The relative humidity at Singleton is higher than that recorded at Jerrys Plains. On average, the relative humidity at Singleton is 12% higher than Jerrys Plains at 9am, and 6% higher at 3pm.

7.3.3 Rainfall

Historical rainfall patterns in the region have been analysed using monitoring data from the BoM stations at the Singleton Sewage Treatment Plant (STP) (between 2002 and 2009) and Jerrys Plains (1884 to 2009). The rainfall data from Jerrys Plains has been used to summarise the long term rainfall patterns for the region. The monitoring site at Singleton has only been operating since November 2002 and has been used to summarise the most recent rainfall patterns in the region.

The monthly distributions of rainfall at Singleton and Jerrys Plains are presented in Table 18 and Table 19, respectively, and as histograms in Figure 8. The annual average rainfall for 1884 to 2009 at Jerrys Plains was 643.2 mm. The annual average rainfall at Singleton was 582.1 mm for the 2003 to 2006 period. There was insufficient rainfall data at the Singleton monitoring site for 2002, 2007, 2008 and 2009 to include these years in the annual rainfall averages.

The seasonal data indicates the spring and summer months tend to be wetter, on average. Much of the rainfall in the region is likely to be associated with the passage of frontal systems and the orographic affects of the range. The autumn and winter months tend to be drier, with relatively low average rainfall during March to May and June to August.

Table 18 Mean, minimum and maximum monthly rainfall at Singleton (November 2002 to June 2009)

Month	Minimum (mm)	Maximum (mm)	Average (mm)	Average Rainfall (%)
January	1.6	108.8	41.2	6.6
February	21.8	172.3	109.0	17.5
March	34.2	100.8	53.5	8.6
April	9.2	55.4	24.8	4.0
May	2.8	43.4	24.7	4.0
June	9.6	249.3	71.6	11.5
July	7.6	32.0	20.1	3.2
August	4.9	69.7	34.4	5.5
September	0.4	113.8	47.6	7.6
October	1.0	102.9	50.1	8.1
November	54.8	143.4	93.1	15.0
December	11.6	76.2	52.2	8.4

Table 19 Mean, minimum and maximum monthly rainfall at Jerrys Plains (1884 to June 2009)

Month	Minimum (mm)	Maximum (mm)	Average (mm)	Average Rainfall (%)
January	0.0	226.3	76.9	12.0
February	0.0	340.4	72.5	11.3
March	0.0	264.3	59.1	9.2
April	0.0	172.2	44.7	6.9
May	0.0	314.3	40.4	6.3
June	2.3	288.4	47.5	7.4
July	0.3	231.6	43.6	6.8
August	0.0	206.9	36.7	5.7
September	0.0	156.1	41.7	6.5
October	1.4	170.0	52.2	8.1
November	1.0	222.0	59.9	9.3
December	0.0	233.1	67.6	10.5

7.3.4 Surface Pressure

The monthly averaged surface pressure at Cessnock (June 1994 to July 2009) is presented in Figure 9. The biannual pattern of peaks and troughs in the monthly averaged pressure field indicates that the months of October through March are dominated by low pressure synoptic conditions that are typically associated with wetter summer conditions, while the months of April through September are dominated by high pressure synoptic conditions that are typically associated with clear, drier conditions.

7.3.5 Inter-annual variability of the regional climate

Historical monitoring data from 1994 to 2009 recorded at the BoM monitoring station at Cessnock has been used to analyse the inter-annual variability in the region for the period to be modelled. The period 1994 to 2009 has been assessed to assist in the process of selecting a representative year of meteorological conditions for the atmospheric dispersion modelling, and covers the period of time monitoring station information was available from MacGen. The inter-annual variability in temperature, relative humidity and rainfall has been summarised in the following sections.

7.3.5.1 Temperature

A summary of the annual temperature variability at Cessnock over the past fifteen years has been presented in Table 20 for each March to February period. A box and whisker plot of this data is presented in Figure 10.

Figure 10 and Table 20 show that there is very little variation in the temperatures recorded at the Cessnock site during 1994 and 2009, with a 1°C maximum difference in the annual mean temperatures recorded at the site during this period. The greatest annual variation in temperature was during 1994 to 1995, with a standard deviation of 7.7. The highest temperature recorded at the site was 43.3°C (2003 – 2004) while the lowest temperature was -6.0°C (2002 – 2003).

Table 20 Annual temperature summary for Cessnock for June 1994 to February 2009 (in °C)

Period	Maximum	95th percentile	Mean	5th percentile	Minimum	Standard deviation
1994 - 1995	40.5	28.0	16.5	3.0	-5.0	7.7
1995 – 1996	39.2	27.3	16.5	5.4	-5.2	6.6
1996 – 1997	36.2	27.5	16.3	5.3	-2.7	6.6
1997 – 1998	41.6	30.1	17.2	4.8	-2.4	7.6
1998 - 1999	38.1	28.1	17.1	6.7	-2.0	6.4
1999 – 2000	39.5	26.7	16.2	5.6	-2.3	6.3
2000 – 2001	42.9	28.6	16.8	4.3	-2.3	7.2
2001 – 2002	37.6	27.1	16.3	4.9	-1.7	6.7
2002 – 2003	41.6	29.4	16.8	4.1	-6.0	7.6
2003 - 2004	43.3	29.0	16.8	5.3	-3.9	7.0
2004 – 2005	42.4	28.5	16.8	4.8	-3.3	7.1
2005 – 2006	42.8	29.6	17.2	4.6	-3.1	7.4
2006 – 2007	41.0	29.5	17.0	4.4	-3.5	7.5
2007 – 2008	36.2	27.2	17.0	6.2	-1.2	6.3
2008 – 2009	40.2	29.0	16.3	4.6	-2.6	7.2

7.3.5.2 Relative humidity

A summary of the annual variability in the relative humidity recorded at Cessnock over the past 15 years has been presented in Table 21 for each March to February period. A box and whisker plot of this data is presented in Figure 11.

Table 21 and Figure 11 show that the lowest relative humidity at the Cessnock site was 2006 to 2007, with a mean relative humidity of 63%. The data also show that the period prior to March 2003 was significantly more humid than the years following, with an annual mean relative humidity between 1994-2003 and 2003-2009 of 75% and 68%, respectively. In addition to this, the data indicates that 95th percentile relative humidity during the years before 2003 was between 99% and 100%, falling to between 92% and 96% after March 2003. This illustrates the drying of the climate during the drought years, particularly the 2006 to 2008 period.

Table 21 Annual relative humidity summary for Cessnock (in %)

Period	Maximum	95th percentile	Mean	5th percentile	Minimum	Standard deviation
1994 – 1995	100	100	69	22	11	25
1995 – 1996	100	100	78	36	13	22
1996 – 1997	100	100	76	33	12	23
1997 – 1998	100	99	76	36	16	21
1998 – 1999	100	100	78	44	15	19
1999 – 2000	100	100	79	43	14	20
2000 – 2001	100	99	75	37	13	21
2001 – 2002	100	100	75	34	9	22
2002 – 2003	100	100	72	27	7	25
2003 – 2004	100	96	69	29	8	22
2004 – 2005	97	94	67	27	8	22
2005 - 2006	95	93	68	29	6	21
2006 - 2007	96	93	64	24	8	23
2007 - 2008	96	93	70	31	8	20
2008 - 2009	94	92	69	31	11	20

7.3.5.3 Rainfall

Historical rainfall data at the Cessnock monitoring site has been used to summarise the annual variability in rainfall patterns in the Hunter Valley region between 1994 and 2009. A box and whisker plot of the rainfall (since 9am) recorded during each March to February period between 1994 and 2009 is presented in Figure 12. The mean, maximum and standard deviation of the recorded daily rainfall (to 9am) for each period is presented in Table 22.

Figure 12 and Table 22 show that there is some variation in the mean daily rainfall (to 9am) recorded between the years, with the mean rainfall ranging from 0.7 mm to 1.5 mm. Based on the mean and peak rainfall recorded to 9am, the periods between 1994 to 1998 and 2002 to 2007 were relatively dry, while the periods between 1996 to 1997, 1998 to 2002 and 2007 to 2009 were relatively wet. The highest recorded rainfall at this site was 114.4 mm, recorded on 15 February 2009.

Table 22 Mean and maximum daily rainfall (to 9am) for each March to February period between 1994 and 2009 at Cessnock Airport

Period	Maximum	Mean	Standard Deviation
1994 – 1995	40.2	0.8	3.7
1995 – 1996	40.4	0.8	3.2
1996 – 1997	68.4	1.1	4.3
1997 – 1998	37.2	0.9	3.7
1998 – 1999	65.4	1.3	4.6
1999 – 2000	54.6	1.1	4.2
2000 – 2001	59.8	1.3	4.7
2001 – 2002	80.6	1.3	5.2
2002 – 2003	68.3	0.7	4.1
2003 – 2004	78.6	1.0	4.3
2004 – 2005	62.8	0.9	3.9
2005 - 2006	62.8	0.9	3.4
2006 - 2007	63.4	0.7	3.2
2007 - 2008	53.1	1.5	5.1
2008 - 2009	114.4	1.4	5.8

The analysis of inter-annual variability indicates that there were only subtle variations in the overall climate during the period 1994 to 2009. This variability was in relation to rainfall and humidity, indicating a general drying of the climate during the periods 1994 to 1998 and 2002 to 2007. This, of course, corresponds to the drought conditions being experienced by much of NSW during this period. This variability has been considered further in the selection of the most representative years to include in the atmospheric dispersion modelling study.

7.4 Local Meteorology

This section presents a summary of the local meteorology (wind speed and wind direction) using monitoring data recorded at the sites operated by MacGen at Mount Arthur North, Lake Liddell and Ravensworth.

7.4.1 Wind speed and wind direction

Wind speed and direction are important parameters for the transport and dispersion of air pollutants. The meteorology of the Upper Hunter Valley region is strongly influenced by topographic effects such as valley drainage and anabatic and katabatic slope flows, as well as synoptic scale patterns and fronts.

The annual, seasonal and diurnal frequency distributions of observed winds at the Mount Arthur North, Lake Liddell and Ravensworth monitoring sites are presented as wind roses in Figure 13 to Figure 20. Table 23, Table 24 and Table 25 present a summary of the distribution of wind speed and direction at the three monitoring sites for the period January 1995 to May 2009, indicating the dominant wind flows for the region.

Table 23 Hourly frequency distribution of wind speeds by direction at Mount Arthur North monitoring station

Wind direction	Wind speed frequency (% of total winds)			
	Light (< 2 m/s)	Moderate (2 – 4.9 m/s)	Strong (≥ 5.0 m/s)	Total
All winds	16	29	55	100
Northwest[1]	3	8	21	32
Southeast[2]	4	12	24	40
Other	8	9	11	28

Table note:
[1] Winds from the northwest (as referenced above) refer to winds from the WNW, NW and NNW directions and have been measured within the compass range of 315° ±33.75 degrees.
[2] Winds from the northwest (as referenced above) refer to winds from the ESE, SE and SSE directions and have been measured within the compass range of 135° ±33.75 degrees.

Table 24 Hourly frequency distribution of wind speeds by direction at Liddell monitoring station

Wind direction	Wind speed frequency (% of total winds)			
	Light (< 2 m/s)	Moderate (2 – 4.9 m/s)	Strong (≥ 5.0 m/s)	Total
All winds	39	49	12	100
Northwest[1]	11	20	5	36
Southeast[2]	13	22	5	40
Other	16	7	1	23

Table note:
[1] Winds from the northwest (as referenced above) refer to winds from the WNW, NW and NNW directions and have been measured within the compass range of 315° ±33.75 degrees.
[2] Winds from the northwest (as referenced above) refer to winds from the ESE, SE and SSE directions and have been measured within the compass range of 135° ±33.75 degrees.

Table 25 Hourly frequency distribution of wind speeds by direction at Ravensworth monitoring station

Wind direction	Wind speed frequency (% of total winds)			
	Light (< 2 m/s)	Moderate (2 – 4.9 m/s)	Strong (≥ 5.0 m/s)	Total
All winds	48	39	13	100
Northwest[1]	14	16	6	37
Southeast[2]	14	18	6	38
Other	20	4	1	25

Table note:
[1] Winds from the northwest (as referenced above) refer to winds from the WNW, NW and NNW directions and have been measured within the compass range of 315° ±33.75 degrees.
[2] Winds from the northwest (as referenced above) refer to winds from the ESE, SE and SSE directions and have been measured within the compass range of 135° ±33.75 degrees.

The region's predominant wind flows are along the northwest to southeast axis of the valley as observed at the Mount Arthur, Liddell and Ravensworth monitoring sites and illustrated in the annual, seasonal and diurnal wind roses. The annual distributions indicate a significantly higher frequency of strong winds above 5 m/s at the Mount Arthur monitoring station, to the north of the Bayswater and Liddell Power Stations, in comparison to the winds observed at the Ravensworth and Liddell sites. This is due to the monitoring station's elevated location near the top of Mount Arthur. The Liddell and Ravensworth locations have a similar frequency of light to moderate winds less than 5 m/s, with 88% and 87%, respectively. The Ravensworth site has the highest frequency of light winds with 49% of the total winds less than 2 m/s.

Figure 16 and Figure 18 indicate there is very little diurnal variation in wind speeds recorded at the Mount Arthur and Liddell sites, while winds at the Ravensworth site are significantly lower during the night compared to the day. At the Ravensworth site light winds from the north are observed predominantly during the hours of midnight to 6am (Figure 20), representing the nocturnal drainage flows.

Figure 16, Figure 18 and Figure 20 identify seasonal variation in the dominant wind flows at the three sites. Winds from the southeast quadrant dominate summer flows, while winds during winter predominantly flow from the northwest quadrant. Autumn and spring months record a similar frequency of winds from both the northwest and southeast quadrant directions.

7.5 Existing Industries in Local Region

A review of the National Pollutant Inventory has identified the following industries within the Upper Hunter Valley region, extending from Muswellbrook in the north to Singleton in the south:

- Coal mining
- Fossil fuel electricity generation
- Petroleum product wholesaling
- Explosive manufacturing
- Other mining support services
- Wine and other alcoholic beverage manufacturing

Table 26 presents a summary of the industries in the Upper Hunter Valley region reporting to the National Pollutant Inventory during the 2007-2008 reporting year. The table includes the reported substances relevant to this air quality impact assessment.

Table 26 Inventory of emission sources reported to the National Pollutant Inventory (NPI) for 2007

Facility Name	Locality	ANZSIC Class Name	Substances
Anglo Coal Drayton Management Pty Ltd	Muswellbrook	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Ashton Coal Mine Camberwell	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Bayswater Power Station	Muswellbrook	Fossil fuel electricity generation	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Bengalla Operations	Muswellbrook	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Buchanans Bulk Fuel Supplies Muswellbrook Depot	Muswellbrook	Mineral, metal and chemical wholesaling	VOC
Cumnock No.1 Colliery	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Dyno Nobel Warkworth Plant	Singleton	Explosive manufacturing	VOC
Glendell Mine	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Hunter Bottling Company	Singleton	Wine and other alcoholic beverage manufacturing	VOC
Hunter Valley Operations	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Integra Coal Mine (Open Cut)	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Integra Coal Underground Mine	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Liddell Colliery	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Liddell Power Station	Muswellbrook	Fossil fuel electricity generation	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Mount Arthur North Coal Mine and Bayswater Colliery	Muswellbrook	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Mt Owen Mine	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Muswellbrook Coal no.1 and no.2 Open Cut Mines	Muswellbrook	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Orica Bayswater Mining Services Plant	Muswellbrook	Explosive manufacturing	VOC
Orica Liddell Mining Services Plant	Singleton	Explosive manufacturing	VOC
Orica Mt Owen Mining Services Plant	Singleton	Explosive manufacturing	VOC
Ravensworth Coal Terminal	Singleton	Other mining support services	F, Pb, VOC
Ravensworth East Mine	Muswellbrook	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Ravensworth Operations (Narama and Ravensworth West Mines)	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Ravensworth Underground Mine	Singleton	Coal mining	F, Pb
Redbank Power	Singleton	Fossil fuel electricity generation	CO, F, Pb, NO_X, PM, dioxins and furans, PAH, SO_2, VOC

Facility Name	Locality	ANZSIC Class Name	Substances
Rix's Creek Pty Ltd	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
United Colliery	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC
Wambo Mine	Singleton	Coal mining	CO, F, Pb, NO_X, PM, PAH, SO_2, VOC

7.6 Existing Air Quality

MacGen has conducted ambient air quality monitoring in the Hunter Valley since 1986. Katestone Environmental has previously carried out a detailed analysis of the monitoring station observations for the period 1994 to 2004 (Katestone Environmental, 2005a). This report includes an analysis of meteorological conditions and the NO_X/SO_2 ground-level concentration ratio is provided to investigate high ground-level concentrations and exceedances of the impact assessment criteria. Analysis of elevated ground-level concentrations of SO_2, NO_2 and PM are provided in Bayswater Power Station's annual Environment Protection Licence returns to DECC. While the annual returns are not discussed in this report, the analysis for the period since 2004 indicates that high ground-level concentrations and exceedances measured during this period were the result of meteorological conditions at the time. They were not caused by operations of Bayswater and Liddell Power Stations outside of their Environment Protection Licence conditions.

This section provides a summary of the ambient air quality data for SO_2, NO_2 and PM, measured at the six air quality monitoring stations operated by MacGen in the period 1994 to 2009. This summary has then been incorporated into the process for the selection of three representative years to be modelled and in the development of the contemporaneous background used in this air quality impact assessment.

7.6.1 Overview of Monitoring Stations

There are currently six monitoring stations recording 10-minute average data for SO_2 and NO_X (this incorporates NO and NO_2). One of the monitoring stations also measures particulate matter. Table 27 provides information on the location of each monitoring station, which pollutants are measured and the recording period. Figure 4 shows the location of the MacGen monitoring stations in the Hunter Valley.

Table 27 Summary of the Macquarie Generation air quality monitoring network

Monitoring Site	Location[1]		Pollutants monitored	Monitoring duration	
	x	y		Start	End
Lake Liddell	311481	6419007	SO_2, NO_2, NOx, NO	June 1994	May 2009
Mount Arthur North	299949	6424208	SO_2, NO_2, NOx, NO	July 1994	June 2004
Ravensworth	317193	6409808	SO_2, NO_2, NOx, NO	January 1995	May 2009
			PM_{10} & TSP	March 2004	June 2009
Muswellbrook	302604	6426232	SO_2, NO_2, NOx, NO	July 1994	May 2009
Singleton	325986	6396963	SO_2, NO_2, NOx, NO	January 1995	May 2009
Mitchell Line Road	299821	6424713	SO_2, NO_2, NOx, NO	July 2006	May 2009

Table note:
[1] MGA94 coordinates

The ambient air quality monitoring data has been analysed in a similar manner to the meteorological observations on an annual basis from 1 March to 28 or 29 February. This allows for the analysis of consecutive months on a seasonal basis. This method has provided for the comparative analysis of ambient air quality and meteorological observations for the selection of the most suitable years to include in the impact assessment. This section provides a detailed summary of ambient air quality in the region for the period 1995 to 2009 for SO_2, NO_2 and PM_{10}.

7.6.2 Nitrogen Dioxide

Table 28, Table 29, Table 30, Table 31, Table 32 and Table 33 provide a summary of the 1-hour and annual average ground-level concentrations of NO_2 recorded at the Singleton, Ravensworth, Lake Liddell, Mount Arthur North, Mitchell Line Road and Muswellbrook monitoring stations during the past fifteen years, respectively. The year in the table's column header refers to the annual period beginning in March, as the data set has been analysed as the period 1 March to 28 to 29 February.

The data indicates that ground-level concentrations of NO_2 in the region are generally well below the ambient air quality objectives. There have been no exceedances of the annual average concentration of NO_2 of 62 µg/m^3 at any of the monitoring stations during the recording period. The maximum annual average ground-level concentration of NO_2 measured at any of the monitoring stations was 26.7µg/m^3 at Ravensworth (for the March 2006 – February 2007) period, which is 41% of the air quality objective.

For the shorter-term 1-hour average, there have been seven exceedances recorded of the air quality objective of 246 µg/m^3 during the fifteen years analysed. Five of the seven exceedances occurred during the 2005-2006 period at the Singleton site and can be attributed to its proximity to a major road. Emissions from motor vehicles are likely to contribute significantly to higher measurements of NO_2 at this site. The 95th percentile value for the 1-hour average of NO_2 for each year at all monitoring stations is less than 60 µg/m^3, which indicates that for the majority of the time, the ambient concentration of NO_2 is less than 25% of the air quality objective.

Table 28 Nitrogen dioxide concentrations (µg/m³) measured at Singleton for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	16	100	95	100	100	100	100	98	100	100	98	95	100	100	98	80
1-hour average (maximum)	49.5	74.4	83.7	117.9	113.9	65.8	68.0	113.0	109.8	82.3	126.5	339.2	85.5	80.3	78.9	339.2
Number of exceedances (1-hour average)	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5
1-hour average (95th percentile)	24.1	39.4	41.9	49.4	42.6	35.4	37.0	40.8	43.0	42.1	44.0	51.3	45.3	43.8	43.2	43.0
Annual average	9.6	14.5	16.2	22.0	18.6	12.7	13.5	15.3	16.0	16.4	17.9	18.9	17.0	16.0	15.8	16.4
Exceedance	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	0

Table note: Impact assessment criteria
- 246 µg/m^3 (1-hour average)
- 62 µg/m^3(annual average)

Table 29 Nitrogen dioxide concentrations (µg/m³) measured at Ravensworth for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	16	97	98	97	96	100	99	100	100	92	47	92	96	96	94	87
1-hour average (maximum)	66.6	154.0	140.5	104.3	93.2	86.7	145.9	96.5	88.3	126.3	60.1	96.5	93.7	103.8	99.7	154
Number of exceedances (1-hour average)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-hour average (95th percentile)	31.3	44.5	65.7	50.8	47.2	43.0	39.6	40.2	42.4	47.5	46.2	52.2	51.9	46.8	43.7	47.5
Annual average	13.7	17.9	26.4	24.0	23.1	19.9	17.2	18.9	18.3	22.0	19.1	22.6	26.7	21.7	21.1	21.3
Exceedance	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Table note: Impact assessment criteria
- 246 µg/m^3 (1-hour average)
- 62 µg/m^3(annual average)

Table 30 Nitrogen dioxide concentrations (µg/m³) measured at Lake Liddell for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	60	95	100	100	98	100	100	99	100	100	91	77	100	99	99	94
1-hour average (maximum)	99.5	85.5	95.0	127.4	143.2	80.9	80.7	150.0	140.1	95.6	92.1	77.2	104.1	116.5	100.6	150.0
Number of exceedances (1-hour average)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-hour average (95th percentile)	20.9	30.6	27.7	37.7	33.9	30.7	30.5	32.0	40.5	38.9	38.0	38.6	41.1	37.0	38.0	35.8
Annual average	6.8	10.4	9.9	14.3	14.2	11.8	11.6	12.2	15.2	17.2	16.0	15.0	17.4	15.6	16.0	13.8
Exceedance	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Table note: Impact assessment criteria
- 246 µg/m^3 (1-hour average)
- 62 µg/m^3(annual average)

Table 31 Nitrogen dioxide concentrations (µg/m³) measured at Mt Arthur for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	61	97	99	97	89	100	100	100	100	100	91	14	0	21	0	70
1-hour average (maximum)	86.4	115.4	78.0	132.9	96.7	69.9	178.5	171.9	165.8	101.0	111.1	79.1	-	68.4	-	178.5
Number of exceedances (1-hour average)	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	0
1-hour average (95th percentile)	36.6	31.5	33.7	41.8	43.5	35.9	36.1	42.1	66.5	45.9	40.8	43.7	-	37.0	-	42.4
Annual average	13.9	10.8	13.2	16.7	19.0	15.3	14.6	15.9	26.9	20.3	16.3	19.8	-	14.7	-	16.7
Exceedance	no	no	no	no	no	no	no	no	no	no	no	no	-	no	-	no

Table note: Impact assessment criteria
- 246 µg/m^3 (1-hour average)
- 62 µg/m^3(annual average)

Table 32 Nitrogen dioxide concentrations (µg/m³) measured at Mitchell Line Road for the duration of monitoring

Period	2006	2007	2008
Data Capture (%)	36.9	100	99.6
1-hour average (maximum)	76.6	85.0	108.2
Number of exceedances (1-hour average)	0	0	0
95th percentile	41.0	42.2	45.5
Annual Average	19.5	18.3	23.3
Exceedance	0	0	0
Table note: Impact assessment criteria - 246 µg/m^3 (1-hour average) - 62 µg/m^3(annual average)			

Table 33 Nitrogen dioxide concentrations (µg/m³) measured at Muswellbrook for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	65	100	97	100	100	98	100	98	100	100	90	95	100	99	98	91
1-hour average (maximum)	70.7	74.2	181.2	229.8	70.4	202.2	102.5	246.9	88.3	187.7	222.5	205.4	91.2	77.2	81.0	246.9
Number of exceedances (1-hour average)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
1-hour average (95th percentile)	30.4	35.6	33.6	47.8	36.2	35.4	32.3	34.2	35.1	56.7	42.1	42.1	38.9	36.4	38.9	38.9
Annual average	12.5	14.6	14.2	20.6	16.0	16.0	14.5	13.8	14.8	26.3	18.2	17.8	17.1	14.9	16.7	16.7
Exceedance	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Table note: Impact assessment criteria - 246 µg/m^3 (1-hour average) - 62 µg/m^3(annual average)																

7.6.3 Sulfur Dioxide

The major source of SO_2 in the region is from the combustion of coal in the Bayswater and Liddell Power Stations. Table 34 shows the number of exceedances for the 10-minute and 1-hour averages of SO_2 at each monitoring station. Table 35, Table 36, Table 37, Table 38, Table 39 and Table 40 provide a summary of the 10-minute, 1-hour, 24-hour and annual average observed ground-level concentrations of SO_2 at the Singleton, Ravensworth, Lake Liddell, Mount Arthur North, Muswellbrook and Mitchell Line Road monitoring stations during the period 1995 to 2009, respectively. The year in the column header refers to the annual period beginning in March, as the data set has been analysed as the period 1 March to 28 or 29 February.

The data indicates the following over the fifteen year period:

- There have been no exceedances of the annual average air quality objective for SO_2 of 60 µg/m^3 at any monitoring station during the period 1995 to 2009
- There has been one exceedance of the 24-hour average air quality objective for SO_2 of 228 µg/m^3, during the period 1995 to 2009, measured on 12 March 2004 at the Mount Arthur Monitoring Station
- There have been several exceedances of the 1-hour average air quality objective for SO_2 of 570 µg/m^3 during the period 1995 to 2009
- There have been several exceedances of the 10-minute average air quality objective for SO_2 of 712 µg/m^3 during the period 1995 to 2009.
- An investigation of the high number of ground-level concentrations of SO_2 that exceeded the impact assessment criteria at Mount Arthur North in 2005 found that the source of the SO_2 emissions was the spontaneous combustion of coal mine spoil heaps situated in close proximity to the monitoring station. After consultation with the DECC, the monitoring station was moved to the Mitchell Line Road location.

Table 34 Number of exceedances of the air quality objective for the 10-minute and 1-hour average for SO_2

Period	Lake Liddell		Mt Arthur		Ravensworth		Muswellbrook		Singleton		Mitchell Line	
	10 minute	1 hour	10 minute	1 hour	10 minute	1 hour	10 minute	1 hour	10 minute	1 hour	10 minute	1 hour
1994	6	2	4	1	0	0	1	1	0	0	-	-
1995	5	1	3	0	0	0	0	0	0	0	-	-
1996	9	3	0	0	1	0	0	0	0	0	-	-
1997	26	5	0	1	1	1	0	0	0	0	-	-
1998	8	1	3	0	0	0	1	0	5	1	-	-
1999	45	12	9	2	0	0	7	1	0	0	-	-
2000	4	1	0	0	4	1	2	0	0	0	-	-
2001	4	0	5	1	5	1	0	0	0	0	-	-
2002	1	0	9	3	0	0	0	0	0	0	-	-
2003	0	0	0	0	0	0	0	0	0	0	-	-
2004	0	0	6	2	1	0	6	2	0	0	-	-
2005	1	1	62	21	0	0	4	2	0	0	-	-
2006	24	6	-	-	0	0	3	1	0	0	1	0
2007	4	0	0	0	17	5	6	1	0	0	1	0
2008	22	7	-	-	7	1	4	0	0	0	5	0

Table 35 Sulfur dioxide concentrations (µg/m³) measured at Singleton for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	16	89	95	98	100	100	100	100	100	100	94	62	45	54	57	93
10 minute average (maximum)	170.5	392.6	338.4	297.5	1002.1	327.9	587.0	465.3	637.2	515.6	587.0	370.2	594.9	428.3	461.9	1002.1
Number of exceedances (10-minute)	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	5
1-hour average (maximum)	126.0	322.3	223.0	213.7	821.0	276.7	442.4	257.8	449.5	108.4	385.1	280.7	376.8	339.7	350.5	821.0
Number of exceedances (1-hour)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
95th percentile (1-hour)	15.0	30.2	21.8	23.1	21.2	25.1	22.5	20.7	30.8	8.4	36.1	39.2	42.7	48.2	42.5	27.3
24 hour average (maximum)	27.5	69.3	42.0	32.2	41.9	52.9	72.5	37.3	58.6	19.6	141.6	68.0	60.0	73.8	61.1	141.6
Number of exceedances (24-hour)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95th percentile (24-hour)	16.8	23.1	19.0	18.7	17.8	22.2	18.8	18.2	29.8	9.9	26.4	32.7	26.8	35.1	29.5	23.6
Annual average	5.5	8.2	6.6	6.4	6.8	8.1	6.1	5.3	7.1	2.1	8.2	9.3	9.3	12.5	10.2	7.1
Exceedance (Annual)	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	0

Table note: Impact assessment criteria
- 712 µg/m^3 (10-minute average)
- 570 µg/m^3 (1-hour average)
- 228 µg/m^3 (24-hour average)
- 60 µg/m^3(annual average)

Table 36 Sulfur dioxide concentrations (µg/m³) measured at Ravensworth for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	13	94	85	79	92	100	99	100	100	92	93	86	91	90	69	85
10 minute average (maximum)	473.3	561.9	813.0	744.3	679.5	634.6	801.1	901.6	605.5	536.7	774.7	682.2	531.4	1163.4	1308.8	1163.4
Number of exceedances (10-minute)	0	0	1	1	0	0	4	5	0	0	1	0	0	17	7	36
1-hour average (maximum)	287.3	309.3	498.0	583.2	402.8	434.7	667.6	592.3	467.1	430.5	529.7	476.4	468.0	1018.8	772.5	1018.8
Number of exceedances (1-hour)	0	0	0	1	0	0	1	1	0	0	0	0	0	5	1	9
95th percentile (1-hour)	43.2	52.9	58.4	66.1	57.1	56.4	54.6	55.5	58.2	56.8	47.6	71.4	66.5	80.6	77.6	60.6
24 hour average (maximum)	58.5	53.0	132.0	83.3	70.4	85.2	117.2	93.3	78.0	88.4	86.6	121.1	122.1	136.6	116.4	136.6
Number of exceedances (24-hour)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95th percentile (24-hour)	38.7	35.1	36.0	43.1	36.1	42.2	44.4	41.0	43.0	42.6	38.2	51.1	46.9	51.2	57.4	43.0
Annual average	11.1	14.2	16.1	15.9	13.6	14.1	12.6	11.4	14.1	14.4	14.4	16.0	12.8	15.6	15.0	14.1
Exceedance (Annual)	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Table note: Impact assessment criteria
- 712 µg/m^3 (10-minute average)
- 570 µg/m^3 (1-hour average)
- 228 µg/m^3 (24-hour average)
- 60 µg/m^3(annual average)

Table 37 Sulfur dioxide concentrations (µg/m³) measured at Lake Liddell for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	34	91	97	89	79	96	100	100	100	100	88	39	69	93	91	84
10 minute average (maximum)	1073.5	992.8	1189.8	1159.4	1294.2	1771.5	1324.6	832.9	740.3	613.4	497.1	811.7	1626.1	943.9	1102.6	1771.5
Number of exceedances (10-minute)	6	5	9	26	8	45	4	4	1	0	0	1	24	4	22	159
1-hour average (maximum)	733.9	616.1	803.3	821.4	665.6	1311.4	633.2	504.6	482.1	466.2	400.6	595.8	1122.8	546	779.1	1311.4
Number of exceedances (1-hour)	2	1	3	5	1	12	1	0	0	0	0	1	6	0	7	39
95th percentile (1-hour)	20.49	12.34	13.44	22.25	19.17	19.83	23.36	18.95	23.80	11.46	26.44	66.98	40.54	14.98	18.07	20.71
24 hour average (maximum)	112.6	77.4	120.3	162.1	153.6	198.5	65.4	97.7	71.7	76.7	164.5	226.9	181.8	115.1	120	226.9
Number of exceedances (24-hour)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95th percentile (24-hour)	31.5	18.5	17	36.3	43	36.3	25.9	28.6	35	16.9	32.4	46.1	47.6	21.3	33.8	30.3
Annual average	6.9	4.8	5.3	9.1	8.1	8.6	6.2	7.2	7.9	3.5	6.8	13	10.6	4.5	7.5	7
Exceedance (Annual)	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Table note: Impact assessment criteria
- 712 µg/m^3 (10-minute average)
- 570 µg/m^3 (1-hour average)
- 228 µg/m^3 (24-hour average)
- 60 µg/m^3(annual average)

Table 38 Sulfur dioxide concentrations (µg/m³) measured at Mount Arthur North for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	46	91	96	90	84	99	100	100	100	100	93	14	-	24	-	67
10 minute average (maximum)	977.0	916.1	540.7	649.1	859.3	1567.9	579.0	1176.6	1237.4	637.2	925.4	1819.1	-	199.9	-	1819.1
Number of exceedances (10-minute)	4	3	0	0	3	9	0	5	9	0	6	62	-	0	-	101
1-hour average (maximum)	732.2	517.1	434.1	602.2	558.1	953.6	531.4	656.6	868.6	486.5	741.2	1153.7	-	170.7	-	1153.7
Number of exceedances (1-hour)	1	0	0	1	0	2	0	1	3	0	2	21	-	0	-	31
95th percentile (1-hour)	98.5	55.7	59.3	85.0	96.3	93.4	78.9	75.2	108.8	100.0	110.6	304.9	-	5.9	-	88.6
24 hour average (maximum)	106.3	64.3	78.1	124.3	94.3	115.5	150.4	80.8	180.1	128.3	228.9	227.1	-	53.7	-	228.9
Number of exceedances (24-hour)	0	0	0	0	0	0	0	0	0	0	1	0	-	0	-	1
95th percentile (24-hour)	70.0	41.1	44.6	54.6	58.7	59.1	47.5	47.9	67.4	66.5	77.6	187.9	-	8.8	-	59.4
Annual average	31.3	15.2	17.2	21.3	24.8	23.7	15.8	13.5	24.0	21.1	21.5	74.6	-	2.3	-	20.6
Exceedance (Annual)	no	no	no	no	no	no	no	no	no	no	no	no	-	no	-	0

Table note: Impact assessment criteria
- 712 µg/m^3 (10-minute average)
- 570 µg/m^3 (1-hour average)
- 228 µg/m^3 (24-hour average)
- 60 µg/m^3(annual average)

Table 39 Sulfur dioxide concentrations (µg/m³) measured at Muswellbrook for the duration of monitoring

Period	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	All Years
Data Capture (%)	64	84	88	75	88	100	100	100	100	100	90	92	100	100	89	96
10 minute average (maximum)	753.5	350.3	502.4	616.1	813.0	1086.7	1031.2	639.8	658.4	454.8	1916.9	1023.2	954.5	1078.8	859.3	1916.9
Number of exceedances (10-minute)	1	0	0	0	1	7	2	0	0	0	6	4	3	6	4	34
1-hour average (maximum)	624.6	280.7	394.2	304.5	489.4	579.5	503.2	388.2	431.0	374.6	959.8	637.6	693.2	589.2	513.8	959.8
Number of exceedances (1-hour)	1	0	0	0	0	1	0	0	0	0	2	2	1	1	0	8
95th percentile (1-hour)	50.9	27.1	28.6	41.6	45.4	48.0	40.5	37.9	36.6	27.8	28.6	48.9	48.9	37.0	33.7	39.2
24 hour average (maximum)	130.4	116.2	69.9	59.2	161.8	81.6	77.5	51.0	75.9	55.3	143.9	103.2	103.0	63.6	102.2	161.8
Number of exceedances (24-hour)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95th percentile (24-hour)	46.5	23.9	25.0	30.3	28.4	37.5	29.4	29.1	27.6	26.0	35.3	41.5	37.6	32.6	32.9	31.7
Annual average	13.6	7.8	8.2	9.2	10.1	10.1	8.4	7.4	7.5	5.3	7.5	9.9	10.1	8.5	7.6	8.6
Exceedance (Annual)	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	0

Table note: Impact assessment criteria
- 712 µg/m^3 (10-minute average)
- 570 µg/m^3 (1-hour average)
- 228 µg/m^3 (24-hour average)
- 60 µg/m^3(annual average)

Table 40 Sulfur dioxide concentrations (µg/m³) measured at Mitchell Line Road for the duration of monitoring

Period	06-07	07-08	08-09
Data Capture (%)	32.9	92.2	88.4
10 minute average (maximum)	777.6	723.7	882.8
Number of exceedances (10-minute)	1	1	5
1-hour average (maximum)	495.6	432.3	525.1
Number of exceedances (1-hour)	0	0	0
95th percentile (1-hour)	101.8	82.4	85.0
24 hour average (maximum)	80.1	72.3	88.2
Number of exceedances (24-hour)	0	0	0
95th percentile (24-hour)	61.1	43.5	49.4
Annual average	22.8	15.5	15.4
Exceedance (Annual)	no	no	no

7.6.4 TSP and PM_{10}

The monitoring of airborne particulate matter as fine particles (PM_{10}) and total suspended particulates (TSP) is carried out at the Ravensworth monitoring station only. A high volume air sampler is used to measure levels of PM_{10} and TSP for 1 day in 6 in accordance with the Australian Standard AS3580.9.6-1990. Hence, the monitoring data is unsuitable for use as a contemporaneous background. Figure 28 presents a summary of the monitoring information for solid particles supplied MacGen. There are a number of exceedances of both the 24-hour average air quality objective for PM_{10} and the annual average objective for TSP. Table 41 presents the number of exceedances for PM_{10} at the Ravensworth monitoring site for the period 2004 to 2009. It is important to note that this monitor is located in close proximity to several open cut coal mines and coal handling activities unrelated to MacGen operations.

Table 41 Number of exceedances of the air quality criteria for the 24-hour average of PM_{10} and Annual average measurement of TSP

Period	Number of Exceedances
	PM_{10}
2004-2005	4
2005-2006	9
2006-2007	2
2007-2008	7
2008-2009	3
2009-present	0
Air quality objective	50 µg/m^3

7.6.5 Fluoride

Ambient concentrations of fluoride are monitored by MacGen in two ways, as part of its ambient air quality monitoring programme in the Upper Hunter Valley Vineyard region. The ambient air monitoring of fluoride has been undertaken at the Ravensworth and Mitchell Line Road since the 1990s. Sampling and testing has also been undertaken at several vineyards, to determine the uptake of fluoride in grapevine leaves over the same period.

Table 42 presents the results of the ambient monitoring for fluoride at Ravensworth and Mitchell Line Road for the period 2004 – 2008.

Table 42 Monthly ambient fluoride monitoring information for the Ravensworth and Mitchell Line Road monitoring stations for the period 2004 - 2008

Month	Ravensworth			Mitchell Line Road		
	Gaseous HF	Particulate HF	Total HF	Gaseous HF	Particulate HF	Total HF
Mar-04	0.19	0.01	0.20	-	-	-
Apr-04	0.10	0.01	0.11	-	-	-
May-04	0.10	0.01	0.11	-	-	-
Jun-04	0.09	0.05	0.15	-	-	-
Jul-04	0.26	0.04	0.30	-	-	-
Nov-04	0.05	0.08	0.13	-	-	-
Dec-04	0.02	0.04	0.06	-	-	-
Jan-05	0.14	0.01	0.15	-	-	-
Feb-05	0.05	0.01	0.07	-	-	-
Mar-05	0.08	0.01	0.09	-	-	-
Apr-05	0.13	0.02	0.15	-	-	-
Sep-06	0.34	0.18	0.53	N/A	N /A	N/A
Oct-06	0.23	0.01	0.24	0.02	0.01	0.03
Nov-06	0.15	0.01	0.16	0.06	0.01	0.06
Dec-06	0.09	<0.01	0.09	0.14	<0.01	0.14
Jan-07	0.14	0.01	0.15	0.28	0.03	0.31
Feb-07	0.16	0.01	0.17	0.36	0.01	0.37
Sept-07	0.07	0.02	0.09	0.08	0.01	0.09
Oct-07	0.14	0.01	0.15	0.08	0.01	0.09
Nov-07	0.16	0.01	0.17	0.20	0.01	0.22
Dec-07	0.14	0.01	0.15	0.34	0.01	0.35
Jan-08	0.16	0.01	0.17	0.28	0.01	0.29
Feb-08	0.11	0.01	0.12	0.14	0.01	0.15

Table note:
Impact assessment criteria -

Averaging Period	Specialised land use (grape vines)	General land use
90 days	0.25 µg/m^3	0.5 µg/m^3
30 days	0.4 µg/m^3	0.84 µg/m^3
7 days	0.8 µg/m^3	1.7 µg/m^3
24 hours	1.5 µg/m^3	2.9 µg/m^3

The monthly average ground-level concentrations of total fluoride at Ravensworth for the period March 2004 to February 2008 ranged between 0.17 µg/m^3 - 0.53 µg/m^3, while at Mitchell Line Road monthly average ground-level concentrations of fluoride were between was 0.03 µg/m^3 and 0.37 µg/m^3. The 30-day average impact assessment criterion for fluoride is 0.4 µg/m^3 for specialised land use such as grape vines, while the criterion for general land use is 0.84 µg/m^3.

As part of the Macquarie Generation's ambient air quality monitoring programme, the concentration of fluoride in grapevine leaves is monitored through sampling and testing surveys at seven vineyards in the Upper Hunter Valley. The vines are sampled at the end of the growing season in January or February, as fluoride is thought to accumulate in the leaves of grape vines during the growing season (September - January).

Connell Wagner's (2007) report indicates that the average concentration of fluoride in grapevine leaves analysed in 2007 across all samples (from ten grape varieties) was 4 μgFg^{-1}, with a maximum of 10 μgFg^{-1} at the Rothbury vineyard. The leaves from some of the vines showed some visible fluoride damage.

For the 2008 sampling program, the average concentration of fluoride in grapevine leaves analysed across all samples (from ten vineyards) was 6 μgFg^{-1}, with a maximum of 10 μgFg^{-1} at the Rothbury vineyard. The leaves from the vines showed no visible fluoride damage.

Connell Wagner (2008) indicates that the maximum concentration recorded in the time in which sampling has been carried out (1995 – 2008) is 62 μgFg^{-1} in the samples from Edinglassie. The Edinglassie vineyard was not sampled during 2007 and 2008 because the old vines were removed in 2007 and replaced with new vines. The Connell Wagner (2008) report indicates that Edinglassie vineyard had the highest mean concentration of fluoride over the period 1995 - 2006 at 26.7 μgFg^{-1}.

As monitoring for ambient fluoride concentrations is conducted on a monthly average basis at two monitoring stations, a contemporaneous background could not be incorporated into the assessment of cumulative fluoride impacts, particularly for the shorter term 24-hour and 7 day average periods. Consequently, fluoride emissions associated with the Bayswater and Liddell Power Stations have been modelled to provide background concentrations. The emission rate for fluoride is presented in Table 43.

7.6.6 Assessment of background concentrations of carbon monoxide, lead and fluoride

Background levels of carbon monoxide and lead have not been quantified due to:

- The lack of CO and Pb monitoring information in the region
- The insignificant emission rate for CO and Pb associated with the Bayswater and Liddell Power Stations

The emission rates of these pollutants have been based on the information reported by these power stations to the NPI, and are presented in Table 43. The maximum emission rate from the past four reporting years has been used.

The emission rate of CO and Pb from the proposed Bayswater B Power Station are similar to those from the existing Bayswater and Liddell Power Stations. Since, the predicted ground-level concentrations of CO and Pb due to the proposed power station are predicted to be insignificant compared with the impact assessment criteria, the contribution of Bayswater and Liddell Power Stations are unlikely to add considerably to the cumulative impact. Consequently, the assessment for CO and Pb has been presented in isolation.

Table 43 Emissions of carbon monoxide, fluoride and lead from Bayswater and Liddell Power Stations from 2004 to 2008

Source	Year	CO (kg/year)	Fluoride (kg/year)	Lead (kg/year)	CO (g/s)	Fluoride (g/s)	Lead (g/s)
Bayswater Power Station	2004/05	2,000,000	320,000	59	63.4	10.1	1.87E-03
	2005/06	2,000,000	440,000	78	63.4	14.0	2.47E-03
	2006/07	1,800,000	360,000	79	57.1	11.4	2.51E-03
	2007/08	1,800,000	410,000	100	57.1	13.0	3.17E-03
	Maximum	2,000,000	440,000	100	63.4	14.0	3.17E-03
Liddell Power Station	2004/05	1,200,000	150,000	3	38.1	4.8	9.51E-05
	2005/06	1,200,000	150,000	8.2	38.1	4.8	2.60E-04
	2006/07	1,400,000	270,000	9.4	44.4	8.6	2.98E-04
	2007/08	1,400,000	80,000	17	44.4	2.5	5.39E-04
	Maximum	1,400,000	270,000	17	44.4	8.6	5.39E-04

8. Impact Assessment Methodology

The following section details the methodology adopted for the assessment of air quality impacts from the proposed Bayswater B Power Station.

8.1 Atmospheric Dispersion Model Selection

In 2005, Katestone Environmental conducted an initial air quality impact assessment study for the proposed Bayswater B Power Station. This study comprised a model selection study that compared the performance of the TAPM and CALMET/CALPUFF atmospheric dispersion models with observed meteorological and ambient air quality measurements. The Katestone Environmental (2005b) study evaluated the performance of meteorological predictions by TAPM and CALMET with observations at the Ravensworth, Liddell, Mount Arthur and Bengalla meteorological stations, and predictions of ground-level concentrations of SO_2 by TAPM and CALPUFF with observations at the Singleton, Ravensworth, Liddell, Mount Arthur and Muswellbrook ambient air quality monitoring stations for the period 1 July 2000 to 30 June 2001.

The study found that the TAPM model performance performed the best and was selected for use in the air quality impact assessment study. Consequently, TAPM has been selected for use in this air quality study. The TAPM model used in the 2005 study was version 2, and in the time since, a further two versions of the TAPM model have been released. The most recent, version 4, includes several significant improvements, particularly in the simulation of low wind speeds (Hurley, 2002; Hurley, 2008).

As TAPM version 4 has been selected for use in this air quality impact assessment, a comprehensive evaluation of the performance of the model has been undertaken utilising the same observational data set used in the Katestone Environmental (2005b) study. This evaluation is discussed in Section 8.2.

8.2 Evaluation of Dispersion Model Performance

A comprehensive evaluation of the performance of TAPM version 4 was carried out using standard statistical methods for air dispersion model evaluation. This study focussed on the correlation of TAPM model predictions and monitoring station observations for the following:

- Ground-level concentrations of SO_2
- Meteorological parameters including –
    - Surface and upper level wind speed
    - Surface and upper level wind speed and direction as their U and V vector components
    - Surface and upper level temperature

Several conclusions can be drawn from the evaluation of the TAPMv4 model, including:

- The evaluation of the models ability to simulate the local wind conditions and temperature indicates good general agreement between the predictions and observations at both the surface and upper levels.

- Overall, the model performs well with regard to the prediction of the maximum 1-hour average ground-level concentrations, particularly at Liddell, Mount Arthur and Muswellbrook, and is considered suitable for use in the assessment of criteria pollutants.

- Overall, the model performs reasonably well with regard to the prediction of the ninth highest 1-hour average ground-level concentrations, and is considered suitable for use in the assessment of non-criteria air pollutants.

- For the correlation of ground-level concentrations of SO_2 at the five monitoring stations, the location which performed least well in the prediction of the highest percentiles (maximum, ninth highest and Robust Highest Concentration), Ravensworth, is shown to illustrate good skill in the prediction of wind speed and direction.

- The bias illustrated in the correlation statistics at Ravensworth, Liddell, Mount Arthur and Muswellbrook indicate the model's tendency to under-predict ground-level concentrations of SO_2. Further analysis shows that the model tends to under-estimate ground-level concentrations of SO_2 when the observed SO_2 concentration is less than 100 $\mu g/m^3$, and particularly when less than 50 $\mu g/m^3$, by approximately 30 $\mu g/m^3$ - 40 $\mu g/m^3$ for between 35% and 50% of the time. This result is less important for the assessment of impacts from the proposed power stations where the 100^{th} percentile and 99.9^{th} percentile are used and can be largely explained by the issues concerned with the lower detection limit (LDL) and measurement uncertainty of the ambient monitors and the contribution of other sources of SO_2 in the region.

Further detail of the evaluation of the performance of the TAPM model for use in this air quality impact assessment is presented in Appendix B.

8.3 Selection of Representative Meteorological Period for Impact Assessment

To represent the local and regional variability in meteorological and pollution conditions observed in the Upper Hunter Valley, fifteen years of observational data was analysed. The analysis comprised five stages:

1. Meteorological and pollutant concentration observations such as wind speed, wind direction, SO_2 and NO_2 ground-level concentrations were converted to frequency space, represented as a probability density function (pdf) for each year in the dataset.
2. The average bin frequency was taken as the fifteen year climatological and pollutant concentration baseline distribution, against which, each year is assessed for deviations from the average.
3. A correlation matrix was designed to determine the degree of departure each year has from the average and between years. A high correlation (>0.9) shows very little deviation.
4. Weighting in the selection process was also given to those years with observed high maximum concentrations and at the largest variety of locations. Where the highest observed year at Muswellbrook may be different from the highest observed year in Singleton, thereby insuring that all sensitive receptor locations are well represented in the selected dispersion modelling scenarios.
5. A selection of years representative of the variety of conditions was presented to MacGen, and three representative years were selected

The distribution of wind speed and wind direction was determined on an annual basis for all meteorological monitoring sites. The individual frequencies are then averaged across all years, and a climatological baseline produced. The departure of each year from this baseline can then be quantified and anomalous features extracted. The World Meteorological Organisation (WMO) recommends that when calculating a climatological average, annual datasets with a capture rate less than 80% be omitted from the analysis (WMO 2007). This is due to the fact that 20% of the data is equivalent to an entire season (e.g. summer) and further analysis of these years would adversely skew the results towards a year that is only representative of a particular season or missing an entire seasonal component. Years that have been excluded from the analysis due to the above criteria are noted for each site (Appendix C).

In the selection process those years that contain the highest quality and amount of data for both meteorological variables and pollutant concentrations for all monitoring locations was given a higher weighting. Thereby a robust and accurate evaluation of the models performance was possible while ensuring that each location is well represented in the data and the analysis of potential impacts.

Three representative years have been selected based on the analysis detailed in Appendix C. These years are:

- March 1 1999 to February 28 2000
- March 1 2000 to February 28 2001
- March 1 2007 to February 28 2008

These years were selected as being the most representative of the range of likely impacts to be experienced at sensitive locations while maintaining a conservative element to the assessment and enabling a robust evaluation of the dispersion models performance.

Appendix C Section C1.3 showed that the inter-annual variability of wind speed and wind direction does not vary significantly from year to year or site to site. This indicates that other meteorological variables such as the exchanges of surface energy fluxes, boundary layer development or the formation of nocturnal jets are more important to the dispersion of pollutants in the Upper Hunter Valley.

8.4 TAPM Atmospheric Dispersion Model Configuration

The Air Pollution Model (TAPM) version 4.0.2 was used as the meteorological model and air dispersion model for the air quality assessment of the proposed Bayswater B Power Station. TAPM consists of a three-dimensional ‘inline’, nested, prognostic meteorological and air pollution model that solves the fundamental equations of atmospheric flow, thermodynamics, moisture conservation, turbulence and dispersion.

The meteorological component of the model is initialised at the boundary of its outer grid with synoptic analyses provided by the Bureau of Meteorology’s (BoM) Local Area Prediction System (LAPS) at six hourly intervals. The model includes land surface schemes for vegetated canopies, soil type and monthly varying soil moisture, leaf area index (LAI) and sea surface temperature (Hurley 2008).

The air pollution component of TAPM consists of an Eulerian Grid Module (EGM) and a Lagrangian Particle Module (LPM). The EGM computes the mean and variance of a concentration across a grid cell, while the LPM tracks the mass of up to 1,000,000 particles within the modelling domain. In order to improve computational efficiency, a combination of EGM and LPM can be used in the same model run, where after a user specified time-step the particle is no longer tracked and its mass is converted to concentration and put onto the EGM grid. This ensures that maximum ground-level concentrations from elevated point sources are represented in by the LPM before converting to EGM, thereby greatly improving the accuracy of the model in predicting near source (< 2 km) impacts. For this modelling configuration, a Lagrangian time-step of 900 seconds was used.

The prognostic meteorology is passed to the air pollution model every 5 minutes of simulated time allowing pollution calculations to adjust for rapidly changing meteorological conditions.

8.4.1 TAPM Meteorological Setup

TAPM was initialised with synoptic analyses provided by BoM LAPS data at a resolution of 75 km by 75 km. Three modelling years were selected to represent the local and regional variability in meteorological conditions observed in the Upper Hunter Valley. Fifteen years (1994 to 2008) of observational data was analysed and three representative years were selected, as discussed in Section 8.3. The years selected were as follows:

- 1 March 1999 to 28 February 2000
- 1 March 2000 to 28 February 2001
- 1 March 2007 to 29 February 2008

The March to February timeframe was chosen to maintain seasonal continuity throughout the modelling scenarios.

TAPM meteorology was configured as follows:

- Mother domain grid cell resolution of 30 km with 3 nested daughter grids of 10 km, 3 km and 1 km
- 50 x 50 grid points for all modelling domains resulting in a 50 x 50 km grid at 1 kilometre resolution
- 25 vertical levels, from the surface up to an altitude of 8000 metres above ground level
- Geoscience Australia 9 second Digital Elevation Model (DEM) terrain data
- Monthly varying sea surface temperature
- Version 4 land surface scheme
- Prognostic turbulent kinetic energy (TKE) and eddy dissipation rate
- Boundary conditions on outer grid from LAPS synoptic analysis

8.4.2 TAPM Pollution Setup

The TAPM pollution component was set to tracer mode with no chemistry, and with pollution variance to enable the computation of statistical averages at sub 1-hour intervals. The memory resources required to calculate and store sub 1-hour concentration grids in a model as complex as TAPM is unfortunately prohibitive, hence the lack of time-series data for sensitive receptor locations at this finer time resolution.

TAPM pollution was configured as follows:

- Inner most grid 500 metres
- 99 by 99 grid points resulting in a 50 km by 50 km pollution domain
- All emission sources initialised in LPM
- 900 second particle travel time before converting to EGM
- Prognostic pollution concentration variance calculated

8.5 Description of Dispersion Meteorology

The following sections present a summary of the meteorology predicted by TAPM for the Bayswater B Power Station site for the selected modelling years only (1999 – 2000, 2000 – 2001 and 2007 – 2008). The summary includes an overview of the wind speed and direction, atmospheric stability and mixing height at the proposed site.

8.5.1 Wind Speed and Direction

The annual, seasonal and diurnal distribution of winds predicted by TAPM for the Bayswater B Power Station site for the three monitoring periods are presented in Figure 29, Figure 30 and Figure 31, respectively for 1999 – 2000; Figure 32, Figure 33 and Figure 34, respectively for 2000 – 2001; and Figure 35, Figure 36 and Figure 37, respectively for 2007 – 2008. The wind rose diagrams present the winds at ten metres above ground.

The dominant wind flows along the northwest to southeast axis of the valley that were shown in the monitoring data at the Mount Arthur, Lake Liddell and Ravensworth sites (Section 7.4.1) are also seen in the annual, seasonal and diurnal distribution of winds predicted by TAPM for the Bayswater B Power Station site.

The predicted annual wind roses show a predominance of light to strong winds from the east-southeast to south-southeast and moderate to strong winds from the west-northwest to northwest. The annual distribution of winds is similar between modelled periods, with slightly stronger winds predicted from the northwest quadrant and fewer light winds from the south during 2000 to 2001. There is also a slightly higher frequency of moderate to strong winds predicted from the west during 2000 – 2001 and 2007 – 2008 compared to 1999 – 2000.

Seasonally, winds from the east-southeast to south-southeast sector tend to dominate during summer months. Winds from the west-northwest to northwest sector dominate during the winter months, with the exception of 1999 to 2000. The winter of 1999 and the autumn and spring months for all periods have a similar frequency of winds from both sectors (east to south and west to north). The autumn months show a lower frequency of strong winds compared to the other seasons.

The diurnal wind roses show that the predominance of wind flows along the northwest to southeast axis of the valley is predicted to occur during all hours of the day. However, the winds for all three modelled periods are predicted to be stronger during the day compared to the night, and there is a slight deviation from these dominant wind flows during the afternoon and early evening periods. During midday to midnight TAPM predicts a relatively high frequency of winds from the east-southeast to south-southeast sector; however, there are fewer winds predicted from the west-northwest to northwest sector. There is also a low frequency of winds predicted from the northeast and southwest quadrants.

8.5.2 Temperature

A summary of the predicted seasonal maximum, minimum and average temperatures at the Bayswater B Power Station site for the three modelled periods is presented in Table 44. The average temperature at the proposed site is predicted to range from around 11.3 – 11.8 °C during winter to around 21.2 – 23.4 °C during summer. The highest predicted temperature at the site is 41.1°C during summer 2000 – 2001, while the lowest predicted temperature at the site is 0.7 °C during winter 2007.

Table 44 Predicted seasonal temperature summary (°C at 10m) for proposed Bayswater B Power Station site for three modelled periods

Period	Autumn			Winter			Spring			Summer		
	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave
1999-2000	34.0	5.7	17.8	23.0	2.5	11.8	31.9	4.2	17.2	35.7	12.0	21.3
2000-2001	31.8	3.0	17.8	19.9	2.6	11.3	34.3	6.3	18.6	41.1	12.8	23.4
2007-2008	37.7	4.8	18.4	24.2	0.7	11.8	34.5	7.3	18.7	35.1	12.4	21.2

Figure 38 presents box and whisker plots for the hourly distribution of the TAPM predicted temperature at a height of 10 metres at the proposed Bayswater B Power Station site for the three modelled periods. The figures show temperature at the site is predicted to increase steadily from around 6 – 7 am, peak at around 2 – 3 pm before reducing steadily around sunset (5 – 6 pm). These plots also show that the maximum temperatures are predicted to be higher during 2000 – 2001 compared to the other modelled periods.

8.5.3 Atmospheric Stability

The monitoring station operated by Macquarie Generation at the Liddell site records meteorological parameters including wind speed, wind direction and temperature; however, there is insufficient data available recorded at this location to calculate stability class and mixing height. Upper level temperature data is required to calculate the temperature gradient in order to determine the stability class and mixing height. The nearest upper level meteorological monitoring station is operated by the Bureau of Meteorology at the Williamtown RAAF base, approximately 98 kilometres to the southeast of the proposed Bayswater B Power Station. The upper level monitoring station located in Williamtown is not representative of the upper-level meteorology at the Bayswater B site due to topographical differences and the relative distances of the sites from the coast.

Where local meteorological data are insufficient for the purpose of dispersion modelling the DECC accept the use of a meteorological model to generate site specific meteorological data. The meteorological model TAPM has been used to generate a site-specific meteorological data file for the site. Stability class has been calculated from the TAPM meteorological data using the solar radiation/delta T method.

Stability classification is a measure of the stability of the atmosphere. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day to F Class stability, which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Unstable conditions (Classes A to C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for the most frequently occurring Class D conditions are dominated by mechanical turbulence generated as the

wind passes over irregularities in the local surface. During the night time, the atmospheric conditions are generally stable (often Classes E and F).

Table 45 shows the percentage of stability classes at the Bayswater B power station site. There is a high percentage of D class stability (45.1% to 51.6%). This is due to the high frequency of winds with a velocity greater than 2 m/s. The relatively high proportion of B and C class stability is due to the combination of daytime surface heating and moderate wind speeds, with the small percentage of extremely unstable (Class A) conditions the result of the low proportion of light winds. The stable (Class F) conditions occur during light wind conditions at night.

Table 45 Frequency of occurrence of surface atmospheric stability conditions for the Bayswater B power station site

Pasquill-Gifford Stability Classification	Frequency (%)		
	1999 - 2000	2000 - 2001	2007 - 2008
A - Extremely unstable	4.1	4.0	3.7
B - Unstable	10.6	10.3	9.7
C - Slightly unstable	16.0	15.7	15.7
D - Neutral	45.1	47.7	51.6
E - Slightly stable	10.9	10.3	8.7
F - Stable	13.2	12.0	10.6

8.5.4 Mixing Height

The extent of the mixing height and the strength of the temperature inversion are very important features that can limit the degree of dispersion of pollutants. The height of the mixed layer changes with time of day and season. Shallow mixing heights occur at night under stable atmospheric conditions. Generally lower mixing heights occur during winter when stronger temperature inversions and reduced solar radiation restrict the growth of the mixing depth until later in the morning. The degree of dispersion or mixing within the mixed layer is determined by the atmospheric stability.

Mixing height information for the Bayswater B Power Station site has been extracted from TAPM for the three modelling periods (1999 – 2000, 2000 – 2001 and 2007 – 2008) and has been presented as hourly box and whisker plots in Figure 39. The figure shows that the mixing height tends to develop around 8 – 9 am, peaks around 1 – 2 pm before decreasing gradually around sunset (5 – 6 pm).

8.6 Impact Assessment Method and Scenarios

8.6.1 Overview

Table 46 presents an outline of the application of the impact assessment criteria in accordance with the Approved Methods (2005) for all air pollutants. The assessments for NO_2 and SO_2 have been made by comparison of the incremental impact plus the background added contemporaneously at each monitoring station location with the impact assessment criteria. For NO_2 and SO_2, the background has been determined from observations recorded at the network of monitoring stations, with receptors not co-located with a monitoring station having a representative background assigned from a monitoring station located nearby. For PM_{10}, the observations recorded at the Ravensworth monitoring station are not considered representative of the entire modelling domain and other sensitive receptor locations due to the proximity of the monitor to local open cut coal mines, and consequently the assessment has been made in isolation. Notwithstanding this, the

predicted 24-average ground-level concentrations of PM_{10} at receptor locations for all three power stations combined is likely to be insignificant considering the incremental impact of Bayswater B in isolation, and particularly when compared with the impacts associated with the local coal mines.

For HF, only 30-day average observed data was available at the Mitchell Line Road and Ravensworth monitoring stations during the 2007 - 2008 period for the years assessed. Consequently, the cumulative assessment has been carried out by modelling the predicted ground-level concentrations of HF associated with the Bayswater and Liddell Power Stations and combining the concentrations with Bayswater B contemporaneously.

For CO and Pb, insufficient monitoring information was available to add a contemporaneous background at each receptor location. As the predicted ground-level concentrations of CO and Pb are extremely low in comparison to the impact assessment criteria, an assessment of the cumulative effects associated with emissions from the existing power stations was not considered necessary as the cumulative impact will not compromise the air quality in the region.

Monitoring of ambient concentrations of PM_{10} is only carried out at the Ravensworth monitoring station according to AS3580.9.6.-1990 for one day in six. Consequently, a background could not be added contemporaneously. Notwithstanding this, the monitoring location is surrounded by coal mines and is unlikely to be representative of the ambient concentrations of PM_{10} at Singleton and Muswellbrook, the main population centres in the region.

A detailed description of the methodology for quantifying and assessing ground-level concentrations of all air pollutants is presented in Table 46.

Table 46 Application of the Approved Methods impact assessment criteria for all air pollutants

Pollutant	Averaging period	Determination of background concentrations	Impact assessment		
			Assessment	Percentile	Results Presentation
Nitrogen dioxide	1-hour	Observations at 5 monitoring stations	Incremental impact and cumulative	100th	1, 2
	Annual				1, 2
Sulfur dioxide	10-minute	Observations at 5 monitoring stations	Incremental and cumulative impact	100th	1, 2
	1-hour (average coal sulfur content)				1, 2
	1-hour (maximum coal sulfur content)				1, 2
	24-hour				1, 2
	Annual				1, 2
PM_{10}	24-hour	Background not assessed	Incremental impact	100th	3
	Annual				3
Carbon monoxide	15-minute	Background not assessed	Incremental impact	100th	3
	1-hour				3
	8-hour				2, 3
Hydrogen fluoride	24-hour	Model predictions for Bayswater and Liddell PSs	Incremental impact and cumulative	100th	1, 2
	7 days				1
	30 days				1
	90 days				1
Lead	Annual	Background not assessed	Incremental impact	100th	3
Volatile Organic Compounds	1-hour	Background not assessed	Incremental impact	99.9th	3
Polycyclic Aromatic Hydrocarbons (as BaP)	1-hour	Background not assessed	Incremental impact	99.9th	3
Metals and metalloids	1-hour	Background not assessed	Incremental impact	99.9th	3
Acid gases	1-hour	Background not assessed	Incremental impact	99.9th	3
Dioxins and furans	1-hour	Background not assessed	Incremental impact	99.9th	3

Table note: Results presentation
[1] Impact assessment presented as a table of maximum incremental impact plus background at sensitive receptor locations
[2] Impact assessment presented as a contour plot of incremental impact
[3] Impact assessment presented as a table of maximum incremental impact at sensitive receptor locations

8.6.2 Method for the conversion of oxides of nitrogen to nitrogen dioxide

The Approved Methods (2005) prescribes the use of two approaches for the calculation of the rate of conversion of NO_X to NO_2 in the plume, for the calculation of ground-level concentrations of NO_2 at sensitive receptor locations. The two approaches are as follows:

- Janssen method - Janssen *et al*. 1988
- USEPA's Ozone Limiting Method – Cole and Summerhays 1979, Tikvart 1996

For this air quality impact assessment, the method described by Janssen has been employed.

The Janssen method is based on three main variables:

- The rates of the chemical reactions involving NO, NO_2 and O_3
- The time it takes for the plume to reach the receptor, providing for the length of time the plume is exposed to solar radiation
- Ambient concentration of O_3

Plume travel time is incorporated in to the equation as a function of wind speed and the downwind distance of the receptor from the emission source.

The method incorporates two reaction rates, one constant and the other variable:

- A constant reaction rate between NO and ambient O_3
- A variable photo-dissociation rate, that varies according to solar radiation

The following assumptions and parameters were then incorporated into the Janssen equation to calculate the ground-level concentration of NO_2 at each of the sensitive receptor locations:

- Hourly averaged solar radiation levels were extracted from the TAPM model and used to calculate the photo-dissociation rate on a linear scale.
- The wind speed at the stack top was extracted from the TAPM output file.
- The in-stack NO_2/NO_X ratio was assumed to be 10% - i.e., 90% of NO_X emitted from the stack is NO.
- A range of possible ground-level concentrations of NO_2 were calculated by assuming an average and a maximum value for ambient concentrations of O_3,
    - 35 ppb representing average conditions
    - 120 ppb representing a high ozone event

8.6.3 Sulfur Dioxide Stochastic Modelling Methodology

Stochastic modelling has been conducted using the methods outlined in Heuff *et al.* (2007). This paper was published after previous studies carried out by Katestone Environmental (2006) for MacGen developed a method for the quantification of the probability of exceeding of the impact assessment criteria due to coal sulfur content variability. The paper is presented in Appendix D.

The combustion of coal with a sulfur content in the upper range of the distribution has the potential to increase the concentration of SO_2 in the emission stream and cause ground-level concentrations of SO_2 that exceed the impact assessment criteria. In order to assess the probability of the combustion of a high sulfur coal coinciding with poor dispersion meteorology and cause an exceedance, the distribution of predicted ground-level concentrations for Bayswater B were convolved with the distribution of SO_2 emissions using a Monte Carlo process. As discussed in Section 5.1.2.1, the expected distribution of stack SO_2 concentrations and emission rates were based on the frequency distribution for coal sulfur content illustrated in Figure 1.

The stochastic simulations comprised the repetition of the Monte Carlo process for 1,000,000 times each hour for each grid point, and the number of times the predicted ground-level concentration exceeded the criteria at each grid point was recorded. To ensure all possible combinations of varying coal sulfur contents and meteorological conditions were compared, the simulations were forced to run for an equivalent of an arbitrary 1,000 years.

The results were then presented as contour plots illustrating the predicted number of exceedences of the impact assessment criteria for the 1-hour average of 570 µg/m^3 in a year.

8.6.4 Photochemical Smog

In December 2004, Katestone Environmental conducted a pre-feasibility air quality study of Bayswater B (Katestone, 2005). Based on conservative estimates, this study established that the local airshed was capable of accommodating the proposed expansion to the existing power station. The pre-feasibility study was subsequently extended (Katestone, 2006a and 2006b) to examine updated operating scenarios and source configurations. Katestone Environmental worked in conjunction with the CSIRO to identify inter-regional transport pathways for and quantify the impact of photochemical smog formation in the Sydney, Newcastle and Wollongong areas.

Four case study periods were examine in detail to quantify the affect of the inter-regional transport of air emissions from Bayswater B on ozone levels. The case study periods correspond to those identified by CSIRO in the Inter-Regional Transport of Air Pollutants Study (IRTAPS 2002).

The study found that the maximum increase in the 1-hour average concentration of ozone within the study region for the study period did not exceed 10.8 ppb and 11.3 ppb for the two model configurations. Regions predicted to experience these variations in the 1-hour average concentration of ozone were found to be located outside the Sydney, Newcastle and Wollongong areas, primarily in the northern portion of the domain, to the west and south of Muswellbrook. The study also found that there was no significant change to the predicted peak 1-hour or 4-hour average concentration of ozone (with values differing by less than 0.3%).

The study concluded that the proposed expansion of Bayswater Power Station was not found to have a significant effect on ozone levels within the Sydney airshed during the case days investigated, and the inclusion of Bayswater B did not lead to additional exceedences of the 1-hour impact assessment criterion for ozone within the study region.

Consequently, no further assessment of the effects air pollutants from the proposed Bayswater B Power Station project will have on the generation of photochemical smog in the Greater Metropolitan Region (GMR) and Hunter Valley has been carried out for this air quality impact assessment.

8.6.5 Assessment of dust emissions from coal stockpiles

The proposed Bayswater B Coal-fired Power Station stack is situated approximately 600 metres from the western boundary of the Macquarie Generation site. The coal stockpiles have been proposed to be located in the area to the west of the plant stack. The area to the west of the boundary is largely occupied by other coal mining operations and forested land. Trees will provide a windbreak and reduce wind speeds, thereby minimising the transport of dust in the direction. In addition to this, the nearest sensitive receptor to the coal stockpile is Arrowfield Winery, approximately eight kilometres to the southwest of Bayswater B. Winds from the northeast that are likely to transport dust in this direction are relatively infrequent in comparison to the annual wind flows and tend to be quite light at less than 3 m/s. Consequently, it is very unlikely that dust emissions generated at the Bayswater B coal stockpiles could be transported the significant distance to the nearest sensitive receptor to cause a nuisance to amenity. Receptor R7 is also close to the existing MacGen power

generation complex and we understand that dust emissions generated by activities at Liddell and Bayswater Power Stations do not provide a nuisance at that location.

Katestone Environmental considers that with the application of appropriate management and dust suppression techniques, dust emissions from the coal stockpiles at the proposed Bayswater B Coal-fired Power Station will not affect air quality at any sensitive receptor locations. Dust management techniques may include:

- Application of a dust suppression veneer to raw material stockpiles
- Minimisation of drop heights for raw materials
- Application of water sprays on haul roads and stockpile pads
- Wind guards on raw material transfer systems and conveyors
- Development of windbreak walls or tree stands downwind of stockpile pad to suppress the transport of dust

9. Interpretation of Air Quality Impacts for the Bayswater B Coal-fired Power Station Option

9.1 Sulfur Dioxide (SO_2)

9.1.1 SO_2 1-hour and 10-minute averages

Predicted ground-level concentrations of SO_2 at nearest sensitive receptor locations are shown in and Table 47 for the proposed coal fired power station with a 250 metre stack. The predictions represent the maximum ground-level concentrations of the three simulation years for 1-hour averages, the ground-level concentrations are represented by the 100th percentile in accordance with the Approved Methods.

The predicted ground level concentrations are presented for Bayswater B in isolation and with a contemporaneous hourly average background concentration added for each simulation year. As the amount of SO_2 emitted by the power station will vary depending on coal sulphur content it is necessary for the model to make predictions based on this variability and provide a range of likely ground-level concentrations. This was achieved by deriving a coal-sulfur frequency distribution based on data supplied by Macquarie Generation of the range of coal-sulfur content found in the coal to be used as fuel at the proposed power station (Figure 1). To be conservative in the assessment, the maximum coal-sulphur content was used to calculate the emission rate from the proposed Bayswater B power station. This was then applied to the tracer concentration from the model and the contemporaneous background for each hour of the simulation year added. The same process was adopted for the average coal-sulfur content. The results illustrate the worst case scenario (maximum coal-sulfur content) and the typical scenario (average coal-sulfur content).

The model results show that the typical scenario will result in no exceedences of the 1-hour SO_2 impact assessment criteria of 570 µg/m^3 at any sensitive receptor location over the three simulation periods due to the proposed power station in isolation. The addition of contemporaneous background concentrations to this scenario results in a maximum of four additional times that the air quality criterion is exceeded across all simulation years.

The model results for the worst case scenario of maximum coal sulfur indicate that there could be two occasions when the 1-hour SO_2 impact assessment criterion of 570 µg/m^3 may be exceeded at Mount Arthur North in year 2000 and, Muswellbrook in simulation year 2007 due to the power station in isolation. The addition of contemporaneous background concentrations to this scenario saw a total increase of seven additional times that the air quality criterion is exceeded across all simulation years.

Table 48 shows the predicted ground-level concentrations of SO_2 at nearest sensitive receptor locations with a 300 metre stack. The same methodology for deriving an equivalent emission rate from the modelled tracer concentration was applied, using the maximum and average coal-sulfur content ratio and the addition of a contemporaneous background.

The model results show that with the implementation of a 300 metre stack the typical scenario will result in no exceedences of the 1-hour SO_2 impact assessment criterion of 570 µg/m^3 at any sensitive receptor location over the three simulation periods due to the proposed power station in isolation. The addition of contemporaneous background concentrations to this scenario is predicted to increase the number exceedances of the 1-hour impact assessment criterion for SO_2 by two, across all simulation years.

The model results for the worst case scenario of maximum coal sulfur indicate that there will be no exceedences of the 1 hour SO_2 impact assessment criteria of 570 µg/m^3 at any sensitive receptor location over the three simulation periods due to the power station in isolation. The addition of contemporaneous background concentrations to this scenario is predicted to increase the number exceedances of the 1-hour impact assessment criterion for SO_2 by three, across all simulation years.

Table 49 shows the predicted 10-minute average ground-level concentrations of SO_2 at nearest sensitive receptor locations due to the proposed Bayswater B coal-fired Power Station in isolation. The model results show that the typical scenario will result in up to one additional exceedence of the 10-minute SO_2 impact assessment criterion of 712 µg/m^3 at up to two sensitive receptor locations over the three simulation periods due to the proposed power station in isolation. Contemporaneous background concentrations cannot be added for this scenario because the model can predict only one 10-minute average prediction per hour.

The model results show that for the worst case scenario of maximum coal sulfur there could be up to two additional exceedence of the 10-minute SO_2 impact assessment criterion of 712 µg/m^3 at up to three sensitive receptor locations over the three simulation periods due to the proposed power station in isolation. Contemporaneous background concentrations cannot be added for this scenario because the model can predict only one 10-minute average prediction per hour.

Figure 40 and Figure 41 present the predicted maximum 10-minute average ground-level concentrations of sulfur dioxide from the proposed Bayswater B coal-fired Power Station in isolation for average and maximum coal sulfur content, respectively, as a composite of the three modelled periods. The results show that elevated concentrations occur within the vicinity of the stack to the west in addition to areas to the north and southwest of the power station where the impacts are terrain induced.

Figure 42 and Figure 43 present the predicted maximum 1-hour average ground-level concentrations of sulfur dioxide from the proposed Bayswater B coal-fired Power Station in isolation for average and maximum coal sulfur content, respectively, as a composite of the three modelled periods. Similar regions of elevated concentrations exist for the 1-hour average as for the 10-minute.

9.1.2 SO_2 24-hour averages

The model results show that the typical scenario will result in no exceedences of the 24-hour SO_2 impact assessment criteria of 228 µg/m^3 at any sensitive receptor location over the three simulation periods due to the proposed power station in isolation (Table 52). The addition of contemporaneous background concentrations to this scenario does not cause any additional exceedances of the air quality criterion across all simulation years.

The model results for the worst case scenario of maximum coal sulfur indicate no exceedences of the 24-hour SO_2 impact assessment criteria of 228 µg/m^3 at any sensitive receptor location over the three simulation periods due to the proposed power station in isolation (Table 52). The addition of contemporaneous background concentrations to this scenario does not cause any additional exceedances of the air quality criterion across all simulation years.

Figure 44 and Figure 45 present the predicted maximum 24-hour average ground-level concentrations of sulfur dioxide from the proposed Bayswater B coal-fired Power Station in isolation for average and maximum coal sulfur content, respectively, as a composite of the

three modelled periods. Ground-level concentrations for the power station in isolation are well below the air quality objectives.

9.1.3 SO_2 annual averages

The model results show that the typical scenario will result in no exceedences of the annual average SO_2 impact assessment criteria of 60 µg/m^3 at any sensitive receptor location over the three simulation periods due to the proposed power station in isolation (Table 53). The addition of contemporaneous background concentrations to this scenario does not cause any additional exceedances of the air quality criterion across all simulation years.

The model results for the worst case scenario of maximum coal sulfur indicate no exceedences of the annual average SO_2 impact assessment criteria of 60 µg/m^3 at any sensitive receptor location over the three simulation periods due to the proposed power station in isolation (Table 53). The addition of contemporaneous background concentrations to this scenario does not cause any additional exceedances of the air quality criterion across all simulation years.

Figure 46 and Figure 47 present the predicted annual average ground-level concentrations of sulfur dioxide from the proposed Bayswater B coal-fired Power Station in isolation for average and maximum coal sulfur content, respectively, as a composite of the three modelled periods. Highest ground-level concentrations for the power station in isolation are located to the west and are well below the air quality objectives.