Revised Report

21532 Cockle Bay Park Precinct Air Quality Assessment

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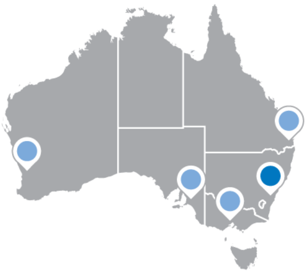

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Executive Summary

The Minister for Planning's Approval Condition 274 for the Cross City Tunnel (CCT) states that any development in the vicinity of the CCT stack requires an air quality assessment of potential impacts from the stack plume. The development at Cockle Bay Park is within 300 metres of the CCT stack and therefore triggers the requirement to undertake an air quality assessment. Pacific Environment have completed an air quality assessment of the CCT ventilation stack and nearby Western Distributor roadway to determine the potential air quality impact of these sources on the proposed development.

The assessment concludes that the emissions from the CCT stack and Western Distributor are not anticipated to result in any exceedances of the NSW EPA criteria for the air quality metrics assessed in the vicinity of the proposed development.

The modelling completed to date indicates that higher concentrations of the air quality metrics evaluated are predicted to occur at the top of the proposed development compared with those at ground level.

It is noted however, that given the complexity of the modelled scenario, optimisation of any air intakes' locations for the proposed development should necessarily occur during the detailed design stage for the development. It is recommended that this be completed using a micro-scale modelling technique such as computational fluid dynamics (CFD) or the GRAL roadway assessment modelling scheme.

In addition to evaluating the interaction between the CCT ventilation stack and the proposed Cockle Bay Park development, an air quality assessment was completed (Aurecon, 2017) to quantify the internal air quality below a new land bridge structure that forms part of the development. The land bridge has been proposed to be built over the Western Distributor as part of the office tower and retail complex development at Cockle Bay Park.

Aurecon, 2017 concludes that the maximum concentrations below the land bridge are anticipated to be well below the limits specified.

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1. Introduction

This Air Quality Assessment supports the response to submissions and amended concept proposal associated with a State Significant Development Application (SSDA 7684) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) is seeking to secure approval to establish concept proposal details for the redevelopment of the Cockle Bay Wharf Building and surrounding area to create a new area of open space and commercial, retail and tourist precinct in the heart of the CBD (now referred to as Cockle Bay Park). The amended concept plan includes:

- up to 14,000m^2 of publicly accessible open space;
- new retail outlets, including new food and beverage destinations;
- new cultural and entertainment destinations; and
- a new commercial office tower.

The project will add new open space to the Sydney CBD and help to reconnect the city to the Darling Harbour waterfront. Cockle Bay Park will take its place in a revitalised Sydney CBD and speaks directly to local government objectives to create a 'Green, Global and Connected City' (City of Sydney) as well as the strategic vision outlined in 'Towards Greater Sydney 2056' to grow the "developing central city". The vision for this project was developed with consideration for the NSW Government objectives to support and "grow the knowledge industry", double tourism expenditure and "strengthen our local environment and communities" as outlined in 'NSW 2021: A Plan to Make NSW Number One'.

Please note that all plans, diagrams, images and graphics within this report and the supporting documentation (excluding the amended Concept Proposal Envelope Plans prepared by Francis-Jones Morehen Thorp Pty Ltd) are indicative only and have been included to communicate the intent of the amended Concept Proposal, including representative building shapes, forms, locations, layouts and relationships. It is proposed that these representations, together with acceptance of the building envelopes and massing, and associated design principles, will then be used to inform the Design Excellence process to follow the Stage 1 SSD Determination. Design Excellence outcomes will form the basis of the Stage 2 SSDA.

This report is a revision of Pacific Environment's air quality assessment (ref: AQ-NW-001-2153) dated 25 October 2016. This report has been revised to include alterations to the project design, as well as reference the conclusions of the appended Aurecon air quality study (ref: 253427) dated 26 July 2017, thereby comprising a precinct-wide air quality assessment.

The Aurecon air quality study addresses the internal air quality below a new land bridge structure over the Western Distributor. This land bridge forms part of the office tower and retail complex development at Cockle Bay Park and is further detailed in the appended report.

1.1 Background

The Proponent controls the lease of the site, and also of the adjacent Darling Park precinct. The Darling Park site is a successful premium grade office precinct located on the west of the Sydney CBD, the associated Crescent Garden, located to the west of the three existing Darling Park towers, is a key area of open space in this part of the city.

The Proponent has recognised a number key issues with the existing layout of the Darling Park and Cockle Bay precinct, these being:

- The existing Cockle Bay Wharf building is not well integrated with the city, the Western Distributor freeway currently acts as a barrier to separate this area from the CBD;
- Publicly accessible open space is limited to the existing Crescent Garden in Darling Park; and
- The existing Cockle Bay Wharf building is outdated and is not in keeping with the future of Darling Harbour area as a vibrant entertainment and tourist destination.

The Cockle Bay precinct is at risk of being left behind and undermining the significant investment being made in Darling Harbour that will see it return to the world stage as a destination for events and entertainment. Accordingly, the Proponent is taking a carefully considered and staged approach to the complete revitalisation of the site and its surrounds. The envisaged development, which will be facilitated by the proposed building envelopes will:

- Reconnect the city with the Darling Harbour waterfront and the Darling Park;
- Create new publicly accessible open space in the heart of the Sydney CBD;
- Create new public land above Western Distributor;
- Provide new access routes between the city and the ICC Sydney / Darling Harbour Live precinct;
- Support the Sydney economy by providing a new premium commercial building; and
- Refresh and renew an existing entertainment and tourist destination.

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1.2 Site Description

The Site is located within Darling Harbour. Darling Harbour is a 60 hectare waterfront precinct on the south-western edge of the Sydney Central Business District that provides a mix of functions including recreational, tourist, entertainment and business.

The Site is located to the immediate south of Pyrmont Bridge, within the Sydney CBD on the eastern side of the Darling Harbour precinct. The Cross City Tunnel (CCT) ventilation outlet is located approximately 300 m south of the Site. The Site is located within the City of Sydney local government area (LGA). A locational context area plan and location plan are provided in **Figure 1-1** and **Figure 1-2** below.

The Darling Harbour precinct is undergoing significant redevelopment as part of the SICEEP, Darling Square, and IMAX renewal projects. The urban, built form and public transport / pedestrian context for Harbourside will fundamentally change as these developments are progressively completed.

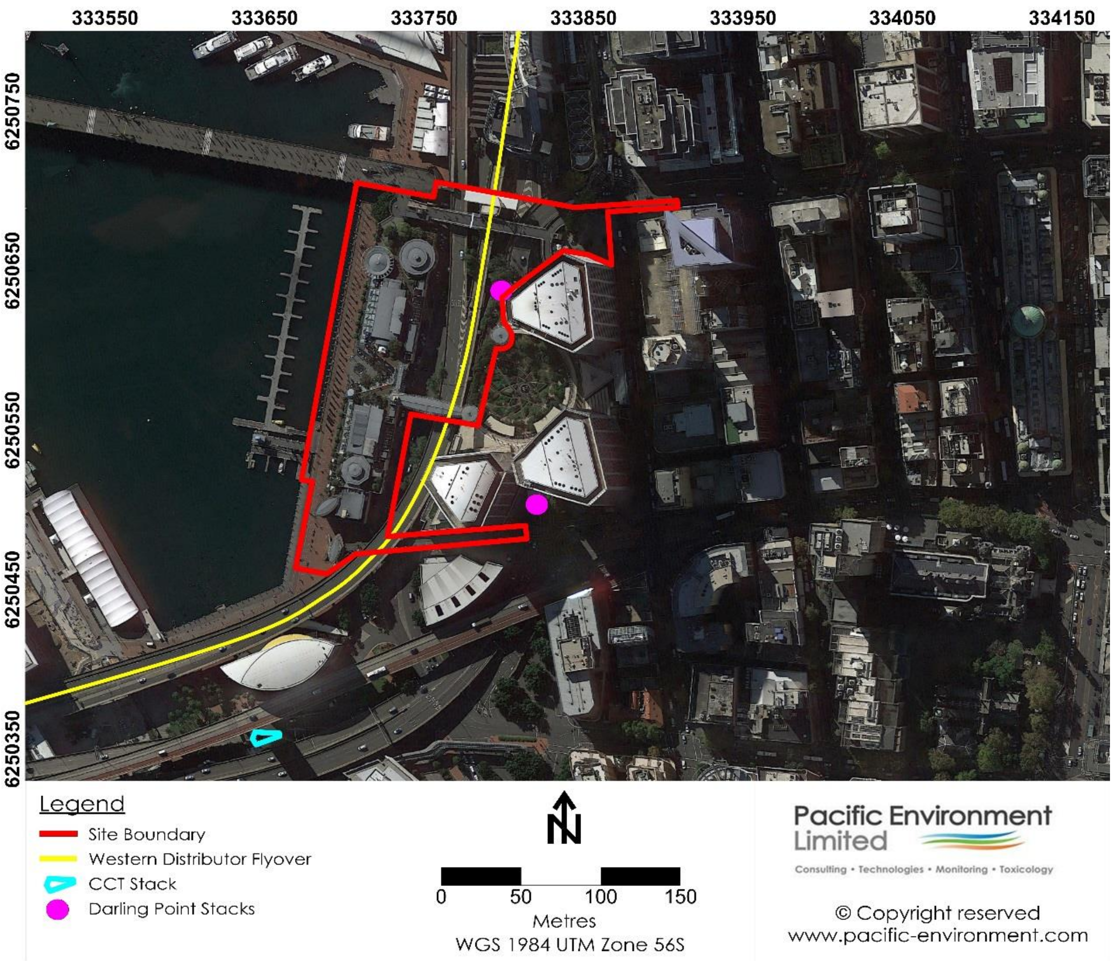

Figure 1-1: Local setting

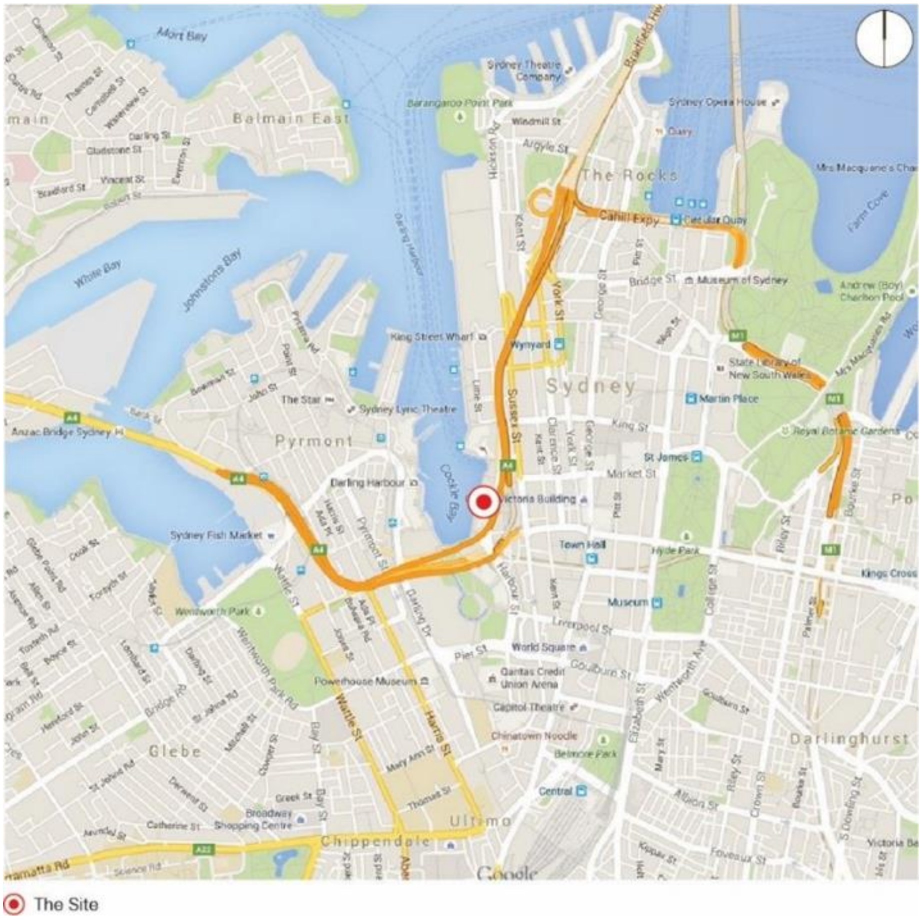

Figure 1-2: Local context area plan

1.3 Overview of Proposed Development

The proposal relates to a staged development application and seeks to establish concept proposal details for the renewal and re-imagining of Cockle Bay Park. The concept proposal establishes the vision and planning and development framework which will be the basis for the consent authority to assess future detailed development proposals. The Cockle Bay Park site is to be developed for a mix retail, cultural and commercial (office) uses, including retail and restaurants, commercial offices, and publicly accessible open space.

The Concept Proposal seeks approval for the following key components and development parameters:

- Demolition of existing site improvements, including the existing Cockle Bay Wharf building complex, pedestrian bridge links across the Western Distributor, and obsolete monorail infrastructure;
- Building envelopes;
- Land uses across the site;

- A maximum total Gross Floor Area (GFA) across the Cockle Bay Park of 75,000m^2 for commercial development and 14,000m^2 for retail (including food and beverage) development;
- Urban Design and Public Realm design principles to provide a Design Excellence; and
- Strategies for utilities and services provision, drainage and flooding, and ecological sustainable development.

1.4 Background to the Study

An air quality assessment was undertaken during the Environmental Assessment phase of the CCT project to determine the potential impact of the ventilation stack on future buildings in the vicinity of the (then proposed) stack. Part of the Minister for Planning's Approval Condition 274 for the project was that for any future building, a protocol would need to be developed to allow an assessment of the impact of both the ventilation stack plume on any proposed building and the potential for the building to affect dispersion of the plume. A Protocol has now been prepared and sets out a methodology for identifying and assessing developments which may be impacted by or impact upon the plume from the CCT ventilation stack in the vicinity of Darling Harbour.

As well as an assessment of the interaction between the CCT stack and new developments in its vicinity, there was the need to develop an air quality assessment on the proposed new land bridge structure over the Western Distributor. Part of the project requirement was the demonstration that the internal air quality contained in the portals below the land bridge complied with relevant Australian standards. This has been further detailed in the appended Aurecon air quality study (ref: 253427) dated 26 July 2017.

1.5 Scope of Works

The following outlines the scope of work covered within this report:

- Review the preliminary project drawings and incorporate the proposed design (as accurately as possible) into the Building Profile Input Program (BPIP) for assessment of building downwash effects;
- Conduct a modelling assessment to predict pollutant concentrations from the CCT stack at a number of heights corresponding to levels of the proposed building;
- Modelling assessment to predict pollutant concentrations from the existing Darling Park Tunnel ventilation points;
- Assess anticipated air quality impacts with distance from the Western Distributor using a conventional roadway dispersion modelling);
- Obtain traffic count data for the Western Distributor flyover and combine this with (NSW EPA) vehicle emission data to produce road line source emission estimates;
- Compare ground level concentrations of pollutants with and without the building, to assess any potential impact that building downwash might have on ground level concentrations;

- Use the above information to inform an air quality constraints analysis, including detail on any limitations to the siting of building air intakes; and
- Provide high level design advice in the form of a short report as to the potential for operable windows / balconies at height and setback distances from the CCT stack, Western Distributor and existing Darling Park Tunnel ventilation outlets.
- Review and incorporate findings from the Aurecon air quality study (ref: 253427), addressing internal air quality below the land bridge between the portals it creates.

2. Air Quality Criteria

The principal emissions of concern in this assessment are as follows:

- Oxides of nitrogen (NO_x)
- Particulate matter (PM_{10})

2.1 Impact Assessment Criteria

Table 2-1 summarises the air quality goals for the stated air quality metrics that are relevant to this study.

Table 2-1: EPA Air Quality Standards/Goals for PM_{10} and NO_2 concentrations (**NSW DEC, 2005**)

Pollutant	Standard	Averaging Period
NO_2	246 µg/m^3	1-hour
	62 µg/m^3	Annual
PM_{10}	50 µg/m^3	24-hour
	30 µg/m^3	Annual

Notes: µg/m^3 – micrograms per cubic metre.

3. Existing Environment

3.1 Climate Data

The Bureau of Meteorology (BoM) collects climatic information in the vicinity of the site at Sydney Observatory Hill located approximately 1.5 km north of the site. This climatic information is presented in **Table 3-1** (**BoM, 2016**).

Table 3-1: Climate averages for the Sydney Observatory Hill

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
9am Mean Dry-bulb Temperatures (ºC) and Relative Humidity (%)													
Dry-bulb	22.5	22.3	21.1	18.2	14.6	11.9	10.9	12.5	15.7	18.5	19.9	21.6	17.5
Humidity	71.0	74.0	74.0	72.0	74.0	74.0	71.0	66.0	62.0	61.0	66.0	67.0	69.0
3pm Mean Dry-bulb Temperatures (ºC) and Relative Humidity (%)													
Dry-bulb	24.8	24.9	24.0	22.0	19.4	16.9	16.4	17.5	19.2	20.7	22.1	23.8	21.0
Humidity	62.0	64.0	62.0	59.0	57.0	57.0	51.0	49.0	51.0	56.0	58.0	59.0	57.0
Daily Maximum Temperature (ºC)													
Mean	25.9	25.8	24.8	22.5	19.5	17.0	16.3	17.8	20.0	22.1	23.6	25.2	21.7
Daily Minimum Temperature (ºC)													
Mean	18.7	18.8	17.6	14.7	11.6	9.3	8.1	9.0	11.1	13.6	15.7	17.5	13.8
Rainfall (mm)													
Mean	102.5	117.0	129.6	128.8	119.2	133.0	97.1	80.6	68.4	76.7	84.1	77.7	1214.6
Rain days (Number)													
Mean	12.2	12.5	13.6	12.9	13.0	12.5	11.2	10.4	10.6	11.6	11.7	11.5	143.7

Station number: 066062; Commenced 1858; Status: Open; Elevation: 39 m AHD
Latitude: 33.86 °S; Longitude: 151.21 °E. Source: **BoM (2016)**

3.2 Meteorology

3.2.1 Wind Speed and Direction

Air quality impacts are influenced by meteorological conditions, primarily in the form of gradient wind flow regimes, and by local conditions that are generally driven by topographical features and interactions with coastal influences, such as the sea breeze.

As no site-specific meteorological data were available, CALMET was used to incorporate data from the surrounding weather stations[1] in order to provide representative meteorology for the site. Cloud cover and height were generated using The Air Pollution Model, or TAPM (a prognostic model). Model inputs and specifications are presented in **Appendix A**.

The annual and seasonal wind roses generated for the study area (representative year 2013) are presented in **Figure 3-1**. The average wind speeds for the period was determined to be 2.9 m/s. The percentage of calms (wind speeds below 0.5 m/s) for the meteorological file are relatively low at 1.7%.

The dominant winds are from the north-west, south and west quadrants on an annual basis. Typical of the Sydney basin, winter and autumn show a higher percentage of winds from the west, with summer receiving a higher percentage from the north-east.

[1] BoM Sydney Olympic Park (Archery Centre), BoM Sydney Airport, BoM Bankstown Airport, BoM Canterbury Racecourse, BoM Fort Denison, EPA Chullora, EPA Earlwood and EPA Rozelle.

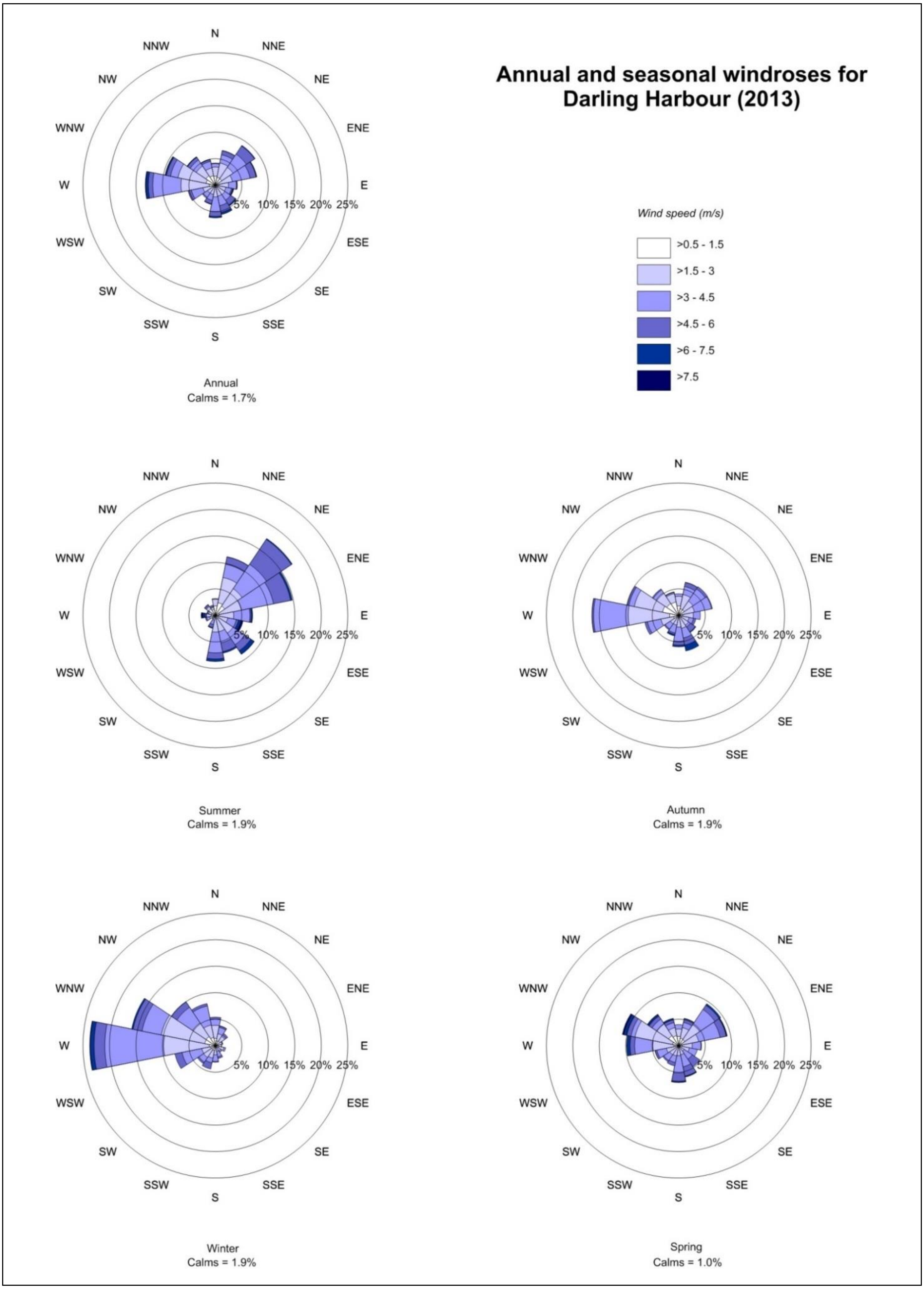

Figure 3-1: Annual and seasonal windroses representative of Darling Harbour, NSW

3.2.2 Atmospheric Stability

An important aspect of atmospheric dispersion is the level of turbulence in the lowest 1 km or so of the atmosphere, known as the planetary boundary layer (PBL). Turbulence controls how effectively a plume is diffused into the surrounding air and hence diluted. It acts by increasing the cross-sectional area of the plume due to random motions. With stronger turbulence, the rate of plume dispersion increases. Weak turbulence limits dispersion and contributes to high plume concentrations downwind of a source.

Turbulence is generated by both thermal and mechanical effects to varying degrees. Thermally driven turbulence occurs when the surface is being heated, in turn transferring heat to the air above by convection. Mechanical turbulence is caused by the frictional effects of wind moving over the earth's surface, and depends on the roughness of the surface as well as the flow characteristics.

Turbulence in the boundary layer is influenced by the vertical temperature gradient, which is one of several indicators of stability. Plume models use indicators of atmospheric stability in conjunction with other meteorological data to estimate the dispersion conditions in the atmosphere.

Stability can be described across a spectrum ranging from highly unstable through neutral to highly stable. A highly unstable boundary layer is characterised by strong surface heating and relatively light winds, leading to intense convective turbulence and enhanced plume diffusion. At the other extreme, very stable conditions are often 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. Neutral conditions are linked to windy and/or cloudy weather, and short periods around sunset and sunrise, when surface rates of heating or cooling are very low.

The stability of the atmosphere plays a large role in determining the dispersion of a plume and it is important to have it correctly represented in dispersion models. Current air quality dispersion models (such as AERMOD and CALPUFF) use the Monin-Obukhov Similarity Theory (MOST) to characterise turbulence and other processes in the PBL. One of the measures of the PBL is the Monin-Obukhov length (L), which approximates the height at which turbulence is generated equally by thermal and mechanical effects (**Seinfeld and Pandis, 2006).** It is a measure of the relative importance of mechanical and thermal forcing on atmospheric turbulence. Because values of L diverge to + and - infinity as stability approaches neutral from the stable and unstable sides, respectively, it is often more convenient to use the inverse of L (i.e., 1/L) when describing stability.

Figure 3-2 shows the hourly averaged 1/L for the site computed from all data in the meteorological modelling file. Based on **Table 3-2** this plot indicates that, as to be expected, the PBL is stable overnight and becomes unstable as radiation from the sun heats the surface layer of the atmosphere and drives convection. The changes from positive to negative occur at the shifts between day and night. This indicates that the diurnal patterns of stability are realistic within the modelling.

Table 3-2: Inverse of the Monin-Obukhov length L with respect to atmospheric stability

1/L	Atmospheric Stability
Negative	Unstable
Zero	Neutral
Positive	Stable

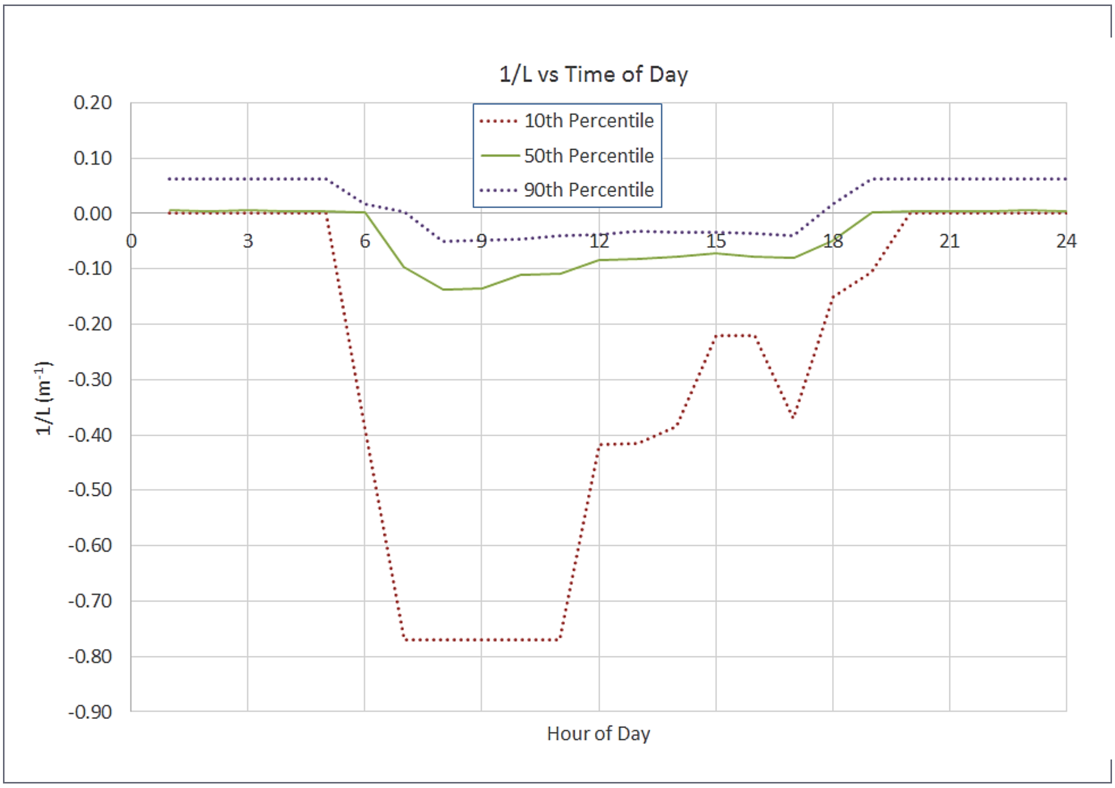

Figure 3-2: Annual statistics of 1/L by hour of the day

Figure 3-3 shows the variations in stability over the year by hour of the day, with reference to the widely known Pasquill-Gifford classes of stability. The relationship between L and stability classes is based on values derived by **Golder (1972)** set out in **NSW DEC (2005)**. Note that the reference to stability categories here is only for convenience in describing stability. The AERMET/AERMOD modelling system uses calculated values of L across a continuum.

Figure 3-3 shows that stable and very stable conditions occur for about 40-50% of the time, which is typical for onshore locations. Atmospheric instability increases during the morning and reaches a peak around 8 am. A stable atmosphere is prevalent during the night. These profiles indicate that pollutant dispersion is most effective during the daytime and least effective at night.

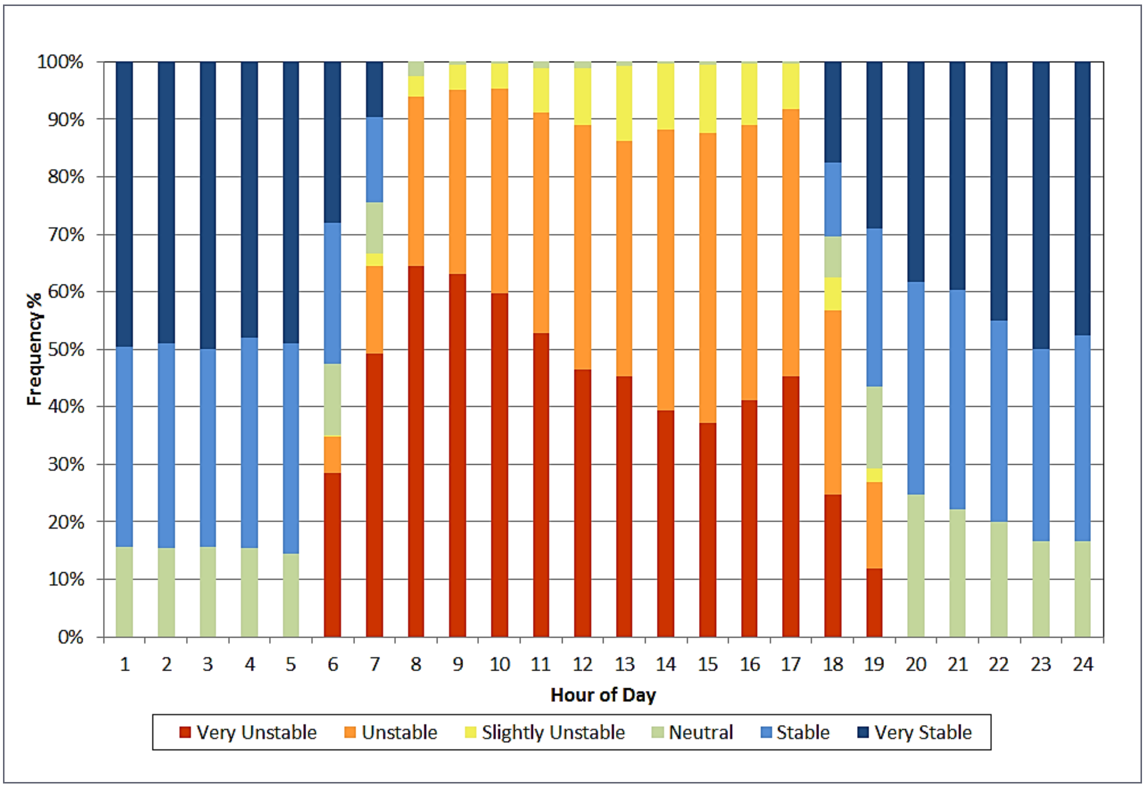

Figure 3-3: Annual distribution of stability type by hour of the day

3.3 Existing Air Quality

The NSW Office of Environment and Heritage (OEH) monitors air quality at several urban background locations around Sydney. The closest OEH urban background monitoring station to the site is at Rozelle. The air quality observations at Rozelle were therefore considered to be the most representative of background air quality in the study area.

Table 3-3 summarises the NO_2 and PM_{10} data from the Rozelle monitoring station for the years 2010 to 2016 inclusive.

Table 3-3: Summary of monitoring data from OEH's Rozelle site

Year	NO_2 (µg/m^3)		PM_{10} (µg/m^3)	
	Maximum 1-hour mean	Annual Mean	Maximum 24-hour mean	Annual Mean
2010	100.5	22.6	37.6	16.1
2011	102.5	22.6	39.4	16.6
2012	127.1	24.6	40.7	16.9
2013	143.5	22.6	58.5	18.3
2014	112.8	22.6	43.8	17.9
2015	123.0	22.6	60.3	16.7
2016	100.25	22.1	58.8	16.8

The monitoring data indicate that, with the exception of 24-hour PM_{10}, the concentrations of NO_2 and PM_{10} across the time periods presented are well below their respective NSW EPA criteria.

As shown in **Table 3-3** above, the 24 hour average PM_{10} criterion of 50 µg/m^3 was exceeded at the Rozelle site in 2013, 2015 and 2016. These exceedances are anticipated to be due to regional events such as bushfires or dust storms rather than as a result of specific local sources.

For this assessment the maximum monitored concentrations have been used to represent the background air quality in the area, with the contribution of the emission sources modelled subsequently added. It must be noted that this assumption is overly conservative and unrealistic, particularly in the case of the 24-hour average PM_{10}, where an alternative approach was taken.

Figure 3-4 presents a time series of the 24-hour mean PM_{10} measurements at Rozelle from 2010 to 2016. The figure demonstrates that the majority of concentrations are below 30 µg/m^3, with a number of elevated observations occurring in October 2013 when severe bushfires were present in the Sydney region.

There were only 112 occasions in the six years]\ of data presented when the 24-hour mean PM_{10} concentration exceeded 30 µg/m^3. To assess the cumulative PM_{10} impacts of the emission sources added, it was therefore deemed appropriate to remove the influence of these short-term regional peaks in the monitoring data used to represent background air quality.

For the purposes of this assessment, it was considered reasonable (yet still conservative) to take a background 24-hour mean concentration for PM_{10} as the 99th percentile of these data (i.e. the concentration that would only be exceeded on one per cent of days) presented in **Figure 3-4**. This value was determined to be 37.1 µg/m^3.

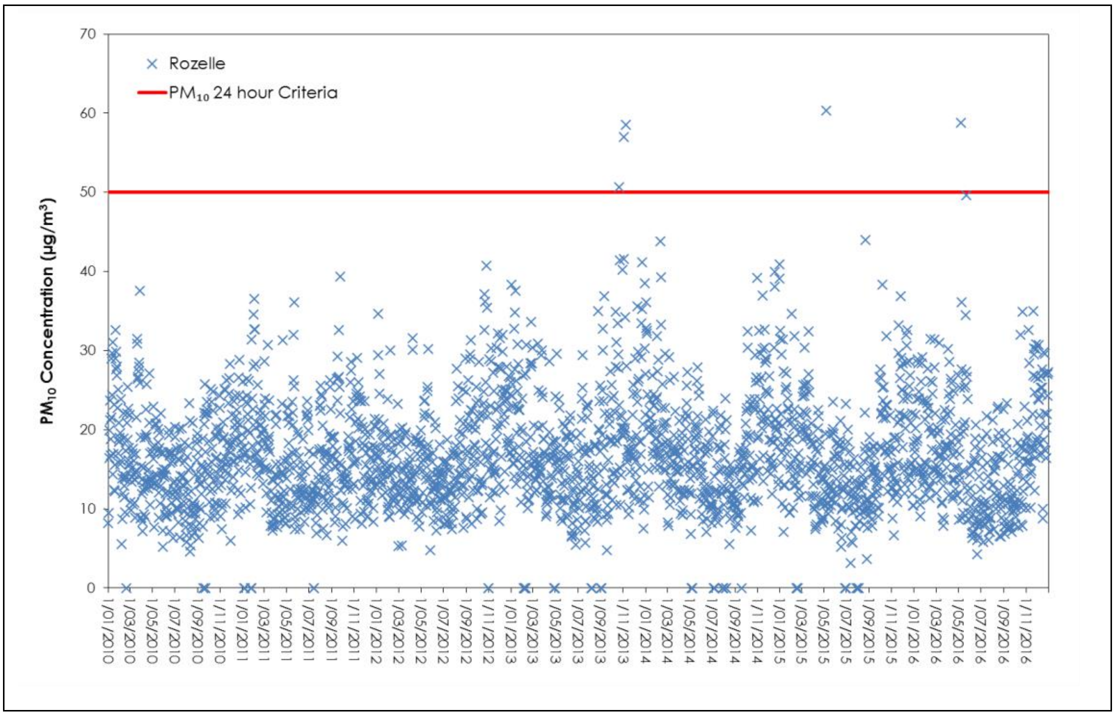

Figure 3-4: 24-hour PM_{10} concentrations measured at Rozelle from 2010 to 2016 inclusive

A summary of the background concentrations used in the assessment is provided in **Table** 3-4.

Table 3-4: Summary of background concentrations referenced within this assessment

Pollutant	Background Concentration (µg/m^3)		
	Annual Mean	24-hour Mean	1-hour Mean
NO_2	24.6^{i}	*N/A*	143.5^{i}
PM_{10}	18.3^{i}	37.1^{ii}	*N/A*

^{i} 100th percentile (maximum) of monitoring data
^{ii} 99th percentile of monitoring data

4. Modelling Approach

The approach to the assessment generally follows the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (**NSW DEC, 2005**) using the Level 2 assessment methodology. The Approved Methods specify how assessments based on the use of air dispersion models should be completed. They include guidelines for the preparation of meteorological data to be used in dispersion models and the relevant air quality criteria for assessing the significance of predicted concentration and deposition rates from projects.

4.1 Stack Modelling System

AERMOD was chosen as the most suitable model for the evaluation of the impact of nearby ventilation stacks due to the source types, location of nearest receivers and nature of local topography. AERMOD is the US-EPA's recommended steady-state plume dispersion model for regulatory purposes and it is an accepted model of the NSW EPA.

The AERMOD system includes AERMET, used for the preparation of meteorological input files and AERMAP, used for the preparation of terrain data.

Terrain data was sourced from NASA's Shuttle Radar Topography Mission (SRTM) Data (3 arc second (~30m) resolution) and processed within AERMAP to create the necessary input files.

AERMET requires surface and upper air meteorological data as input. The surface data was sourced from CALMET (**Section 3.2**), modelled over the site. Appropriate values for three surface characteristics are required for AERMET as follows:

- Surface roughness, which is the height at which the mean horizontal wind speed approaches zero, based on a logarithmic profile.
- Bowen ratio, which is an indicator of surface moisture.
- Albedo, which is an indicator of reflectivity of the surface.

Values of surface roughness, Bowen ratio and albedo were determined based on a review of aerial photography for a radius of 3 km centred on the site. A conservative default value of urban were selected in AERMOD to represent the area around the site.

Building wake effects were included in the modelling simulations to represent the commercial/urban setting that the proposed site would be located. The CCT ventilation outlet was represented as a point source 60 m above ground level.

A summary of the modelling inputs is presented in **Appendix A**.

4.2 Roadway Modelling System

The CAL3QHCR dispersion model was used to estimate the worst-case concentrations of vehicle emissions from the current traffic along the Western Distributor. This model is a steady state Gaussian model which can determine concentrations at receptor locations downwind of "at grade", "fill", "bridges" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, roadway orientation and receptor location.

5. Emissions Estimation

5.1 Stack Emissions

5.1.1 Cross City Tunnel Ventilation Outlet

Predictions were made for three CCT operating scenarios, as follows:

- Low Emissions (night time, low traffic, reduced fan speed).
- Medium Emissions (off peak traffic, medium fan speed).
- High Emissions (peak hour, maximum fan speed).

Stack parameters are based on the Approved Design of the CCT ventilation stack. NO_2 emission rates have been (conservatively) based on predicted rather than actual traffic volumes through the CCT. This provides a worse-case scenario but is appropriate as traffic volumes could ultimately reach levels predicted within the CCT Environmental Assessment and subsequent studies. Emission rates for PM_{10} are based upon the maximum allowable 1.6 mg/m^3 in-stack concentration outlined in the consent conditions for the CCT.

The modelled emission parameters are given in **Table 5-1**. The stack temperature has been set at the ambient level to reflect neutral buoyancy of the plume (i.e. equivalent to the meteorological input file).

Table 5-1: Stack parameters adopted for Cross City Tunnel stack

	Value		
MGA Coordinates	333655, 6250358		
Stack Height (m)	60		
Stack Diameter (m)	5.97		
Stack Temperature (K)	293		
	NO_2 Emission Rate (g/s)	**PM_{10} Emission Rate (g/s)**	**Exit Velocity (m/s)**
Low Emissions (night time)	0.4	0.2	5
Medium Emissions (off peak)	1.0	0.5	11
High Emissions (peak hour)	1.8	0.9	21

A 3-dimensional extract from the AERMOD dispersion model showing the CCT stack, surrounding buildings included in the model and proposed development is presented in **Figure 5-1**.

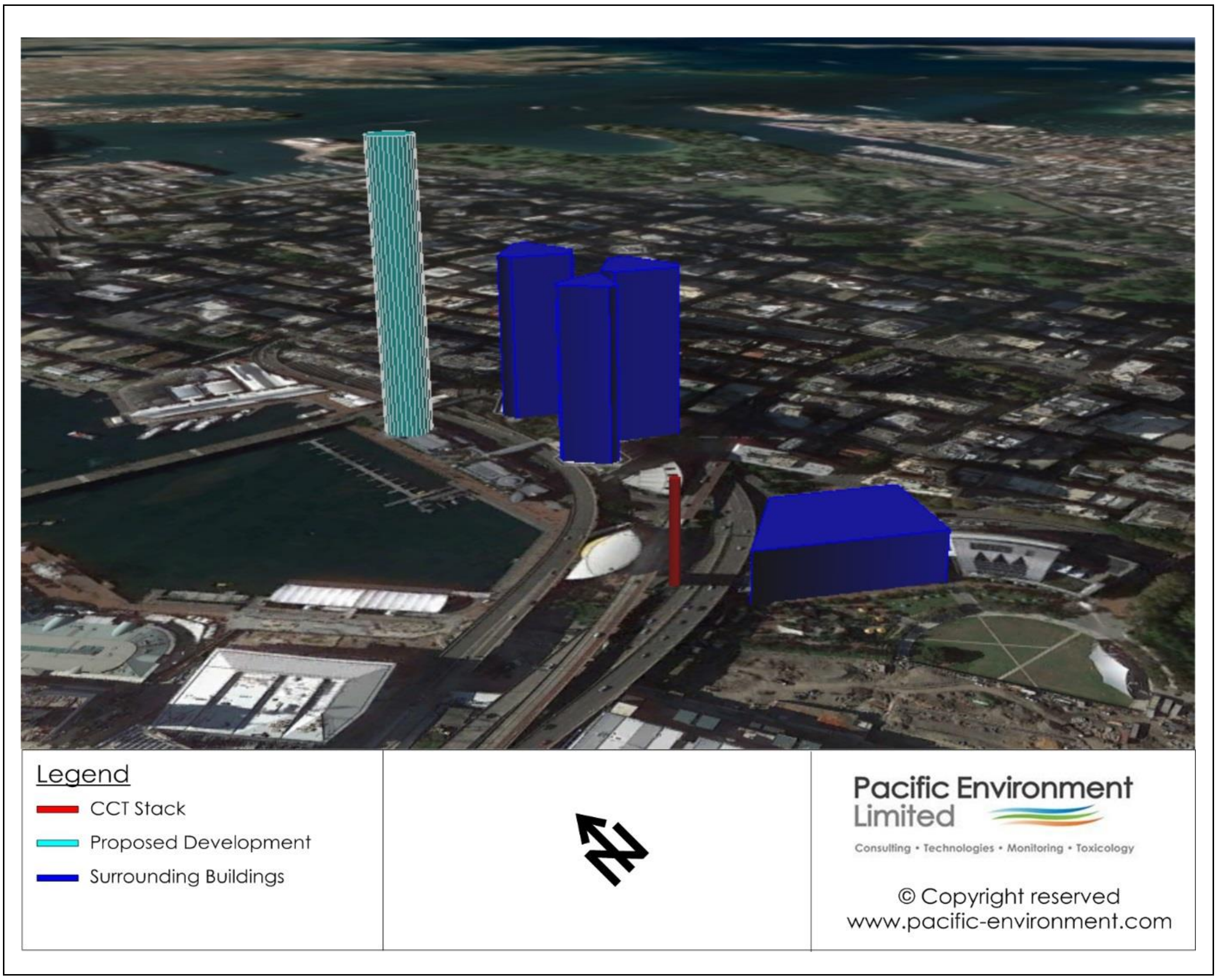

Figure 5-1: Three-dimensional representation of assessment area

5.1.2 Darling Park Tunnel Ventilation Points

The Darling Park Tunnel ventilation points release emissions from the underpass adjacent to the proposed development (see **Figure 1-1**). **Figure 5-2** below identifies the two emission points.

These vents were not considered in the assessment as they are not anticipated to be a major source of air pollution in comparison to the CCT stack (**Section 5.1.1**) and the roadside Western Distributor emissions (**Section 5.2**) which have been accounted for.

These two existing ventilation points are located in close proximity to existing high rise buildings and recreational areas, and do not appear from site inspection to be equipped with any mechanical ventilation.

Their comparatively low release heights, lack of mechanical ventilation, and length of underpass being serviced by the vents (less than 150 m) supports that their specific characterisation within the modelling is not warranted for the current assessment.

Rather, all vehicle emissions that potentially report to these ventilation points are accounted for within the roadway modelling (i.e. emissions from these areas are simulated to occur at the two portals of the Darling Park Tunnel, approximately 150m apart.

Vent 1

Vent 2

Figure 5-2: Darling Park Ventilation Points evaluated during site inspection (30/08/2016)

5.2 Roadside Emissions

5.2.1 Western Distributor Flyover (Vehicle Emissions)

Roadside vehicle emissions along the Western Distributor have been considered in the assessment. The vehicle movements along these roads were sourced from the RTA online traffic database (**RMS, 2016**).

Vehicle emission data from PIARC[2] (**PIARC, 2004**) were adjusted to reflect the NSW vehicle fleet. The modified tables include emissions of NO_x and PM_{10} by age and type of vehicle. The ages of vehicles are categorised into seven periods which correspond to the introduction of emission standards. The types of vehicle are categorised into light and heavy vehicle groups.

The modelling assumptions for the Western Distributor are as follows:

- The peak traffic flow is 6,498 vehicles per hour in the southbound direction.
- The peak traffic flow is 8,262 vehicles per hour in the northbound direction.
- The traffic speed is 80 km/h (modelled as 60km/hr during peak periods and 70 km/hr in the intermittent periods).

Emission estimates are summarised in **Table 5-2**.

Table 5-2: Emissions from Western Distributor (g/km/hr)

	Western Distributor (Southbound)		Western Distributor (Northbound)	
Hour of Day	Nitrogen Oxides (NO_x)	Particulate Matter (PM_{10})	Nitrogen Oxides (NO_x)	Particulate Matter (PM_{10})
1	200	0.04	375	0.04
2	153	0.04	265	0.04
3	134	0.04	231	0.04
4	203	0.04	357	0.04
5	664	0.04	972	0.04
6	1,937	0.04	2,260	0.04
7	2,659	0.05	2,643	0.05
8	2,926	0.05	2,413	0.05
9	2,706	0.05	2,448	0.05
10	2,355	0.05	2,410	0.05
11	2,321	0.05	2,482	0.05
12	2,480	0.04	2,707	0.04
13	2,274	0.04	2,693	0.04
14	2,283	0.04	2,920	0.04
15	2,568	0.04	3,265	0.04
16	2,669	0.05	3,283	0.05
17	2,784	0.05	3,087	0.05
18	2,579	0.05	2,739	0.05
19	1,796	0.05	2,009	0.05
20	1,129	0.05	1,587	0.05
21	1,146	0.04	1,734	0.04
22	1,108	0.04	1,782	0.04
23	626	0.04	1,249	0.04
24	358	0.04	665	0.04

[2] The acronym PIARC refers to the Permanent International Association of Road Congress. While this body is now known as the World Road Association, the PIARC acronym has been retained.

5.3 Building Wake Effects

Wind flow is often disrupted in the immediate vicinity of buildings. Plumes emitted nearby are assumed to be unaffected by building wakes if they reach building height plus 1.5 times the lesser of building height or projected building width. If this is not the case, pollutants can be brought to ground within a highly turbulent, generally recirculating cavity region in the immediate lee of the building and/or be subject to plume downwash and enhanced dispersion in a turbulent region which extends further downwind behind the building (**EPAV, 1999**).

The simulation of building wake effects, modelled using the BPIP-PRIME model is based on a relatively simple building geometry, as it is not possible to incorporate complex building shapes adequately within the AERMOD model. A simplified building geometry shown in **Figure 5-1** was incorporated for assessment purposes.

BPIP-PRIME uses heights and corner locations of buildings in the vicinity of the plume to simulate the effective height and width of the structures. The downwash algorithm calculates effective building dimensions relative to the plume, resolved down to ten degree intervals. AERMOD then calculates the impact of these buildings on plume dispersion and consequently on ground level concentrations. Although a simplified building geometry is used, it should provide a reasonable indication of how the building may disrupt wind flow in the immediate vicinity.

5.3.1 Impact of Proposed Development on the CCT Plume

To determine the impact of the building downwash (the effect of the proposed development upon the CCT plume) on ground level concentrations, a model run was completed without the building located within the modelling domain.

There was found to be no difference in the ground level concentration predictions for the model runs with and without the proposed building incorporated within the model. This is since the building is a considerable distance from the CCT stack, and hence not anticipated to cause building wake effects, or adversely impact upon CCT stack plume dispersion.

5.4 Nitrogen Dioxide Characterisation

Much of the oxides of nitrogen (NO_x) emissions from the roadway source (Western Distributor) are released as nitric oxide (NO), with some nitrogen dioxide (NO_2) emitted at the point of release. The rate at which the NO undergoes oxidation to form NO_2 depends on prevailing atmospheric conditions including temperature, humidity and the presence of other substances in the atmosphere, such as ozone.

Based upon previous air quality assessments completed by Pacific Environment, a conversion rate of NO to NO_2, was assumed to be 20%. This is considered to be a conservative assumption for such a near-field assessment.

6. Dispersion Modelling

6.1 CCT Stack

The AERMOD model was run to determine any potential air quality impacts from the CCT ventilation outlet in the vicinity of the proposed development site. To account for the worst case impacts, receptors were placed at the southern edge of the site closest to the ventilation outlet emission source.

Further, in addition to predictions at ground level of the proposed overpass / land bridge (modelled at 9 m above the ground), concentrations were also determined at heights corresponding to the building storeys (or levels), up to a maximum of 217 m above ground (see **Table 6-2**).

The resultant maximum 1-hour ground level contours for NO_2 associated with the operation of the CCT stack under the high emission scenario is presented in **Figure 6-1**. Contour plots for the other emission scenarios are not presented as the high emission scenario predicts the greatest potential impact upon the proposed development location.

Figure 6-1: Predicted maximum 1-hour NO_2 concentrations at ground level associated with the operation of the CCT stack

6.2 Vehicle Emissions

The CAL3QHCR dispersion model was used to estimate the worst-case concentration of oxides of nitrogen and particulate matter, from the current traffic along the Western Distributor.

The Western Distributor was modelled with different traffic volumes across the northbound and southbound lanes (**Section 5.2**).

Although that the pollutant concentrations were modelled at the same receptor locations in both assessments, only the ground level receptors were assessed in the roadside dispersion model as they are anticipated to be the most impacted (i.e. closest to the road surface).

The maximum 1-hour ground level contours for NO_2 associated with Western Distributor vehicle emissions is presented in **Figure 6-2**. The NO_x to NO_2 ratio of 20% has been accounted for in this figure.

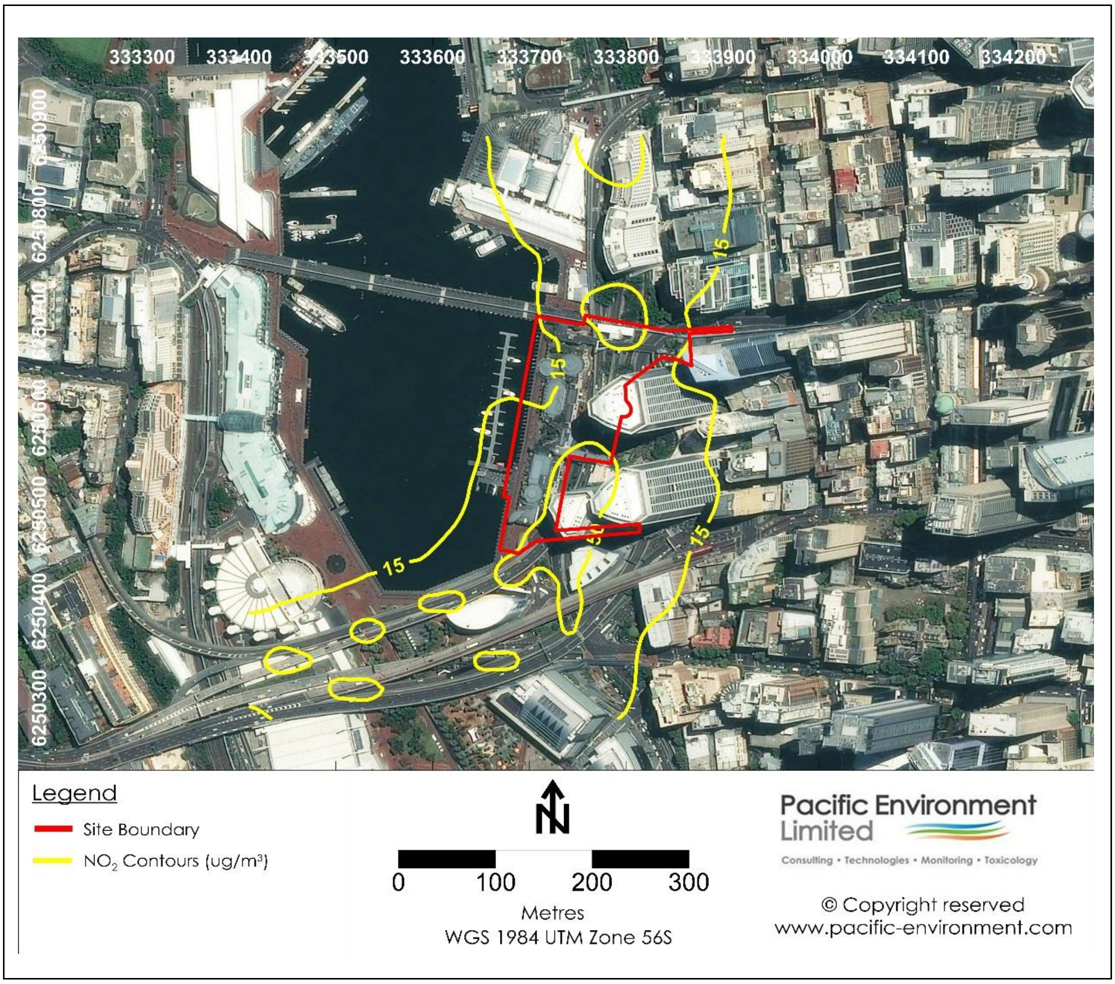

Figure 6-2: Predicted maximum 1-hour NO_2 concentrations at ground level associated with vehicle movements on the Western Distributor

6.3 Air Quality Assessment

Presented in **Table 6-1** are the maximum predicted ground level concentrations of NO_2 and PM_{10} from the CCT stack and Western Distributor at the proposed development area in Cockle Bay Park.

Note that the results presented show the maximum predicted ground level concentrations at the proposed development for the CCT stack and roadside emissions separately. These maximum events, when added to the background concentration (i.e. a conservative estimation of cumulative impacts), are still well below the respective NSW EPA air quality impact assessment criteria.

This approach is considered highly conservative, as in reality it would not be expected that peak concentrations from the CCT would occur concurrently with peak concentrations from the Western Distributor.

The highest predicted concentrations from the CCT stack on the building occur at approximately 110m above ground level (see **Table 6-2**), with up to an approximate 70 $\mu g/m^3$ difference between the maximum predicted 1-hour NO_2 values between ground level and the proposed maximum concentration measured at the building. This contrasts with the Western Distributor emissions where it would be expected that greater impacts would occur at the base of the proposed development.

Table 6-1: Predicted maximum NO_2 and PM_{10} concentrations at ground level of the proposed development

Pollutant	Units	Period	Assessment Criterion	Maximum Predicted Concentration at ground level of development area		Background Concentration	Cumulative Ground Level Concentration
				CCT Stack	Western Distributor		
NO_2	µg/m³	1-hour	246	15.7	33.4[1]	143.5	192.6
		Annual	62	0.1	2.1[1]	24.6	26.8
PM_{10}	µg/m³	24-hour	50	0.68	1.7	37.6	40.0
		Annual	30	0.06	0.5	18.3	18.9

Note: [1] 20% conversion of NO_X assumed.

Table 6-2: Concentrations of NO_2 and PM_{10} at varying heights above sea level (ASL) of the proposed development

Modelled height above ground (mASL)	NO_2 (µg/m³)		PM_{10} (µg/m³)	
	1-hour	Annual	24-hr	Annual
9	11.8	0.1	0.3	0.0
30	21.2	0.1	0.6	0.0
60	35.9	0.2	1.1	0.1
90	41.7	0.3	2.4	0.2
100	74.5	0.4	3.8	0.2
110[1]	82.2	0.4	4.5	0.2
120	68.0	0.3	4.3	0.2
150	52.0	0.2	1.4	0.1
180	31.3	0.2	1.0	0.1
210	11.8	0.1	0.7	0.1

Note: [1] Building height of 110 m anticipated to have the highest air quality impacts from the CCT stack.
Elevation of the development's ground floor is considered 2.75 mASL.
Maximum concentration at each height across all emission scenarios presented.

7. Conclusions

The Minister for Planning's Approval Condition 274 for the Cross City Tunnel (CCT) states that any development in the vicinity of the CCT stack requires an air quality assessment of potential impacts from the stack plume. The proposed development at Cockle Bay Park is within 300 metres of the CCT stack and therefore triggered the requirement to undertake an air quality assessment.

Pacific Environment completed an air quality assessment of the CCT ventilation stack and Western Distributor in order to determine the air quality impact of these sources on the proposed development.

The assessment concludes that the emissions from the CCT stack and Western Distributor are not anticipated to result in any exceedances of the NSW EPA criteria for the air quality metrics assessed in the vicinity of the proposed development.

The modelling completed to date indicates that higher concentrations of the air quality metrics evaluated are predicted to occur at approximately half the maximum height of the proposed development (110mASL) compared with those at ground level.

It is noted however, that given the complexity of the modelled scenario, optimisation of any air intakes' locations for the proposed development should necessarily occur during the detailed design stage for the development. It is recommended that this be completed using a micro-scale modelling technique such as computational fluid dynamics (CFD) or the GRAL roadway assessment modelling scheme.

In addition to this assessment, a desktop study completed by Aurecon (appended to this report) has evaluated the internal air quality below the land bridge concludes that in-tunnel air quality is anticipated to be satisfactory under all flow scenarios.

8. References

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Appendix A

Model Inputs

Table 8-1: Model Inputs for CCT Dispersion Modelling

AERMOD	
Meteorology	
Meteorological data for Surface Files –(Samson file)	CALMET generate meteorology (integrating surrounding BOM weather stations) • Air temperature • Relative Humidity • Wind speed • Wind direction TAPM centred over Darling Harbour • Cloud cover • Cloud height
Land Use	Urban (Albedo – 0.2075, Bowen ratio- 1.625 and Surface roughness – 1)
AERMET PFL	Upper Air estimator
Year of analysis	January 2013 - December 2013
Model Set up	
Centre of domain (lat, long)	-33°52'25" S, 151°12'20" E
Centre of domain (easting, northing)	333600, 6250400
MGA coordinate zone	56 S
Grid domain size	5km x 5km
Grid spacing	100m
South west corner of gridded receptor domain (m)	331600, 6248400
Number of grid points	40 x 40
Terrain data	SRTM3 at 30m resolution
Rural Mode	Selected
Output Options	
Highest values	

Appendix B

Aurecon Air Quality Study

aurecon

Cockle Bay Park – Land Bridge over the Western Distributor

Internal Air Quality Study

DPT and DPPT Operator Pty Ltd

26 July 2017

Revision: 1

Reference: 253427

Bringing ideas to life

Document control record

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Client contact	Greg Mannes		**Client reference**			
Rev	**Date**	**Revision details/status**	**Author**	**Reviewer**	**Verifier** (if required)	**Approver**
0	25 May 2017		**Christian Sahayanathan**	**Cristian Biotto**		**Ewan Bennett**
1	26 July 2017		**Christian Sahayanathan**	**Cristian Biotto**		**Ewan Bennett**
Current revision	**1**					

Approval			
Author signature		Approver signature	
Name	Christian Sahayanathan	Name	Ewan Bennett
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Cockle Bay Park – Land Bridge over the Western Distributor

Date 26 July 2017
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Contents

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Tables

1 Introduction

This report is a response to submissions and amended development application associated with a State Significant Development Application (SSDA) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) is seeking to secure approval to establish concept proposal details for the redevelopment of the Cockle Bay Wharf Building and surrounding areas (now referred to as Cockle Bay Park).

As part of this redevelopment a new land bridge structure over the Western Distributor has been proposed. This land bridge would create a partial enclosure to the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, and the on grade northbound and southbound Western Distributor and northbound Wheat Rd.

This report addresses the internal air quality below the land bridge between the portals it creates and forms part of Pacific Environment's precinct wide air quality assessment.

2 Methodology

Internal air quality assessments for Carbon monoxide (CO), Nitrogen Dioxide (NO_2) and visibility will be undertaken by means of a desktop assessment. The visibility parameters to be examined are $PM_{2.5}$ and PM_{10} which represent a subset of particulate matter with sizes in the order of 2.5 and 10 microns respectively. Only these pollutants are modelled as they have the most stringent requirements (PIARC - Road tunnels: vehicle emissions and air demand for ventilation, 2012R05EN).

These assessments will consider the following operations:

- Normal operations: Free flowing traffic moving at 80km/hr
- Congested operations: Traffic moving at 40km/hr
- Congested operations: Traffic moving at 10 km/hr
- Stationary vehicles

Due to moving traffic, all desktop assessments will assume flow through the enclosure is unidirectional, exiting the northbound portal. Desktop assessments consider the condition in the enclosure and at the portals to be averages over the cross-section.

3 Model and Inputs

3.1 Geometry

The enclosure consists of the on grade northbound and southbound Western Distributor, northbound Wheat Rd and an elevated northbound Western Distributor and southbound Market St towards Anzac Bridge which connects with an existing underpass.

Figure 1 displays the approximate extent of the proposed land bridge and the existing underpass southbound of Market St. Figure 2 shows the cross-sections along the proposed land bridge, and estimated dimensions of the enclosure.

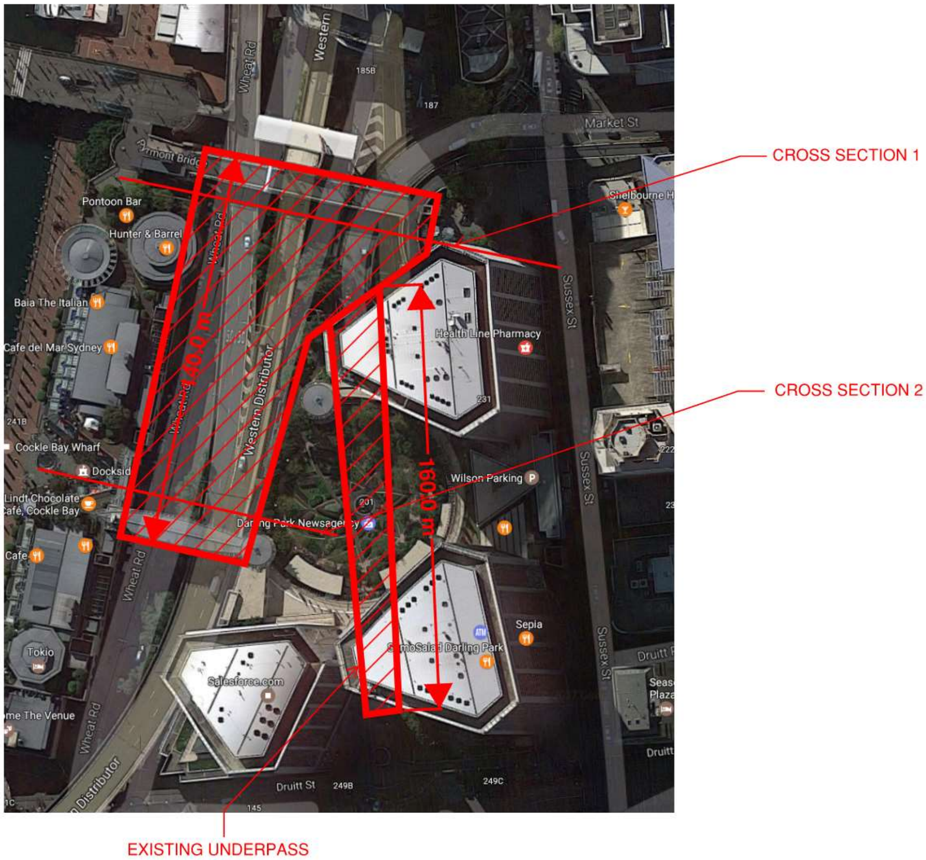

Figure 1: Extent of proposed land bridge and existing underpass – plan.

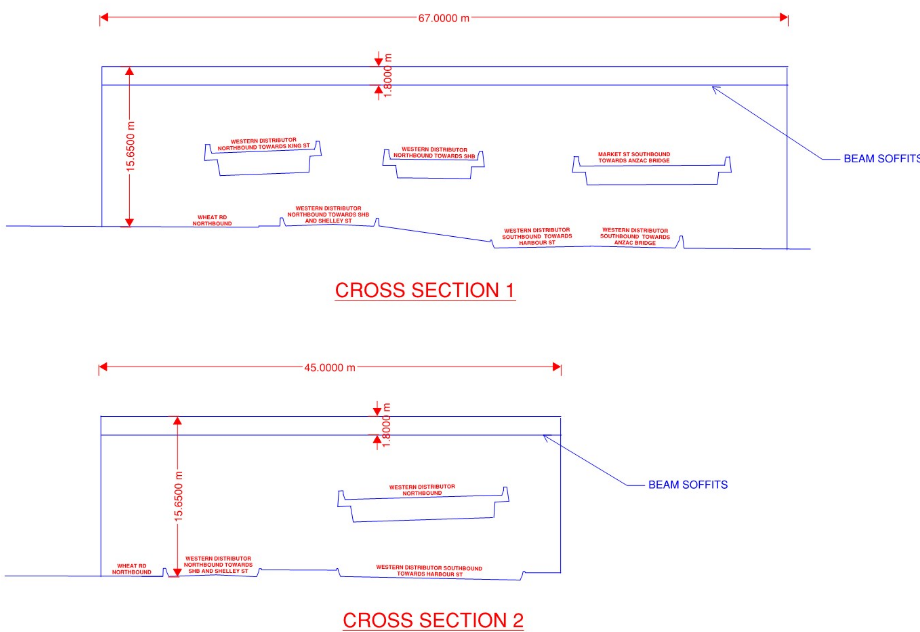

Figure 2: Cross sections of roadways beneath the proposed land bridge (dimensions are approximate only).

The model considers openings only at the portals. It has been assumed that the future tower to the west of the enclosure will feature a solid wall that will not provide any means of ventilation on the western face of the enclosure. On the eastern wall of the new structure there are openings to an existing car park. It is expected that the induced flow from the enclosure will be larger than the forced ventilation from the car-park, thus always leading to a flow from the proposed enclosure to the car park. A conservative assumption that there is zero flow from the underpass to the carpark has been taken and the wall is modelled without ventilation. The effects of the underpass on the existing building ventilation will need to be assessed in time. No ventilation is assumed for the existing underpass below Darling Park.

3.2 Inputs

3.2.1 Traffic and vehicle parameters

Traffic and vehicle parameters are not available for the Western Distributor at the location of the underpass and estimates for these parameters were made based on the following data. A permanent vehicle-type classifier on the Sydney Harbour Bridge, approximately 2.5km from the proposed underpass, was used to determine the traffic split. It was determined that in 2016 on average 94% of traffic was classified as passenger cars and 6% as heavy goods vehicles (HGV). To be conservative, for this study, 10% of the total traffic was considered to be composed of HGVs. Additionally, international standard PIARC (Road tunnels: vehicle emissions and air demand for ventilation, 2012R05EN) suggests that where the traffic split for light commercial vehicles (LCV) is not provided, it is suitable to assume that 10% of passenger car vehicles are comprised of LCVs.

PIARC also provides estimates on how many vehicles are expected to be present in a section of road for a given number of lanes, road length and vehicle speed. The number of vehicles per lane over a 15 minute period used for this study are presented in Table 1. These values are comparable with those used in the fire engineering study that has been undertaken separately.

Table 1: Vehicle type split

Simulation	80 km/h	40 km/h	10 km/h	Stationary
Vehicle count	Veh/h-lane	Veh/h-lane	Veh/h-lane	Veh/km-lane
Passenger car – Petrol	1378	1378	624	95
Passenger car – Diesel	243	243	117	17
Light commercial vehicle	193	193	91	13
Heavy goods vehicle	193	193	91	13

Moreover, PIARC provides values for the coefficient of drag (C_D) and the cross-sectional area (A) for each of the vehicle types; Passenger cars, light vehicles and heavy goods vehicles. The values are summarised in Table 2.

Table 2: Standard drag coefficient and cross sectional areas of vehicle types (PIARC, 1995)

Description	C_D (-)	A (m^2)
Passenger Cars	0.4	2
Light Vehicles	1.0	3
Heavy Goods Vehicles	1.0	7

PIARC also provides values for the expected level of emissions per car given a road gradient, travel speed and vehicle type. Given the shallow gradient in the enclosures, the road gradient for the car emissions is taken as 0%. The bidirectional nature of traffic counterbalances any small gradients. A conservative assumption was made that 20% of NO_X is comprised of NO_2. The values found in the table are then multiplied by year-factor which accounts for the changes in vehicle emissions over time, to the design year 2020.

Table 3 provides a list of average vehicle exhaust parameters based on the data in Table 1 and Table 2.

Table 3: Vehicle exhaust parameters

Description	Value	Unit
Average vehicle exhaust diameter	0.05	m
Average exhaust velocity	1.8	m/s
Average exhaust temperature	100	˚C
Average exhaust density	1.1675	kg/m^3
CO yield	9.364×10^{-4}	$kg_{CO}/kg_{exhaust}$
NO_2 yield	6.184×10^{-5}	$kg_{NO_2}/kg_{exhaust}$
PM_{10} yield	2.625×10^{-5}	$kg_{PM10}/kg_{exhaust}$
$PM_{2.5}$ yield	3.500×10^{-5}	$kg_{PM2.5}/kg_{exhaust}$

3.2.2 Ambient conditions

The ambient conditions for Sydney were taken from the Bureau of Meteorology (BOM) (Sydney (Observatory Hill) Site No: 066062), where the mean daily high temperature for 2016 of 30˚C was used.

No wind pressure is conservatively considered at the portals, as this would induce a flow, and subsequently lower the concentrations of the vehicle emissions within the enclosure.

The background air quality was obtained from 2016 observations at the Rozelle station, an air quality monitoring site located in Rozelle, East Sydney. The air quality data is presented in Table 4.

Table 4: Ambient air quality (Rozelle Station)

Pollutant	Averaging period	Max	Units
NO_2	1 hour	94	μg/m^3
CO	8 hour	1.38	mg/m^3
CO (calculated)	1 hour	2.09	mg/m^3
PM_{10}	24 hour	58.8	μg/m^3
$PM_{2.5}$	24 hour	49.4	μg/m^3

The CO concentration for an averaging period of 1 hour was not available however, some guidance for the conversion from an averaging period of 8 hours to 1 hour is available through the regulatory air pollution model AERMOD in Victoria. The conversion is provided by Equation 1.

Equation 1: Conversion of average period concentrations

$$c(t) = c(t_0) \times (\frac{t_0}{t})^{0.2}$$

Where:

t is the averaging period of interest

t_0 is the averaging period available

$c(t_0)$ is the concentration at the available averaging period

3.2.3 Emission Limits

3.2.3.1 External Emission Limits

The concentration limits of CO, NO_2 and visibility are provided by the NSW EPA (Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, 2016). The limits are shown in Table 5.

Table 5: Emission and visibility limits

Pollutant	Averaging period	Concentration ppm	Concentration mg/m^3	Concentration μg/m^3	Reference
CO	1 hour	25	30	-	WHO (2000)
NO_2	1 hour	0.12	-	246	NEPC (1998)
PM_{10}	24 hour	-	-	50	DoE (2016)
$PM_{2.5}$	24 hour	-	-	25	DoE (2016)

3.2.3.2 Internal Emission Limits

An approved set of limits for internal emissions does not exist. Hence, pollutant limits were taken from the specification of WestConnex. The limits for 15 min averaging period are summarised in Table 6.

PIARC provides a correlation factor between particulate matter 2.5 ($PM_{2.5}$) emissions in visibility (m^{-1}) and concentration (μg/m^3).

Equation 2: $PM_{2.5}$ convesion from concentration to visibility

$$K = 0.0047\mu$$

Where:

K is in m^{-1}

μ is in μg/m^3

The Australian Motor Vehicle Emission Inventory (AMVEI) provides a total annual Australian NPI emissions for industry and motor vehicles. Based on this data we are able to determine an average ratio between $PM_{2.5}$ and PM_{10}; this was calculated to be 0.808:1.000. The conversions were considered in Table 6.

Table 6: Values for internal emission and visibility limits

Pollutant	Averaging period	Concentration ppm	Visibility m^{-1}	Concentration mg/m^3	Reference
CO	15 minute	87		100	WHO (2000)
NO_2	15 minute	0.5		0.94	WestConnex
$PM_{2.5}$	15 minute	-	0.005	1.063	WestConnex
PM_{10}	15 minute	-	0.005	1.315	WestConnex

4 Results

4.1 Internal Air Quality Assessment

The internal air quality desktop assessments were conducted for normal, congested and stationary operations and the results are summarised in Table 8. In this table, the assessments with moving traffic were based on the steady-state methods described in PIARC 1995 and the assessment with stationary traffic was based on air flows driven by the buoyancy of the vehicle exhaust in a tunnel with no other forces acting on the air. The results indicate that the air pollutants are well within the internal air quality limits from Table 7.

All pollutants and visibility parameters shown in Table 7 and Table 8 are 15 minutes averaging period values.

Table 7: Internal air quality limits and ambient air quality

	Limit		Ambient	
	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$
CO	100		2.75	
NO_2		940		124
$PM_{2.5}$		1063		123
PM_{10}		1315		146

Table 8: Total concentration of outflow for internal air quality

	Normal 80 km/hr		Congested 40 km/hr		Congested 10 km/hr		Stationary – SB portal		Stationary – NB portal	
	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$
CO	3		4		5		9		9	
NO_2		163		190		366		647		647
$PM_{2.5}$		146		160		207		230		230
PM_{10}		174		193		251		279		279

5 Conclusion

The desktop study has looked at internal air quality below the land bridge for the proposed development at Cockle Bay, Sydney.

The internal air quality shows that the limits are satisfied under all the flow scenarios when the bulk flow is considered.

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