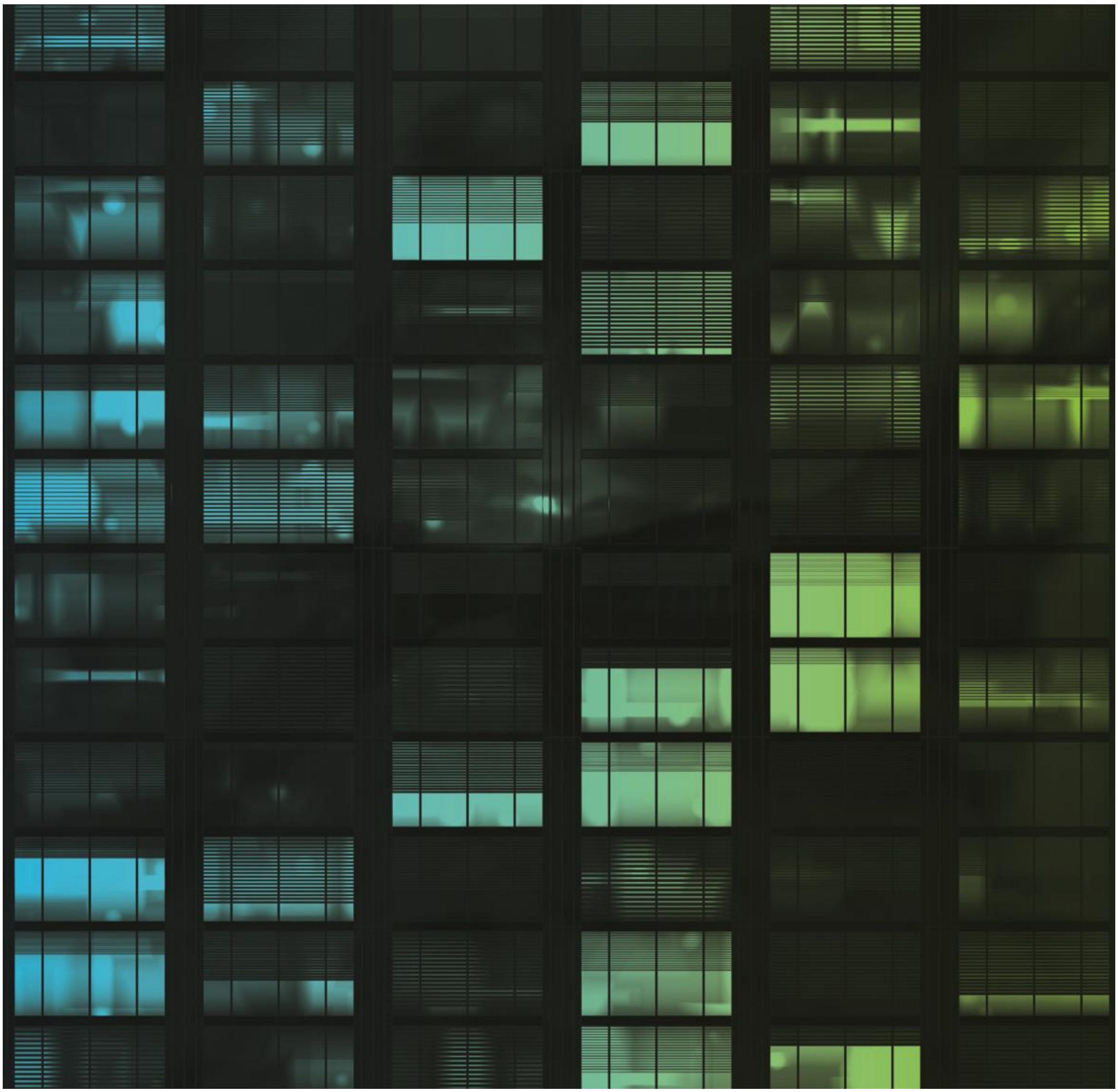
Barangaroo Stage 1A Construction

Lend Lease Project Management and Construction

19 November 2012

# Air Quality Impact Assessment

## Barangaroo Stage 1A Cumulative Construction Assessment



# Air Quality Impact Assessment

Barangaroo Stage 1A Cumulative Construction Assessment

Prepared for

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# Quality Information

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# 1.0 Introduction

This report supports a Project Application (MP11_0002) submitted to the Minister for Planning pursuant to Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Application seeks approval for construction of two residential flat buildings (known as Buildings R8 and R9) and associated works at Barangaroo South as described in the Overview of Proposed Development section of this report.

This Air Quality Impact Assessment (AQIA) addresses the air quality impacts predicted for the R8 and R9 building construction works on behalf of Lend Lease Project Management and Construction (Lend Lease). Due to the concurrent works on other portions of the Barangaroo South development, specifically the approved construction of the commercial buildings C3, C4 and C5 and the operation of an on-site concrete batching plant, a cumulative assessment was undertaken.

## 1.1 Overview of Proposed Development

The R8 and R9 Project Application seeks approval for the construction and use of two residential flat buildings comprising 159 apartments, ground floor retail, allocation of car parking spaces from the Bulk Excavation and Basement Car Parking Project Application, and the construction of the surrounding ancillary temporary public domain and landscaping.

## 1.2 Purpose of this Report

This report was prepared to accompany the Project Application for the R8 and R9 Residential Building and associated works at Barangaroo South. It addresses air quality issues associated with the construction of the project.

## 1.3 Scope of Works

The Director General's Requirements (DGRs) for the R8 and R9 buildings were issued on 21 January 2011. At the time of issue, the nature of the Barangaroo development approvals process as a whole was less well understood; as such, the DGRs focus on management and remediation of contaminated material; these issues have, however, been addressed under separate development applications. This report, therefore, focuses on the construction of the R8 and R9 buildings. As the construction of these buildings will overlap with the construction of other buildings on site (namely the C3, C4 and C5 commercial buildings) and the operation of an on-site concrete batching plant, the assessment considered the cumulative impacts associated with these other sources as well as ambient pollutant concentrations.

The proposed construction works for the R8, R9, C3, C4 and C5 buildings are expected to generate air emissions associated with fuel combustion at the site. Furthermore, the operation of the concrete batching plant on site will generate particulate emissions associated with materials handling and stockpiling of raw materials. This AQIA estimated the worst-case emissions expected during the construction works associated with buildings listed above.

This report assessed impacts on the air environment from the following activities and sources:

- The construction of the R8 and R9 Buildings;
- The parallel construction of sections of buildings C3, C4 and C5; and
- Operation of an on-site concrete batching plant.

The proposed construction works are not expected to be a source of odour; as such, the assessment was limited to nitrogen dioxide ($NO_2$), emitted as a product of combustion by plant and equipment, and particulates ($PM_{10}$ and TSP), emitted as combustion products and by the concrete batching plant.

The assessment was undertaken in accordance with the Environment Protection Authority's (EPA's) Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (2005). Emission rates were estimated using emission factors from the National Pollutant Inventory and other sources as described in the report.

This report:

- Describes the proposed works and their associated pollutant emissions and emission sources;
- Provides a description of existing air quality and meteorology at the site;
- Outlines the methodology used in the assessment, including choice of model, modelling parameters, and quantification of results;
- Assesses the predicted pollutant concentrations against the EPA impact assessment criteria; and
- Provides recommendations on the management and monitoring procedures for the project.

# 2.0 Site Description

## 2.1 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Central and Barangaroo South. The R8 and R9 Project Application Site area is located within Barangaroo South as shown in **Figure 1**. The Project Application Site extends over land generally known and identified in the approved Concept Plan as Block X.

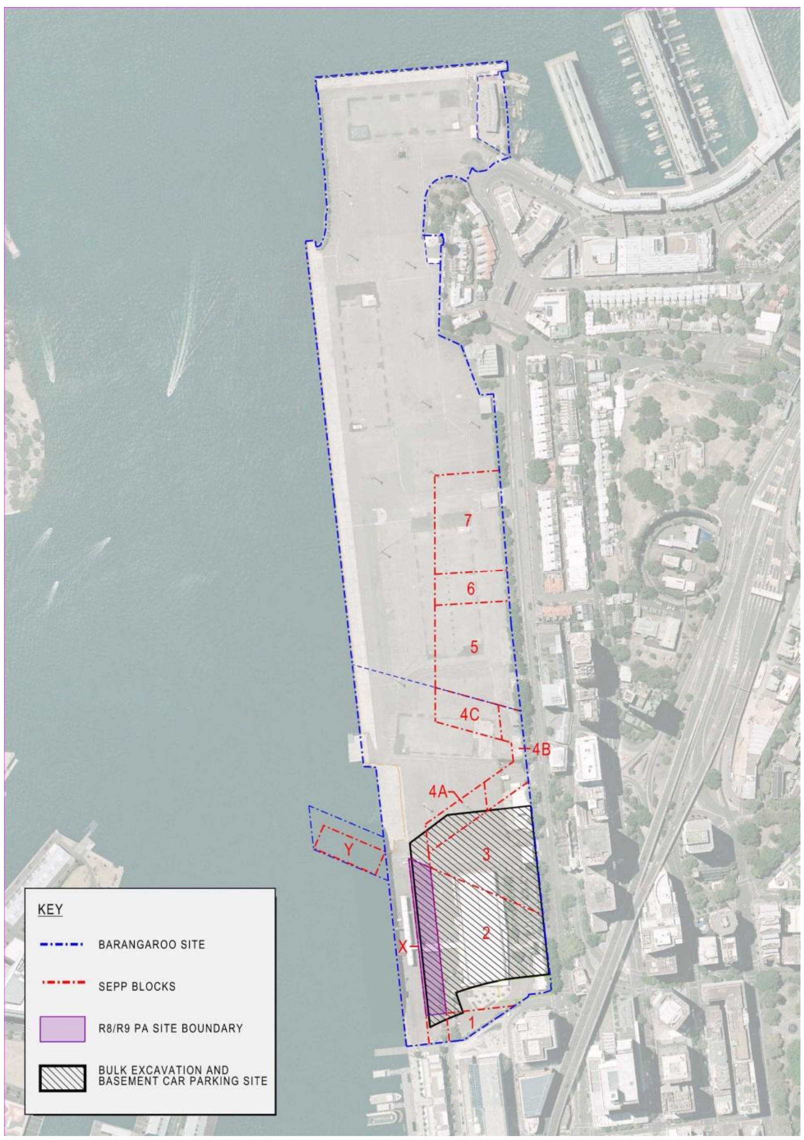


**Figure 1: R8 and R9 Residential Building Project Application (MP11_0002) Aerial Site Location Plan**

## 2.2 Surrounding Land Use and Receptors

Barangaroo is bordered by Sydney Harbour on the western side and by Hickson Road to the east. The closest receptors are located approximately 65 m to the east of the site, in a multilevel residential building located on Hickson Road (38 Hickson Road). A child care centre is located 70 m to the north of 38 Hickson Road at the ground level of a multilevel office building (the Bond Building), which is currently open to the street. Commercial development is located approximately 40 m south of the site. A number of finger wharves containing a mixture of residential and commercial developments are located directly opposite the site, the closest being approximately 250 m west of the site, while the residential suburb of Balmain East is located approximately 400 m to the west of the northern end of the site. Details of the sensitive receptors incorporated into the dispersion modelling are provided in **Section 6.4**.

## 2.3 Cumulative Impacts

A major area of concern for regulatory authorities when preparing an air quality impact assessment for a construction project such as Barangaroo is the degree of cumulative impacts between different stages of a development. As outlined in **Section 1.3**, this assessment included emissions from the construction of a number of buildings on the Barangaroo site (namely buildings C3, C4, C5, R8, R9 and the associated concrete batching plant).

In addition to the construction activities able to be included in the model (due to availability of data to be entered into a dispersion model), a number of other potential contributors to air quality were identified. The additional construction activities occurring on the site were identified as follows:

- Headland Park;
- Basement Car Park Project;
- Wynyard Walk; and
- Barangaroo Central Waterfront Promenade and Interim Public Domain.

The expected contributions to the cumulative impacts for these areas were qualitatively assessed as described below.

***Headland Park**.*

AECOM reviewed the AQIA prepared for the Headland Park excavation and filling works as part of the analysis undertaken for the proposed remediation works within Blocks 4 and 5 and Hickson Road. Due to the distance and orientation of the Headland Park and Blocks 1 - 3 sites and their associated sensitive receptors, it is considered unlikely that the impacts on receptors at one site will be increased due to the contribution of pollutants from the other site.

Consider, for example, wind blowing from the south, as it does for a large proportion of the year. Ambient monitoring at the northern boundary of Barangaroo South would serve as an early warning mechanism of elevated dust levels, which would be managed through Lend Lease's reactive air quality management plan (further described in **Section 8.0**), such that the dust emissions would be controlled to an extent that the northern migration of the dust would be limited. Furthermore, any dust generated from the Barangaroo South area would be expected to be largely dispersed by the time it reached Headland Park. The harbour north of Headland Park contains no sensitive receptors (all sensitive receptors at Headland Park are to the east of the site); as such, any residual dust blown over the harbour would not be a cause for concern from an air quality perspective.

If the wind was blowing from the west, the air quality impacts would be expected to occur to the east of Headland Park and Barangaroo South. As the dust plumes from each site would be travelling along parallel paths in this instance, the plumes would not be likely to combine and, as such, no cumulative impacts would be expected to result from the two projects.

Northerly winds would carry dust from Headland Park toward Barangaroo South. As is the case for southerly winds, however, any dust travelling from Headland Park would be expected to disperse to a degree that is not considered likely to result in cumulative impacts at receptors located south of the site. Again, monitoring at the northern boundary of Barangaroo South would enable times of elevated dust levels to be identified, such that action would be taken on site to limit off-site emissions.

On the basis of the information presented above, the Headland Park works are not expected to increase the cumulative impacts of the R8/R9 project.

***Basement Car Park Project***

The construction of the Basement Car Park (Stage 1B) is expected to be largely complete when the construction of Buildings C3, C4 and C5 commences, with works complete by the time that works for the R8 and R9 buildings commence. The only area of the basement excavation works expected to coincide with the R8/R9 construction work is that being undertaken within the Declaration Area of the Barangaroo site (i.e. within Block 4); these works are the subject of a separate application, which included consideration of the cumulative impacts of the Declaration Area works and the R8/R9 project. While some exceedences of the 24 hour $PM_{10}$ criterion were predicted to occur when the projects were considered cumulatively, the exceedences were attributed to the concrete batching plant included in the R8/R9 assessment, which will be separately assessed and designed to reduce emissions as discussed in **Section 7.0**).

The residual portion of the basement car park will be submitted as a separate application at a future date, and the cumulative impacts with the R8/R9 project will be assessed in that report.

***Wynyard Walk***

At the time of preparation of this AQIA, limited information was known about the Wynyard Walk development. As such, it was not included in the impact assessment. Given the nature of the Wynyard Walk project, however, (i.e. a tunnel) the earthworks and associated construction activities are not expected to add a large quantity of pollutants into the atmosphere to cumulatively affect receptors around the Barangaroo development.

***Barangaroo Central Waterfront Promenade and Interim Public Domain***

The works associated with the Barangaroo Central waterfront promenade and interim public domain area are the works to provide the public domain along the western area of the Barangaroo development. These works will be subject to a separate application at a future date, with the cumulative impacts with the R8/R9 project assessed at that time. That being said, the works are expected to be minor in nature from an air quality perspective, with minor earthworks to accompany landscaping and paving activities.

# 3.0 Proposed Development

## 3.1 The Project

The Project Application for Buildings R8 and R9 will seek approval for the construction of two predominantly residential buildings within Block X of the approved Concept Plan (as modified), and associated public domain works within the Project Application site. The proposed location of Buildings R8 and R9 within Barangaroo South is illustrated indicatively in **Figure 1**.

Buildings R8 and R9 sit entirely within the Lot 5 and Lot 6 of DP 876514, which are owned by the Barangaroo Delivery Authority. The Building R8 and R9 Project Application site has an area of approximately 11,997 $m^2$.

The Project Application will seek approval for:

- Building R8
  - Total Gross Floor Area (GFA) of approximately 8,948 $m^2$, including predominantly ground floor retail uses (approximately 1,048 $m^2$ GFA) and approximately 80 residential apartments;
  - Maximum height of approximately RL 41.5;
- Building R9
  - Total GFA of approximately 8,400 $m^2$ including predominantly ground floor retail uses (approximately 1,050 $m^2$ GFA) and approximately 70 residential apartments;
  - Maximum height of approximately RL 36.7.

Basement car parking spaces for each building's future tenants and servicing and loading dock spaces and bicycle spaces (within the basement car park structure approved under Project Application MP10_0023) will be allocated as part of the proposal.

Landscaping and public domain works within the Buildings R8 and R9 Project Application site area will also be undertaken, including landscaping of the waterfront promenade to the west.

## 3.2 Potential Impacts

As the project is still in the relatively early phases of planning, quantification of emissions during the operation of the proposed buildings could not be achieved at the time of preparation of this assessment report. Industry standard design and construction techniques will, however, be expected to be utilised to address and treat exhaust points such that emissions meet the requirements of relevant Australian Standards. As such, operational emissions were not addressed in this assessment. Details regarding general emission requirements and mitigation measures are provided in **Section 8.0**.

Construction plant and equipment would primarily utilise electrical and diesel-powered plant and equipment. The combustion of diesel fuel generates a range of pollutant emissions, primarily $NO_X$ and particulate matter ($PM_{10}$). Other emissions, such as carbon monoxide, sulphur dioxide and volatile organic compounds, are also emitted from combustion engines, but were not assessed as they were considered to be lower risk than particulate and $NO_X$ emissions due to their generally higher trigger values.

Emissions from the plant and equipment to be used on site were estimated using factors published by the Australian Government for use in the National Pollutant Inventory, measured vehicle emissions from the M5 Freeway Project[1] and emission factors published for a large construction project (The Cadiz Valley Groundwater Storage Project, 2001[2]).

[1] SKM. (2002). M5 East Freeway Sub-Regional Air Quality Management Plan.
[2] Pacific Institute (2001) The Cadiz Valley Groundwater Storage Project; http://www.pacinst.org/reports/cadiz/feir/volumes/vol1/appendix/v1a_c1.pdf

## 3.3 Potential Emission Sources

Details of plant and equipment expected to be used during the construction works were provided by Lend Lease, and consist of:

- Concrete trucks;
- Cranes
- Forklifts;
- Concrete pumps; and
- Concrete batching plant.

Other equipment expected to be used during the construction works, such as the framework, compressors and man and material hoists, would be electrically-powered and, as such, would not generate combustion products during their operation.

The following assumptions were made in the determination of potential emission sources:

- The excavation works undertaken prior to the construction works would be completed prior to the commencement of construction works, to the extent that the site would be covered with hardstand.
- Paved roads were assumed to be maintained, swept and free of dust, with watering undertaken where required such that wheel-generated dust would be minimal;
- Trucks delivering construction materials were assumed to drive on sealed hard stand areas or on watered roads.

Further emission source details are provided in **Section 6.3**. Pollutants of potential concern are discussed in **Section 4.0**.

# 4.0 Pollutants of Potential Concern

The pollutants considered in this assessment were:

- Particulate matter ($PM_{10}$);
- Total suspended particulates (TSP); and
- Oxides of nitrogen [as nitrogen dioxide ($NO_2$)].

A brief discussion regarding these pollutants and their potential effects on health and the environment is provided in the following sections.

## 4.1 Particulates

Particulate matter can be emitted from natural sources (bushfires, dust storms, pollens and sea spray) or as a result of human activities such as combustion activities (motor vehicle emissions, power generation and incineration), excavation works, bulk material handling, crushing operations, unpaved roads and wood heaters.

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. Particles with a diameter of less than or equal to approximately 50 micrometres ($\mu$m) are collectively referred to as total suspended particulates (TSP). TSP primarily causes aesthetic impacts associated with coarse particles settling on surfaces, which also causes soiling and discolouration. These large particles, however, can cause some irritation of mucosal membranes and can increase health risks from ingestion if contaminated. Particles with diameters less than or equal to 10 $\mu$m (known as $PM_{10}$) tend to remain suspended in the air for longer periods than larger particles, and can penetrate into human lungs.

Exposure to particulate matter has been linked to a variety of health effects, such as respiratory problems (such as coughing, aggravated asthma, chronic bronchitis) and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from the inhalation of the dust. Particulate matter, specifically $PM_{10}$, is considered to be a primary pollutant of concern by the EPA and the National Environmental Protection Council.

## 4.2 Nitrogen Dioxide

Nitrogen dioxide ($NO_2$) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide. The mixture of these two gases is commonly referred to as oxides of nitrogen ($NO_x$). $NO_x$ is a product of combustion processes. In urban areas, motor vehicles and industrial combustion processes are the major sources of ambient $NO_x$. $NO_2$ can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. $NO_2$ can also cause damage to plants, especially in the present of other pollutants such as $O_3$ and $SO_2$. $NO_x$ are also primary ingredients in the reactions that lead to photochemical smog formation.

## 4.3 Impact Assessment Criteria

The EPA has specified ground level concentration criteria that are intended to minimise the adverse effects of airborne pollutants on sensitive receptors (DEC, 2005). The ambient air quality criteria for the pollutants considered in this assessment are shown in **Table 1**.

**Table 1: EPA Impact Assessment Criteria**

| Pollutant | Averaging Period | Criteria ($\mu g/m^3$) |
|---|---|---|
| $PM_{10}$ | 24 hour maximum | 50 |
| | Annual | 30 |
| TSP | Annual | 90 |
| $NO_2$ | 1 hour maximum | 246 |
| | Annual | 62 |

# 5.0 Existing Environment

## 5.1 Regional Air Quality

The EPA operates a network of air quality monitoring stations around the state. The closest station to the site is located at Rozelle, (approximately 3.5 km to the west). Ambient pollutant concentrations recorded at this station in 2008 were adopted for this assessment for consistency with previous assessments undertaken for the Barangaroo site.

Ambient TSP concentrations have not been monitored at Rozelle since 2004. The ratio of $PM_{10}$ to TSP from Rozelle for 2004 (the last recorded year of TSP monitoring at Rozelle) was used with the ambient annual $PM_{10}$ concentration from Rozelle in 2008 to estimate the annual TSP concentration. The ratio of $PM_{10}$ to TSP for 2004 was calculated to be 49 % at Rozelle (i.e. 49 % of TSP in the region monitored by Rozelle was $PM_{10}$), which, when applied to the 2008 ambient annual PM10 concentration of 17.4 $\mu g/m^3$, equates to an annual TSP concentration of 35.5 $\mu g/m^3$.

The background concentrations used in the AQIA are summarised in **Table 2**. It should be noted that contemporaneous assessments of 24 hour $PM_{10}$ and 1 hour $NO_2$ were conducted as part of the modelling assessment, which added actual measured pollutant concentrations for each averaging period to the corresponding concentrations predicted by the dispersion modelling; as such, the respective background concentrations provided in **Table 2** were not used in the cumulative assessment and should be considered as indicative concentrations only.

**Table 2: Ambient Pollutant Concentrations, Rozelle Monitoring Stations**

| Air Emission | Averaging Period | Background Concentration ($\mu g/m^3$) | Assessment Criteria ($\mu g/m^3$) |
|---|---|---|---|
| $NO_2$ [1] | 1 hour maximum | 75.2 | 246 |
| | Annual | 20.7 | 62 |
| $PM_{10}$ | 24 hour maximum | 43.1 | 50 |
| | Annual | 17.4 | 30 |
| TSP [2] | Annual | 35.5 | 90 |
| Ozone [3] | 1 hour maximum | 109.8 | 214 |
| | 1 hour maximum | 93.6 | 171 |
| | Annual | 27.1 | - |

[1] $NO_2$ contemporaneous background data used to predict background concentrations using the OLM detailed in **Section 6.6**.
[2] Calculated from annual PM10 concentration as described in text.
[3] Ozone concentrations used for $NO_2$ contemporaneous assessment calculations. Ozone was not modelled as a pollutant.

## 5.2 Climate

The BOM collects meteorological data from various sites in the Sydney Basin. The station at Observatory Hill is less than 200 m from the eastern boundary of the Barangaroo site, while Fort Denison is approximately 2 km to the east of the site. The meteorological data collected from these two stations is complementary and, together, provides an indication of the climate in the immediate area around Barangaroo. Long term data averages recorded between 1859 and May, 2010 are summarised in **Appendix A**.

Average maximum temperatures in summer range from 25.9 °C to 25.2 °C, while minimum temperatures range from 17.5 °C to 18.8 °C. In winter, the average maximum temperature ranges from 16.3 °C to 17.8 °C and the average minimum temperature ranges from 8.0 °C to 9.3 °C.

The annual average humidity reading collected at 9 am from the site is 69 %, and at 3 pm the annual average is 57 %. Rainfall data collected at Observatory Hill shows, on average, that the wettest months are January to June, with average rainfall of greater than 100 mm for each of the intervening months.

Further analysis of the meteorological data is provided in **Section 6.2.1** and **Appendix B**.

## 5.3 Terrain

The Barangaroo project site is located on Sydney Harbour. The ground surface of the entire Barangaroo Site is at an elevation of approximately 2 - 5 m (AHD). The surrounding landform (outside the bounds of the Site) rises rapidly to the east, with a 10 m high sandstone cliff situated east of Hickson Road and Sussex Street. This is the most substantial natural terrain feature in the area; high rise buildings may potentially also affect wind patterns in the project site.

# 6.0 Air Dispersion Modelling Methodology

## 6.1 Overview

Dispersion modelling was undertaken to predict the potential effects of the construction of residential blocks R8 and R9 at the same time as construction of commercial buildings C3, C4 and C5 and operation of the proposed on-site concrete batching plant. The following sections outline details of the dispersion model used and its inputs (specifically meteorology, terrain, building parameters, modelling scenarios, source characteristics and an emissions inventory), sensitive receptor locations, and the methodology used in the estimation of pollutant concentrations.

The modelling was conducted in accordance and/or in consideration of the following statutory documents:

- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC, 2005); and
- Protection of the Environment Operations (Clean Air) Regulation 2010.

## 6.2 Dispersion Model

The CALPUFF air dispersion model was used in the AQIA in accordance with the EPA Approved Methods (DEC, 2005). CALPUFF is a non steady-state, three-dimensional Gaussian puff model developed for the US Environmental Protection Agency (USEPA) for use in situations where basic Gaussian plume models are not effective, such as areas with complex meteorological or topographical conditions, including coastal areas with re-circulating sea breezes.

Input parameters used in the CALPUFF dispersion modelling are summarised in **Table 3**.

**Table 3: CALPUFF Input Parameters**

| Parameter | Input |
|---|---|
| CALPUFF Version | 6.42 - March 2011 |
| Modelling Domain | 3 km x 3 km |
| Modelling Grid Resolution | 20 m |
| Terrain Data | Included in CALMET |
| Building Wake Data | Not included in model |
| Dispersion Algorithm | PG (Rural, ISC curves) & MP Coeff. (urban) |
| Hours Modelled | 8760 hours (365 days) |
| Meteorological Data Period | 1 January 2008 – 31 December 2008 |

CALPUFF requires the following data to determine the dispersion of pollutants:

- Meteorology;
- Terrain;
- Modelling scenarios;
- Source characteristics; and
- Emissions inventory.

The above inputs are addressed separately in the following sections.

### 6.2.1 Meteorology

Meteorology in the area surrounding the site is affected by several factors such as terrain and land use. Wind speed and direction are largely affected by topography at the small scale, while factors such as synoptic scale winds (which are modified by sea breezes near the coast in the daytime), affect wind speed and direction on the larger scale.

Meteorological and topographical data were used to develop the CALMET wind fields to ensure the data used in the dispersion modelling were representative of local conditions. Data used in previous air quality assessments for the Barangaroo Project were used in this assessment for consistency.

The CALMET meteorological model uses actual meteorological observations to generate three dimensional wind fields on an hourly time step at a grid of points covering the area under investigation. Topographical features and land use factors are then used to further refine the wind fields, which are subsequently used in the CALPUFF dispersion model.

Meteorological data were obtained from two sources in the area immediately surrounding the Barangaroo site. Hourly averaged meteorological data for 2008 were sourced from the Rozelle monitoring station (operated by the EPA) and the Fort Denison and Observatory Hill meteorological stations operated by the Bureau of Meteorology (BOM) for the following parameters:

- Observatory Hill - rainfall and temperature;
- Fort Denison - wind speed and direction; and
- Rozelle - wind speed, wind direction, sigma theta, temperature, relative humidity, and solar radiation.

These data were used as input to CALMET as surface file data. In order to assess whether these data were representative of general conditions at the Barangaroo site, they were compared to long-term climate averages obtained from the Observatory Hill and Fort Denison meteorological stations as discussed in **Appendix B**.

The CSIRO-developed prognostic model, TAPM (The Air Pollution Model), was used to define the upper air meteorology for the area surrounding Barangaroo. TAPM data were entered into CALMET as an initial guess for the site meteorological conditions, together with the surface meteorological data recorded at Rozelle, Observatory Hill and Fort Denison.

In order to assess whether the generated meteorological data were representative of long-term average conditions in the area, selected long term climate parameters from the BOM monitoring stations were compared against the CALMET dataset as shown in **Appendix B**. The meteorological data were considered to be representative of meteorology in the area surrounding Barangaroo and acceptable for use in the dispersion modelling.

#### 6.2.2 Terrain

The NASA Shuttle Radar Topographic Mission (SRTM) provides digital elevation data (DEM) for over 80 % of the globe. The SRTM data are available as 3 arc second DEMs, which provide a resolution of approximately 90 m. The vertical error of the DEMs is reported to be less than 16 m.

Digital terrain data required by CALMET were obtained for an area of approximately 7.2 km x 7.2 km (corresponding to the innermost grid of the TAPM meteorological data modelling), approximately centred on the site, from the global SRTM database. The 90 m resolution data were included in the CALMET GEO.dat input file and used together with the TAPM, EPA and BOM meteorological data for determination of the three dimensional modelling meteorological data file required by CALPUFF.

### 6.2.3 Modelling Scenario

A single scenario was assessed. This scenario assumed the following activities:

- Construction of the following buildings occurring simultaneously:
  - R8 and R9 (ground level);
  - C3 and C5 (60 m high);
  - C4 (120 m high); and
- Operation of an on-site concrete batching plant at full operational capacity of 2,000m$^3$/day.

## 6.3 Emissions Inventory

Emission sources that were included in the modelling are listed in **Table 4**. No mitigation measures were applied to the building sources. Mitigation measures applicable to the concrete batching plant were advised by Boral, who will design and operate the plant if approved. Boral's advice was as follows:

- The cementitious points (cement silo and weigh hopper) will be filtered down to a low micron level (about 5 microns), so, in effect, zero emissions will result from these areas.
- The conveyor transfer points are hooded, which will keep the dust enclosed and only small amounts would escape the enclosure; again, effectively zero emissions will be expected from these sources.
- The yard and stockpile areas will be the only source of discernible dust. These areas would be managed via shade cloth wind walls 1.5 m above the height of the stockpile bin walls (3 m concrete wall plus 1.5 m wind wall); sprinklers will also be installed around all of the bins, which will be manually operated depending on the local conditions.
- Emissions from the conveyors, silos and cement hopper discharge points would be negligible or below background levels.
- Lend Lease will operate a water cart that will wet down the yard and hardstand areas as and when required to minimise dust from traffic movements.

The mitigation measures for the concrete batching activities applied in the emissions inventory were based on the mitigation measures described above.

**Table 4: Emission Sources**

| Construction Aspect | Source | Number | Mitigation |
|---|---|---|---|
| Buildings | Cement Trucks | 18 (4 each for C3 – C5; 3 each for R8 & R9) | N/A |
| | Cranes | 13 (3 each for C3 – C5; 2 each for R8 & R9) | N/A |
| | Forklifts | 10 (2 per building) | N/A |
| | Concrete Pumps | 10 (2 per building) | N/A |
| Concrete Batching Plant | Storage bins - loading | 2 | Enclosure (3 walls); wind breaks; water sprays |
| | Storage bins - wind erosion | 2 | Enclosure (3 walls); wind breaks; water sprays |
| | Front end loader | 1 | Water sprays |
| | Materials processing (up to and including loading to concrete truck) | 1 | Fabric filters (cement handling); enclosure on 2/3 sides (other activities) |

Expected operational times for the construction works are 7 am – 6 pm Monday to Friday and 7 am – 5 pm Saturdays. No works are expected on Sundays. For modelling purposes, emission rates were entered into the model as 7 am – 6 pm, 7 days per week for all activities excluding raw material deliveries for the concrete batching plant, which were assumed to occur between 9 am and 4 pm, and wind erosion (continuous). Applying these emission times may over-predict the ground level concentrations over the long term but adds a level of conservativeness in the modelling approach.

Source characteristics of the emission sources for the buildings are outlined in **Table 5**. Two of the three cranes for each of buildings C3, C4 and C5 were modelled as elevated sources (at the height of building); all other plant was assumed to remain at ground level. All emission sources associated with the buildings were modelled as point sources; sources within the concrete batching plant were modelled as area and volume sources. The concrete batching plant was assumed to be located on a hardstand area, and the concrete trucks were assumed to drive on paved areas.

**Table 5: Emission Source Characteristics - Buildings**

| Source | Stack Height (m) | Base Elevation (m) | Stack Diameter (m) | Exit Velocity (m/s) | Exit Temperature (K) | Emission Rates (g/s) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | $NO_X$ | $PM_{10}$ | TSP |
| Cement Trucks | 4 | 5 | 0.1 | 10 | 349.2 | 0.11 | 0.01 | 0.01 |
| Cranes | 3 | 5 | 0.1 | 14.6 | 624.2 | 0.24 | 0.02 | 0.02 |
| Forklifts | 3 | 5 | 0.3 | 14.6 | 624.2 | 0.19 | 0.01 | 0.01 |
| Concrete Pumps | 3 | 5 | 0.1 | 14.6 | 624.2 | 0.36 | 0.001 | 0.001 |

Source characteristics of the concrete batching plant sources are outlined in **Table 6**. Wind erosion and stockpiling were modelled as area sources; the front end loader and materials processing were modelling as volume sources. In cases where there was no emission factor for TSP, TSP emissions were taken to be equal to PM10. TSP emission factors are not provided by the NPI for wind erosion, stockpiling and materials processing for concrete batching plants; TSP was assumed to comprise only PM10 for these sources.

**Table 6: Emission Source Characteristics and Emission Rates – Concrete Batching Plant**

| Sources | $PM_{10}$ (g/s) | PM10 ($g/s/m^2$) | TSP (g/s) | TSP ($g/s/m^2$) | Hours of operation |
|---|---|---|---|---|---|
| Wind erosion - storage bins, eastern side | 0.001 | 0.000004 | 0.001 | 0.000004 | continuous |
| Wind erosion - storage bins, southern side | 0.001 | 0.000004 | 0.001 | 0.000004 | continuous |
| Stockpiling/dumping raw materials | 0.2894 | 0.000673 | 0.808 | 0.00188 | 10 am - 4 pm |
| Front end loader | 0.550 | - | 0.982 | - | 7 am - 6 pm |
| Materials processing | 0.413 | - | 0.413 | - | 7 am - 6 pm |

The sources included in the materials processing, and the assumptions made in calculating emission rates, are detailed in **Table 7**.

**Table 7: Emission Calculations - Materials Handling**

| Activity | Value | Units | Notes |
|---|---|---|---|
| **Sand and aggregate transfer to bin** | | | |
| Activity rate | 404 | t/hour | |
| Overall control efficiency | 90 | % | Enclosed conveyor (2/3 sides) |
| Emissions | 0.5654 | kg/hour | |
| **Cement unloading to elevated storage silo** | | | |
| Activity rate | 38 | t/hour | pneumatic |
| Overall control efficiency | 99.9 | % | enclosed and filtered |
| Emissions | 0.005 | kg/hour | |
| **Weigh hopper loading** | | | |
| Activity rate | 442 | t/hour | |
| Overall control efficiency | 99.9 | % | enclosed and filtered |
| Emissions | 0.0044 | kg/hour | |
| **Mixer loading** | | | |
| Activity rate | 455 | t/hour | |
| Overall control efficiency | 90 | % | enclosed (2/3 sides) |
| Emissions | 0.9103 | kg/hour | |
| **Total emissions** | **1.485** | **kg/hour** | |
| | **0.413** | **g/s** | |

Emission factors for specific construction plant and equipment were sourced from a report on a large construction project[3]. A detailed emissions inventory can be provided on request.

## 6.4 Sensitive Receptors

Sensitive receptors are identified by the EPA as anywhere someone works or resides or may work or reside, including residential areas, hospitals, hotels, shopping centres, play grounds, recreational centres, and the like. The primary sensitive receptors associated with the site are residences located along Hickson Road, which are approximately 20 m from the site boundary.

The location of sensitive receptors included in the modelling are detailed in **Table 8** and shown on **Figure 2**.

**Table 8: Sensitive Receptors – Ground Level**

| Receptor Id | Location | Coordinates (m) | | Receptor Height (m) | Classification |
|---|---|---|---|---|---|
| | | X | Y | | |
| R1 | Hickson Rd | 333.778 | 6251.503 | 0 | Public |
| R2 | Hickson Rd | 333.796 | 6251.496 | 18 | Commercial |
| R3 | Hickson Rd | 333.789 | 6251.492 | 0 | Public |

[3] Pacific Institute (2001) The Cadiz Valley Groundwater Storage Project; http://www.pacinst.org/reports/cadiz/feir/volumes/vol1/appendix/v1a_c1.pdf

| Receptor Id | Location | Coordinates (m) | | Receptor Height (m) | Classification |
|---|---|---|---|---|---|
| | | X | Y | | |
| R4 | Napoleon St | 333.795 | 6251.466 | 0 | Public |
| R5 | Napoleon St | 333.793 | 6251.456 | 0 | Public |
| R6 | Napoleon St | 333.823 | 6251.475 | 25 | Commercial |
| R7 | Napoleon St | 333.822 | 6251.462 | 25 | Commercial |
| R8 | Cnr Napoleon & Sussex St | 333.800 | 6251.439 | 0 | Public |
| R9 | Napoleon St | 333.828 | 6251.447 | 48 | Commercial |
| R10 | Napoleon St | 333.825 | 6251.435 | 50 | Commercial |
| R11 | Sussex St | 333.803 | 6251.418 | 0 | Public |
| R12 | Sussex St | 333805 | 6251.400 | 0 | Public |
| R13 | Sussex St | 333.812 | 6251.361 | 8 | Commercial |
| R14 | Moreton Hotel, Sussex St | 333.809 | 6251.339 | 12 | Commercial |
| R15 | Sussex Hotel, Sussex St | 333.813 | 6251.327 | 15 | Commercial |
| R16 | Sussex St | 333.792 | 6251.319 | 0 | Public |
| R17 | Sussex St | 333.788 | 6251.299 | 35 | Commercial |
| R18 | Margaret St West | 333.769 | 6251.306 | 35 | Commercial |
| R19 | Margaret St West | 333.757 | 6251.310 | 0 | Public |
| R20 | KPMG Margaret St West | 333.775 | 6251.289 | 40 | Commercial |
| R21 | KPMG Margaret St West | 333.756 | 6251.293 | 48 | Commercial |
| R22 | KPMG Margaret St West | 333.738 | 6251.286 | 40 | Commercial |
| R23 | KPMG Building | 333.724 | 6251.285 | 0 | Public |
| R24 | Macquarie Building | 333.714 | 6251.272 | 10 | Commercial |
| R25 | Macquarie Building | 333.706 | 6251.245 | 15 | Commercial |
| R26 | Macquarie Building | 333.695 | 6251.260 | 10 | Commercial |
| R27 | Lime St/Shelly Lane | 333.674 | 6251.251 | 12 | Commercial |
| R28 | King St Wharf | 333.664 | 6251.260 | 0 | Public |
| R29 | Lime St/Shelly Lane | 333.643 | 6251.251 | 15 | Commercial |
| R30 | King St Wharf | 333.616 | 6251.255 | 0 | Public |
| R31 | Hickson Road | 333.793 | 6251.538 | 0 | Residential |
| R32 | Hickson Road | 333.791 | 6251.576 | 0 | Residential |
| R33 | Hickson Road | 333.790 | 6251.614 | 0 | Public |

| Receptor Id | Location | Coordinates (m) | | Receptor Height (m) | Classification |
|---|---|---|---|---|---|
| | | X | Y | | |
| R34 | Hickson Road | 333.787 | 6251.655 | 0 | Commercial |
| R35 | Hickson Road | 333.782 | 6251.699 | 0 | Commercial |
| R36 | Hickson Road | 333.778 | 6251.748 | 0 | Commercial |

## 6.5 Prediction of Cumulative Impacts

EPA (DEC, 2005) specifies that AQIAs are to assess the cumulative impact of a proposal against their impact assessment criteria. This involves adding existing background pollutant levels and expected pollutant levels from other concurrent developments to maximum pollutant concentrations predicted by dispersion modelling. The cumulative assessments for $PM_{10}$ and $NO_2$ were contemporaneous assessments made using data for the modelling period from the EPA's Rozelle monitoring station.

As construction works for the C3, C4 and C5 buildings will be underway at the time the proposed R8 and R9 construction works will commence, emission sources associated with those buildings were incorporated into the assessment. Additionally, the operation of a concrete batching plant on site was also included.

## 6.6 Ozone Limiting Method (OLM)

Oxides of nitrogen are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed including nitric oxide (NO) and nitrogen dioxide ($NO_2$). Generally, at the point of emission, NO will comprise the greatest proportion of the emission, representing 95 % by volume of the $NO_X$. The remaining $NO_X$ will consist of $NO_2$. Ultimately, however, all nitric oxides emitted into the atmosphere are oxidised to $NO_2$ and then further to other higher oxides of nitrogen.

The USEPA's Ozone Limiting Method (OLM) was used to predict ground-level concentrations of $NO_2$. The OLM is based on the assumption that approximately 10 % of the initial $NO_X$ emissions are emitted as $NO_2$. If the ozone ($O_3$) concentration is greater than 90 % of the predicted $NO_X$ concentrations, all the $NO_X$ is assumed to be converted to $NO_2$, otherwise $NO_2$ concentrations are predicted using the equation $NO_2 = 46/48 * O_3 + 0.1 * NO_X$. This method assumes instant conversion of NO to $NO_2$ in the plume, which overestimates concentrations close to the source since conversion typically occurs over periods of hours. This method is described in detail in the EPA Approved Methods (DEC, 2005).

Background $O_3$ data from the Rozelle monitoring station (refer to **Section 5.1**) were used to convert the modelled $NO_x$ concentrations to $NO_2$ concentrations in accordance with the EPA-approved OLM (Method 2, Level 2 Assessment; DEC, 2005).


**Figure 2: Sensitive Receptor Locations**

# 7.0 Results

Results of the dispersion modelling are shown in **Table 9** ($NO_2$), **Table 10** ($PM_{10}$) and **Table 11** (TSP).

**Table 9** presents the predicted $NO_2$ concentrations at each of the sensitive receptor locations, with both maximum contribution (emissions from the Barangaroo works only) and cumulative (Barangaroo results added to ambient background concentrations – refer to **Section 5.1** for ambient concentrations) concentrations provided for each receptor. For the 1 hour data, a contemporaneous assessment was undertaken, where hourly ambient concentrations were added to the hourly predicted contribution concentrations. For the annual data, annual average ambient concentrations of $NO_2$ and ozone were used in accordance with the OLM (refer to **Section 6.6**). It should be noted that the maximum contribution and cumulative concentrations are not paired in time; i.e. the maximum contribution value is unlikely to have occurred at the same time as the maximum background concentration.

**Table 9: Dispersion Modelling Predictions – Maximum $NO_2$ Concentrations ($\mu g/m^3$)**

| Receptor | 1 Hour NO2 | | | Annual NO2 | |
|---|---|---|---|---|---|
| | Max Concentrations | | No. Additional Exceedences | Max Concentrations | |
| | Contribution | Cumulative | | Contribution | Cumulative |
| 1 | 226.5 | **266.4** | 3 | 31.6 | 52.3 |
| 2 | 170.1 | 207.5 | 0 | 29.9 | 50.6 |
| 3 | 215.2 | 245.3 | 0 | 31.8 | 52.5 |
| 4 | 229.0 | **259.1** | 1 | 33.2 | 53.9 |
| 5 | 256.0 | **286.1** | 1 | 33.8 | 54.5 |
| 6 | 161.6 | 204.8 | 0 | 29.4 | 50.1 |
| 7 | 165.4 | 208.7 | 0 | 29.7 | 50.4 |
| 8 | 252.3 | **282.3** | 1 | 33.6 | 54.3 |
| 9 | 142.3 | 185.5 | 0 | 19.2 | 39.9 |
| 10 | 141.8 | 185.1 | 0 | 18.6 | 39.3 |
| 11 | 243.2 | **273.2** | 3 | 33.9 | 54.6 |
| 12 | 249.2 | **279.3** | 3 | 34.2 | 54.9 |
| 13 | 224.0 | **254.1** | 1 | 32.9 | 53.6 |
| 14 | 205.5 | 236.8 | 0 | 32.6 | 53.3 |
| 15 | 199.6 | 233.0 | 0 | 32.0 | 52.7 |
| 16 | 253.9 | **283.9** | 5 | 35.0 | 55.7 |
| 17 | 165.1 | 201.2 | 0 | 29.2 | 49.9 |
| 18 | 166.3 | 201.2 | 0 | 29.6 | 50.3 |
| 19 | 375.9 | **417.2** | 45 | 42.1 | **62.8** |
| 20 | 156.3 | 190.3 | 0 | 24.6 | 45.3 |
| 21 | 148.2 | 182.1 | 0 | 19.0 | 39.7 |
| 22 | 212.9 | **246.7** | 1 | 24.8 | 45.5 |
| 23 | 359.8 | **376.8** | 17 | 33.4 | 54.1 |
| 24 | 256.1 | **289.9** | 1 | 30.6 | 51.3 |

| Receptor | 1 Hour $NO_2$ | | | Annual $NO_2$ | |
|---|---|---|---|---|---|
| | Max Concentrations | | No. Additional Exceedences | Max Concentrations | |
| | Contribution | Cumulative | | Contribution | Cumulative |
| 25 | 193.5 | 227.4 | 0 | 28.6 | 49.3 |
| 26 | 255.8 | **289.6** | 1 | 30.0 | 50.7 |
| 27 | 229.9 | **263.7** | 1 | 29.6 | 50.3 |
| 28 | 291.6 | **325.5** | 1 | 30.5 | 51.2 |
| 29 | 187.4 | 221.3 | 0 | 29.4 | 50.1 |
| 30 | 265.0 | **298.8** | 2 | 29.7 | 50.4 |
| 31 | 220.8 | **250.9** | 1 | 28.9 | 49.6 |
| 32 | 214.7 | 244.8 | 0 | 21.1 | 41.8 |
| 33 | 198.6 | 228.7 | 0 | 16.4 | 37.1 |
| 34 | 173.5 | 203.6 | 0 | 13.2 | 33.9 |
| 35 | 142.3 | 172.4 | 0 | 10.4 | 31.1 |
| 36 | 109.5 | 139.5 | 0 | 7.9 | 28.6 |
| *Criteria* | - | *246* | - | - | *62* |

As shown, exceedences of the 1 hour $NO_2$ criterion were predicted to occur at 17 of the 36 receptors assessed, and the annual $NO_2$ criterion was predicted to be slightly exceeded at one receptor (Receptor 19).

**Table 10: Dispersion Modelling Predictions – Maximum $PM_{10}$ Concentrations ($\mu g/m^3$)**

| Receptor | 24 Hour $PM_{10}$ | | | Annual $PM_{10}$ | |
|---|---|---|---|---|---|
| | Max Concentrations | | No. Additional Exceedences | Max Concentrations | |
| | Contribution | Cumulative | | Contribution | Cumulative |
| 1 | 97.0 | **106.4** | 35 | 12.05 | 29.5 |
| 2 | 42.8 | **65.7** | 6 | 7.60 | 25.0 |
| 3 | 94.5 | **103.9** | 28 | 10.69 | 28.1 |
| 4 | 89.2 | **98.6** | 18 | 9.52 | 26.9 |
| 5 | 87.2 | **96.6** | 17 | 9.39 | 26.8 |
| 6 | 31.2 | **53.4** | 1 | 5.30 | 22.7 |
| 7 | 31.0 | **53.3** | 1 | 5.17 | 22.6 |
| 8 | 94.1 | **103.6** | 14 | 8.61 | 26.0 |
| 9 | 22.0 | 44.6 | 0 | 2.76 | 20.2 |
| 10 | 20.7 | 44.4 | 0 | 2.57 | 20.0 |
| 11 | 91.9 | **101.3** | 12 | 8.02 | 25.4 |
| 12 | 91.9 | **101.3** | 9 | 7.60 | 25.0 |
| 13 | 34.8 | **57.5** | 1 | 5.53 | 22.9 |
| 14 | 27.3 | 49.4 | 0 | 4.98 | 22.4 |
| 15 | 24.6 | 48.0 | 0 | 4.48 | 21.9 |
| 16 | 46.3 | **62.5** | 4 | 5.98 | 23.4 |

| Receptor | 24 Hour PM10 | | | Annual PM10 | |
|---|---|---|---|---|---|
| | Max Concentrations | | No. Additional Exceedences | Max Concentrations | |
| | Contribution | Cumulative | | Contribution | Cumulative |
| 17 | 17.9 | 43.6 | 0 | 2.66 | 20.1 |
| 18 | 20.5 | 43.8 | 0 | 3.03 | 20.4 |
| 19 | 48.6 | **64.8** | 13 | 8.91 | 26.3 |
| 20 | 18.2 | 43.2 | 0 | 2.17 | 19.6 |
| 21 | 16.4 | 43.2 | 0 | 1.82 | 19.2 |
| 22 | 23.8 | 45.0 | 0 | 2.21 | 19.6 |
| 23 | 40.3 | **64.1** | 9 | 5.47 | 22.9 |
| 24 | 28.9 | **50.2** | 1 | 3.51 | 20.9 |
| 25 | 19.6 | 45.6 | 0 | 2.30 | 19.7 |
| 26 | 24.2 | 46.2 | 0 | 3.05 | 20.5 |
| 27 | 18.8 | 45.3 | 0 | 2.76 | 20.2 |
| 28 | 30.3 | 46.9 | 0 | 3.49 | 20.9 |
| 29 | 16.7 | 44.1 | 0 | 2.59 | 20.0 |
| 30 | 27.4 | 43.8 | 0 | 2.89 | 20.3 |
| 31 | 97.0 | **106.4** | 30 | 11.31 | 28.7 |
| 32 | 93.8 | **103.2** | 21 | 10.34 | 27.7 |
| 33 | 95.3 | **110.5** | 9 | 7.26 | 24.7 |
| 34 | 82.3 | **97.5** | 7 | 4.74 | 22.1 |
| 35 | 59.9 | **75.2** | 4 | 3.18 | 20.6 |
| 36 | 44.5 | **59.7** | 3 | 2.27 | 19.7 |
| *Criteria* | - | *50* | - | - | *30* |

Exceedences of the 24 hour PM10 criterion were predicted to occur at 21 of the 36 receptors assessed. The maximum number of additional exceedences predicted was 35 at Receptor 1. No exceedences of the annual PM10 criterion were predicted.

No exceedences of the annual TSP criterion were predicted, with maximum predicted concentrations reaching approximately half the criterion level.

**Table 11: Dispersion Modelling Predictions – Maximum TSP Concentrations ($\mu g/m^3$)**

| Receptor | Annual TSP | |
|---|---|---|
| | Max Concentrations | |
| | Contribution | Cumulative |
| 1 | 13.5 | 49.0 |
| 2 | 8.8 | 44.3 |
| 3 | 11.7 | 47.2 |
| 4 | 9.8 | 45.3 |
| 5 | 9.5 | 45.0 |

| Receptor | Annual TSP | |
|---|---|---|
| | Max Concentrations | |
| | Contribution | Cumulative |
| 6 | 5.9 | 41.4 |
| 7 | 5.6 | 41.1 |
| 8 | 8.5 | 44.0 |
| 9 | 3.1 | 38.6 |
| 10 | 2.8 | 38.3 |
| 11 | 7.7 | 43.2 |
| 12 | 7.2 | 42.7 |
| 13 | 5.1 | 40.6 |
| 14 | 4.5 | 40.0 |
| 15 | 4.0 | 39.5 |
| 16 | 5.3 | 40.8 |
| 17 | 2.5 | 38.0 |
| 18 | 2.9 | 38.4 |
| 19 | 8.1 | 43.6 |
| 20 | 2.1 | 37.6 |
| 21 | 1.8 | 37.3 |
| 22 | 2.2 | 37.7 |
| 23 | 5.1 | 40.6 |
| 24 | 3.3 | 38.8 |
| 25 | 2.2 | 37.7 |
| 26 | 2.9 | 38.4 |
| 27 | 2.5 | 38.1 |
| 28 | 3.2 | 38.7 |
| 29 | 2.4 | 37.9 |
| 30 | 2.7 | 38.2 |
| 31 | 14.2 | 49.7 |
| 32 | 14.8 | 50.3 |
| 33 | 10.6 | 46.1 |
| 34 | 6.6 | 42.1 |
| 35 | 4.2 | 39.7 |
| 36 | 2.8 | 38.3 |
| *Criteria* | - | *90* |

Based on the modelling results, adverse effects on air quality may result from the proposed construction activities.

The concrete batching plant is considered to be the primary cause of the predicted exceedences of the 24 hour $PM_{10}$ criterion. When the emissions associated with the concrete batching plant were excluded from the modelling (i.e. modelling only all emissions from buildings C3, C4, C5, R8 and R9), no changes to the number of exceedences of the $NO_2$ criteria were predicted, as the concrete batching plant is primarily a source of particulate emissions. The number of exceedences of the 24 hour $PM_{10}$ criterion were, however, substantially reduced, with only single exceedences predicted for Receptors 1, 3, 4, 5, 8, 11 and 12, two exceedences for Receptor 19 and three exceedences for Receptor 23. These exceedences could be effectively managed through the mitigation measures proposed to be implemented for the project (refer to **Section 8.0**). Results of modelling the R8 and R9 buildings in isolation from the other construction works (but including ambient pollutant levels) indicated that no exceedences would occur for any pollutant or averaging period assessed.

Lend Lease is currently undertaking the excavation works for Blocks 1 – 3 at the Barangaroo site, which involve significant earthworks and plant use. Lend Lease has implemented an extensive monitoring and management system to mitigate adverse impacts associated with those works, with the result being that exceedences of air quality criteria have not been detected at the site. As such, the proposed construction works, excluding the operation of the on-site concrete batching plant, are considered to be achievable without adverse effects on air quality. In order to ensure that the predicted adverse effects do not occur as a result of the proposed works considered in this assessment, the existing monitoring and management procedures must be extended to cover the proposed works.

It should be noted that the operation of an on-site concrete batching plant will be the subject of a separate approval. Based on the results of this assessment, modifications to the proposed activities and emissions management systems associated with the concrete batching plant will be made, which will then be assessed as part of the approval process.

## 7.1 Limitations

Best efforts were made to estimate the likely numbers and operational parameters (including operational hours and handling volumes) of plant and equipment in the AQIA. The numbers used were based on information available at the time of preparation of this report, and may change to reflect the detailed design of the excavation and emplacement activities.

If major changes are proposed to pollutant emitting activities during excavation or emplacement, further modelling may be required to assess the effects of those changes on local air quality.

# 8.0 Mitigation Measures

Mitigation and work practices that should be implemented at the site to minimise pollutant emissions are described in **Table 12**.

**Table 12: Pollutant Minimisation Strategies**

| Trigger | Impact | Pollutants | Control Measure |
|---|---|---|---|
| Fuel combustion emissions from vehicles and equipment | Increased risk to human health | $NO_x$<br>$PM_{10}$<br>TSP | Continue the dust and meteorological monitoring program currently undertaken. |
| | | | Use mains power where available and suitable. |
| | | | Turn engines off while parked on site. |
| | | | Confine vehicular access to designated access roads. |
| | | | Appropriately tune, modify or maintain equipment, plant and machinery to minimise visible smoke and emissions. |
| | | | Implement site speed limits. |
| | | | Minimise haul road lengths. |
| Fugitive dust from exposed surfaces and vehicles | Nuisance (dust)<br><br>Discoloration of buildings or structures<br><br>Increased risk to human health | $PM_{10}$<br>TSP | Continue the dust and meteorological monitoring program currently undertaken. |
| | | | Cover loads during off-site transport |
| | | | Erect windbreak barriers on the Site boundary where practicable. |
| | | | Control roadways i.e. defined road access to minimise dust |
| | | | Immediately clean up spills |
| | | | Implement a complaints management system |
| | | | Adjust work practices (as required) based on wind observations |
| | | | Adjust work practices (as required) based on real time dust monitoring results |
| | | | Use water sprays and/or surfactants wherever necessary |

## 8.1 Contingency Measures

When monitoring systems continuously measure pollutant concentrations, an early warning system based on trigger levels can be used to minimise adverse impacts on the environment. The trigger levels are generally set below a relevant assessment criterion adverse effects occurring.

A reactive management plan was developed for the site, based on a three-stage approach: Investigate, Action and Stop Work, as described below:

- Investigate: designed to identify the likely reasons for the elevated pollutant concentration and to formulate a contingency response should the action stage be reached. Action should be undertaken at this stage if deemed necessary;
- Action: designed to implement those measures formulated in the investigative stage and to review their effectiveness; and

- Stop Work: this level is associated with a high probability of an exceedence of the pollution criterion occurring if works continue to generate dust at the current rate. All works should stop at this stage until the measured pollutant levels are below the action level.

**Table 13: Reactive Management Procedure**

| Reactive Management Procedure | | | | | |
|---|---|---|---|---|---|
| **Pollutant Monitored** | **Trigger Stage** | **Averaging Period** | **Trigger Value ($\mu g/m^3$)** | **Primary Responsibility** | **Action Required** |
| $PM_{10}$ | 1 Investigate | 1 Hour | 85 | Environment Manager | Environmental Manager to contact site operations manager and undertake review of possible dust sources operating during the average period. Identify possible control measures for these activities, action taken if deemed necessary. Complete Lend Lease Environmental Response Form |
| | | 3 Hour | 80 | | |
| | 2 Action | 1 Hour | 470 | | Environment Manager to attend site and ensure implementation of the control actions identified in stage 1. Effectiveness of control actions to be reviewed and escalate where appropriate. Identify long-term solutions to dust issues. Complete Lend Lease Environmental Response Form |
| | | 3 Hour | 160 | | |
| | 3 Stop Work | 1 Hour | 940 | | Targeted shut down of site activities until the measured pollutant levels are below the stated Action period trigger value. Complete Lend Lease Environmental Response Form |
| | | 3 Hour | 320 | | |
| Total VOC | 1 Investigate | 1 Hour | 0.8 | Environment Manager | Environmental Manager to contact site operations manager and undertake review of possible VOC sources operating during the average period. Identify possible control measures for these activities, action taken if deemed necessary. Complete Lend Lease Environmental Response Form |
| | | 3 Hour | 0.5 | | |
| | 2 Action | 1 Hour | 8.3 | | Environment manager to attend site and ensure implementation of the control actions identified in stage 1. Effectiveness of control actions to be reviewed and escalate where appropriate. If VOC deemed to be coming from excavation area, speciation using a Summa canister will be undertaken. Complete Lend Lease Environmental Response Form |
| | | 3 Hour | 5.0 | | |

Should the investigation trigger level for $PM_{10}$ be reached, an investigation should be conducted to determine the source/s of the dust and to evaluate the appropriate measures to be implemented. Measures (in addition to those already included as assumed dust control measures) may include the following actions:

- Increased use of a water cart and/or water sprays to suppress dust in open areas or roadways;
- Installation of temporary sheeting to cover localised exposed areas or stockpiles;
- Consolidation of material stockpiles;
- Conducting the work in more favourable weather conditions;
- Use of chemical dust-suppressants provided the chemicals do not pose a contamination or occupational health and safety hazard;
- Use of additional dust suppression features on items of dust generating plant and equipment;
- Securing work approval hours that permit emergency dust suppression on non-work days, if the need arises; and
- Ceasing works when works are generating unacceptable dust levels (as defined by the Air Quality Management Plan).

## 8.2 Air Quality Monitoring Program

Ambient air quality monitoring around the Barangaroo site has been undertaken by AECOM since October 2011 in accordance with the Air Quality Management Plan and Environment Protection Licence for the site. The monitoring has the following objectives:

- Allow a real time assessment of the various activities on the site, which can then be related back to operational changes to reduce off-site impacts; and to
- Allow reactive dust mitigation measures to be implemented based on real time monitoring data.

The monitoring is undertaken generally in accordance with the following guidelines and Australian Standards:

- The EPA’s Approved methods for sampling and analysis of air pollutants in New South Wales;
- AS/NZS 3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method;
- AS 3580.9.8-2008 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - $PM_{10}$ continuous direct mass method using a tapered element oscillating microbalance analyser;
- AS/NZS 3580.1.1:2007 Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment; and
- AS 2923-1987 Ambient air - Guide for measurement of horizontal wind for air quality applications.

Details of the relevant monitoring equipment and locations are provided in **Table 14** and **Figure 3**.

**Table 14: Ambient Monitoring Agenda**

| Parameter | Equipment | Frequency | Locations | EPA Criteria | Sampling Method |
|---|---|---|---|---|---|
| TSP | HVAS | 24 hours every 6 days * | EPL Points 5, 8 & 13 | 90 µg/m$^3$ as an annual average. | AM-15 AS3580.9.3 – 2003 |
| $PM_{10}$ | TEOM | Continuous | EPL Points 5, 8 & 13 | 50 µg/m$^3$ as a 24 hour average.** 30 µg/m$^3$ as an annual average. | AM-22 AS3580.9.6 - 2003 |
| $NO_2$ | $NO_X$ monitor | Continuous | EPL Points 8 | 246 µg/m$^3$ as a 1 hour average.** 62 µg/m$^3$ as an annual average. | AM-12 AS3580.5.1-1993 |
| Meteorological station | -- | Continuous | On site near the cruise passenger terminal | A site that complies with the *Approved Methods* | AM-1 to AM-4 USEPA (2000) EPA 454/R-99-005 |

* If noise complaints are likely to occur or do occur this 24 hour time frame may be reduced to 12 hours operation e.g. 7am to 7pm and compared with the same criteria.
** 24 hour average of a calendar day defined as midnight to midnight.
*** Assessed as benzo[a]pyrene - must be calculated using the potency equivalency factors provided in the DEC (2005) Table 7.2c
**** Too many criteria to note here; criteria based on DEC (2005)

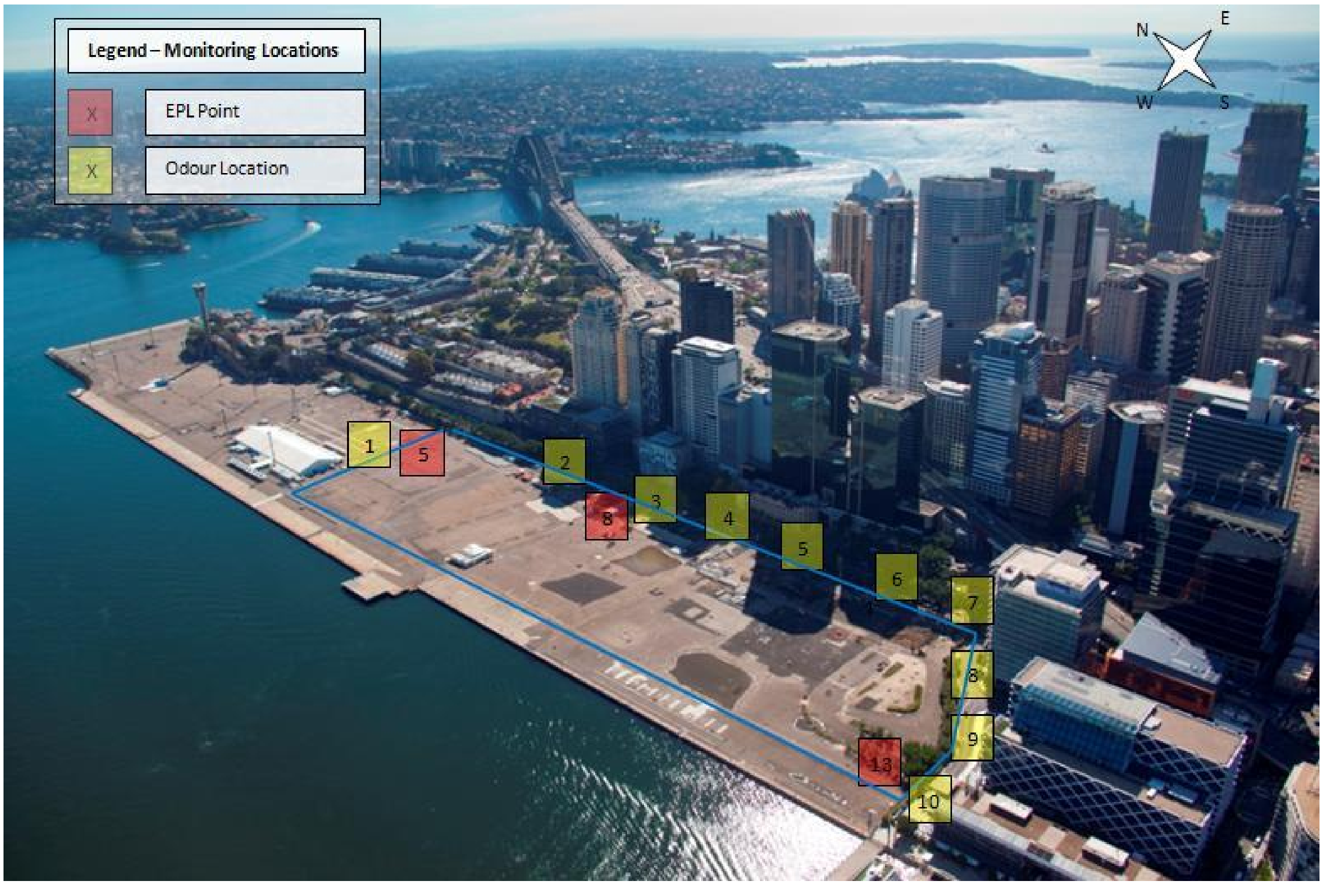


**Figure 3: Approximate Barangaroo South Monitoring Locations**

# 9.0 Conclusion

This report assessed emissions of $NO_2$, $PM_{10}$ and TSP from the following activities:

- The construction of the R8 and R9 Buildings;
- The parallel construction of sections of buildings C3, C4 and C5; and
- Operation of an on-site concrete batching plant.

Dispersion modelling was undertaken using CALPUFF and meteorological data generated for the site using TAPM (based on local meteorological data). Exceedences of the 24 hour $PM_{10}$ and 1 hour and annual $NO_2$ criteria were predicted, with the concrete batching plant identified as the primary source of particulate emissions. Lend Lease has, however, demonstrated that it can undertake significant materials handling activities with substantial plant and equipment numbers on site without exceeding the relevant air quality criteria. As such, provided the existing monitoring and management plan for the site is modified to incorporate the proposed activities, particularly addressing the activities of the concrete batching plant, adverse effects on local air quality are not expected to occur as a result of the proposed construction works.

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Appendix A

# Climate Averages

# Appendix A Climate Averages

**Average Climate Data – Observatory Hill and Fort Denison, 1859 – 2010 (May)**

| Statistic | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Average temperature** | | | | | | | | | | | | | |
| Maximum ($^0$C) | 25.9 | 25.8 | 24.7 | 22.4 | 19.4 | 16.9 | 16.3 | 17.8 | 20 | 22.1 | 23.6 | 25.2 | 21.7 |
| Minimum ($^0$C) | 18.7 | 18.8 | 17.5 | 14.7 | 11.5 | 9.3 | 8 | 8.9 | 11.1 | 13.5 | 15.6 | 17.5 | 13.8 |
| **Average wind speed** | | | | | | | | | | | | | |
| 9 am (km/h) | 8.6 | 8.2 | 7.9 | 8.8 | 10.5 | 11.9 | 13.1 | 13.3 | 12.4 | 12.2 | 11 | 9.8 | 10.6 |
| 3 pm (km/h) | 17.9 | 16.8 | 15.2 | 13.8 | 12.7 | 13.6 | 15.3 | 17.6 | 18.3 | 19.1 | 19.4 | 19.5 | 16.6 |
| **Average relative humidity** | | | | | | | | | | | | | |
| 9 am (%) | 71 | 74 | 74 | 72 | 73 | 74 | 71 | 66 | 62 | 61 | 66 | 67 | 69 |
| 3 pm (%) | 62 | 64 | 62 | 59 | 57 | 57 | 51 | 49 | 51 | 56 | 58 | 59 | 57 |
| **Rainfall** | | | | | | | | | | | | | |
| Mean rainfall (mm) | 101.5 | 118.7 | 128.9 | 125.8 | 120.7 | 130.6 | 97.3 | 81.2 | 69.1 | 77.6 | 83.1 | 77.8 | 1212 |

Appendix B

# Meteorological Data Review

# Appendix B Meteorological Data Review

## A.1 Introduction

The following appendix discusses the characteristics associated with the meteorological data used for the Barangaroo dispersion modelling. The characteristics examined include the following:

- Wind speed and direction;
- Stability Class; and
- Mixing height.

## A.2 Wind speed and direction

Long term average wind rose diagrams for data collected at the Bureau of Meteorology station at Fort Denison shows the frequency of occurrence of winds by direction and strength (refer **Figures B1** and **B2**). Morning winds are lighter than average and dominated by north-westerly flows, representing a land breeze generated on clear nights with light prevailing wind conditions, most common in winter. Winds from the east coming from the coast in the afternoon are generally stronger than the land breeze winds. By afternoon, winds are stronger and most frequently from the southeast to northeast, representing both common synoptic scale influences and some sea breeze effects, respectively. Significant seasonal differences in the wind conditions measured at the site are apparent - the winds are predominantly from the north-east to south direction in the warmer months (i.e. summer and spring), while north-westerly winds dominate in the cooler months.

The Rozelle EPA meteorological data shows a different pattern to the data from the Sydney BOM site. The Rozelle site is characterised by strong southerly or light north-westerly winds throughout the year with the diurnal pattern dominated by light north-westerlies during the morning tending to stronger southerlies during the afternoon. This pattern is replicated throughout the year with strong southerly winds dominating during summer with strong north-westerlies during winter (refer **Figures B3**).

Wind rose compiled from the meteorological data developed for the Barangaroo site from CALMET (1 January 2008 to 31 December 2008) are provided below (wind roses shown in **Figure B4** and **B5**). The following trends in data were observed:

- Annual wind patterns are dominated by winds from the west, northwest and northeast. The average wind was 2.6 m/s with a calm wind percentage of 2.5% (winds less than 0.5 m/s);
- Summer wind patterns are dominated by winds from the northeast to the south, with minor winds from the northwest and west. The average wind was 2.68 m/s with a calm wind percentage of 2.73%;
- Autumn wind patterns are dominated by winds from the west, southeast and northeast. The average wind was 2.23 m/s with a calm wind percentage of 3.13%;
- Winter wind patterns are dominated by winds from the west. The average wind was 2.65 m/s with a calm wind percentage of 2.26%; and
- Spring wind patterns are dominated by winds from the northeast with a minor portion of winds also from the all other directions. The average wind was 2.79m/s with a calm wind percentage of1.88%.

The wind roses for the Barangaroo site are dominated by winds from the west and east, which are closely aligned with the observed diurnal wind patterns observed for the 9 am and 3 pm winds at Fort Denison (refer **Figures B1** and **B2**. On this basis, receptors situated to the east of the Barangaroo site, and to a lesser degree to the southwest of the Barangaroo site, are likely to be the most significantly affected receptors. The closest receptors, located to the east of the Barangaroo site, would be expected to be more affected by potential pollution from the works during the autumn and winter months, where air flows are predominantly westerly.

The frequency distribution of hourly averaged wind speed values from the Barangaroo data is shown below in **Figure B6**. Wind speeds around 3 - 4 m/s are most common, with medium to strong winds (> 4 m/s) occurring approximately 16% of the time.

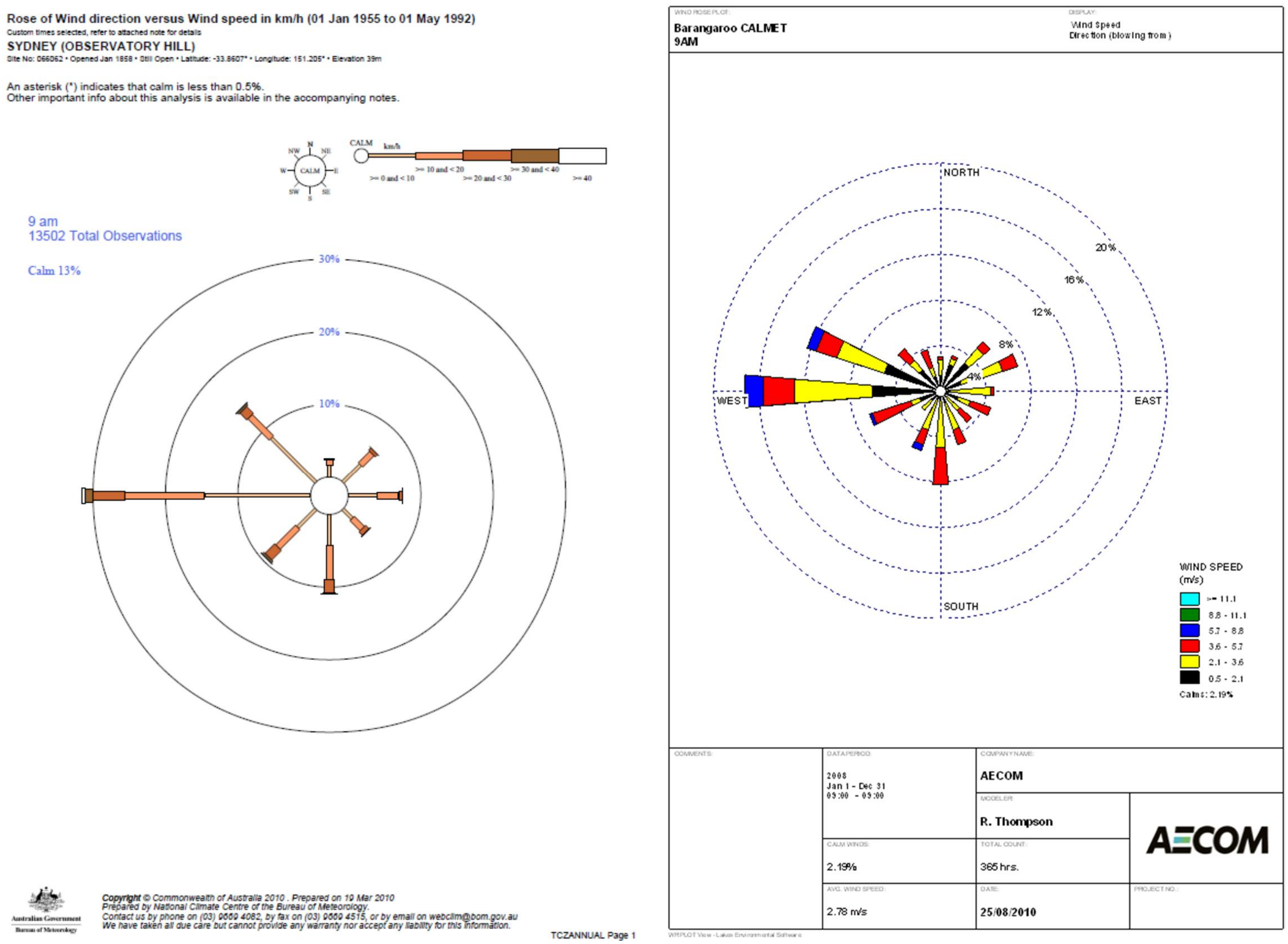



**Figure B1: 9am Wind Rose for BOM Fort Denison (left) and Barangaroo (right) CALMET Meteorological Data**

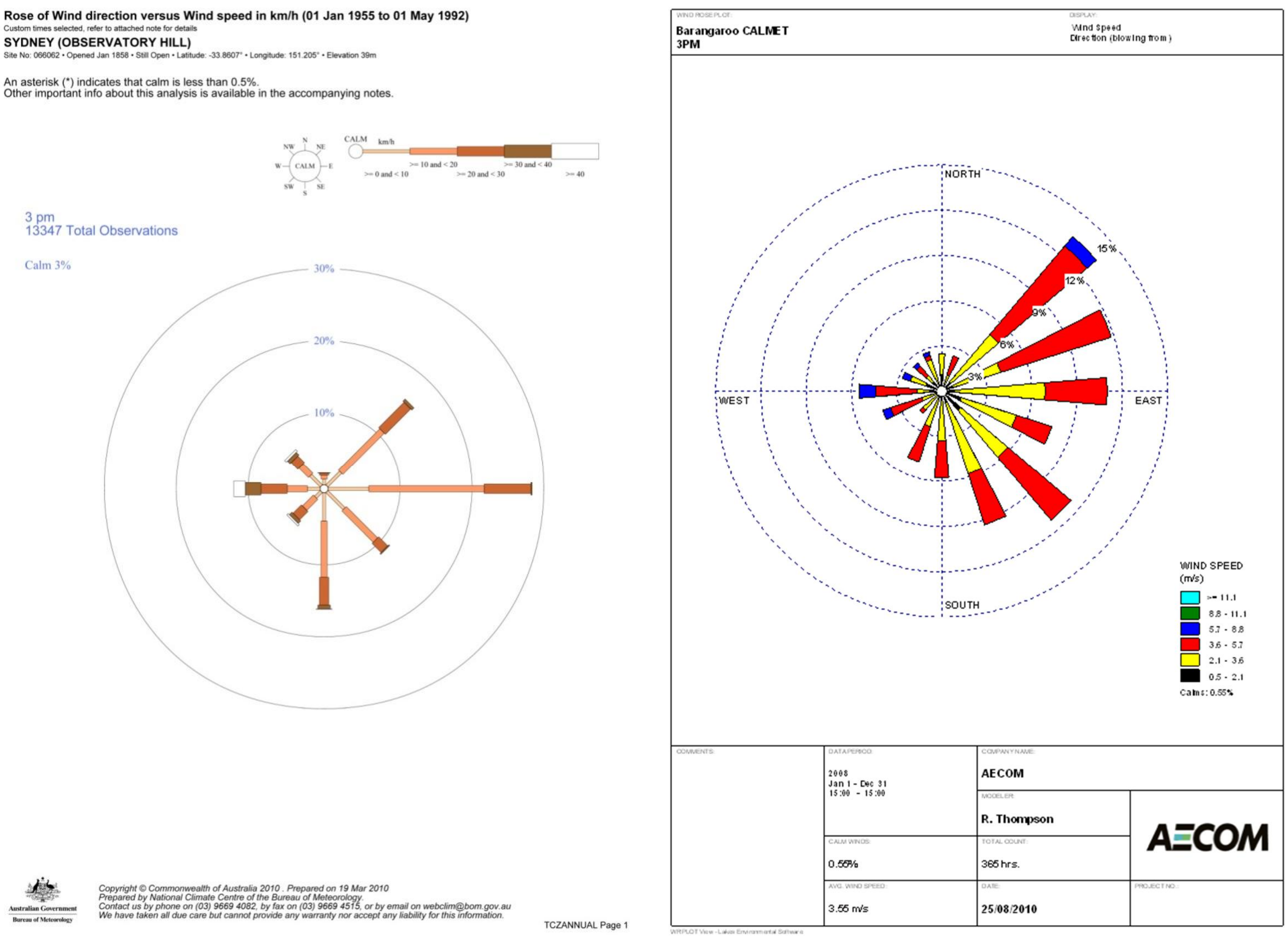



**Figure B2: 3pm Wind Rose for BOM Fort Denison (left) and Barangaroo (right) CALMET Meteorological Data**

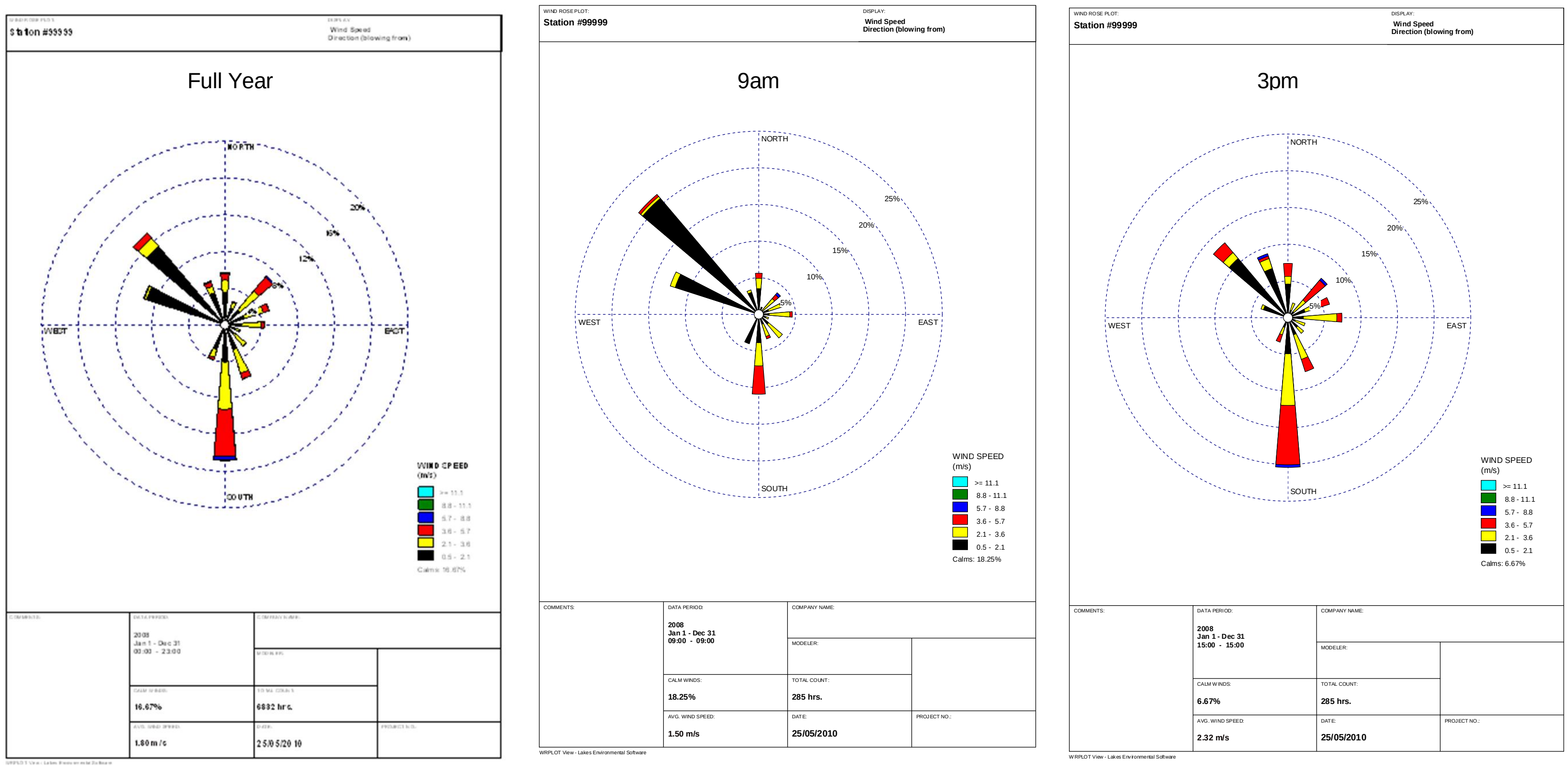



**Figure B3: Wind Rose for EPA Rozelle Meteorological Data**

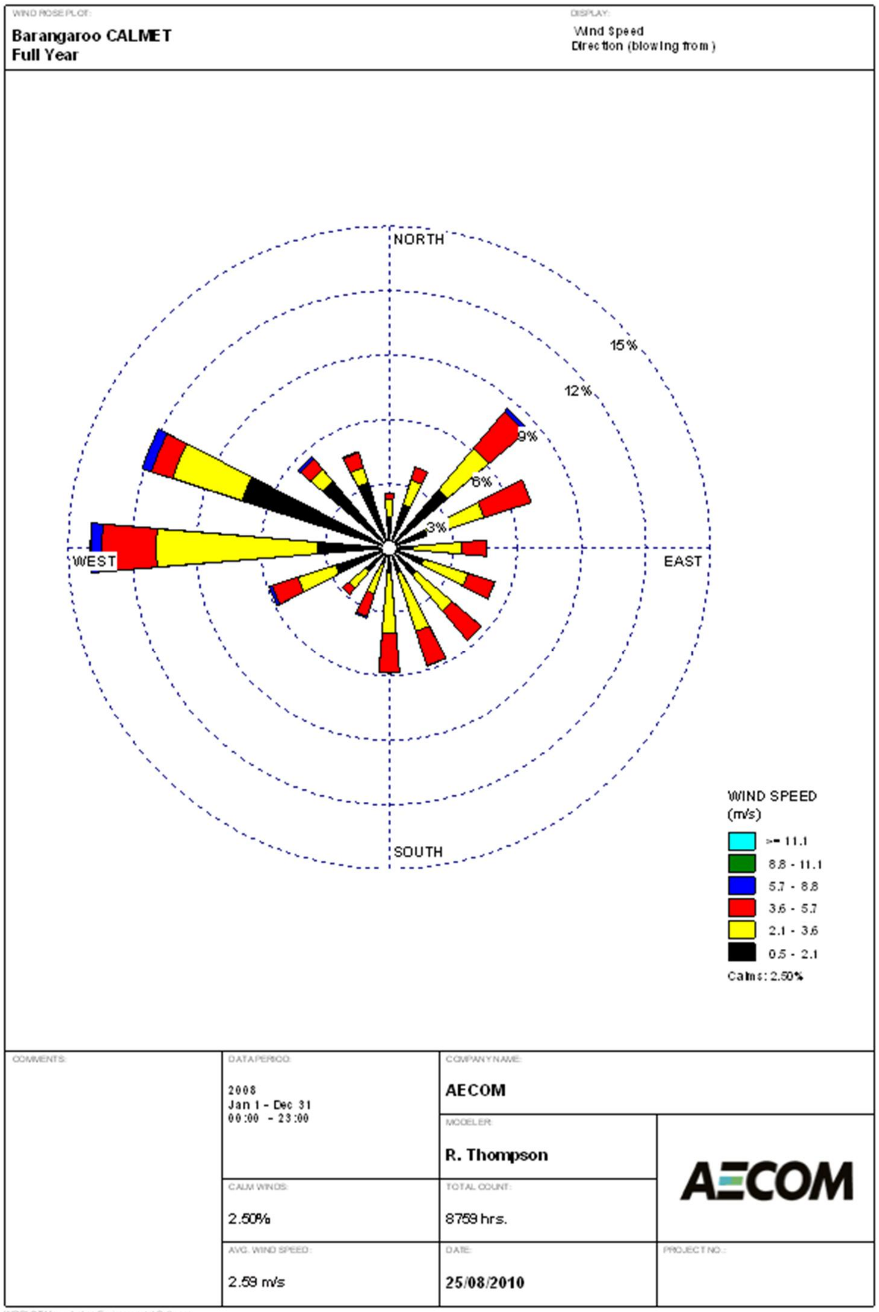
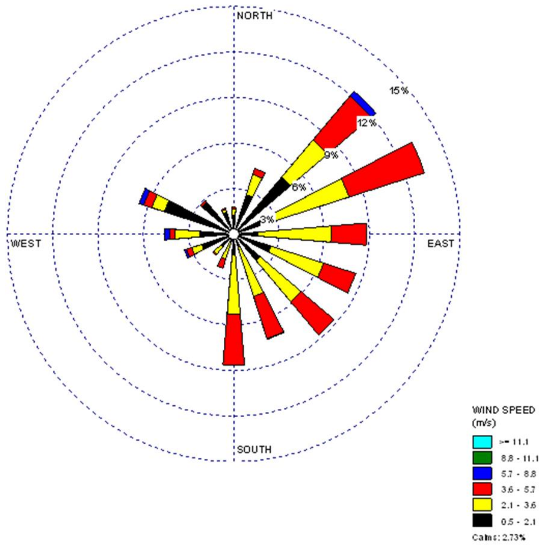
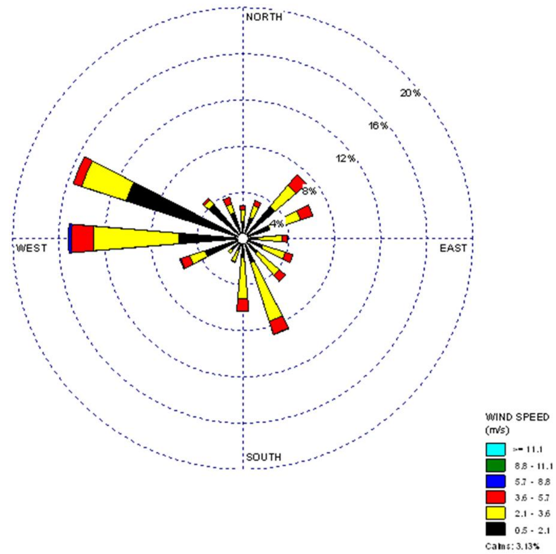


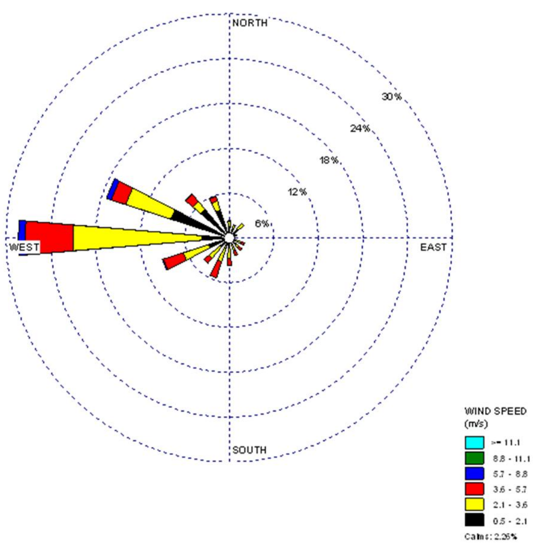

**Figure B4: Wind Rose for Barangaroo CALMET Data Meteorological Data - Full Year**



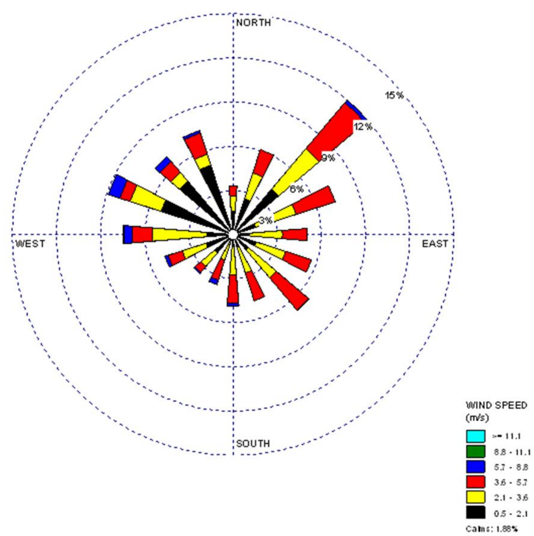

**Summer**




**Autumn**




**Winter**




**Spring**

**Figure B5: Seasonal Wind Roses for Barangaroo CALMET Data Meteorological Data**

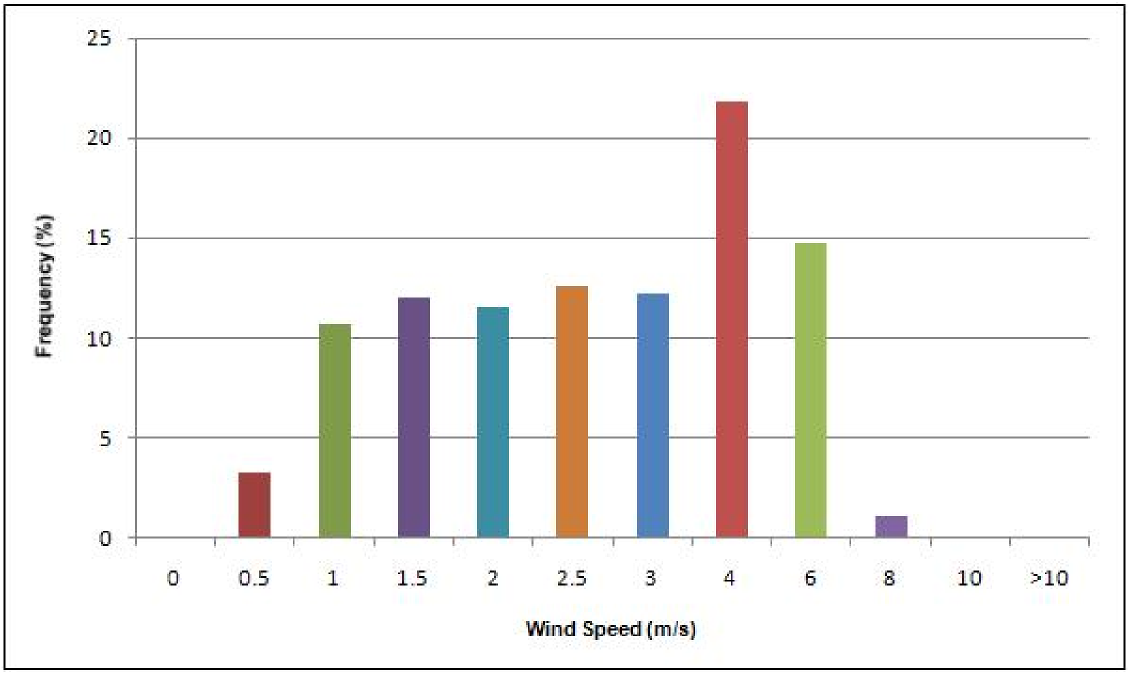



**Figure B6: Frequency Distribution of Wind Speed for Barangaroo CALMET, January – December 2008**

## A.3 Stability Class

An important aspect of plume dispersion is the atmospheric turbulence level in the region of the plume, near the ground in this case. Turbulence acts to increase the cross-sectional area of the plume due to random motions, thus diluting or diffusing a plume. For traditional dispersion modelling using Gaussian plume models, categories of atmospheric stability are used in conjunction with other meteorological data to describe atmospheric conditions and thus dispersion.

The most well-known stability classification is the Pasquill-Gifford scheme, which denotes stability classes from A to F. Class A is described as highly unstable and occurs in association with strong surface heating and light winds, leading to intense convective turbulence and much enhanced plume dilution. At the other extreme, class F denotes very stable conditions associated with strong temperature inversions and light winds, which commonly occur under clear skies at night and in the early morning. Under these conditions plumes can remain relatively undiluted for considerable distances downwind. Intermediate stability classes grade from moderately unstable (B), through neutral (D) to slightly stable (E). Whilst classes A and F are strongly associated with clear skies, class D is linked to windy and/or cloudy weather, and short periods around sunset and sunrise when surface heating or cooling is small.

As a general rule, unstable (or convective) conditions dominate during the daytime and stable flows are dominant at night. This diurnal pattern is most pronounced when there is relatively little cloud cover and light to moderate winds. The frequency distribution of estimated stability classes in the meteorological file is shown in **Figure B7**. The data show a total of 48% of hours with either E or F class. This is consistent with the expected occurrence of slightly stable conditions at such a location, given the coastal location.

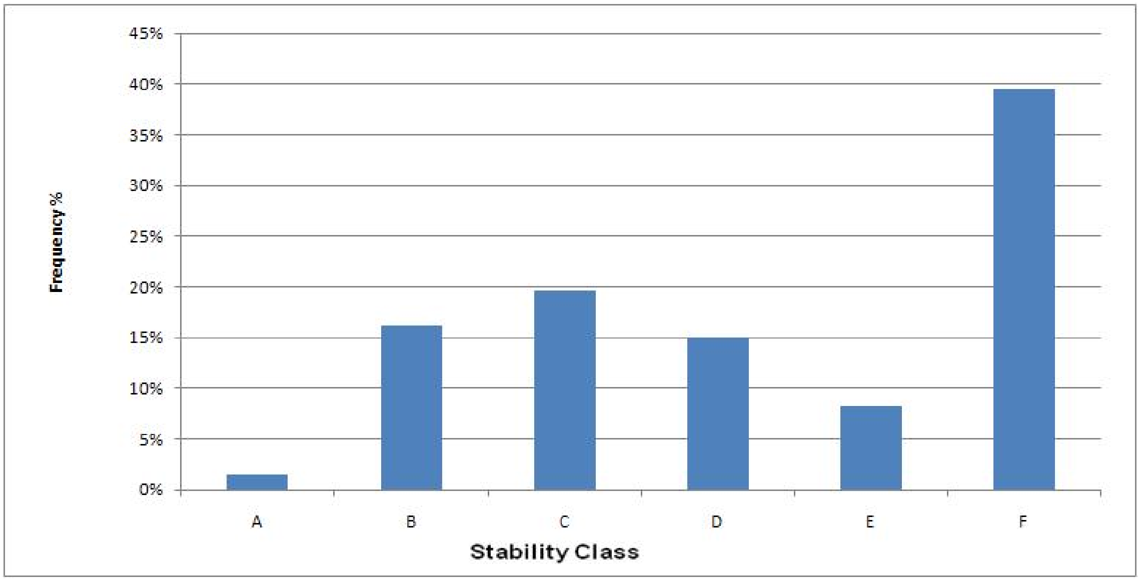



**Figure B7: Frequency Distribution of Stability Class from CALMET Output**

## A.4 Mixing Height

Mixing height is the depth of the atmospheric surface layer beneath an elevated temperature inversion. It is an important parameter within air pollution meteorology. Vertical diffusion or mixing of a plume is generally considered to be limited by the mixing height, as the air above this layer tends to be stable, with restricted vertical motions.

CALMET was used to calculate mixing heights at Barangaroo. The diurnal variation of mixing height is summarised in **Figure B8**. Mixing heights are lower during the night and early morning hours (~ 200 m), increasing after sunrise to a maximum of 700 -800 m by mid-afternoon. This pattern of a small diurnal cycle is consistent with the coastal site.

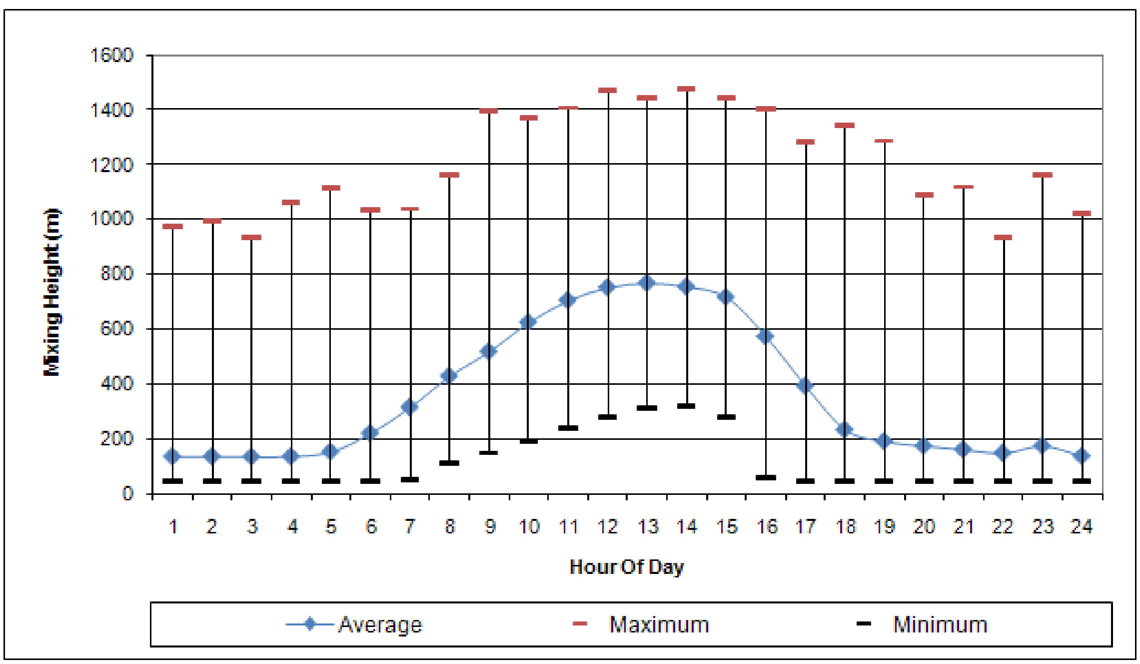



**Figure B8: Hourly Mixing Height from CALMET Output**

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