Central Barangaroo Concept Plan MOD 9

Air Quality Impact Assessment

17-Nov-2021

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Air Quality Impact Assessment

Prepared by

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Executive Summary

An Air Quality Impact Assessment (AQIA) was prepared by AECOM to assess the potential impact associated with the proposed modification (Mod 9) to the Concept Plan (MP06_0162). Key modifications to the Concept Plan include:

- An increase in total GFA permissible on the Central Barangaroo site;
- Provision of GFA allowable within the total Barangaroo site to reflect spaces which are not currently included in the Barangaroo Concept Plan approval (MOD 11)
- Modification to the approved building envelopes of Block 5, 6 and 7 for additional height
- A re-adjustment of the Block 5 site and building envelope towards the alignment prior to the MOD 8 approval, whilst providing building setbacks to both Barangaroo South and Hickson Park.
- Modification to create Barton Street as a permanent street connecting Barangaroo Avenue with Hickson Road and servicing the Barangaroo precinct.
- Consequential amendments to the State Significant Precincts SEPP to supports modifications to the Barangaroo Concept Plan (MOD 9) - Central Barangaroo; and
- Revised Statement of Commitments.

Following a review of the proposed modification and current staging plan of the Central Barangaroo development a qualitative impact assessment was undertaken to identify the likely potential impacts to air quality at nearby existing and future sensitive receptors during construction and operation.

For MOD 9 potential dust generating impacts (and associated minor impacts from soil contaminants) during construction; particularly during excavation activities pose the greatest potential air quality impacts from the project to nearby receptors. There is also the potential for minor cumulative impacts associated with construction of Sydney Metro Station and other development projects within Barangaroo. As for previous Development Applications for Barangaroo dust generating impacts from individual development applications within the Central Barangaroo site would need to be assessed in accordance with the EP&A Act. The level of assessment would be dependant on the nature of the works involved at the detailed Development Application stage.

Other potential air quality impacts during construction would include combustion from mobile and stationary plant equipment which may be managed appropriately by maintaining equipment and using standard management practices. There is also the potential for minor odour impacts during operation of the water treatment plant.

Potential operational impacts may include minor air quality impacts from commercial properties and vehicle emissions from traffic generating development, particularly along Hickson Road and to a smaller extent Barangaroo Avenue. These may be managed with appropriate planning and design considerations. Current traffic generation estimates predict only slightly higher vehicle numbers for the proposed modification when compared to previous estimates for Mod 10 for two way AM and PM Peak hour traffic forecasts (ARUP 2019 cited in ARUP 2021). The concept plan also allows for the provision of large landscaped areas and green roofs which would have potentially beneficial impact on local air quality by reducing air pollutant concentrations through both direct and indirect pathways.

In conclusion provided that a detailed AQIA for each individual Development Applications specific to the Central Barangaroo is undertaken and appropriate project-specific mitigation strategies are implemented, no adverse effects on local air quality are expected to occur as a result of the proposed modifications to the Concept Plan.

1.0 Introduction

1.1 Background

Barangaroo is a globally recognised 22 hectare urban renewal project located on the western waterfront of Sydney's Central Business District (CBD).

As Australia's first carbon neutral urban precinct, Barangaroo showcases world-class sustainability, whilst delivering extensive new foreshore public spaces on Sydney Harbour, international design excellence, the implementation of leading technologies and public art and cultural programs.

- The *Barangaroo Delivery Authority Act 2009* was established in March 2009 to ensure management and compliance of Barangaroo in achieving the following objectives: Encourage the development of Barangaroo as an active, vibrant and sustainable community and as a location for national and global business;
- Create a high-quality commercial and mixed-use precinct connected to, and supporting, the economic development of Sydney;
- Facilitate the establishment of Barangaroo Reserve and public domain land;
- Promote the orderly and sustainable development of Barangaroo, balancing social, economic and environmental outcomes; and
- Create in Barangaroo an opportunity for design excellence outcomes in architecture and public domain design.

Infrastructure NSW (INSW) was established in July 2011 to assist the NSW Government in identifying and prioritising the delivery of critical public infrastructure for NSW. As of 1 July 2019, INSW is the State Government agency responsible for the development of Barangaroo and management of its public spaces.

1.2 Barangaroo Concept Design

The original environmental assessment requirements for the overall Barangaroo renewal project were issued in June 2006 (MP06_0162) and the original Concept Plan for the redevelopment of Barangaroo was approved in February 2007 by the Minister for Planning.

The Barangaroo Concept Plan creates a development framework of streets and development blocks that can deliver a future mix of commercial, residential, tourist, retail and community uses, whilst dedicating approximately 50% of the 22 hectare site for new public open space or public domain, on or close to the harbour foreshore. The approved Barangaroo Concept Plan has since been modified a number of times and the most recent approved modification is MOD 11 approved on 22 October 2020.

- The Barangaroo Concept Plan defines three distinct precincts referred to as *Barangaroo South, Central Barangaroo and Barangaroo Reserve*. These three precincts together form the overall mixed use development framework as approved under Modification 11 to Barangaroo Concept Plan (MP10_0048 MOD 11) comprise the following: *A mixed use development involving a maximum gross floor area (GFA) of 602,354 sqm, comprised of:*
    - *A maximum 191,031 sq.m of residential GFA of which a maximum of 154,000sqm will be in Barangaroo South.*
    - *A maximum of 76,000sq.m of GFA for tourist uses, of which a maximum of 59,000sqm will be in Barangaroo South.*
    - *A maximum of 34,000sq.m of GFA for retail uses, of which a maximum of 30,000sqm will be in Barangaroo South.*
    - *A maximum of 5,000sq.m of GFA for active uses in the Public Recreation zone, of which 3,500sqm will be in Barangaroo South; and*
    - *A minimum of 12,000sq.m GFA for community uses.*

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- *Approximately 11 hectares of new public open space/public domain, with a range of formal and informal open spaces serving separate recreational functions and including an approximate 2.2km public foreshore promenade.*
- *Built form design principles, maximum building heights and GFA for each development block within the mixed-use zone*
- *Public domain landscape concept, including parks, streets and pedestrian connections.*
- *Alteration of the existing seawalls and creation of a partial new shoreline to the harbour.*

Within the Central Barangaroo precinct, Blocks 5, 6 and 7 of the approved Barangaroo Concept Plan provide for future mixed use development, located west of Hickson Road to the east of foreshore land to be dedicated for new public open space and a continuous waterfront promenade.

The Section 75W Modification to the Approved Concept Plan for Barangaroo (MOD 9) was initially commenced in 2014 and has been recommenced in 2020. Mod 9 incorporates significant further master planning work and public consultation to realise the delivery of the final stage of the Barangaroo renewal project.

1.3 Central Barangaroo

Central Barangaroo is located between the Barangaroo Reserve, Barangaroo South and the nearby historic suburbs of Miller Point and Walsh Bay and adjacent to Barangaroo Station.

As Barangaroo's keystone project, Central Barangaroo will complete the sweep of city and foreshore experiences along the western waterfront of Sydney's CBD to become the vibrant civic and community heart of Barangaroo.

Central Barangaroo is proposed as a dynamic mixed-use foreshore precinct that draws together and integrates high quality foreshore public spaces with city living, next generation workspace, community and cultural uses, a bustling shopping and dining precinct, all easily connected to Sydney's new metro network.

Barangaroo Station will significantly improve access for visitors, residents, workers and shoppers alike and transform how people arrive in Sydney CBD and on the harbour foreshore. Central Barangaroo will connect seamlessly to the new metro station and create the new place to arrive in and experience the city.

Central Barangaroo comprises the remaining development blocks 5, 6 and 7 of the approved Barangaroo Concept Plan and the Central Waterfront Park connecting to the harbour foreshore.

The Central Barangaroo Urban Design Report builds upon the key objectives and core principles of the SOM Master Plan Framework to ensure the proposed built form creates an appropriately scaled visual transition between the natural setting and scale of Barangaroo Reserve and Nawi Cove, to the bustling, high rise central business district scale of Barangaroo South.

The recently completed Wulugul Walk now extends along the entire Barangaroo waterfront as a vital section of the 14km Woolloomooloo to Glebe foreshore walk. Central Barangaroo's Harbour Park will create a major western harbour public open space that seamlessly integrates with Wulugul Walk, to diversify and enhance the city's waterfront experience. To the south, Central Barangaroo will shape and activate Hickson Park as a city park and to the north, help create Nawi Cove as the new place to arrive in the city.

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1.4 Proposed Modification to Barangaroo Concept Plan for Central Barangaroo (MOD 9)

To allow for development within the Central Barangaroo precinct and below Barangaroo Reserve, Modification 9 to Barangaroo Concept Plan for Central Barangaroo (MP06_0162 MOD 9) proposes:

1. An increase in total permissible **GFA** from 602,354 sqm to 708,041 sqm, with the following within the Central Barangaroo and Barangaroo Reserve:
   on the Central Barangaroo site to allow for the development of a maximum of:
   a. up to 116,189 sqm of above ground GFA within Blocks 5, 6 and 7;
   b. up 28,166sqm of below ground GFA within Blocks 5, 6 and 7;
   c. a minimum of 2,800sqm of Community uses GFA within Blocks 5, 6 and 7;
   d. a minimum of 6, 000sqm and up to 18,000sqm of Community uses GFA within the RE1 Zone of Barangaroo Reserve, to allow for future community / cultural facilities located in the Cutaway.
2. An increase in the overall provision of **new public open space / public domain**, including three new publicly accessible spaces within the development blocks and a new pedestrian bridge over Hickson Road.
3. Modifications to Barangaroo's **movement network** to redirect and reduce the impact of vehicular traffic and significantly improve pedestrian movement, safety, and amenity, including the removal of vehicular traffic from Block 5 and 6 and the extension of Central Barangaroo's Harbour Park.
4. Modifications to the central Barangaroo **building envelope** that allow for greater variation in building heights across Blocks 5, 6 and 7 to enable building form, massing and modulation that is responsive to context.
5. Introduction of **Design Guidelines** for Barangaroo.
6. Consequential amendments to the **State Significant Precincts SEPP**.
7. Revision to the Barangaroo Concept Plan **Statement of Commitments**.

1.5 Central Barangaroo - Proposed GFA and maximum building heights

The existing and proposed GFA and maximum building heights for each Barangaroo development block, comprising Barangaroo South, Central Barangaroo and including Barangaroo public domain (RE1) are shown in **Table 1**.

Table 1 Existing and Proposed GFA and Maximum Building Heights for Individual Barangaroo Development Blocks

Precinct and Block	Total GFA (sqm)	Residential GFA Max (sqm)	Height (m) (Max AGL)	Hight Above Existing Ground Level (m)
Barangaroo South - Existing				
Block 1	1,927	0	RL 25	23
Block 2	197,280	0	RL 180	178
Block 3	129,934	10,515	RL 209	207
Block 4A	92,629	91,816	RL 250	248
Block 4B	21,508	20,637	RL 107	173
Block X	18,908	16,463	RL41.5	39.5
Block Y	77,500	22,600	RL 275	273
Barangaroo South subtotals	539,686	162,031		
Central Barangaroo - Proposed				
Blocks 5, 6 and 7 above ground	116,189	28,000	Block 5 & 6: RL 44.5 Block 7: RL 73.7	Block 5 & 6: 42.0 Block 7: 71.2
Blocks 5, 6 and 7 (below ground)	28,166	0	N/A	N/A
Block 5, 6 and 7 subtotals	144,355	28,000		
Community and Active Uses (RE1)				
Community uses (in the Cutaway, located below the Barangaroo Reserve RE1 Zone.	18,000	0	n/a	n/a
Active uses in the RE1 Zone	5,000		RL 25	23.0
Community uses in the RE1 Zone (Central Barangaroo and Barangaroo South)	1,000		RL 25	23.0
Community and active uses subtotals	24,000			
Barangaroo Concept Plan Total	**708,041**			

NOTE: The approved Barangaroo Concept Plan defines *Community uses* and *Active uses* as follows:

- **Community uses** include child care centres, community facilities, educational establishments, entertainment facilities (other than cinemas and amusement centres) information and education facilities, landside ferry facilities, places of public worship, public administration buildings, public halls, recreations areas, recreation facilities (major, outdoor and indoor) and health services facility;
- Active uses include café kiosks, retail kiosks, pavilions, ferry ticket office, public convenience (toilet facilities) and small equipment storage spaces and the like.

1.6 Project Objectives and Scope

AECOM Pty Ltd (AECOM) were commissioned to provide a qualitative air quality impact assessment (AQIA) to address the air quality and odour requirements of the Director General Requirement 14 (DGRs) issued for Mod 9 to the Barangaroo Concept Plan (MP06_0162).

The air quality assessment has been undertaken in accordance with the following documents:

- *Protection of the Environment Operations (Clean Air) Regulation 2010* (NSW);
- *The Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2017) (The Approved Methods);
- *Assessment and Management of Odour from stationary sources in NSW, Technical framework (and notes)* (DEC 2006); and
- *Institute of Air Quality Management: Guidance on the assessment of dust from demolition and construction* (IAQM 2014)

The project scope includes:

- Description of the proposed modification
- Identification of ambient air quality and odour criteria as listed under the Approved Methods (EPA 2017)
- Description of the existing environment including:
  - Local meteorology and climate;
  - Existing air quality
  - Terrain and land use including identification of future and existing nearby sensitive receptors.
- A qualitative assessment of the potential air quality impacts from construction including:
  - Potential dust impacts during construction using the UK IAQM 2014 guidance document;
  - Potential air quality impacts from combustion;
  - Potential air quality impacts from airborne contaminants in the soil from dust generating activities; and
  - Potential odour impacts from treatment of groundwater.
- A qualitative assessment of potential operational impacts including:
  - Potential impacts from traffic generating development and commercial industries;
  - Beneficial impacts from inclusion of green roofs.
- Discussion and recommendations of potential air quality impacts including:
  - Any safeguard measures to manage or mitigate potential air emissions from proposed works; and
  - Any additional assessment requirements that may be required for further development application within Central Barangaroo including identification of relevant legislation and guidance documents as listed under DGR 14.

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1.7 Acknowledgment of Country

We would like to acknowledge the Gadigal people who are the Traditional Custodians of this land. We would also like to pay respect to the Elders both past and present of the Eora Nation and extend that respect to all Aboriginal people.

2.0 Site Background and Air Emission Sources

2.1 Barangaroo Site History and Contamination

Between 1820 and 1930 Barangaroo was used for wharf and port related uses. Coupled with operation of the previous Millers Gas Works and uncontrolled filling have resulted in contamination of local soil and ground water. Specifically within the Central Barangaroo site no significant contamination has been observed with the exception of shallow tar impacted material with associated ground water impacts on the boundary of the EPA Declaration Area and the area of asbestos impacted fill material; outside the boundary of Block 7 (SESL 2017).

The EPA Declaration Area refers to a portion of land underneath Hickson Road between addresses 30-34 and 38 Hickson Road the northern area of Barangaroo South and the areas known as Block 4 and Block 5. In May 2009, the EPA determined that this portion of land was contaminated in such a way as to present a significant risk of harm to human health and the environment. As a consequence, the EPA declared the area to be a remediation site (Declaration Number 21122; Area Number 3221) under the *Contaminated Land Management Act 1997*. Formerly the site to which this declaration relates is part of the former Millers Point gasworks and is described as:

- Part Lot 5 and Part Lot 3 in Deposited Plan (DP) 876514, Hickson Rd, Millers Point
- The part of Hickson Road adjacent to:
  - 30 – 34 Hickson Road being Lot 11 DP1065410,
  - 36 Hickson Road being Lot 5 DP873158 and Lot 12 DP1065410; and
  - 38 Hickson Road being SP72797, Millers Point

On 18 December 2015 the Department of Planning and Environment approved a Development Application (SDD 14_6533) lodged by Lend Lease to remediate the portion of the Declaration Area known as Block 5 and adjacent areas which forms part of Central Barangaroo. Block 5 remediation work was completed in February 2020 and NSW EPA determined that the site had been successfully remediated, formally ending the declaration in June 2020. This includes the southern end of the basement on Block 5 that extends into a portion of the former Declaration Area that has been remediated and validated to a depth of 10m below existing ground levels.

Following completion of remediation work it was however identified by EDP Consultants Pty Ltd (EDP) in October 2020 that under the MOD 9 concept plan further excavation of the Block 5 site may encounter some minor localised tar deposits still be present in deep fill, marine sediment or fractured bedrock below a depth of 10m (EDP 2020).

The potential contaminants of concern identified through previous investigations in Barangaroo included:

- Total recoverable hydrocarbons (TPH),
- Benzene, toluene, ethylbenzene, xylenes (BTEX),
- Naphthalene,
- Polycyclic aromatic hydrocarbons (PAH),
- Cyanide,
- Phenols; and
- Heavy Metals

2.2 Excavation Activities and Waste Volumes

In February 2020 EDP prepared an updated Insitu Waste Classification Report (EDP 2020a) for excavated subsurface materials requiring off-site disposal during INSWs Central Barangaroo development at the Central Barangaroo site. As part of the waste classification report EDP were required to characterise the spoil material to be removed as part of the proposed basement excavation works in accordance with the NSW EPA (2014) Waste Classification Guidelines and estimate spoil volumes based on the current basement design plans and public domain areas.

Section 2.2.1 and **Section 2.2.2** provide a description of the proposed excavation activities and estimated waste volumes as described in the Insitu Waste Classification Report (EDP 2020a).

2.2.1 Excavation Activities.

Several areas would require excavation:

- within the Central Barangaroo precinct to accommodate a common basement spanning Block 5, Block 6 and Block 7, designed to a nominal depth of 15m below ground level (EPD 2020).
- within the Public Domain area to south of the Blocks.

The total basement excavation footprint would be approximately 26,100m^2; with an expected volume of 350,900m^3 requiring offsite disposal (EDP 2020a).

2.2.2 Waste Volumes

Waste estimates provided in the EDP 2020 report were based on total site area and volumes provided by Aqualand and classified using historical borehole data into General Solid Waste (GSW), Restricted Solid Waste (RSW), Hazardous Waste (HW) and Special Waste (SW) in accordance with the NSW EPA (2014) Waste Classification Guidelines. A summary of estimated waste volumes by preliminary waste classification for each block is provided in **Table 2**.

Table 2 Waste Volume Estimates and Preliminary Waste Classification (EDP 2020)

Region	Bulk Volume (m^3)	ENM	GSW (m^3)	RSW (m^3)	HW (m^3)	Special waste (m^3)
Block 5	58,406	1,274	42,352	6,264	8,012	504
Block 6	98,877	7,687	63,980	19,743	7,466	
Block 7	175,140	31,946	93,937	38,170	11,087	
Public Domain	18,450	4,437	7,073	4,703	2,237	
Total	350,873	45,344	207,343	68,879	28,802	504

2.2.3 Beneficial Reuse

Beneficial reuse of excavated material from basement areas would be dependent on the chemical and physical properties of the fill material. In the EDP 2020 report a number of potential beneficial reuse options for the basement fill material were identified including:

- On-site retention and reuse in the public domain area of Central Barangaroo foreshore as engineering fill to raise levels and shape the Site.
- On-site retention and reuse in the public domain areas of Central Barangaroo as growing media in the landscape (i.e. garden soils).
- Off-site reuse in the construction projects in the Sydney region as engineering fill to raise levels and shape a site.

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2.2.4 Remediation of Excavated Material

As there is the potential for excavation areas to contain heavy metals and PAHs (both together and independent of tar contamination as discussed in **Section 2.2.1),** onsite remediation of contaminated material may be required. If onsite treatment is required; soil would be remediated via means of stabilisation.

Stabilisation involves the addition of chemical additives such as Portland cement or fly ash until a reduction in contaminant mobility and toxicity can be demonstrated. The type, rate of application and ratio of additives are determined by bench trials as they are unique to each contaminant and soil type.

Bench trails for earlier Barangaroo gas waste were conducted by EnviroPacific in 2010 and 2012, with the findings that Portland cement and fly ash could be added to achieve satisfactory stabilisation; however additional bench trials would be conducted for excavated material in Central Barangaroo if stabilisation was required.

Material classified as Hazardous Waste will require treatment/stabilisation under an Immobilisation Approval to facilitate off-site disposal to an NSW EPA-licensed landfill facility. Materials classified as Restricted Solid Waste may also be treated in accordance with an Immobilisation Approval to facilitate disposal to landfill under a lesser waste classification. Materials with a General Solid Waste classification or better will not require treatment.

2.3 Project Staging and Construction

The proposed construction program for Central Barangaroo is anticipated to commence in the second half of 2022 and be completed in late 2027. The proposed program for all major construction works is presented in **Table 3**, has been used to identify the potential worst-case impacts from the Project. **Table 3** presents a list of scheduled construction activities for construction of the basement and Block 5, Block 6 and Block 7, separated into six-monthly intervals between the third quarter in 2022 and the third quarter in 2027.

Construction activities identified as likely to generate the most notable dust impacts would include any earthworks associated with early works and construction of diaphragm walls, and excavation works associated with the development of basements. Based on the construction program the period where worst case air quality impacts are likely to be experienced would be during excavation works in 2024. Works commencing in 2023 prior to excavation would largely involve site establishment works including development of construction compounds and concrete slab removal. This is discussed in detail in **Section 5.1** and **Section 5.3**.

Table 3 Scheduled Construction Activities for Central Barangaroo

Date	Development	Construction Works
Quarter 3 2022	Basement	Enabling Work s
Quarter 1 2023	Basement	Early Works
Quarter 3 2023	Basement	Remediation and Archaeological Works
		Diaphragm Wall
Quarter 1 2024	Basement	Excavation Works
Quarter 3 2024	Basement	Piling Works
Quarter 1 2025	Basement	Foundation Works
Quarter 3 2024	Basement	Structure
Quarter 1 2025	Basement	Piling Works
		Foundation Works
		Structure
Quarter 3 2025	Basement	Structure
	Block 5 & 6	Structure
Quarter 1 2026	Basement	Services and Finishes
	Block 5	Structure
	Block 6	Structure
Quarter 3 2026	Block 5	Structure
		Services & Finishes
	Block 6	Structure
	Block 7	Structure
Quarter 1 2027	Block 5	Services & Finishes
		Façade
	Block 6	Structure
	Block 7	Structure
Quarter 3 2027	Block 5	Services & Finishes
	Block 6	Services & Finishes
	Block 7	Services & Finishes

2.4 Potential Air Emission Sources

The proposed work has the potential to generate air quality impacts from a number activities including:

- Potential construction impacts such as:
  - Dust emissions from excavation, materials handling and land forming activities,
  - Heavy metals detected within the soil may be released to the air attached to the dust,
  - Dust emissions and other airborne contaminants associated with onsite remediation works of contaminated spoil (if required),
  - Combustion emissions from mobile and plant equipment during construction; and

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  - Odour impacts from exposure of soil contaminants during excavation activities and treatment of contaminated ground water during excavation

- Potential operational impacts including:
  - Increased vehicle emission from traffic generating development
  - Minor emissions associated with commercial activities; and
  - Beneficial air quality effects from implementation of green roofs.

For consistency; with previous air quality impact assessments conducted within Barangaroo South (e.g. AECOM 2013, AECOM 2014) the following pollutants are considered to be of interest for the assessment of the Central Barangaroo site[1] (although it is noted that many of these pollutants will not be present due to the expected completion of the remediation of the Barangaroo South area):

- Total suspended particulates (TSP),
- Particulate matter equal to or less than 10 microns in diameter (PM_{10}),
- Particulate matter equal to or less than 2.5 microns in diameter ($PM_{2.5}$),
- Oxides of Nitrogen (NO_x),
- Benzene, toluene, ethylbenzene, and xylenes (collectively as BTEX),
- Phenol,
- Heavy metals (cadmium, chromium VI, copper, lead, mercury, nickel, zinc) attached to TSP,
- Benzo(a)pyrene,
- Naphthalene; and
- Odour.

Potential air emissions for construction and operation from the development of Central Barangaroo have been assessed in **Section 5.1** and **Section 5.2** of this report respectively. Predicted impacts in **Section 5.0** based on the existing Concept Plan provide a holistic overview of potential air quality impacts for Central Barangaroo with the intent of identifying potential air quality impacts requiring further impact assessment at the Development Application (DA) Stage(s) (see **Section 6.4**). Where proposed individual Development Applications would occur simultaneously or coincide with nearby development these would also need to be taken into consideration.

3.0 Assessment Criteria

3.1 Ambient Air Quality Criteria

As discussed in **Section 2.4** major contributing air pollutants from the existing and proposed operations would include combustion products, dust and soil contaminants. **Table 4** summarises the NSW EPA's impact assessment criteria as detailed in the *NSW Approved Methods for Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2017) for the pollutants included in the assessment. In general, these criteria relate to the total burden of air pollutants in the air and not just the air pollutants from project-specific sources. Therefore, some consideration of background levels needs to be made when using these criteria to assess impacts. A discussion of background levels in the study area is provided in **Section 4.3**.

Table 4 EPA Impact Assessment Criteria – Combustion Products, Dust and Soil Contaminants

Pollutant	Averaging Period	Criteria (µg/m^3)
Combustion Products and Dust		

[1] Asbestos was not assessed in this AQIA. Management of asbestos encountered on the site would be in accordance with the site Asbestos Management Plan to be prepared for the works, which may include monitoring of site works

Pollutant	Averaging Period	Criteria (µg/m^3)
Nitrogen dioxide (NO_2)	1 hour	246
	Annual	62
Total suspended particulates (TSP)	Annual	90
Particulate matter (PM_{10})	24 hours	50
	Annual	25
Fine Particulate Matter ($PM_{2.5}$)	24 hours	25
	Annual	8
Soil Contaminants		
Arsenic	1 hour	0.09
Benzene	1 hour	29
Beryllium	1 hour	0.004
Cadmium	1 hour	0. 018
Chromium VI	1 hour	0.009
Copper (dust and mist)	1 hour	0.018
Cyanide	1 hour	90
Ethylbenzene	1 hour	8,000
Lead	Annual	0.5
Manganese	1 hour	18
Mercury (organic)	1 hour	0.18
Naphthalene	1 hour	440*
Nickel	1 hour	0.18
Phenol	1 hour	20
Polycyclic aromatic compounds (PAHs) (as benzo[α]pyrene)	1 hour	4
Toluene	1 hour	360
Xylenes	1 hour	190
Zinc (as zinc chloride fumes)	1 hour	18

*As adopted for previous Barangaroo assessments undertaken by AECOM (e.g. AECOM 2013, AECOM, 2014, AECOM 2014a, AECOM 2014b). Criterion is equivalent to the odour threshold for naphthalene.

3.2 Odour Criteria

The perception of odour is based on an individual's response to chemical exposure. The odour threshold is the theoretical minimum concentration of a chemical that produces an olfactory response, which, in practice, is used to indicate whether an odour is detectable; the odour threshold defines 1 odour unit (1 OU) for each chemical. The threshold relates to odour detection and does not consider the recognition of an odours character.

The EPA's odour assessment criteria for complex mixtures of odorous air pollutants (EPA 2017) are shown in **Table 5**. These criteria take into account individual sensitivity to odour in the community and use a statistical approach for determining the appropriate criterion for a particular site based on the size of the surrounding population. As population size increases, the likelihood of sensitive individuals being

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within that population also increases; as such, areas with larger populations require more stringent criteria.

Table 5 EPA Impact Assessment Criteria – Complex Odours

Population	Criteria (OU)*
Urban (> ~2000) and/or schools and hospitals	2
~ 500	3
~ 125	4
~ 30	5
~ 10	6
Single residence (< ~2)	7
*99th percentile nose response time	

Central Barangaroo is located within the urban environment on the western edge of Sydney's CBD. Based on the proximity and density of existing sensitive receptors on Hickson Road and Barangaroo South and future receptors within Barangaroo an odour assessment criterion of 2 OU would be applicable for this assessment. This is consistent with the criterion adopted for all Barangaroo South AQIAs.

4.0 Existing Environment

The existing environment has the potential to influence the level of air pollutants adjacent to a particular site. Aspects of the ambient environment relevant to this assessment include:

- Existing air quality due to regional and local sources of air pollution (natural and anthropogenic) that emit similar air pollutants as those being assessed; and
- Meteorological conditions and terrain features.

The following sections provide a description of the existing air quality and general meteorology of the study area.

4.1 Local Meteorology

Meteorology in the area surrounding the resource recovery centre 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 affect wind speed and direction on the larger scale. Wind speed and direction are important variables in assessing potential air quality impacts, as they dictate the direction and distance air pollutant plumes travel.

The Bureau of Meteorology (BoM) operates a network of meteorological monitoring stations around the country. The closest station to the site is located at Observatory Hill approximately 0.7km east of Central Barangaroo. Observatory Hill monitoring station also has long term wind speed and wind direction data collected between 1955 and 1992. Wind speed and wind direction are no longer recorded at this station due to removal of the site's anemometer in April 1992. The next closest monitoring station operated by BoM is at Fort Denison, located approximately 2.2km to the north east of Central Barangaroo. Annual and monthly wind roses for Observatory Hill meteorological station for 9am and 3pm data recorded between 1955 and 1992 are presented in **Appendix A** and include a comparison with 9am and 3pm annual wind roses from the Fort Denison monitoring station.

Closer than the BoM Fort Denison station is the DPIE operated Cook and Phillip Sydney CBD air quality monitoring station commissioned on the 6th September 2019. The station is located at the north-western corner of Cook and Philip park approximately 1.5km southeast of the site. The station was installed as temporary measure to measure air quality within the CBD while NSW Public Works overseas the construction of a permeant station nearby. The station also measures wind speed, wind direction, temperature and humidity. A review of 12 months of data between December 2019 and November 2020 resulted in an annual average wind speed of 0.6 m/s and a maximum wind speed of 3.5 m/s. This is likely attributed to the sheltered location of the monitoring station and is therefore likely to underpredict local wind speeds as such data for this assessment has been sourced from the BoM monitoring station at Fort Denison, located approximately 2.2km to the north east of Central Barangaroo.

Given the proximity of the BoM Fort Denison station to the Barangaroo development it is considered representative of local meteorological conditions at Barangaroo at the macro scale. Due to the high-density urbanised environment micro-meteorological conditions are likely to be highly influenced by surrounding development. The large proportion of nearby high-rise buildings and associated high aspect ratios of nearby roads are likely to have a significant influence on local wind fields at a micro-level. This is further discussed in **Appendix B**.

Annual and seasonal wind roses for the Fort Denison monitoring station showing wind speed and wind direction data recorded between 2013 and 2015 are presented in **Figure 1** to **Figure 2**. It can be seen from **Figure 1** on an annual basis, west to west north westerly winds occur most frequently. The annual average wind speed is moderate at 4.3 metres per second (m/s) and calm conditions (wind speeds of less than 0.5m/s) occur less than one percent of the time. The high occurrence of westerly winds indicates that sensitive receptors along Hickson Road are more likely to be susceptible to air quality impacts during construction works (refer to **Section 5.1**).

During autumn through to spring the dominant wind direction is from the west to west northwest, with a high frequency of northeast to easterly winds also occurring during spring. During the winter months the predominant wind direction is from the northwest (refer to **Figure 2)**. Similar to the annual trend seasonal average wind speeds are also moderate with only small changes observed seasonally. The

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highest seasonal average occurs during summer at 4.5m/s and the lowest during autumn at 4.1m/s. Average wind speeds during winter and spring were found to be 4.2m/s and 4.3m/s respectively.

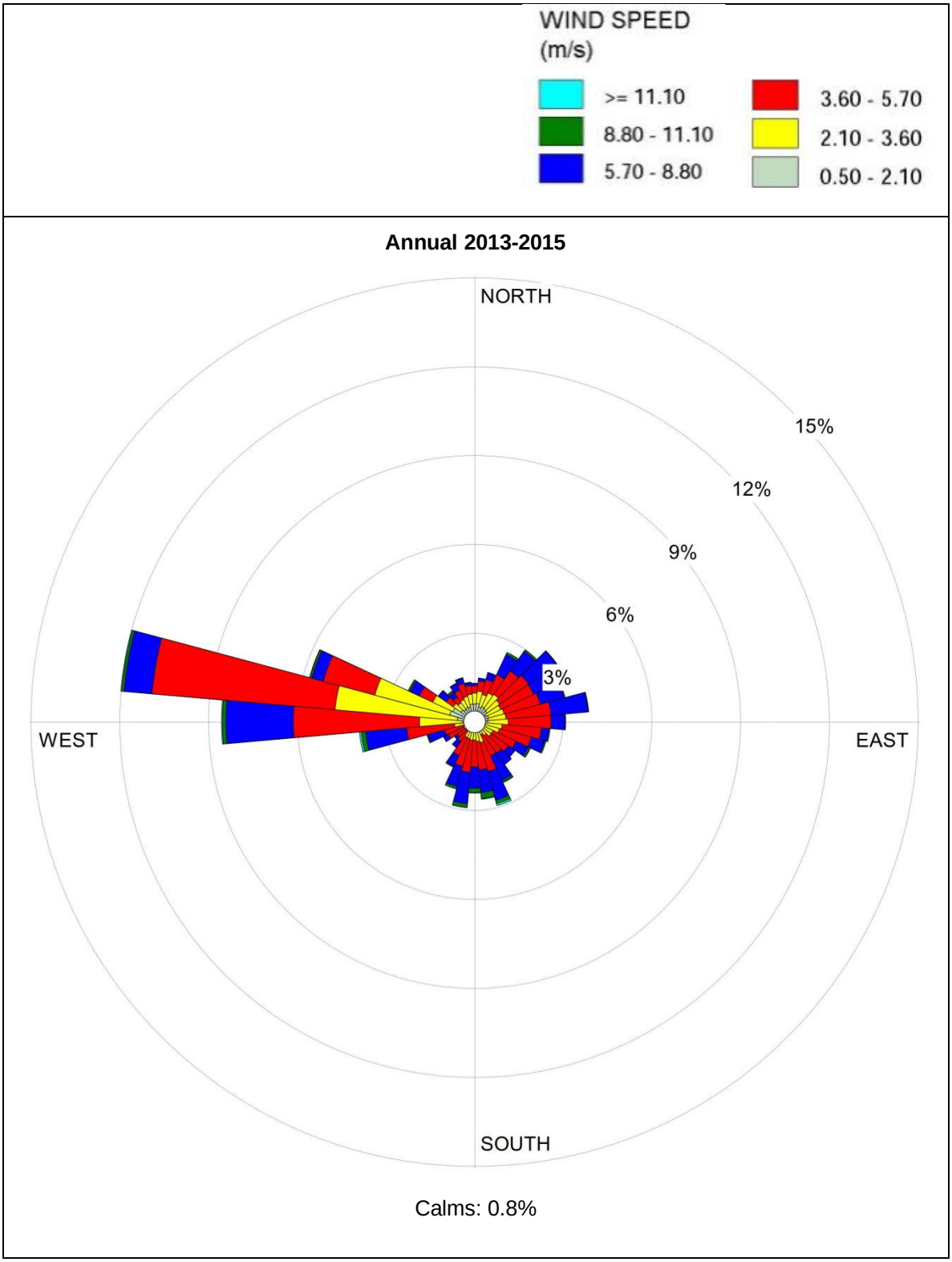

Figure 1 BoM Annual Wind Roses for Fort Denison (2013 to 2015)

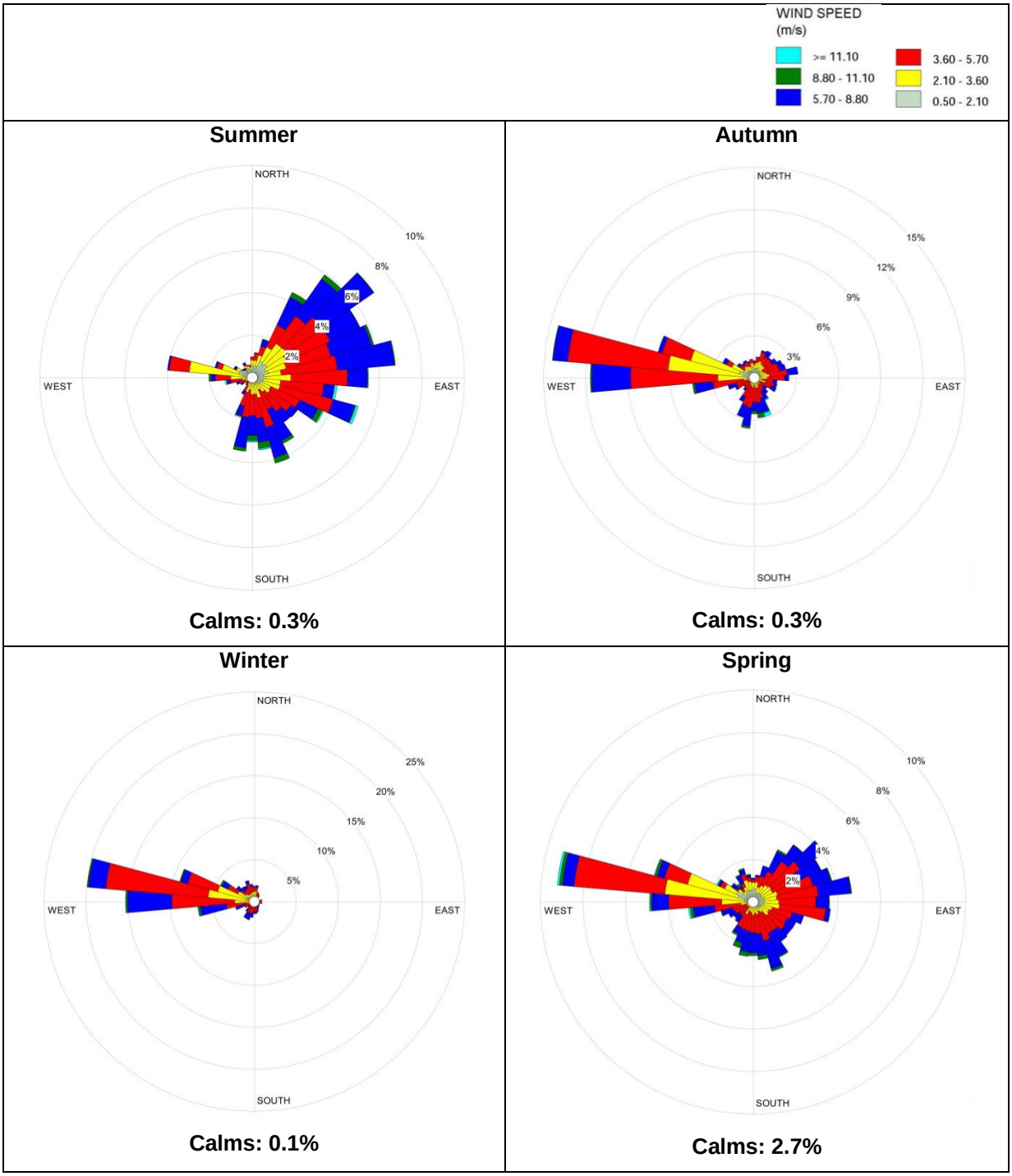

Figure 2 BoM Seasonal Wind Roses for Fort Denison (2013 to 2015)

4.2 Climatic Conditions

The BoM meteorological station at Observatory Hill records climate data for a range of meteorological parameters including, temperature, humidity, rainfall, wind speed and wind direction. Temperature, humidity and rainfall data are currently collected at Observatory Hill, while wind speed and wind direction data for the monitoring location have only been recorded up until April 1992 when the sites site anemometer was decommissioned. A summary of the long-term data recorded at this station between 1955 and 2018 is shown in **Table 6**.The data provide an indication of the regional climate of the area. Long term wind roses for Observatory Hill are provided in **Appendix A**.

Table 6 Climate Summary, BOM Monitoring Station at Observatory Hill, 1955 to 2018

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean maximum temperature (°C)	26.0	25.8	24.8	22.5	19.5	17.0	16.4	17.9	20.1	22.2	23.7	25.2
Mean minimum temperature (°C)	18.8	18.8	17.6	14.7	11.6	9.3	8.1	9.0	11.1	13.6	15.7	17.6
Mean rainfall (mm)	102	118	131	128	118	133	97	81	68	76	84	76
Decile 5 (median) rainfall (mm)	79	94	101	97	90	103	73	55	52	55	67	60
Mean number of days of rain ≥ 1 mm	9	9	10	9	9	9	8	7	7	8	8	8
Mean number of clear days	7	5	7	9	10	9	12	13	11	8	6	7
Mean number of cloudy days	13	13	13	11	11	11	9	8	9	11	13	13
Mean 9am temperature (°C)	22.5	22.3	21.1	18.2	14.6	11.9	10.9	12.5	15.7	18.5	19.9	21.6
Mean 9am relative humidity (%)	71	74	74	72	74	74	71	66	62	61	66	67
Mean 9am wind speed (km/h)	8.6	8.2	7.9	8.8	10.5	11.9	13.1	13.3	12.4	12.2	11.0	9.8
Mean 3pm temperature (°C)	24.8	24.9	24.0	22.0	19.4	16.9	16.4	17.5	19.2	20.7	22.1	23.8
Mean 3pm relative humidity (%)	62	64	62	59	57	57	51	49	51	56	58	59
Mean 3pm wind speed (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

As shown in **Table 6**, the warmest temperatures occur during the summer months, with the highest average maximum temperature (26.0^{o}C) occurring in January. July is the coldest month, with a recorded average minimum temperature of 8.1^{o}C. June is the wettest month, with an average rainfall of 133 millimetres, while September is driest month with an average rainfall of 68 millimetres. Humidity follows a diurnal cycle, with higher humidity in the morning compared to the afternoon. Wind speeds are higher in the afternoon compared to the morning, with the highest average wind speeds occurring in December (19.5 km/h).

4.3 Existing Air Quality

4.3.1 EPA Background Air Quality Data

The DPIE operates a network of air quality monitoring stations around the state. The closest station is the Cook and Philip Sydney CBD air quality monitoring station. This station has only been operational since September 2019. Due to the high level of particulates in the summer of 2019-2020 caused by bushfires; followed by a reduction in ambient pollutant concentrations in 2020 due to reduced activity such as vehicle emissions as a result of Covid-19 this data is not considered representative of typical background concentrations.

The next closest long-term operational station to the site with over 12 months of monitoring data is located at Rozelle (approximately 3.5 km to the west); and is considered representative of background concentrations at Barangaroo. Ambient pollutant concentrations recorded at this station between 2015 and 2017 has been reported below in **Table 7**.

Monitoring data recorded at Rozelle between 2015 and 2017 show:

- Annual average TSP concentrations are below the criterion of 90 µg/m3 with the highest average of 45.1µg/m^3 recorded at in 2017,
- Annual average concentrations for PM_{10} and $PM_{2.5}$ recorded at Rozelle were below EPA criteria for all monitored years.
- Exceedances were recorded for 24-hour average PM_{10} and $PM_{2.5}$ for all monitored years since 2015. Specifically:
  - For PM_{10} the following exceedances were noted:
    - One exceedance of the 24-hour average occurred in 2015 (60.3µg/m^3), one exceedance in 2016 (58.8µg/m^3), one exceedance in 2017 (54.13µg/m^3)
    - The second highest recorded maximums for each year below the criterion of 50µg/m^3 were 44µg/m^3 in 2015 and 49.6µg/m^3 for 2016, 49.6µg/m^3 for 2016 and 34.33µg/m^3.
  - For $PM_{2.5}$ one exceedance of the 24-hour average occurred in 2015 (33.4µg/m^3) and six exceedances in 2016 (maximum concentration of 49.4µg/m^3).
  - Exceedances of the 24-hour criterion in May were likely attributed to back burning events across the Sydney Basin which coincided with period low wind speeds and temperature inversions in the Sydney region resulted in particulate matter being trapped within the Sydney Basin.
  - The annual average for $PM_{2.5}$ at Rozelle for 2015, 2016 and 2017 was found to be close to the OEH criterion of 8µg/m^3.
- Recorded SO_2 concentrations for all years were below the relevant EPA criteria across all averaging periods; and
- The maximum 1 hour and annual average concentration for NO_2 µg/m^3 for 2015 to 2017 were below the respective criteria of 246µg/m^3 and 62 µg/m^3.

Table 7 Ambient Pollutant Concentrations, Rozelle Monitoring Station (OEH 2018)

Pollutant	Averaging Period	Background Concentration (µg/m³)			Criteria (µg/m³)
		2015	2016	2017	
TSP[1]	Annual Average	41.8	41.9	45.1	90
PM_{10}	Maximum 24 Hour	60.3	58.8	54.1	50
	Annual Average	16.7	16.7	18.0	25
$PM_{2.5}$	Maximum 24 Hour	33.4	49.4	36.3	25
	Annual Average	7.2	7.4	7.2	8
SO_2	10 Minute[2]	109	70.7	84.9	712
	1 Hour	80.1	52.4	62.9	570
	24 Hour	14.3	13.1	8.9	228
	Annual Average	2.9	1.4	1.4	60
NO_2	1 Hour Average	123	94	109	246
	Annual Average	22.6	20.1	15.8	62

1. Ambient TSP concentrations have not been monitored at Rozelle since 2004. As PM_{10} is a sub-component of TSP, the annual average concentration of PM_{10} along with the TSP:PM_{10} ratio can be used to calculate the expected background TSP concentration. A TSP:PM_{10} ratio of 0.4 has been used for the calculation of the TSP concentration. This is a common ratio for dust in NSW and is considered appropriate in the absence of recently monitored data.

2 For 10-minute SO_2 data the averaging period was calculated using a power law relationship to convert the 1 hour maximum concentration to a 10 minute averaging period using the equation.

There are no known recent ambient air quality measurement studies undertaken in the immediate vicinity of the Project site that may be used to define the background concentrations of VOC's, PAHs and Heavy Metals. Ambient air concentrations of VOC's, PAHs and Heavy Metals have been recorded at snapshot intervals for assessment of Block 4, Block 5 excavation activities at Barangaroo South but are unable to provide a clear representation of hourly background concentrations for assessment against the relevant criteria. On this basis, no background concentrations have been included in the assessment. In addition, unless there are known significant sources of the pollutants in the area around a source, the pollutants need only be assessed in isolation and not considered cumulatively.

4.3.2 Barangaroo Air Quality Monitoring

The Barangaroo Delivery Authority (Authority), currently hold an Environmental Protection Licence No. 13336 (EPL) that apples to Barangaroo South, Central Barangaroo and a portion of Hickson Road (near to 30-38 Hickson Road). As a condition of the EPL, construction work to be undertaken at Barangaroo South by Lend Lease (on behalf of the Authority) under Environmental Protection Licence No. 13336 (EPL) are required to undertake air quality monitoring.

There is the potential that a variation to EPL No. 13336 would be required by EPA to include some ambient air quality monitoring at Central Barangaroo during excavation works. Any ambient air quality monitoring required would be dictated by the potential impacts on nearby sensitive receptors. Potential monitoring requirements imposed are likely to be less extensive than imposed on Barangaroo South activities due to the lower level of contamination across the site (refer to **Section 2.1**), however dust generating activities are anticipated to be of a similar nature to Barangaroo South activities and may require monitoring (see **Section 5.1.1**).

Under the existing EPL, PM_{10}, TSP, heavy metals, PAHs, and VOCs are monitored at three locations. The most northern and closest air quality monitoring station to Central Barangaroo is EPL 4; and is shown in **Figure 3**.

Ambient air quality concentrations recorded at Barangaroo South between November 2018 and October 2019 were highly influenced by construction activities, such as from excavation and materials handling, onsite remediation, and combustion of mobile construction equipment. As such the data are not considered representative of long-term local background ambient air quality concentrations. However, for further context, monitoring data for particulates may be indicative of ambient air quality concentrations during construction activities at Central Barangaroo, with proposed construction works of a similar nature. Monitoring data for heavy metals, PAHs and VOCs however may not be relevant based on the lower levels of contaminated soil anticipated across the Central Barangaroo Site.

Monthly dust monitoring results for TSP and PM_{10} between November 2018 and October 2019 at EPL monitoring point EPL4 are reported in **Table 8**. During the monitoring period there were some exceedances of the maximum 24-hour PM_{10} EPA criterion of 50µg/m^3. Monthly averages for PM_{10} were below the annual average criterion of 25µg/m^3 for most of the year with an estimated annual average of 24.9 µg/m^3. TSP is measured once every 6 days at the site and monthly averages show that during August and September of 2019 average TSP concentrations were above the annual average criterion of 90µg/m^3. The annual average for TSP however was complaint with the EPA criterion, with an annual average of 88.5µg/m^3 recorded between November 2018 and October 2019.

Table 8 Monthly Monitoring Results at Barangaroo South from November 2018 to October 2019 at EPL Point 4

Pollutant	Avg. Period	Concentration (µg/m^3)												Criteria (µg/m^3)
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
PM_{10}	24h Maximum	**113.5**	**54.3**	**54.7**	46.7	54.6	**51.1**	**54.1**	25.3	32.8	30.3	30.8	**50.8**	**50**
	Average	40.4	**29.1**	**29.5**	**26.3**	24.0	**27.8**	31.9	16.1	18.9	19.2	16.8	19.7	**25**
TSP	Monthly Average	**101.4**	89.3	84.3	**98.6**	81.1	**94.4**	78.7	64.4	76.3	**108**	**132.8**	57.9	**90**
Note the high monthly average recorded for September 2019 was due to a high TSP concentration of 411.91 µg/m^3. The four other recordings taken during the month of September were below 90 µg/m^3. Also EPL Point 6 recorded a TSP concentration of 90.27 on the 13th of September 2019.														

Figure 3 Air Quality Monitoring Locations for EPL 13336, Barangaroo South Construction Works (Lend Lease 2018)

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4.4 Terrain and Land Use

Barangaroo is bordered by Sydney Harbour on the northern and western sides and by Hickson/Sussex Streets to the east. The existing ground surface of Barangaroo 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.

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, playgrounds, recreational centres, and the like. Sensitive receptors associated with the site currently include:

- Residential and commercial receptors approximately 20m to the east of Block 5, 6 and 7 on the adjacent side of Hickson Road,
- Residential and commercial towers at Barangaroo South to the south of Block 5,
- The Barangaroo Guardian Early Learning Childcare Centre, located on Level 1 of Tower 1 on Barangaroo Avenue on the corner of Shipwright Walk and Hickson Road,
- Presence of low sensitivity receptors, where human exposure is transient such as footpaths and walkways within 20m of the project boundary.
- Receptors of high sensitivity associated with the Crown Sydney Hotel Resort located to the South Block (Block Y). The resort contains 350 rooms and suites as well as restaurants and retail outlets and is expected to be opened by early 2021
- Hickson Park adjacent to Block 5, which would be classified as a low sensitive receptor due to the transient nature of the land use (recreational).

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5.0 Impact Assessment

5.1 Potential Construction Impacts

Section 5.1.1 to **Section 5.1.4** of this chapter provides an assessment of potential air quality impacts from construction that include:

- Dust emissions from excavation, materials handling and land forming activities,
- Heavy metals detected within the soil may be released to the air attached to the dust,
- Combustion emissions from mobile and plant equipment during construction; and
- Odour impacts from exposure of soil contaminants during excavation activities and treatment of contaminated ground water during excavation

It should be noted that worst case impacts from the site are likely to be experienced during excavation works; which are semi quantified in terms of potential dust impacts in **Section 5.1.1** and qualitatively assessed in terms of potential odour impacts in **Section 5.1.4**.

5.1.1 Potential Dust Impacts

5.1.1.1 Methodology Overview

A qualitative risk assessment of potential dust impacts on surrounding sensitive receptors has been undertaken for the construction phase. The assessment has been based on the methodology described in the UK Institute of Air Quality Management (IAQM) document, *Guidance on the assessment of dust from demolition and construction*. The risk of dust soiling and human health impacts due to particulate matter (PM_{10}) on surrounding areas were determined based on the scale of activities and proximity to sensitive receptors. The IAQM method uses a four-step process to assess dust impacts:

- Step 1: Screening based on distance to nearest sensitive receptors.
- Step 2: Assess risk of dust impacts from activities based on:
  - Scale and nature of the works, which determines the potential dust emission magnitude; and
  - Sensitivity of the area.
- Step 3: Determine site-specific mitigation for dust-emitting activities.
- Step 4: Reassess risk of dust impacts after mitigation has been considered.

5.1.1.2 Step 1: Screening Assessment

The IAQM method recommends further assessment of dust impacts for construction activities where sensitive receptors are located closer than:

- 350m from the boundary of the site.
- 50m from the route used by construction vehicles on public roads more than 500m from the site entrance.

There are several sensitive receptors located within 350m of the boundary of the Project site and therefore further assessment of dust impacts was undertaken for the Project.

5.1.1.3 Step 2: Risk Assessment of Unmitigated Impacts

5.1.1.3.1 Step 2A: Dust Emission Magnitude

Dust emission magnitudes are estimated according to the scale of works being undertaken and other considerations such as meteorology, types of material being used, or general construction methodology. The IAQM guidance provides examples to aid classification and these are presented in **Appendix C**.

Potential dust emission magnitudes for the Project were estimated based on the IAQM examples listed in **Appendix C**. Justification and the factors used in determining the magnitudes are presented in **Table 9**.

Table 9 Dust Emission Magnitudes in Accordance with IAQM Guidance

Activity	Potential Dust Emission Magnitude	Justification
Demolition	Small	• No demolition of buildings anticipated during construction. Removal of existing pavement and removal of onsite temporary sheds only. • Potential removal of dusty material (concrete) however no concrete crushing or screening onsite is anticipated. • Demolition activities <10m above ground. • Total material volume < 20,000m^3 (based on approximate slab area of 30,000 m^2 and slab thickness of 0.2m).
Earthworks	Large	• Proposed development footprint is approximately 30,000m^2, • Estimated total bulk waste volume of 350,873 m^3 • Excavation areas to include Block 5, Block 6, Block 7 and potentially underneath some retail and cultural. • Depth of excavation varies from RL-3 to RL-12 • Approximately an additional 20,000m^3 of fill to be required for land forming activities on Foreshore Blocks. • Approximately 5-10 heavy earth moving vehicles active at one time, including 30 tonne excavators • Average of 1200 m^3 of fill excavated and removed offsite per day.
Construction	Large	• 143,303 m^2 GFA of above ground primarily for Blocks 5, 6 and 7. • 26,753m^2 GFA of below ground primarily within Blocks 5, 6 and 7. • 1050 m^2 GFA of community facilities in public domain within the RE1 Zone • Total building volume >100,000m^3 for individual blocks (Block 5, 6 and 7) • Assumed no onsite concrete batching. • Assumed wide range of construction materials with variable dust generating potential, including concrete, steel, cladding and timber
Trackout	Large	• Estimated between 60-120 (>3.5t) outward truck movements per day during excavation of basement areas. • Outward truck movements during construction would include from delivery trucks, concrete agitators etc. • Access to site via paved road (Hickson Road), thus low potential for wheel generated dust accessing the site. • Potential for wheel generated dust from onsite vehicle during excavation and construction following removal of pavement.

5.1.1.3.2 Step 2B: Sensitivity of the Surrounding Area

The IAQM methodology allows the sensitivity of an area to dust soiling, human health impacts due to PM_{10}, and ecological effects to be classified as high, medium, or low. Surrounding vegetation within 100m from the bulk of dust-emitting activities are likely to take place is largely limited to street scaping on Hickson Road and the future Hickson Park south of Block 5. The sensitivity of the surrounding area due to ecological effects was therefore not assessed further. The classifications are determined according to matrix tables provided in the IAQM guidance document. Individual matrix tables for dust soiling and human health impacts are provided. Factors used in the matrix tables to determine the sensitivity of the surrounding area are described as follows:

- Receptor sensitivity (for individual receptors in the area):
  - High sensitivity – locations where members of the public are likely to be exposed to elevated concentrations of PM_{10} for eight hours or more in a day. For example, private residences, hospitals, schools, or aged care homes,
  - Medium sensitivity - places of work where exposure is likely to be eight hours or more in a day; and
  - Low sensitivity – locations where exposure is transient – i.e. one or two hours maximum. For example, parks, footpaths, shopping streets, playing fields.
- Ambient annual mean PM_{10} concentrations (only applicable to the human health impact matrix).
- Number of receptors in the area (categorised as 1-10, 10-100 or >100).
- Proximity of receptors to dust sources based on radii of 20m, 50m 100m and 350m from the source.

According to the IAQM guidance listed above, the overall sensitivity of the site to both dust soiling and human health impacts is classified as high. The justification for this classification is provided in **Table 10**. The assessment also takes into account that the Barangaroo area would be considered an area of high sensitivity due to past and ongoing localised dust generating activities at Barangaroo South and Sydney Metro Station.

Table 10 Sensitivity of the Area in Accordance with IAQM Guidance

Potential Impact	Sensitivity of the Area	Justification
Dust Soiling	High	• Area of high sensitivity due to existing dust generating activities at Barangaroo South and at Sydney Metro Station. **Receptors** • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) to the east of Block 5, 6 and 7 on the adjacent side of Hickson Road < 20m of the project boundary. • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) towers at Barangaroo South to the south of Block 5 < 350m of the project boundary. • Presence of low sensitivity receptors, where human exposure is transient such as footpaths < 20m of the project boundary. • Potential transient and medium sensitivity receptors associated with operation of Barangaroo Station once operational in 2024. • Receptors of high sensitivity associated with the Crown Sydney Hotel Resort located to the South Block (Block Y). The resort contains 350 rooms and suites as well as restaurants and retail outlets. • Hickson Park adjacent to Block 5, which would be classified as a low sensitive receptor due to the transient nature of the land use (recreational).

Potential Impact	Sensitivity of the Area	Justification
		Meteorological Conditions • The high occurrence of westerly winds (see Section 4.1) indicates that sensitive receptors along Hickson Road are more likely to be susceptible to air quality impacts during construction works
Human Health (PM_{10})	High	• Area of high sensitivity due to existing dust generating activities at Barangaroo South and at Barangaroo Station. • Annual average PM_{10} concentration in the area between 16µg/m^3 and 18µg/m^3 which is below the EPA criterion of 25 µg/m^3 (see Section 4.3) **Receptors** • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) to the east of Block 5, 6 and 7 on the adjacent side of Hickson Road < 20m of the project boundary. • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) towers at Barangaroo South to the south of Block 5 < 350m of the project boundary. • Presence of low sensitivity receptors, where human exposure is transient such as footpaths < 20m of the project boundary. • Potential transient and medium sensitivity receptors associated with operation of Barangaroo Station once operational in 2024. • Receptors of high sensitivity associated with the Crown Sydney Hotel Resort located to the South Block (Block Y). The resort contains 350 rooms and suites as well as restaurants and retail outlets. • Hickson Park adjacent to Block 5, which would be classified as a low sensitive receptor due to the transient nature of the land use (recreational). **Meteorological Conditions** • The high occurrence of westerly winds (see **Section 4.1**) indicates that sensitive receptors along Hickson Road are more likely to be susceptible to air quality impacts during construction works

5.1.1.3.3 Step 2C: Unmitigated Risks of Impacts

The dust emission magnitudes for each activity in **Section 5.1.1.3.1** were combined with the sensitivity of the area in **Table 10** to determine the risk of construction dust air quality impacts, with no mitigation applied. The risk of impacts for each activity is assessed according to the IAQM risk matrix methodology. An example of the IAQM earthworks risk matrix is provided in **Table 11**. The without mitigation dust risk impacts for each activity are summarised in **Table 12**.

Table 11 Example IAQM Risk Matrix - Earthworks

Sensitivity of Area	Dust Emission Magnitude		
	Large	Medium	Small
High	High Risk	Medium Risk	Low Risk
Medium	Medium Risk	Medium Risk	Low Risk
Low	Low Risk	Low Risk	Negligible

Table 12 Summary of Project Dust Risks

Potential Impact	Risk of Dust Impacts on Sensitive Receptors – Without Mitigation			
	Demolition	Earthworks	Construction	Trackout
Dust Soiling	Low Risk	High Risk	High Risk	High Risk
Human Health (PM_{10})	Low Risk	High Risk	High Risk	High Risk

The outcome of Step 2C is used to determine the level of management that is required to ensure that dust impacts on surrounding sensitive receptors are maintained at an acceptable level. A high or medium-level risk rating means that suitable management measures must be implemented during the project.

The outcome of the semi-quantitative air quality risk assessment shows that the unmitigated air emissions from the construction, track out and construction activities poses a high risk of dust soiling and a high risk of human health impacts. Once mitigation measures are applied (as discussed in **Section 5.1.1.4** and **Section 6.0**), the residual impacts, post mitigation, arising from a proposed development are as described in **Section 5.1.1.5**.

5.1.1.4 Step 3: Mitigation Strategies

A range of in-principle and site-specific mitigation strategies aimed at reducing the likelihood of air quality impacts to offsite sensitive receptors were identified. These mitigation strategies should be considered for all work elements during construction activities carried out on site. Recommended mitigation strategies are discussed in **Section 6.1**. Additionally further air quality impacts assessment would be required at the individual development application stage for each parcel of work to ensure no significant impacts occur as a result of construction and is detailed in **Section 6.4**.

5.1.1.5 Step 4: Reassessment

The final step of the IAQM methodology is to determine whether there are significant residual impacts, post mitigation, arising from a proposed development. The guidance states:

"For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be 'not significant'."

Future development applications will require the preparation of an air quality impact assessment in accordance with approval conditions of the modification to the Concept Plan. Provided that appropriate project-specific mitigation strategies aimed at reducing the likelihood of air quality impacts to offsite sensitive receptors are implemented, the Project would not constitute an atypical case as defined under the IAQM. As such residual effect (impacts) would be "**not significant**" at all locations for both dust

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soiling and human health impacts. Mitigation strategies listed in **Section 6.1** should be incorporated into a future Construction Environmental Management Plan (CEMP) to ensure the measures are implemented during construction of the site.

5.1.2 Potential Heavy Metal and PAH Impacts from Dust Generation

There is the potential for soil contaminants such as heavy metals; PAHs and cyanide to become airborne during excavation works as it attaches to dust particulates with remediation works scheduled for the sit in the third quarter of 2023. Based on previous studies at Barangaroo South (AECOM 2014) the proportion of heavy metals, PAHs (as benzo(α)pyrene) and cyanide in soil within the EPA Declaration Area is as shown in **Table 13**. The proportion of these contaminants within the soil within the Declaration area are relatively low (**Table 13**) with remediation efforts aimed primarily at addressing TPH contamination from the former gasworks site. A similarly low proportion of contaminants are likely to occur outside the Declaration Area (which is inclusive of Block 5); including for Block 6, 7 and the Foreshore Area.

Previous air quality impact assessments undertaken (including AECOM 2013, AECOM 2014, AECOM 2014a and AECOM 2014b) for excavation work at the Barangaroo South site have predicted relatively low ground concentrations at nearby by sensitive receptors which were predicted to be well below the relevant EPA criteria. The results of the modelling are further supported by the monitoring data conducted at Barangaroo South for 24 hours every six days during 2017 which show:

- All monitoring results for both total PAHs (as Benzo(a)pyrene)and Benzo(a)pyrene were found to be below the limit of detection (<3ng/m^3 and <2ng/m^3 respectively) and below the 1-hour average criterion for Benzo(a)pyrene of 0.4 µg/m^3;
- The annual average concentration for lead was found to be 0.00495 µg/m^3 which is well below the annual average criterion of 0.5µg/m^3;
- Small traces of chromium, cobalt, manganese, nickel, tin and vanadium were well below the relevant 1-hour air quality criteria; and
- Concentrations of all other metals monitored were below the relevant limit of detection.

Provided heavy metal proportions are similar or lower to those reported in **Table 13**, no significant impacts to ambient air quality from heavy metals are anticipated during proposed earthworks at Central Barangaroo.

Table 13 Soil Concentrations of Miscellaneous Toxic Pollutants within the EPA Declaration Area

Pollutant	Average Concentration (mg/kg)	Proportion of Metals in Soil (%)
Arsenic	4	0.0004
Benzo[α]pyrene	21	0.002
Beryllium	0.51	0.00005
Cadmium	0.56	0.00006
Chromium (III+VI)	17	0.002
Copper	51	0.005
Cyanide	21	0.002
Lead	239	0.02
Manganese	159	0.02
Mercury	0.27	0.00003
Nickel	12	0.001
Zinc	127	0.01

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5.1.3 Potential Combustion Impacts

The works will primarily use electrical and diesel and/or petrol-powered plant and equipment. The combustion of diesel fuel generates a range of pollutant emissions, primarily oxides of nitrogen (NO_X) and particulate matter (including PM_{10} and TSP), as well as volatile organic compounds (VOCs) (particularly benzene, toluene, ethylbenzene, and xylenes, which are known collectively as BTEX). Other minor emissions, such as carbon monoxide and sulfur dioxide, are also emitted from combustion engines, but are considered to be lower risk than particulate and NO_X emissions due to their generally higher trigger values.

At the time of writing this report, it was assumed that onsite generators would not be required during construction works. Should onsite generators be required, assessment of air quality impacts associated with combustion emissions from onsite diesel generator(s) would be required at the DA Stage(s).

Proposed mitigation and management measures for reducing potential impacts from combustion emissions during construction are discussed in **Section 6.1**.

5.1.4 Potential Odour Impacts

There is the potential for odour emissions to be generated during construction activities including both excavation and soil and from the onsite treatment of groundwater. Excavation of contaminated material within the EPA Declaration area is being undertaken as part of the Barangaroo South works. Should however, any contaminated material be encountered during the excavation of the basement activities at Central Barangaroo there is the potential to generate gaseous emissions of the contaminants and associated odours.

There is the potential to generate odour emissions from the operation of the proposed onsite water treatment plant which would be used to treat groundwater from the site during excavation works. In June 2017 ground water sampling was undertaken by SESL Australia at Central Barangaroo on Block 7 from six onsite wells. The ground water detected no potential contaminants of concern, including TPH, BTEX, Naphthalene, PAHs, Cyanide, Phenols, Ammonia and Heavy Metals above the adopted assessment criteria. One sample however, (MW507) was found to contain a pungent anaerobic, sulphurous odour (SESL Australia); which indicates there may be the potential for odour emissions during operation of the water treatment plant.

Similar to operations proposed at Central Barangaroo; operation of a water treatment plant for the treatment of groundwater during excavation works at Barangaroo South was employed. Dispersion modelling for water treatment plant activities for Block 4 (AECOM 2014a) and Block 5 (AECOM 2014b) was based on a WTP operating at a capacity of 25L/s and a stripping efficiency for BTEX and naphthalene of 99 percent; predicted odour emissions at nearby sensitive receptors were well below the 2 OU odour criteria. Based on the similar operations of Barangaroo South it is unlikely there is the potential for significant offsite odour impacts. Additional consideration to potential odour impacts may need to be taken into account at the DA stage(s) to account for additional sensitive receptors within the adjoining Barangaroo South development, Block Y and Barangaroo Station (once operational in 2024).

5.2 Potential Operational Impact Assessment

The following subsections discuss the potential impacts associated with the operation of the Central Barangaroo development. **Section 5.2.1** provides a discussion of the potential adverse operational air quality impacts, while **Section 5.2.2** provides a discussion of the potential beneficial air quality impacts associated with the development

5.2.1 Potential Adverse Impacts

Potential air emissions during operation of the Central Barangaroo Development would include combustion emissions from traffic generating development discussed in **Section 5.2.1.1** and potentially minor air emissions from commercial businesses discussed in **Section 5.2.1.2**.

5.2.1.1 Emissions from Traffic Generating Development

The proposed changes in land use based on the Concept Plan; including the introduction of commercial and retail space, and residential apartments and the additional public domain and cultural spaces proposed as part of the foreshore would influence road vehicle movements to and from the study area. Changes to traffic movements along Hickson Road and the newly proposed Barangaroo Avenue would result in changes to motor vehicle emissions from fuel combustion, fluid evaporation, brake and tyre wear, and re-suspended road dust. Emissions from motor vehicles would comprise mainly hydrocarbons, PM_{10}, $PM_{2.5}$, CO, NO_x and SO_2.

The initial planning approval for Barangaroo aimed at achieving high usage of public transport, walking and cycling as a method of travel to work; with a targeted journey to work mode share by car of four percent. ARUP (2021) have prepared a Transport Management Accessibility Plan (TMAP) for Mod 9 which compares the traffic generation forecast under Mod 8 TMAP as amended for the MOD 10 Supplementary TMAP and GFA (ARUP 2019 cited in ARUP 2021) with the proposed modification (Mod 9).

Previous and proposed traffic generation forecasts are provided in **Table 14** and indicated under the proposed modification the total volume of traffic generated by the entire precinct will be slightly higher when compared with that previously assessed in the MOD 10 Supplementary TMAP (ARUP 2019 cited in ARUP 2021). While changes to Mod 9 have influenced predicted traffic volumes (largely associated with the residential component) additional factors have also influenced forecast traffic numbers including the introduction of Sydney Metro Station and revised future bus numbers on Hickson Road.

Table 14 Traffic generation comparison (ARUP 2021)

Time Period	Direction	Mod 8/10	Mod 9	Change
AM Peak Hour	In	346	356	10
	Out	355	373	18
	Two-way	**701**	**729**	**28**
PM Peak Hour	In	415	413	-2
	Out	395	416	21
	Two-way	**810**	**829**	**19**

While Mod 9 would result in a slight increase in traffic volumes; changes to associated vehicle emission rates between Mod 10 and Mod 9 would be relatively minor based on the proposed forecast traffic volumes.

Additionally, the proposed modifications to Barangaroo's movement network to redirect and reduce the impact of vehicular traffic, specifically the removal of vehicular traffic from Block 5 and 6 would aid in limiting vehicle emissions at this location.

Urban Canyons

Ground level concentrations of combustion pollutants adjacent to roads are influenced directly by the fleet mix or ratio of light to heavy vehicles, fuel type mix (for example, petrol and diesel), and the distribution of vehicles by age of manufacture. They are also influenced by air circulation and set back distances, and heights of adjacent buildings. Dispersion of vehicle emissions is less affective when development along a road corridor is confined restricting airflow which would typically disperse and transport air pollutants from vehicles away from the source area. The degree to which pollutants disperse is influenced by the orientation and continuity of open spaces, their dimension and shape, topography and the layout of buildings surrounding the subject area. Urban canyons for example where a road is flanked by high density development on each site may channel plumes and prevent them from reaching road level depending on their shape, dimension and orientation. The more confined a space is by buildings, walls or embankments adjacent to or over a roadway, the less opportunity air pollutants have to disperse (DoP 2008).

The MOD 9 Concept Plan proposes relatively consistent building heights fronting Hickson Road are relatively consistent at around 38.5 to 42.45m. Corridors off Hickson Road which may promote air circulation include a 23.2m AGL laneway between Block 5 and Block 6 and road access between Block 6 and Block 7. Building heights fronting Hickson Road are relatively consistent at around 38.5 to 42.45m. The adjacent side of Hickson Road includes both a pedestrian walkway and the High Street cutting, which is approximately 10m in height, The potential for built form within the proposed massing envelope to create urban canyon effects along Hickson Road will need to be addressed during the detailed design and associated development application stage.

Currently proposed design characteristics have the potential to minimise adverse air quality impacts on sensitive receptors from vehicle emissions. These characteristics include:

- There is some variation in building heights within Block 5, Block 6 and Block 7 and interspersion with the cross street between Block 6 and Block 7 to minimise the formation of urban canyons.
- Modifications to Barangaroo's movement network to redirect and reduce the impact of vehicular traffic including the removal of vehicular traffic from Block 5 and 6 would be expected to remove potential vehicle emissions from this location.
- Tallest multi storey building of 73.7m is set back from Hickson Road on the northwest corner of Block 7. It is largely surrounded by open space within Block 7 to the east and south, Nawi Cove to the north and Hickson Park to the east, which would facilitate dispersion.
- Open areas of landscaped public domain at the north and south ends of the 3 blocks (Nawi Cove and Hickson Park) will facilitate dispersion and contribute to improved air quality. The extension of Central Barangaroo's Harbour Park would also facilitate dispersion.
- Public and community facilities would largely be sited within the proposed Foreshore Park area to the west of Block 5, 6 and 7 away from Hickson Road; and
- Additionally proposed, landscaping and provision of green roofs (see **Section 5.2.2**) would aid in in maintaining ambient air quality.

The above concept design features are consistent with the Department of Planning and Environment's (DP&E) design guidelines outlined in *Development Near Rail Corridors and Busy Roads – Interim Guideline*, (DoP 2008; which is discussed in **Section 6.3** of this report.

5.2.1.2 Emissions from Commercial Activities

The Central Barangaroo Concept plan allows for a number of retail and commercial outlets within the development precinct; including within Block 5, 6 and 7 and Foreshore North (retail only). Many commercial businesses include potential air emission sources from various processes including combustion, fuel and organic liquid storage and handling operations, process fugitive emissions and surface coating operations. Potential pollutants may generally include particulates, NOx, SO_2, CO and VOCs (DECC & PAE 2007).

The particulars on commercial properties occupying the future development are currently unknown; however they may include minor potential air emissions from sources such as food product manufacture, laundries and dry cleaners and printing, publishing and recorded media establishments.

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In general emissions from commercial facilities only contribute a minor proportion of air emissions to the Sydney region when compared to other major sources such as vehicle and industrial emissions and commercial activities typically do not require environmental protection licences (EPL) under the *Protection of the Environment Operations Act 1997 (NSW)* POEO Act. As such no significant air quality emissions are anticipated from the operation of commercial facilities within the development area at this stage.

5.2.2 Potential Beneficial Impacts

The Proposed Concept Plan makes provision for the future incorporation of green roof spaces. Green roofs entail growing plants on rooftops; which partially replaces vegetation that was removed prior to urbanisation; providing a number of environmental benefits; including to air quality while enhancing local aesthetics.

Urban vegetation has the potential to reduce air pollutant concentrations through both direct and indirect pathways (Yang *et al*. 2008, *Currie and Bass* 2008 and *Rowe* 2010):

- Urban vegetation directly affects local air pollutant concentrations by:
  - Increasing surface roughness due to the presence of foliage, branches and twigs; which raises dry deposition rates of particulates; and
  - Uptake of gaseous pollutants through stomata on plant leaves; which then react with water to form acids and other compounds; and breaking down of certain organic compounds such as polycyclic hydrocarbons (PAHs) in plant tissue and in soil.
- Urban vegetation also has the potential to modify the existing microclimate indirectly reducing pollution by:
  - Lowering indoor temperatures through shading; resulting in a reduction in electricity usage for cooling purposes; and
  - Lowering ambient temperatures by changing the albedo of urban surfaces and evapotranspiration cooling; which in turn slows down photochemical reactions and leads to less secondary air pollutants such as ozone

The effectiveness of green roofs as a pollutant abatement strategy is largely dependent on the area and type of vegetation. Green roofs can be classified as ‘intensive’ or ‘extensive’ based on their design and intended use. Intensive green roofs a generally designed as public spaces and generally include a mix of trees, shrubs and hardscapes. Extensive green roofs are designed to be low maintenance and are generally comprised of grasses, herbaceous perennials, annuals and drought tolerant succulents (Rowe 2010).

In 2008 Yang *et al.* used big-leaf resistance model used to quantify dry deposition of air pollutants from green roof tops in Chicago, United States of America. The study examined the effectiveness of three vegetation types ‘short grass’ ‘tall herbaceous plants’ and ‘deciduous trees’ to remove SO_2, NO_2, PM_{10} and O_3 from the local air shed. The results of the study are presented in **Table 15**; and are consistent with other studies such as Currie and Bass (2008) that show a higher pollutant load removal rate for trees and shrubs typically found in intensive green roofs (largely due to greater leaf surface area), compared to extensive green roofs, predominantly comprised of grass.

Table 15 Annual Removal Rate of Air Pollutants per canopy cover by different vegetation type (Yang *et al*, 2008)

Vegetation Type	Annual Removal Rate ($g/m^2/y$)				
	SO_2	NO_2	PM_{10}	O_3	Total
Short Grass	0.65	2.33	1.12	4.49	8.59
Tall Herbaceous plants	0.83	2.94	1.52	5.81	11.10
Deciduous Trees	1.01	3.57	2.16	7.17	13.91

The proposed green roofs on Block 5, 6 and 7 may incorporate intensive and or extensive designs including a mix of trees, shrubs and grass. Potential pollutant abatement rates for green roofs may be

loosely approximated for each block and assessed semi-quantitatively using the values in **Table 15** once surface vegetation types and coverage are known. It should be noted that estimated pollutant abatement values would be indicative only as localised pollutant deposition rates would be influenced by a number of factors including vegetation type, pollution concentration, length of growing season and local meteorological conditions. The rate at which pollutants would be removed would also vary seasonally with higher rates observed in spring (when the greatest amount of growth would be expected) and the lowest rates of removal where observed during winter when plants may be dominant or slow growing.

Green roofs are just one form of Green Infrastructure (GI) that may be included as part of Central Barangaroo development. The strategic placement of Green Infrastructure (GI) such as open areas and vegetated areas such as street scaping would need to be considered as part of the development. Placement of GI in urban canyons can used to manage roadside pollutant concentrations at the local scale. Introduction of GI can however promote or disrupt the dispersion of air pollution by either exerting additional mechanical turbulence or decreasing turbulent kinetic energy. Within urban canyons trees have the potential to reduce wind speeds and reduce air exchange between the air above rooftops and within the canyon leading to the accumulation of pollutants inside the street canyon. For street canyons, the aspect ratio is critical to the appropriate GI form. **Table 16** provides a general guide for the determination of appropriate green infrastructure for street canyons based on Aspect Ratio.

Table 16 Determination of Appropriate Green Infrastructure for Street Canyons Based on Aspect Ratio (Barwise & Kumar 2020)

Classification	Aspect Ratio	GI Recommendation
Deep Street Canyon	H/W ≥ 2	• Green walls only
Mid-Depth Street Canyon	H/W 0.5-2	• Green walls • Low-level vegetation (shrubs and low hedges)
Shallow Street Canyon	H/W ≥ 0.5	• Green walls • Low-level vegetation (shrubs and low hedges) • Small and open-crowned trees on the windward side of the canyon spaced broadly apart.

The aspect ratio is determined by the average height-to-width (H/W) ratio of the street canyon. Considering a proposed building height ranging from 38.5 to 42.45m fronting Hickson Road; and the Hickson Road/ High Street cutting approximately 10m in height, the section of Hickson Road adjacent to Central Barangaroo would likely be classified as a Deep Street Canyon. Based on the recommendations in **Table 16**; trees, hedges and shrubs should be avoided along the streetscape where possible; which may restrict dispersion of air pollutants from vehicle emissions. GI in this location should be limited to green walls. Further investigation of potential impacts associated with urban canyons (and GI) may be undertaken at the detailed design stage as described in **Section 6.4**.

The location of green roofs and/or other GI would be confirmed a part of the detailed design process as part of future development applications for Central Barangaroo.

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5.3 Potential Cumulative Impacts

There is the potential for cumulative air quality impacts to occur where construction of Central Barangaroo coincides with the construction works associated with the adjoining Sydney Metro Station. Potential cumulative impacts may occur from a number of construction activities that coincide with the proposed construction works at Barangaroo Central.

Major dust generating works such as tunnelling and excavation activities for Barangaroo Station have now been completed. Fit out of Barangaroo Station is expected to commence in October 2021 and will also include building the station entrance next to Nawi Cove and upgrading Hickson Road. Construction work would also include the addition of new footpaths, trees, street lighting and street furniture.

Barangaroo Station is expected to be operational in 2024. Construction of the CBD basement to ground floor level and construction of infill and waterproofing are expected to be undertaken in 2021; with station fit out works extending into 2022 (METRON 2017). The proposed construction program for Central Barangaroo is anticipated to commence in the second half of 2022 and be completed in early 2027. As such construction periods for both projects are expected to overlap between 2022 and opening of Barangaroo Station in 2024. Specifically, early staging; remediation and potentially some excavation and structural basement works at Central Barangaroo. While the early stages of basement work for Central Barangaroo have been identified as notable dust generating activities; the coinciding station fit out works for Barangaroo Station are unlikely to result in any significant dust generating activities. As such cumulative impacts associated with construction of Barangaroo Station and enabling works for Barangaroo Central are likely to be minor in nature.

Additionally, it is important to note within the context of the wider Barangaroo Project; Central Barangaroo; situated between Barangaroo South and Barangaroo Reserve is the last precinct to be developed as part of the project. Development work within Barangaroo South is largely completed with Waterman's Cove and Hickson's Park opening in late 2020 and the Crown Sydney Hotel Resort also opening in 2021. As such no significant cumulative air quality impacts are anticipated from the adjoining Barangaroo Precincts.

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6.0 Recommended Air Quality Management and Mitigation

6.1 Construction Mitigation Measures

Air quality mitigation measures to be applied during construction should be detailed in the site Construction Environmental Management Plan (CEMP). Proposed safeguards against air quality impacts during construction for inclusion in the CEMP should include:

- Implement an Air Quality Monitoring Program, similar to air quality monitoring practices undertaken for the Barangaroo South; particularly for site excavation works (refer to **Section 6.2**). The program should include air monitoring locations along the southern and eastern boundaries.
- Watering of stockpiles, exposed areas and roads when required to maintain a moisture content that minimises dust generation.
- Use water sprays and/or surfactants wherever and whenever necessary.
- Promptly removing and disposing of spilled materials which may cause a dust nuisance.
- Restrict vehicle movements to within designated access paths; and minimise haul road lengths where possible.
- Ensure machinery is working correctly.
- Remove excavated material and any dust generating materials from site as soon as possible, unless being reused onsite.
- Dust suppression of exposed areas and stockpiles would be undertaken as required using a water cart or equivalent piece of equipment.
- Erect windbreak barriers at the site boundary if required.
- Implement site speed limits
- Cover loads during transport.
- Maintain the complaints management system.
- Adjust work practices (as required) based on wind observations and real time monitoring results.
- Undertake good housekeeping practices to minimise dust on hardstand areas.
- Implementation of any additional mitigation options as required by the Project's Environmental Manager or as identified in future development applications.

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6.2 Air Quality Monitoring

An Air Quality Monitoring Plan should be developed as part of the Air Quality Management Plan for the site. The Air Quality Monitoring Plan should allow for real time assessment of various construction activities onsite which can then be related back to operational changes to reduce off-site impacts, and allow reactive dust mitigation measures to be implemented based on real time monitoring data.

A detailed monitoring pan has not been developed as part of this document (a detailed plan is premature at this stage of the development process). When a plan is developed however, the monitoring should be 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 (DEC, 2005a),
- 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.

6.3 Planning and Design Considerations

Strategic planning should ensure that sensitive land use developments are sited to avoid or appropriately manage vehicle emissions from Hickson Road at the site planning and building construction stages. Planning and design considerations to minimise exposure to vehicle emissions, are presented in **Table 17**. The planning and design considerations in **Table 17** are in line with the DP&E's *Development Near Rail Corridors and Busy Roads – Interim Guideline*, (DoP 2008) and supports the specific rail and road provisions of the *Infrastructure State Environmental Planning Policy (SEPP)* 2007.

Table 17 Planning and Design Considerations for Development near Busy Roads

Consideration	Comment
Building Siting, Heights and Orientation	• Incorporating an appropriate separation distance between sensitive uses and the road using broad scale site planning principles such as building siting and orientation. The location of living areas, outdoor space and bedrooms should be as far away as practicable from the major source of air pollution • Building heights adjacent to busy roads should be varied and interspersed with open areas to minimise the formation of urban canyons; • Where possible step back the upper stories of roadside buildings to increase dispersion of air pollutants and minimise cannoning effects of tall buildings close to the road.
Landscaping	• Using vegetative screens, air amenity barriers or earth mounds where appropriate to assist in maintaining ambient air quality. This may include planting trees and other vegetation in the public domain to assist in maintaining ambient air quality • Any GI planned for Hickson Road would need to take into account the street aspect ratio to ensure trees, hedges and shrubs are avoided along the streetscape; as these may restrict dispersion of air pollutants from vehicle emissions. GI in this location should generally be limited to green walls • Landscaping has the added benefit of improving aesthetics and minimising visual intrusion from an adjacent roadway. • Where possible maximise the amount of space used for green roofs as an air quality abatement strategy. Where possible intensive green roofs that include tall herbaceous plants and/or deciduous trees should be included to maximise potential beneficial air quality impacts. •

Consideration	Comment
Ventilation	• For ventilation of indoor areas, adjacent to Hickson Road or the proposed Barangaroo Avenue mechanical ventilation air inlet ports should be sited to maximise the distance from the road to reduce inflows of air pollutants • The location of open-able windows should be considered in the design of the development located adjacent to the roadway emission sources. • Additional mitigation measures may include the consideration of the use of winter gardens as an alternative to conventional balconies •
Zoning	• Propose less sensitive land use for development that will front Hickson Road such as open space or for commercial or retail use. Here buildings may act as a barrier that shields and protects highly sensitive areas from high-emission zones.

6.4 Additional Studies

Following approval of the Concept Plan Mod 9; Individual development applications for proposed development within the site would require an environmental impact assessment in accordance with the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act). A component of the environmental assessment would involve identifying and assessing potential air quality impacts associated with development. **Table 18** provided a brief outline of potential assessments that may be required for future development of the site, with regards to assessment of air quality impacts.

Table 18 Potential Future Assessment Requirements

Item	Requirements
Development Impacts	Future development at the site would be required to assess the air quality impacts from individual development applications. The level of assessment for each development would be determined on a case by case basis. Where there is the potential for negligible or only minor air quality impacts from proposed developments only a qualitative assessment may be required. Otherwise a quantitative assessment of potential air quality impacts will be required in accordance with the Protection of the Environment Operations Act 1997 (NSW) and the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC 2005)*. The Approved Methods lists the statutory methods for modelling and assessing emissions of air pollutants from stationary sources in NSW and can be used to predict whether emissions from a proposed development would comply with the EPA ambient air quality criteria.
Construction Impacts	Assessment of construction air quality impacts would be required for development applications at the site including earthworks, specifically for basement excavation activities and earthmoving and land forming required for the Foreshore. The level of assessment would depend on the nature of the works and may involve: • A semi-quantitative assessment using the methodology outlined in the UK Institute of Air Quality Management (IAQM) document Guidance on the assessment of dust from demolition and construction; or • Quantitative assessment in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2017)*; and • Quantitative assessment of potential odour impacts in accordance with the *Assessment and Management of Odour from stationary sources in NSW, Technical framework (and notes)* (DEC 2006); and The following items would need to considered as part of the construction impact assessment: • Potential impacts of air quality and odour impacts to existing sensitive receptors onsite including adjacent to Hickson Road and sensitive receptors at Barangaroo South including Block 4 and Block Y.

Item	Requirements
	• Potential impacts to future receptors during dust generating works such as those at Barangaroo Station once operational. • Potential cumulative and staging impacts associated including: - Dust generation from earthworks, construction and/or demolition works that may coincide with existing dust generating activities within Central Barangaroo (as a separate DA) or wider Barangaroo Precinct - Dust generation from excavation and construction works occur concurrently to construction works of the Sydney Metro Station. - Potential cumulative odour impacts from operation of water treatment plant at Central Barangaroo - Cumulative impacts associated with any other nearby proposed development construction works. - In the event contaminated fill is discovered during excavation works appropriate safeguard measures would be required to prevent/minimise generation of airborne contaminants. Further assessment may also be required for onsite stabilisation works where required.
Vehicle Emissions	Proposed development, particularly multi story buildings adjacent to busy roads may require further assessment of vehicle emissions, where formation of urban canyons have the potential to impact receptors, particularly highly sensitive receptors such as childcare facilities. Air dispersion modelling using the lagrangian particle model GRAL developed at the Institute for Internal Combustion Engines and Thermodynamics, Technical University Graz, Austria would be recommended. The GRAL model has algorithms which effectively consider dispersion in low wind speed conditions and allows for very fine scale consideration of buildings to predict receptor concentrations at building facades both fronting and facing away from road corridors.
Reverse Amenity Impacts	Assessment of air quality impacts for future development applications within Barangaroo Central should consider any reverse amenity impacts of sensitive receptors within Central Barangaroo from surrounding development.

7.0 Conclusion

A qualitative air quality impact assessment has been prepared for the proposed modification and development program for the Central Barangaroo development which identified the potential impacts to air quality at nearby existing and future sensitive receptors during construction and operation.

Potential dust generating impacts (and associated minor impacts from soil contaminants) during construction; particularly during excavation activities pose the greatest potential air quality impacts from the project to nearby receptors. There is also the potential for cumulative impacts associated with construction of Barangaroo Station and other development projects within Barangaroo. Dust generating impacts from individual development applications within the Central Barangaroo site would need to be assessed in accordance with the EP&A Act with the level of assessment dependant on the nature of the works involved at the detailed Development Application stage.

Other potential air quality impacts during construction would include fuel combustion from mobile and stationary plant equipment which may be managed appropriately by maintaining equipment and using standard management practices. There is also the potential for minor odour impacts during operation of the water treatment plant.

Potential operational impacts may include minor air quality impacts from commercial properties and vehicle emissions from traffic generating development, particularly along Hickson Road and to a smaller extent Barangaroo Avenue. These may be managed with appropriate planning and design considerations and current traffic generation estimates predicted only slightly higher vehicle numbers for the proposed modification when compared to previous estimates for Mod 10. The concept plan also allows for the provision of large landscaped areas and green roofs which would have potentially beneficial impact on local air quality by reducing air pollutant concentrations through both direct and indirect pathways.

In conclusion provided that a detailed AQIA for each individual Development Applications specific to the Central Barangaroo is undertaken and appropriate project-specific mitigation strategies are implemented, no adverse effects on local air quality are expected to occur as a result of the proposed modifications to the Concept Plan.

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Appendix A

BoM Data

Appendix A BoM Data

The Bureau of Meteorology (BOM) operates a network of meteorological monitoring stations around the country. The closest station to the site is located at Observatory Hill approximately 0.7km east of Central Barangaroo. Observatory Hill monitoring station also has long term wind speed and wind direction data collected between 1955 and 1992. Wind speed and wind direction are no longer recorded at this station due to removal of the sites anemometer in April 1992 as such data for this assessment has been sourced from the BoM monitoring station at Fort Denison, located approximately 2.2km to the north east of Central Barangaroo. Annual and monthly wind roses for Observatory Hill meteorological station for 9am and 3pm data recorded between 1955 and 1992 are presented in **Figure 4** to **Figure 6**. A comparison of 9am and 3pm annual wind roses with 9am and 3pm annual wind roses from the BoM Fort Denison monitoring are also included in **Figure 4**.

It can be seen from **Figure 4** that at Observatory Hill on an annual basis, westerly winds are common during the morning while winds in the afternoon vary from an easterly direction. Annual average wind speed at 9am was 10.6 kilometres per hour (km/h) (2.9 metres per second (m/s)) with a 13% occurrence of calm conditions. Wind speeds are higher during 3pm with a moderate average winds speed of 16.6km/h (4.6m/s) and calms are less frequent occurring 3% of the time (BoM 2017).

When the Observatory Hill data is compared to the Fort Denison data (see **Figure 4**) similar wind patterns are observed with a high frequency of westerly winds at 9am with north easterly to easterly and southerly winds more common at 3pm. A lower frequency of calms is observed at Fort Denison however at both 9am and 3pm. Based on the BoM Data at Observatory Hill residential receivers along Hickson Road were likely to be impacted by unfavourable westerly winds during the morning.

Similar to the annual trend at Observatory Hill, monthly records show a high frequency of westerly winds at 9am throughout the year, with southerly and east to north easterly winds also a common occurrence during the warmer months between October and March (refer to **Figure 5**). Monthly 3pm records show a high proportion of north easterly to easterly winds between September and April, variable winds during May, westerly and southerly winds during June and July and westerly and easterlies in August (refer to **Figure 6**).

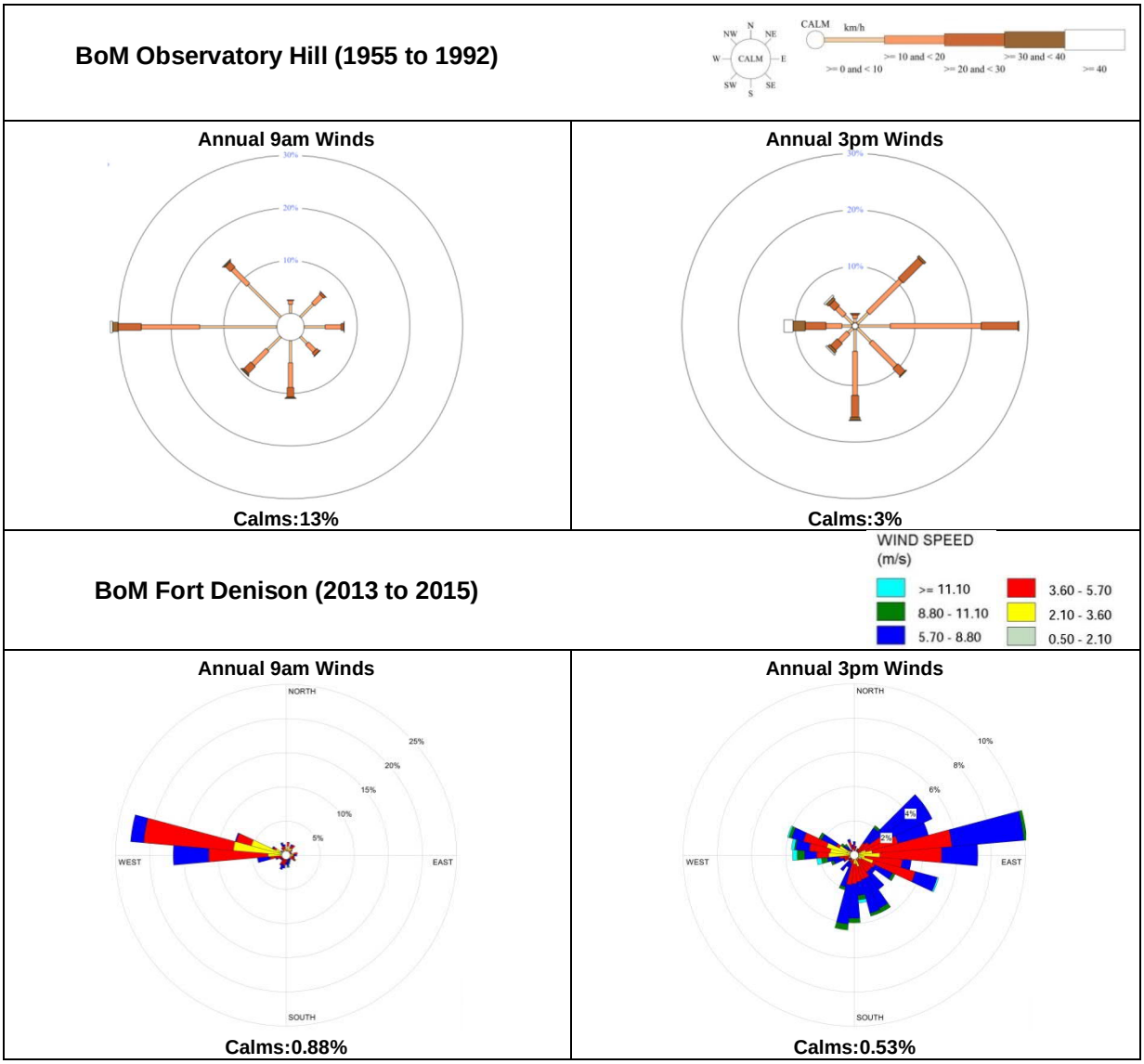

Figure 4 BoM Observatory Hill (1955 to 1992) and Fort Denison (2013 to 2015) Annual 9am and 3pm Wind Roses

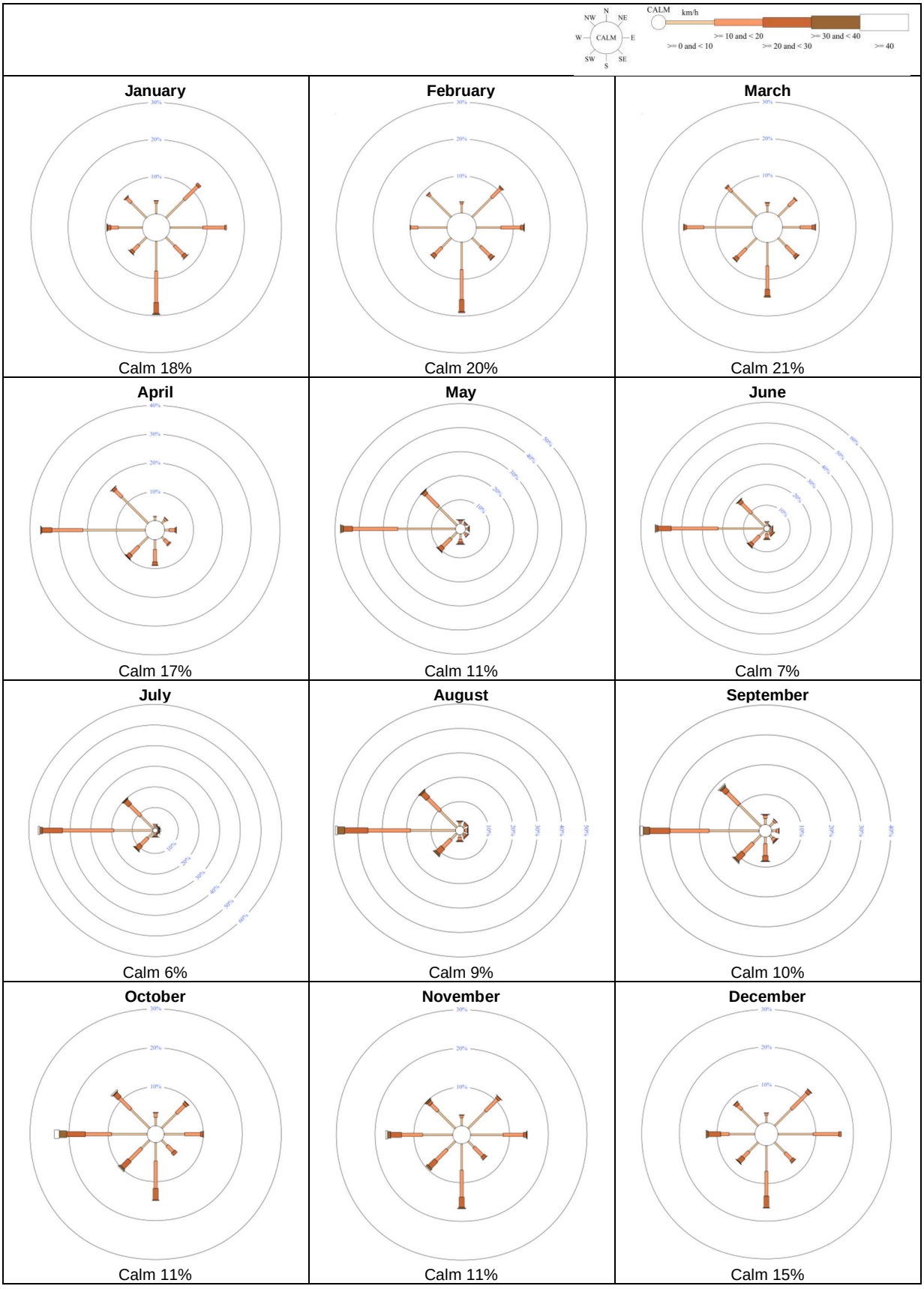

Figure 5 BoM 9am Monthly Wind Roses for Observatory Hill (1955 to 1992) (BoM 2017)

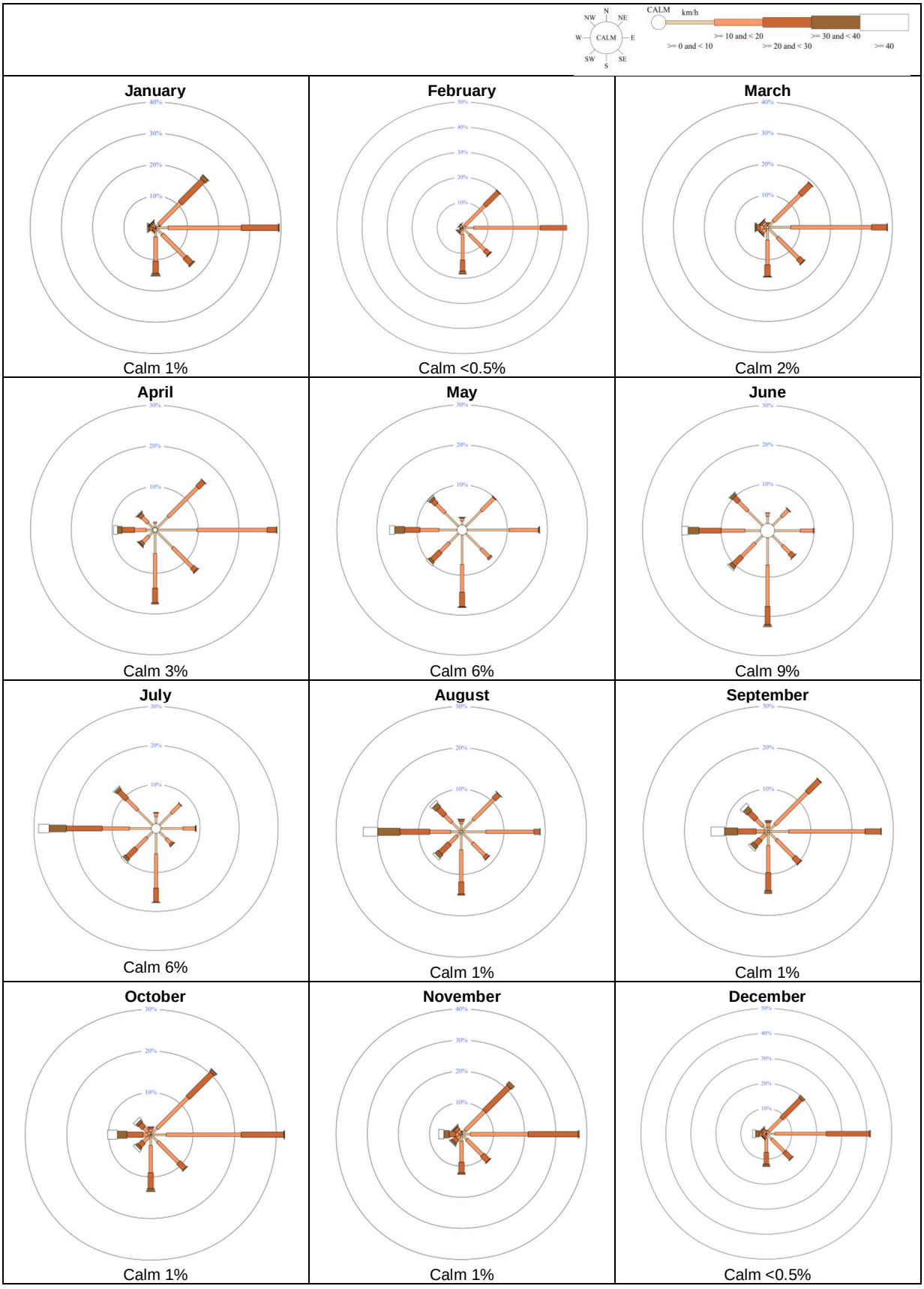

Figure 6 BoM 3pm Monthly Wind Roses for Observatory Hill (1955 to 1992) (BoM 2017)

Appendix B

Influences on Micrometeorology

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Appendix B Influences on Micrometeorology

As discussed in **Section 4.1** meteorological data collected from the BoM monitoring station at Fort Denison, located approximately 2.2km to the north east of Central Barangaroo is considered representative of local meteorological conditions at a macro-scale. Due to the high-density urbanised environment micro-metrological conditions are likely to be more highly influenced by surrounding development than the macro scale winds. A large proportion of nearby high-rise buildings and associated high aspect ratios of nearby roads near the foreshore are expected to have a significant influence on local wind fields at a micro-level.

The Barangaroo redevelopment area on the Western Edge of the Sydney CBD area currently consists of several commercial towers, residential towers, a casino, and a large open space for inner city recreation. The eastern extent of Barangaroo is also bound by Hickson Road, which is bound on the western side by the approximately 10m High Road cutting. The built environment: specifically, where high rise buildings create urban canyons this can influence local meteorology on micro-scale including temperature change, light levels, wind patterns and air quality.

Earlier air quality investigations carried out by AECOM for the Stage 1B Barangaroo South Development (AECOM 2020) have included some micro-scale meteorological modelling using the lagrangian particle model GRAL. GRAL is a model developed at the Institute for Internal Combustion Engines and Thermodynamics, Technical University Graz, Austria specifically to assess the dispersion of pollutants from roadways and tunnel portals (Oettl et al., 2002; Oettl et al., 2003; Oettl et al., 2005). It has been expanded to accommodate a range of additional source types and can be used to assess the flow of air around onstructiuons such as buildings. GRAL was used previously in the Sydney CBD to assess potential impacts from the Barangaroo South development due to the potential urban canyons and complex air flows associated with the Barangaroo development.

Meteorological data used in GRAL (as described in Section 6.4 of the AECOM 2020 report) was extracted from the same CALMET data file that has been used for all Barangaroo projects undertaken by AECOM since 2015; which utilised BoM data from the Fort Denison station. Meteorological wind fields for the most common wind condition (a moderate westerly wind) has been extracted from the GRAL dataset and presented in **Figure 7**.

Figure 7 below shows westerly winds blowing from the foreshore across the Barangaroo site. Micrometeorological conditions across meteorological site are already highly influenced by the formation of urban canyons. The wind fields show that both wind direction and speed are altered at the Barangaroo South location; where winds flow around and between high rise buildings; and wind speeds are increased due to urban canyon effects. The same can also be seen for winds travelling between buildings on High Road west of the site. Currently wind fields to the north of Barangaroo South at Central Barangaroo remain relatively unchanged by westerly winds. Micro-scale meteorological conditions are likely to altered as part of the proposed development at Central Barangaroo and these changes should be examined for the Concept Design at the DA stage.

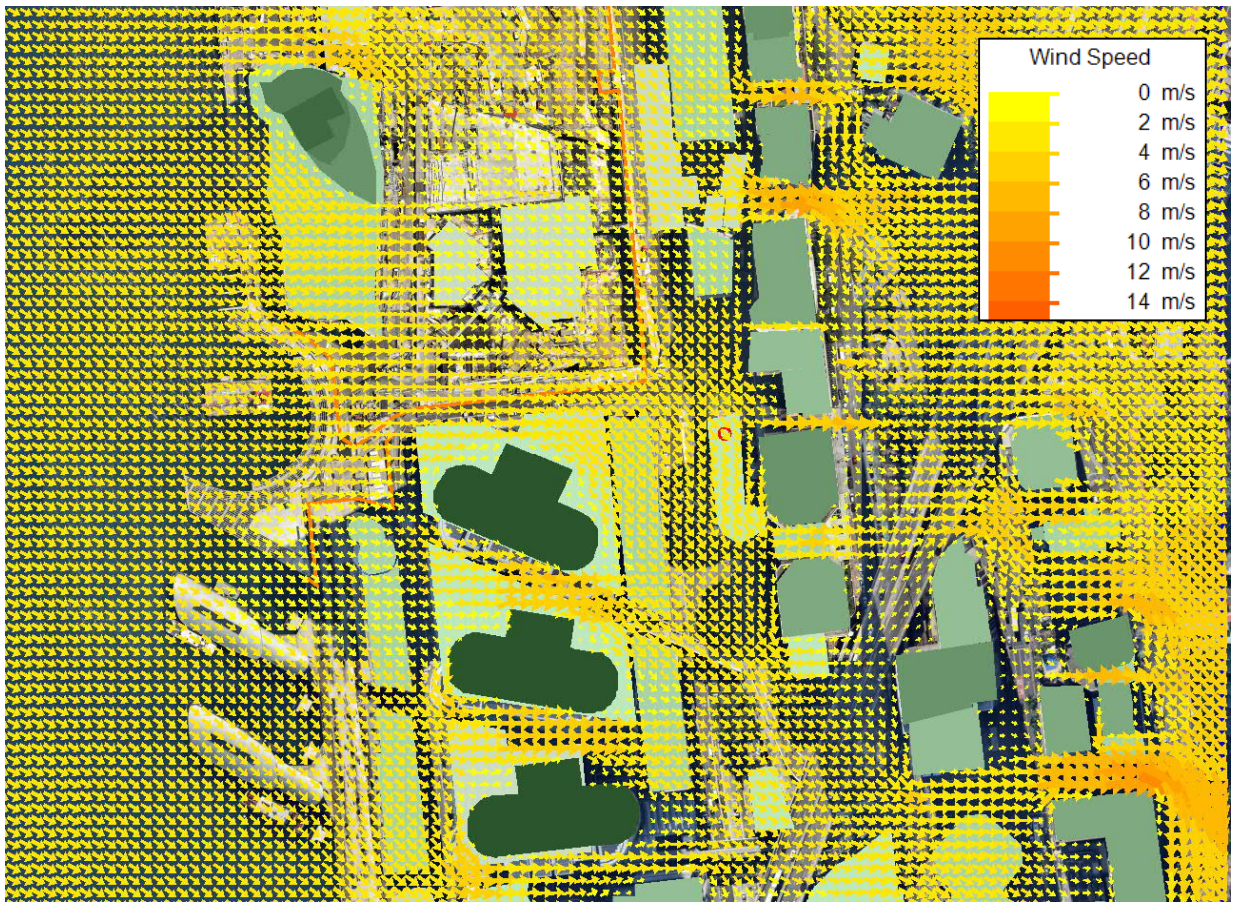

Figure 7 GRAL Winfield for most common frequent wind condition (Moderate Westerly) at Barangaroo

Appendix C

IAQM Dust Emission Magnitude Classification

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Appendix C IAQM Dust Emission Magnitude Classification

Under the UK Institute of Air Quality Management (IAQM) document dust emission magnitudes are estimated according to the scale of works being undertaken and other considerations such as meteorology, types of material being used, or general construction methodology. The IAQM guidance provides examples to aid classification, as presented in the following excerpt from IAQM:

The dust emission magnitude is based on the scale of the anticipated works and should be classified as Small, Medium, or Large. The following are examples of how the potential dust emission magnitude for different activities can be defined. Note that, in each case, not all the criteria need to be met, and that other criteria may be used if justified in the assessment:

Demolition: Example definitions for demolition are:

- Large: Total building volume >50,000m^3, potentially dusty construction material (e.g. concrete), on-site crushing and screening, demolition activities >20m above ground level;
- Medium: Total building volume 20,000m^3 – 50,000m^3 , potentially dusty construction material, demolition activities 10-20m above ground level; and
- Small: Total building volume <20,000m^3, construction material with low potential for dust release (e.g. metal cladding or timber), demolition activities <10m above ground, demolition during wetter months.

Earthworks: Earthworks will primarily involve excavating material, haulage, tipping and stockpiling. This may also involve levelling the site and landscaping. Example definitions for earthworks are:

- Large: Total site area >10,000m^2, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size), >10 heavy earth moving vehicles active at any one time, formation of bunds >8m in height, total material moved >100,000 tonnes;
- Medium: Total site area 2,500m^2 – 10,000m^2, moderately dusty soil type (e.g. silt), 5-10 heavy earth moving vehicles active at any one time, formation of bunds 4m - 8m in height, total material moved 20,000 tonnes – 100,000 tonnes; and
- Small: Total site area <2,000m^2 – soil type with large grain size, e.g. sand, <5 heavy earth moving vehicles at one time, formation of bunds <4m in height, total material moved <20,000 tonnes, earthworks during wetter months.

Construction: The key issues when determining the potential dust emission magnitude during the construction phase include the size of the building(s)/infrastructure, method of construction, construction materials, and duration of build. Example definitions for construction are:

- Large: Total building volume >100, 000m^3, on site concrete batching, sandblasting;
- Medium: Total building volume 25,000m^3 – 100,000m^3, potentially dusty construction material (e.g. concrete), on site concrete batching; and
- Small: Total building volume <25,000m^3, construction material with low potential for dust release (e.g. metal cladding or timber).

Trackout: Factors which determine the dust emission magnitude are vehicle size, vehicle speed, vehicle numbers, geology and duration. As with all other potential sources, professional judgement must be applied when classifying trackout into one of the dust emission magnitude categories. Example definitions for trackout are:

- Large: >50 truck (>3.5t) outward movements in any one day, potentially dusty surface material (e.g. high clay content), unpaved road length >100m;
- Medium: 10-50 truck (>3.5t) outward movements in any one day, moderately dusty surface material (e.g. high clay content), unpaved road length 50m – 100m; and
- Small: <10 truck (>3.5t) outward movements in any one day, surface material with low potential for dust release, unpaved road length <50m.