Appendix N

Pedestrian Wind Assessment

Sydney Metro West

Hunter Street West Over Station Development Pedestrian Wind Assessment

Appendix N

November 2022

NSW GOVERNMENT

sydney METRO

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Glossary

Term	Definition
2D	Two-dimensional
3D	Three-dimensional
AS	Australian Standard
AWES	Australasian Wind Engineering Society
BIM	Building information model
BOM	Bureau of Meteorology
CAD	Computer-aided design
CBD	Central business district
Concept and Stage 1 CSSI Application	Application SSI-10038 including all major civil construction works between Westmead and The Bays, including station excavation and tunnelling, associated with the Sydney Metro West line
Concept SSDA	A concept development application as defined in Section 4.22 of the EP&A Act, as a development application that sets out concept proposals for the development of a site, and for which detailed proposals for the site or for separate parts of the site are to be the subject of a subsequent development application or applications.
Council	City of Sydney
CSSI	Critical state significant infrastructure
DCP	Development control plan
DPE	Department of Planning and Environment
EIS	Environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979*
FSR	Floor space ratio
GFA	Gross floor area
LEP	Local Environment Plan
NZS	New Zealand Standard
OSD	Over station development
POEO Act	*Protection of the Environment Operation Act 1997*
QAM	Quality Assurance Manual
RL	Relative level
SEARs	Secretary’s Environmental Assessment Requirements
SSDA	State Significant Development Application
SSI	State Significant Infrastructure
Stage 2 CSSI Application	Application SSI-19238057, including major civil construction works between The Bays and Hunter Street Station
Stage 3 CSSI Application	Application SSI-22765520, including rail infrastructure, stations, precincts and operation of the Sydney Metro West line
Sydney Metro West	Construction and operation of a metro rail line and associated stations between Westmead and the Sydney CBD as described in section 1.1
TfNSW	Transport for New South Wales

Term	Definition
The site	The Hunter Street Station western site

Executive summary

This Pedestrian Wind Assessment supports a Concept State Significant Development Application (Concept SSDA) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Concept SSDA is made under section 4.22 of the EP&A Act.

Sydney Metro is seeking concept approval for a commercial tower above the Hunter Street Station western site (the site), otherwise known as the over station development (OSD).

The Concept SSDA seeks consent for a building envelope and its use for a commercial and retail premises, a maximum building height of 51 storeys (213 m, reduced level 220.0), a maximum gross floor area (GFA) of 69,863 m^2, pedestrian and vehicular access, circulation arrangements and associated car parking and the strategies and design parameters for the future detailed design of development.

This pedestrian wind assessment responds specifically to the Secretary's Environmental Assessment Requirements (SEARs) and provides an assessment of the wind speeds for the existing site and the proposed development, using wind tunnel assessments, to determine the change in the local wind environment and the wind speeds across the site, and surrounds, based on the proposed development. These wind speeds are then assessed against the local and industry accepted wind criteria to determine the suitability of different areas of the site and to identify if any mitigation is required to ensure a high level of environmental amenity due to the proposed development.

Wind comfort and safety was assessed using a physical wind tunnel model and was tested at Monash University. The methods used were compliant with relevant Australian Standards, the Australasian Wind Engineering Society Quality Insurance Manual and industry best-practice guidelines. Atmospheric wind was simulated according to AS/NZS 1170.2:2021 profiles and the local wind environment modelled via statistical analysis of Bureau of Meteorology historical weather data.

The results of the assessment indicate that wind speeds are generally compliant with the intended usage of each area of the proposed development. All the locations fall below the safety criteria outline by the City of Sydney but there is one location (location 35) that exceeds the prescribed comfort rating. This location is at the northern end of the Richard Johnson Square where seating is currently available for pedestrians. This means that the wind speed at the seating locations is higher than the City of Sydney prescribed comfort level, but the wind tunnel test has shown that the proposed development improves the comfort level (by reducing the wind speed) at this location. Therefore, it is deemed to be acceptable and the no further mitigation measures are required.

1 Introduction

1.1 Sydney Metro West

Sydney Metro West will double rail capacity between Greater Parramatta and the Sydney Central Business District (CBD), transforming Sydney for generations to come. The once in a century infrastructure investment will have a target travel time of about 20 minutes between Parramatta and the Sydney CBD, link new communities to rail services and support employment growth and housing supply.

Stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock, The Bays, Pyrmont and Hunter Street.

Sydney Metro West station locations are shown in Figure 1-1 below.

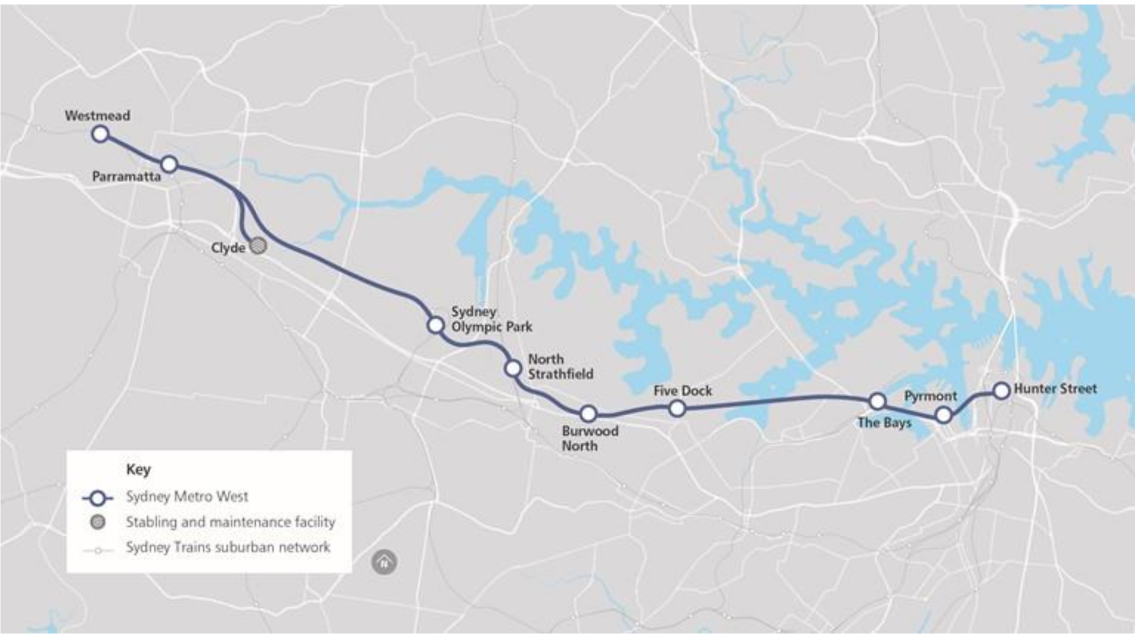

Figure 1-1 Sydney Metro West

1.2 Background and planning context

Sydney Metro is seeking to deliver Hunter Street Station under a two part planning approval process. The station fit out infrastructure is to be delivered under a Critical State Significant Infrastructure (CSSI) application subject to provisions under Division 5.2 of the EP&A Act while the over station developments are to be delivered under a State Significant Development (SSD) subject to the provisions of Part 4 of the EP&A Act. It is noted a Planning Proposal request has been submitted to the City of Sydney Council to amend the planning controls on the site (refer to section 1.2.3).

1.2.1 Critical state significant infrastructure

The state significant infrastructure (SSI) planning approval process for the Sydney Metro West metro line, including delivery of station infrastructure, has been broken down into a number of planning application stages, comprising the following:

- Concept and Stage 1 CSSI Approval (SSI-10038) – All major civil construction works between Westmead and The Bays including station excavation, tunnelling and demolition of existing buildings (approved 11 March 2021)

- Stage 2 CSSI Application (SSI- 19238057) – All major civil construction works between The Bays and Hunter Street Station (approved 24 August 2022)
- Stage 3 CSSI Application (SSI- 22765520) – Tunnel fit-out, construction of stations, ancillary facilities and station precincts between Westmead and the Hunter Street Station, and operation and maintenance of the Sydney Metro West line (under assessment).

1.2.2 State significant development application

The SSD will be undertaken as a staged development with the subject concept state significant development application (Concept SSDA) being consistent with the meaning under section 4.22 of the EP&A Act and seeking conceptual approval for a building envelope, land uses, maximum building heights, a maximum gross floor area, pedestrian and vehicle access, vertical circulation arrangements and associated car parking. A subsequent Detailed SSD/s is to be prepared by a future development partner which will seek consent for detailed design and construction of the development.

1.2.3 Planning proposal

A Planning Proposal request has been submitted to the City of Sydney Council to amend the planning controls that apply to the Hunter Street Station under the Sydney Local Environmental Plan 2012 (LEP). Hunter Street Station includes both a western site (this application) and an eastern site.

The Planning Proposal request seeks to enable the development of a commercial office building on the site that would:

- comprise a maximum building height of between reduced level (RL) 213m and RL 220.0m (as it varies to comply with the relevant sun access plane controls)
- deliver a maximum gross floor area (GFA) of 69,912 m^2 (resulting in a maximum floor space ratio (FSR) of 18.71:1), measured above ground level.
- facilitate the adaptive reuse of the existing Former Skinners Family Hotel within the overall development.
- include site specific controls which ensure the provision of employment and other non-residential land uses,
- require the mandatory consideration of a site-specific Design Guideline
- allow for the provision of up to 70 car parking spaces
- establish an alternative approach to design excellence

The Planning Proposal request was submitted to the City of Sydney in May 2022 and is currently under assessment.

1.3 Purpose of the report

This pedestrian wind report supports a Concept SSDA submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the EP&A Act. The Concept SSDA is made under section 4.22 of the EP&A Act.

This report has been prepared to specifically respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the Concept SSDA on 08 August 2022 which states that the environmental impact statement is to address the following requirements.

SEARs requirements	Where addressed
Assess amenity impacts on the surrounding locality, including lighting impacts, reflectivity, solar access, visual privacy, visual amenity, view loss and view sharing, overshadowing and wind impacts. A high level of environmental amenity for any surrounding residential or other sensitive land uses must be demonstrated	Throughout this report

This Pedestrian Wind Report assesses the proposal for any wind impacts that may affect the environmental amenity of the area. It will assess the wind speeds for the existing site and the proposed development, using wind tunnel assessments, to determine the change in the local wind environment and the wind speeds across the site, and surrounds, based on the proposed development. These wind speeds are then assessed against the local and industry accepted wind criteria to determine the suitability of different areas of the site and to identify if any mitigation is required to ensure a high level of environmental amenity due to the proposed development.

2 The site and proposal

2.1 Site location and description

Hunter Street Station is in the northern part of the Sydney CBD, within the commercial core precinct of Central Sydney and within the Sydney Local Government Area (LGA). The Hunter Street Station includes two sites – the western site and the eastern site. This report relates to the western site only.

The Hunter Street Station western site (the site) is on the corner of George and Hunter Street. It includes De Mestre Place, the heritage listed former Skinners Family Hotel, and land predominantly occupied by the existing Hunter Connection retail plaza. The site is occupied by commercial office buildings, restaurants, shops, as well as a range of business premises and employment and medical/health services premises.

The site area is 3,736 m^2 and will be cleared of all buildings and utilities prior to commencement of station construction activities. The site location is shown in Figure 2-1.

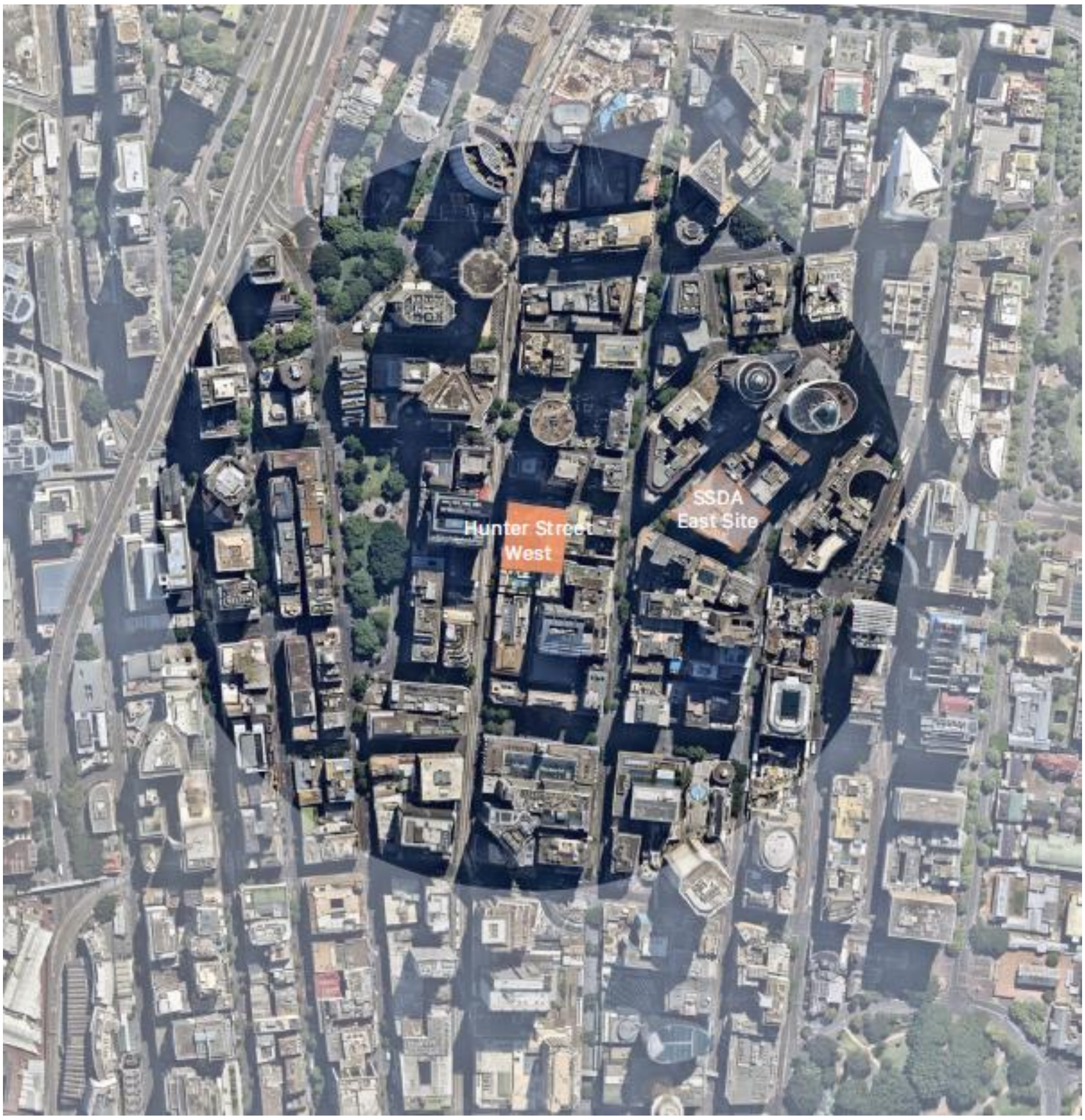

Figure 2-1 Location of the site

Table 2-1 sets out the address and legal description of the parcels of land that comprise the site.

Table 2-1 Site legal description

Address	Lot and DP
296 George Street, Sydney	Lot 1, DP438188
300 George Street, Sydney	CP and Lots 1-43, SP596
312 George Street, Sydney	Lot 1, DP211120
314-318 George Street, Sydney	Lot 13, DP622968
5010 De Mestre Place, Sydney (Over Pass)	Lot 1, DP1003818
9 Hunter Street, Sydney	Lot 2, DP850895
5 Hunter Street, Sydney (Leda House & Hunter Arcade)	CP and Lots 1-63, SP71068
5 Hunter Street, Sydney (Leda House & Hunter Arcade)	CP and Lots 1-14, SP65054
7-13 Hunter Street, Sydney (Hunter Connection)	CP and Lots 1-53, SP50276
7-13 Hunter Street, Sydney (Hunter Connection)	Lots 57 and 58, SP61007
7-13 Hunter Street, Sydney (Hunter Connection)	Lots 54, 55 and 56, SP60441
7-13 Hunter Street, Sydney (Hunter Connection)	Lots 59, 60 and 61, SP62889
7-13 Hunter Street, Sydney (Hunter Connection)	Lots 62, 63, 64 and 65, SP69300
7-13 Hunter Street, Sydney (Hunter Connection)	Lots 66 and 67, SP77409
7-13 Hunter Street, Sydney (Hunter Connection)	Lot 2, SP50276
De Mestre Place, Sydney	N/A
	Total Area: 3,736 m^2

2.2 Overview of the proposal

The Concept SSDA will seek consent for a building envelope above the site (the proposed development). As detailed in Table 2-2 and Figure 2-2.

Table 2-2 Proposed development overview

Built form component	Proposed development outcome
Site area	3,736m^2
Height	Building height up to 213.0m (RL 220.00
Ground floor area	Up to 69,863m^2
Land use(s)	Commercial office and retail
Carparking	Up to 70 car parking spaces

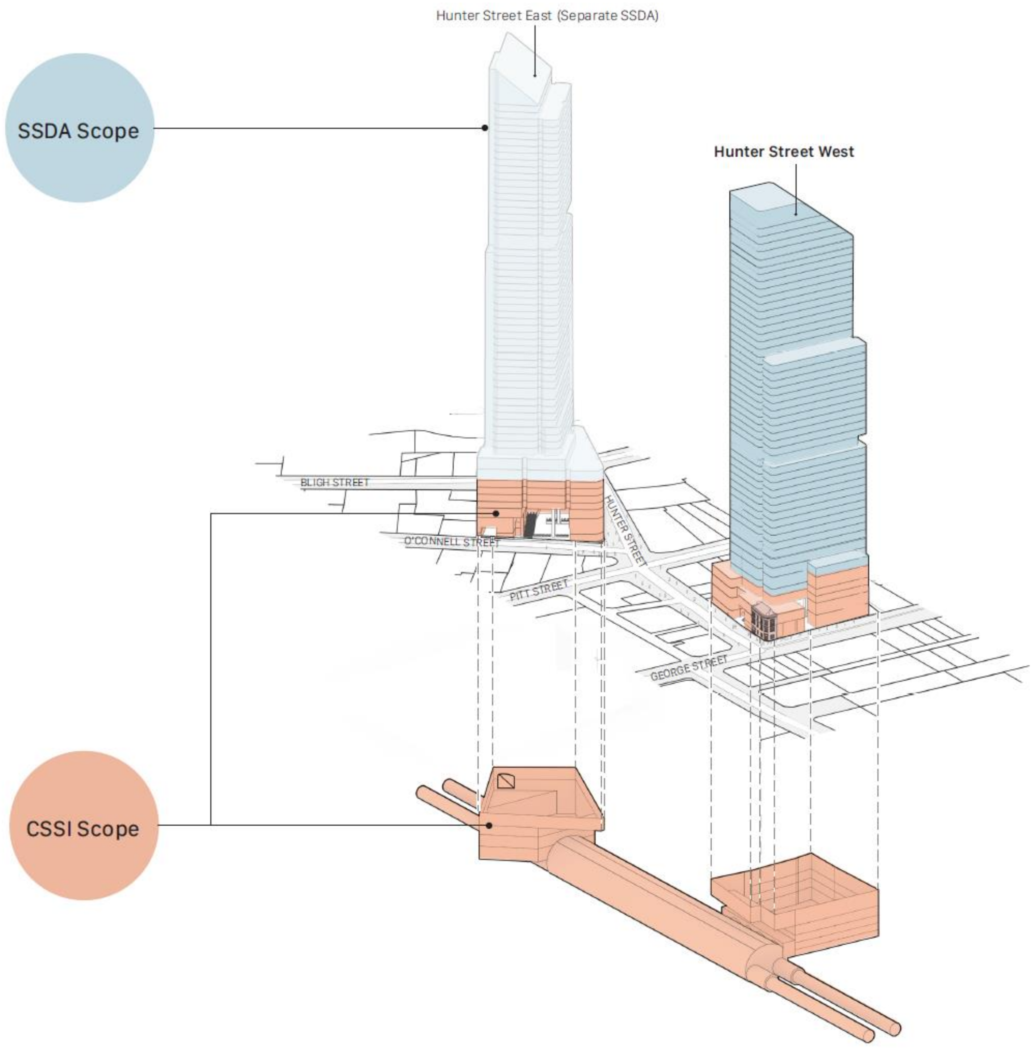

Figure 2-2 Proposed Concept SSDA development and CSSI scope

3 Methodology

This pedestrian wind assessment has been prepared in accordance with the Australasian Wind Engineering Society Quality Assurance Manual (AWES QAM). It also follows the requirements of the City of Sydney in terms of their wind criteria (section 3.1) to determine the suitability of the proposed development.

3.1 City of Sydney criteria

The City of Sydney Development Control Plan (DCP) 2012 covers wind effects from the public realm (section 5.1.9 of the DCP (2012)). The criteria are paraphrased in the below dot points:

- tall buildings can create or exacerbate windy conditions in built up areas and can have a significant effect on the wind environment at street level
- buildings must be designed to mitigate unsafe and uncomfortable wind effects on public places and should create comfortable and pleasant conditions
- a development subject to a quantitative wind effects report (which this development is) must not:
  - cause a wind speed that exceeds the Wind Safety Standard, the Wind Comfort Standard for Walking and the Wind Comfort Standard of Sitting in Parks except where the existing wind speeds exceed the standard
  - worsen, by increasing spatial extent and/or frequency and/or speed, an existing wind speed that exceeds the Wind Safety Standard, the Wind Comfort Standard for Walking and the Wind Comfort Standard for Sitting in Parks.
- for the purposes of complying with the above, the below standards are set out in the DCP (2012):
  - Wind Safety Standard is a wind speed of 24 metres per second
  - Wind Comfort Standard for Walking is a wind speed of 8 metres per second
  - Wind Comfort Standard for Standing is a wind speed of 6 metres per second
  - Wind Comfort Standard for Sitting is a wind speed of 4 metres per second
  - Wind Comfort Standard for Sitting in Parks is a wind speed of 4 metres per second.

Note: The Wind Safety Standard is based on an annual maximum peak 0.5 second gust wind speed in one hour measured between 6 am and 10 pm Eastern Standard Time.

Note: The Wind Comfort Standards are based on an hourly mean wind speed, or gust equivalent mean wind speed, whichever is greater for each wind direction, for no more than 292 hours per annum measured between 6 am and 10 pm Eastern Standard Time (i.e. 5% of those hours).

3.2 Wind climate

Wind is a highly variable meteorological element, both in speed and direction. The selection of data and statistical representation of the wind climate can therefore have a large bearing on the outcome of a wind comfort assessment.

3.2.1 Meteorological data

Historical weather data was used for the analysis and obtained from the Bureau of Meteorology (BOM) weather station at Sydney Airport, which is situated 8.5 km southwest of the site. Airport weather stations are generally the most reliable source of wind data as they are typically free from nearby obstructions and have uninterrupted, quality-controlled data for suitable time periods.

From 2001 to 2020, 10-minute wind observations were converted to hourly means using methods outlined in Grange (2014). Scaling to correct for the difference in terrain roughness surrounding the site (i.e. due to buildings, trees, and other obstructions) was made and detailed in Appendix A.

Details of the statistical methods used and coefficients describing the wind probability distributions (a Weibull analysis for comfort and an extreme value analysis for safety) can also be found in Appendix A.

The scaled data is presented in the wind rose plot below, Figure 3-1. Here, the length and colour of the spoke sections represent the frequency and amplitude of recorded wind events, respectively.

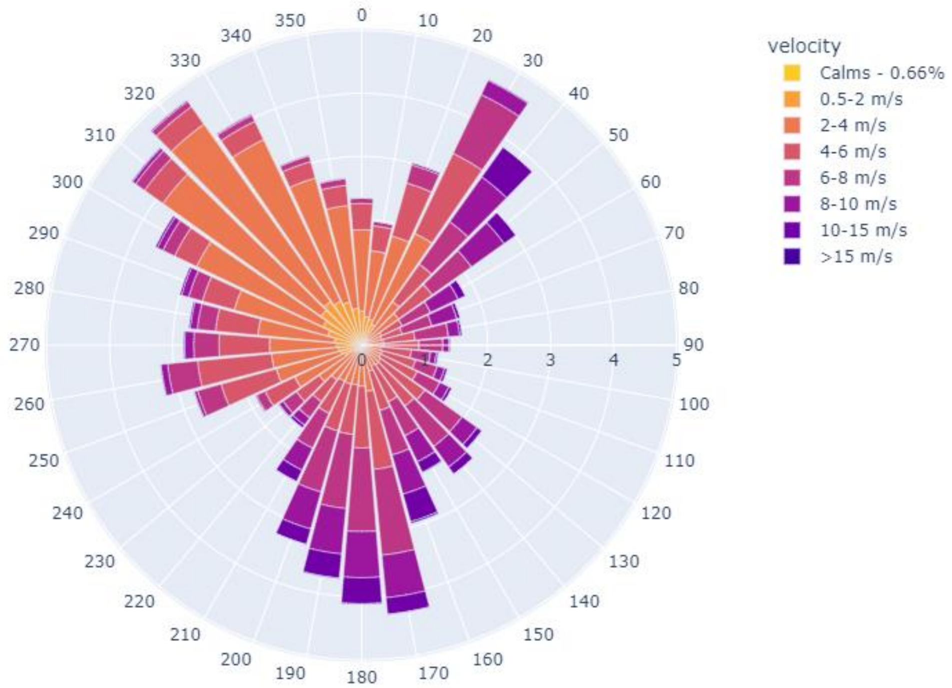

Figure 3-1 Wind rose plot of Sydney Airport BOM Data, 2001-2020

3.3 The wind tunnel model

Wind tunnel experiments were undertaken to determine the site-specific wind speeds for the existing buildings and proposed built form. Due to the nature of wind tunnel experiments, there are several factors that need to be considered (e.g., the wind tunnel configuration, approach flow, built environment, assessment locations, etc.).

3.3.1 Wind tunnel

Testing was conducted in the three-quarter open-jet test section of the Monash University 1.4 MW Wind Tunnel. The wind tunnel is a closed-circuit wind tunnel that is powered by four DC electric motors that drive two fans, each five metres in diameter. Testing was conducted with the jet in a lowered position at a height of 2.6 m and a width of 4.0 m, providing a jet area of ~10.5 m^2. The collector was in the forward position, known as the "ABCD" configuration.

3.3.2 Establishment of the approach flow

The minimum requirements for an acceptable simulation of a neutrally stable atmospheric boundary layer are the modelling of:

- the variation of mean wind speed with height
- the variation of longitudinal component of turbulence with height
- the integral scale of turbulence
- a zero longitudinal pressure gradient.

The mean wind speed and turbulence intensity in the approach flow were modelled to within 10% of their target values. The integral length scale was within a factor of 3 of the value determined from the chosen geometric scaling ratio (1:400 in this case) (refer to Appendix B for the relevant scaling laws). Confirmation that the wind tunnel (using a trip board, turbulence elements and development length) adequately models the variation of mean wind speed with height and the variation of longitudinal component of turbulence with height for each terrain category is provided in Appendix B.

3.3.3 Modelling of the near-field flow

Physical features such as significant buildings, structures, or topography, influence the near field flow and must be included as part of the local wind flow simulation. In general, all major structures and topographical features within a radius of 300 m to 600 m of the building site should be modelled to the correct scale, to an accuracy of 10% or better in accordance with AWES-QAM-1-2019.

A survey of the site shown in Figure 3-2 was carried out to acquire information on the footprint, form, and height of all buildings within a 470 m radius from the Hunter Street and Pitt Street intersection. Figure 3-3 to Figure 3-6 show the wind tunnel model and surroundings.

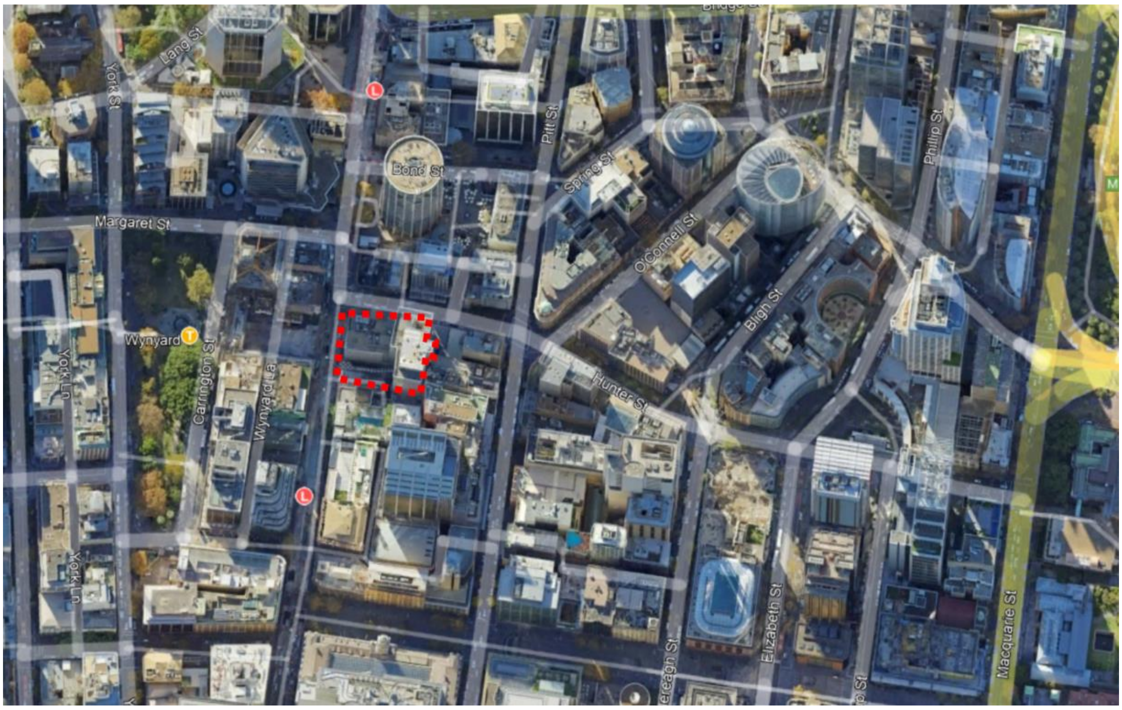

Figure 3-2 Existing buildings in the Sydney CBD region with an overlay of the proposed site (shown in red)

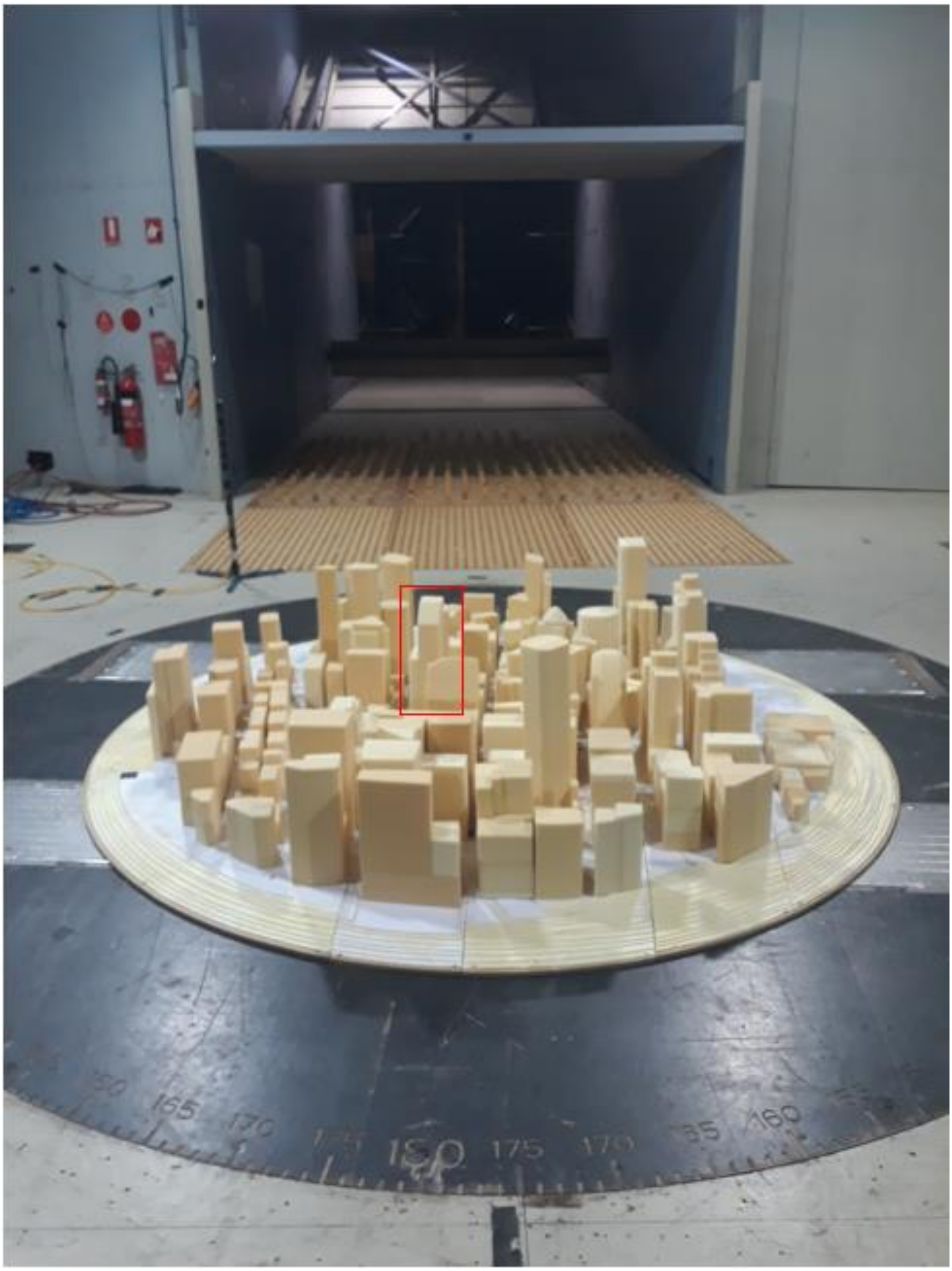

Figure 3-3 Wind tunnel model showing the approach region and overall modelled site for the proposed development (outlined by the red box)

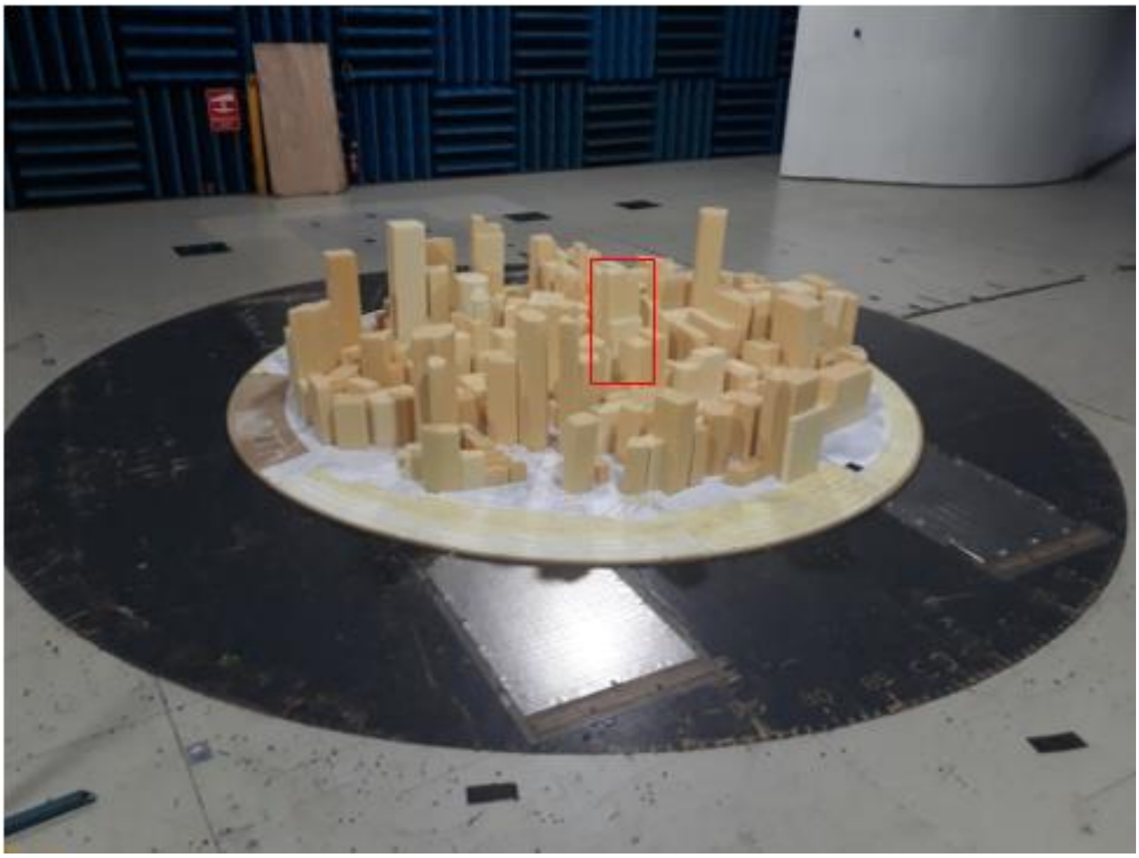

Figure 3-4 Wind tunnel model showing the overall modelled site for the proposed development (outlined by the red box) from an aerial perspective (viewed from the Northwest

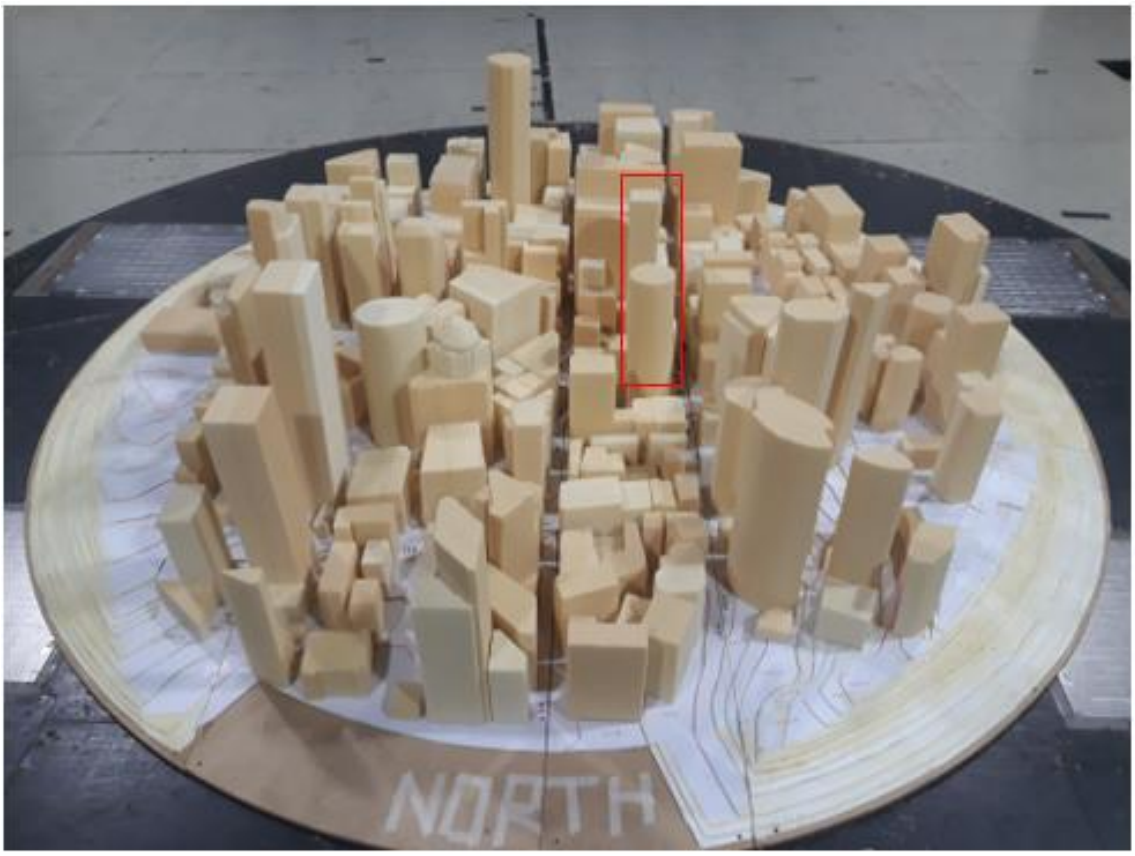

Figure 3-5 Wind tunnel model showing the overall modelled site for the proposed development (outlined by the red box) from an aerial perspective (viewed from the North)

Figure 3-6 Wind tunnel model showing the proposed development

3.4 Test methodology

Measurements from the sensor array were taken for the full 360^{O} azimuth range at 10^{O} intervals, as required by AWES QAM. In addition to the local total and static pressures measured at each Irwin sensor, reference measurements of static and total pressure (measured using a pitot-static tube) were taken at the upstream edge of the turntable at a height of 1.5 m (600 m full-scale). This reference height is required to avoid interference with the flow over the model.

These measurements of ground-level wind speeds at the various locations are combined with the probability distribution of reference wind speed and direction to provide predictions of full-scale ground-level wind speeds. The following method was used for the analysis:

1. time series of ground-level wind speeds were calculated from the Irwin sensor data using the calibration equation (refer to Appendix B)
2. the maximum hourly gusts (3-second gust for comfort and 0.5-second gust for safety) were calculated for each of these time series
3. the gust wind speeds were converted to velocity ratios by dividing by the wind tunnel reference velocity (from the pitot-static tube) (refer to Appendix B for the sensor calibration and conversion from a pressure difference to a velocity)
4. velocity ratios were then scaled to the 10 m reference height of the Bureau of Meteorology anemometer using AS/NZS 1170.2 gust profiles
5. Comfort and safety wind speeds, representing the relative contributions of wind from all directions, were calculated using the statistical methods outlined in Appendix A. For each location, the probability of exceeding a certain wind speed was calculated using an iterative method, with the wind speed varied until the comfort exceedance probability was reached. This method was then repeated using the extreme value distribution and safety exceedance probability.
6. gust wind speeds were converted to gust equivalent mean (GEM) wind speeds by dividing by a scaling factor of 1.85 (Lawson, 2001), to be used for comparison against the comfort criteria.

3.5 Assessment locations

The wind tunnel test is split in to three stages:

- baseline investigations – assessing the existing buildings (pre-demolition) on the site to determine the existing wind climate
- proposed development – assessing the proposed development to determine the future wind climate.

3.5.1 Baseline investigations

For this study, a total of 39 ground level assessment locations within and around the proposed development site have been selected for analysis in the wind tunnel. The locations of the various assessment locations are presented in Figure 3-7 in the form of a marked-up plan drawing.

Figure 3-7 Irwin probe assessment locations for the existing built environment (red outline shows the extent of the proposed development site)

3.5.2 Proposed development

For this study, a total of 52 ground level assessment locations within and around the proposed development site have been selected for analysis in the wind tunnel. The locations of the various assessment locations are presented in Figure 3-8 in the form of a marked-up plan drawing. **Note:** sensor locations 1 – 39 are identical to the sensor locations tested in the baseline investigations (except for those that fall within the site boundary).

Figure 3-8 Irwin probe assessment locations for the proposed development shows the footprint of the proposed development and the surrounding environment

This model is based on the concept building envelope and therefore no detailed architectural or landscaping features have been included as part of this proposal, and detailed design will be subject to a separate SSD. Therefore, the proposed development is modelled as shown in Figure 3-9 does not include any external features (e.g. no awnings, landscaping, etc.).

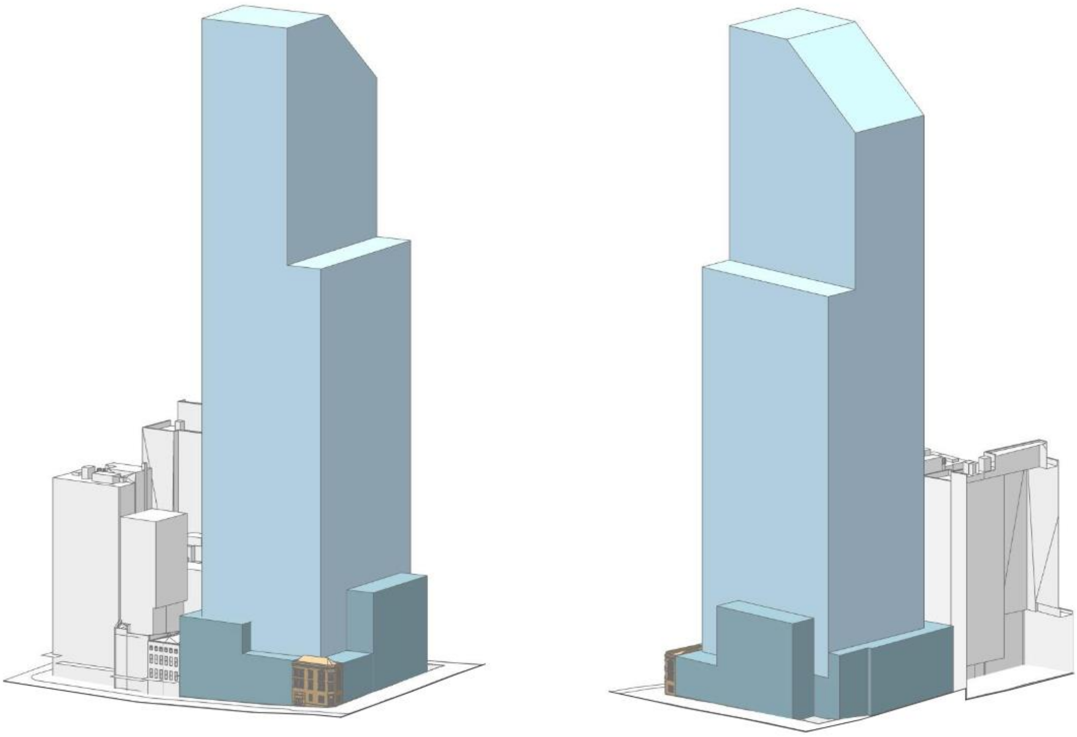

Figure 3-9 3D view of the proposed planning envelope Hunter Street western site (shown in blue)

4 Assessment

The wind tunnel results show wind speeds at 1.5 m above the ground plane at the discrete sensor locations outlined in section 3.5. The wind tunnel test was undertaken to assess the baseline case (pre-demolition) and with the proposed development.

4.1 Baseline investigations

This assessment included 39 Irwin probes, located around the site, and their results are shown against the Sydney DCP (2012) wind criteria in Figure 4-1 (comfort results) and Figure 4-2 (safety results). Results are also tabulated in Table 4-1 to show the wind speeds and the achieved criteria. Conditions are shown to be generally suitable for sitting in parks and can considered safe at all locations, with no adverse conditions that need to be ameliorated (provision three of the Sydney DCP (2012)).

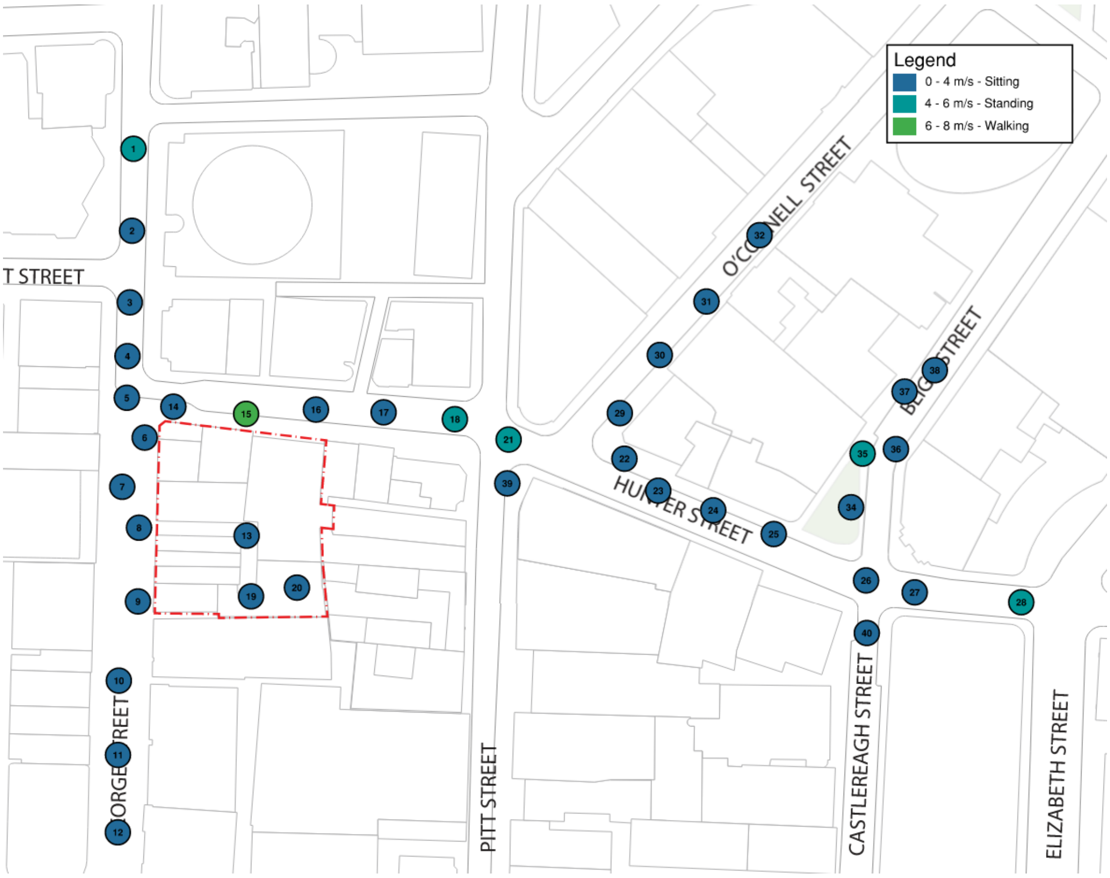

Figure 4-1 Irwin sensor comfort results for existing buildings occupying the development site

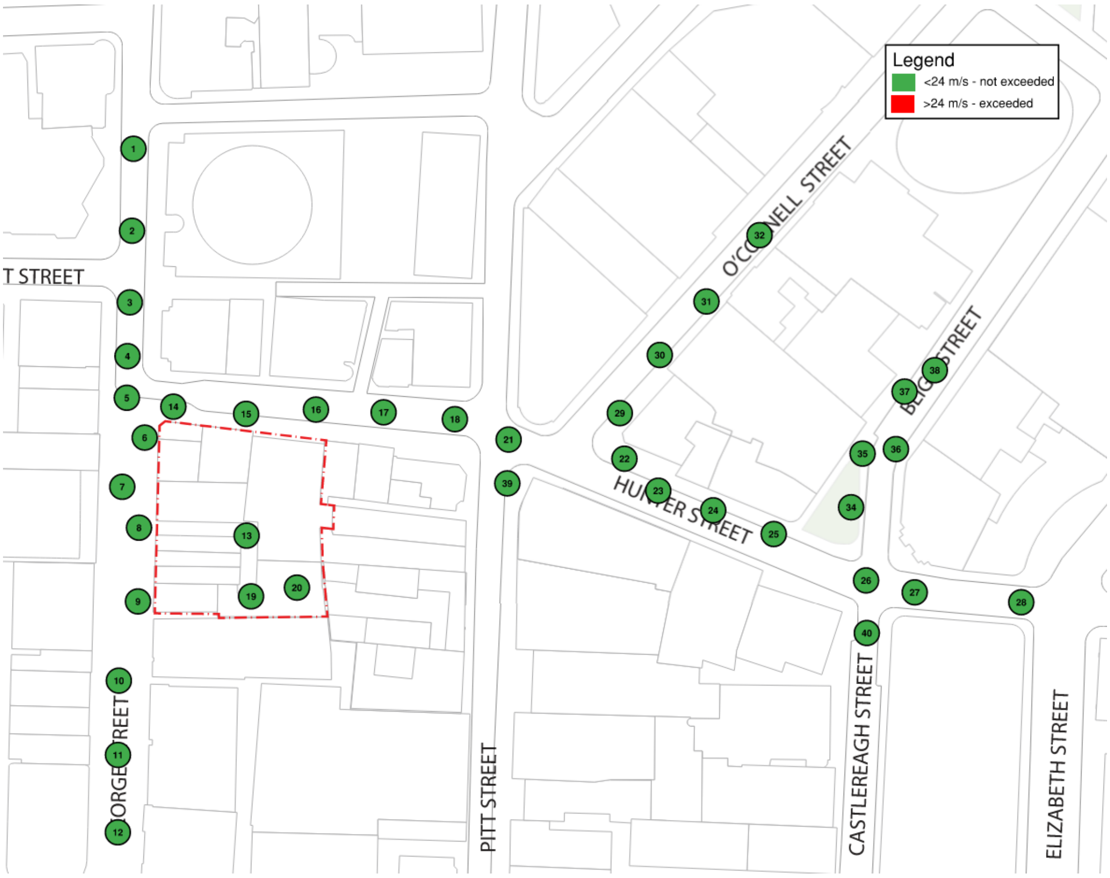

Figure 4-2 Irwin sensor safety results for existing buildings occupying the development site

Table 4-1 Irwin sensor wind speed results for existing buildings occupying the development site

Location	Comfort wind speed [m/s]	Comfort criteria	Safety wind speed [m/s]	Safety criteria
1	4.9	Standing	14.6	Not exceeded
2	3.6	Sitting	10.5	Not exceeded
3	3.2	Sitting	9.6	Not exceeded
4	3.1	Sitting	8.8	Not exceeded
5	3.1	Sitting	9.1	Not exceeded
6	2.9	Sitting	8.4	Not exceeded
7	3.6	Sitting	11.2	Not exceeded
8	3.2	Sitting	8.7	Not exceeded
9	2.4	Sitting	6.3	Not exceeded
10	2.7	Sitting	7.6	Not exceeded
11	3.2	Sitting	9.1	Not exceeded
12	2.3	Sitting	6.8	Not exceeded
13	2.7	Sitting	7.8	Not exceeded
14	2.6	Sitting	7.7	Not exceeded
15	6.3	Walking	16.5	Not exceeded
16	2.9	Sitting	8.2	Not exceeded
17	2.4	Sitting	6.6	Not exceeded
18	4.2	Standing	11.4	Not exceeded
19	2.6	Sitting	8.0	Not exceeded
20	3.7	Sitting	10.9	Not exceeded
21	4.6	Standing	12.5	Not exceeded
22	2.8	Sitting	8.5	Not exceeded
23	1.9	Sitting	5.3	Not exceeded

Location	Comfort wind speed [m/s]	Comfort criteria	Safety wind speed [m/s]	Safety criteria
24	2.6	Sitting	7.9	Not exceeded
25	3.0	Sitting	9.6	Not exceeded
26	3.0	Sitting	8.5	Not exceeded
27	3.6	Sitting	10.3	Not exceeded
28	4.2	Sitting	12.0	Not exceeded
29	3.1	Sitting	9.7	Not exceeded
30	2.1	Sitting	6.2	Not exceeded
31	2.8	Sitting	7.7	Not exceeded
32	2.5	Sitting	7.2	Not exceeded
34	3.7	Sitting	10.7	Not exceeded
35	4.4	Standing	12.3	Not exceeded
36	3.6	Sitting	10.4	Not exceeded
37	3.6	Sitting	10.2	Not exceeded
38	3.9	Sitting	11.7	Not exceeded
39	3.2	Sitting	9.1	Not exceeded
40	3.4	Sitting	10.0	Not exceeded

4.2 Proposed development

This assessment included 52 Irwin probes, located around the site, and their results are shown against the Sydney DCP (2012) wind criteria in Figure 4-3 (comfort results) and Figure 4-4 (safety results). Results are also tabulated in Table 4-2 to show the comparison between the target criteria and the achieved criteria. The results show that the wind results for all locations are suitable for the intended activities and safe.

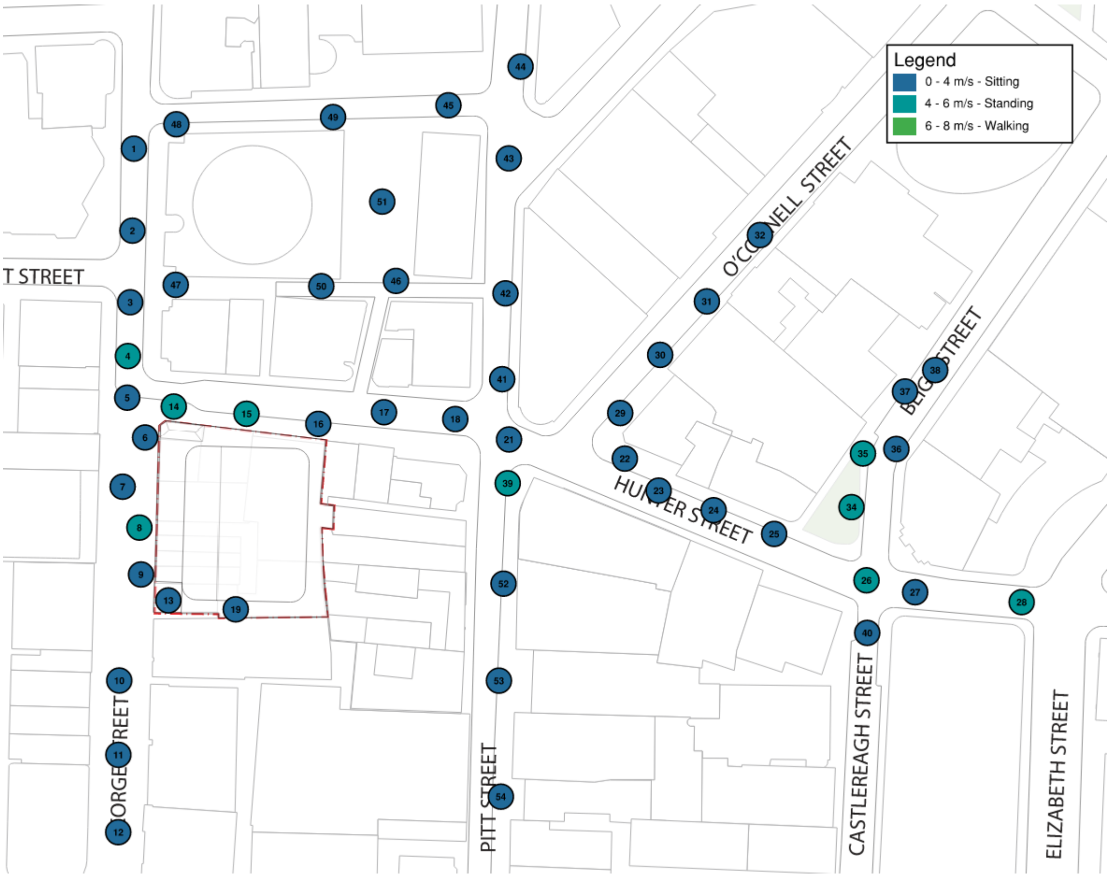

Figure 4-3 Irwin sensor comfort results for proposed development

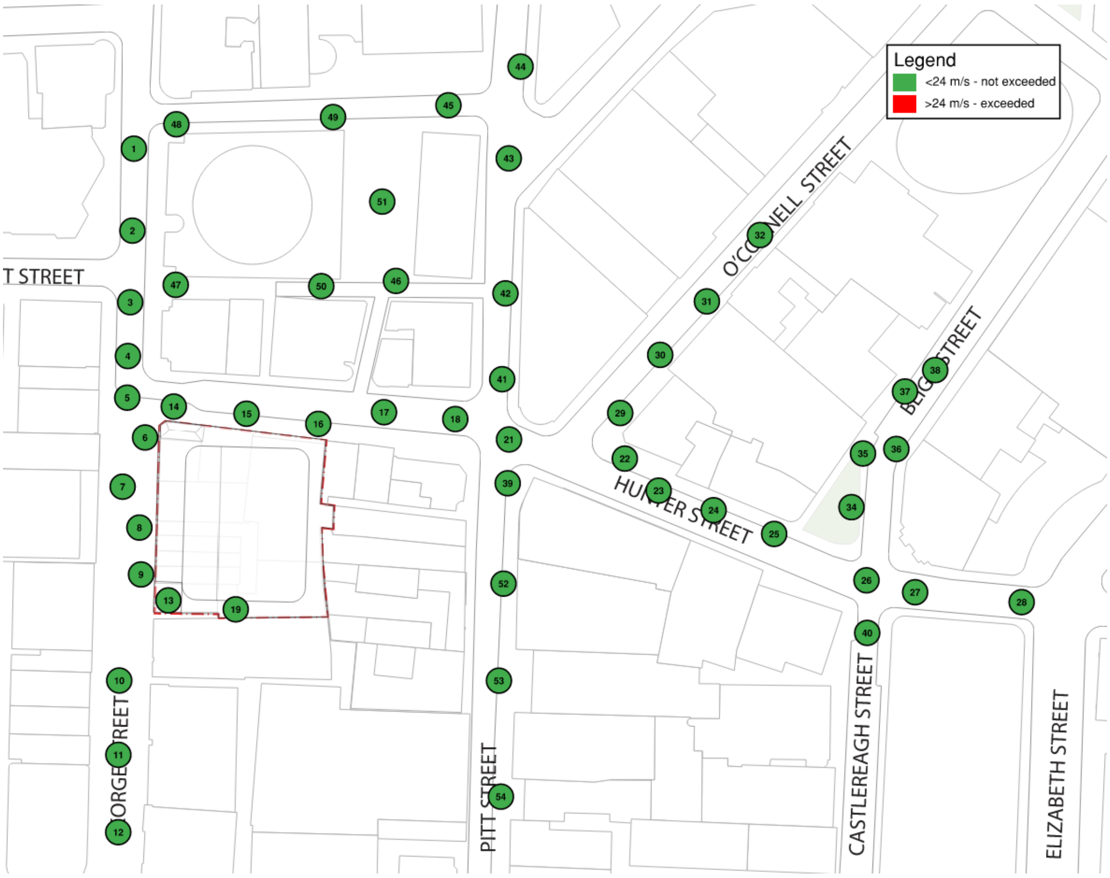

Figure 4-4 Irwin sensor safety results for proposed development

Table 4-2 Irwin sensor wind speed results for the proposed development

Location	Comfort target	Comfort wind speed [m/s]	Comfort criteria	Safety wind speed [m/s]	Safety criteria
1	Walking	3.5	Sitting	10.0	Not exceeded
2	Walking	3.6	Sitting	10.9	Not exceeded
3	Walking	3.2	Sitting	9.9	Not exceeded
4	Walking	4.7	Standing	14.1	Not exceeded
5	Walking	2.1	Sitting	6.2	Not exceeded
6	Standing	2.3	Sitting	7.1	Not exceeded
7	Walking	2.4	Sitting	7.5	Not exceeded
8	Standing	4.5	Standing	13.4	Not exceeded
9	Standing	3.4	Sitting	10.8	Not exceeded
10	Walking	2.8	Sitting	8.7	Not exceeded
11	Walking	2.5	Sitting	8.0	Not exceeded
12	Walking	3.5	Sitting	10.6	Not exceeded
13	Standing	2.1	Sitting	7.2	Not exceeded
14	Standing	4.3	Standing	13.5	Not exceeded
15	Standing	4.4	Standing	14.6	Not exceeded
16	Standing	3.5	Sitting	12.1	Not exceeded
17	Walking	2.8	Sitting	8.6	Not exceeded
18	Walking	3.6	Sitting	11.2	Not exceeded
19	Standing	2.0	Sitting	5.9	Not exceeded
21	Walking	3.8	Sitting	11.8	Not exceeded
22	Walking	2.5	Sitting	6.9	Not exceeded
23	Standing	1.9	Sitting	5.3	Not exceeded
24	Standing	2.1	Sitting	6.2	Not exceeded

Location	Comfort target	Comfort wind speed [m/s]	Comfort criteria	Safety wind speed [m/s]	Safety criteria
25	Standing	2.8	Sitting	8.6	Not exceeded
26	Standing	5.8	Standing	17.8	Not exceeded
27	Walking	2.7	Sitting	7.6	Not exceeded
28	Walking	5.5	Standing	15.1	Not exceeded
29	Walking	2.9	Sitting	8.7	Not exceeded
30	Standing	2.1	Sitting	6.2	Not exceeded
31	Standing	1.7	Sitting	5.3	Not exceeded
32	Standing	2.2	Sitting	6.9	Not exceeded
34	Walking	4.8	Standing	13.6	Not exceeded
35	Sitting	4.2	Standing	11.4	Not exceeded
36	Sitting	2.4	Sitting	6.6	Not exceeded
37	Sitting	3.3	Sitting	10.0	Not exceeded
38	Walking	3.5	Sitting	11.3	Not exceeded
39	Walking	4.2	Standing	12.3	Not exceeded
40	Walking	3.0	Sitting	8.5	Not exceeded
41	Walking	2.3	Sitting	6.7	Not exceeded
42	Walking	3.7	Sitting	10.3	Not exceeded
43	Walking	2.4	Sitting	7.1	Not exceeded
44	Walking	3.8	Sitting	9.8	Not exceeded
45	Walking	2.4	Sitting	7.8	Not exceeded
46	Walking	2.3	Sitting	7.6	Not exceeded
47	Walking	2.8	Sitting	8.4	Not exceeded
48	Walking	3.7	Sitting	11.8	Not exceeded
49	Walking	2.5	Sitting	8.3	Not exceeded

Location	Comfort target	Comfort wind speed [m/s]	Comfort criteria	Safety wind speed [m/s]	Safety criteria
50	Walking	2.8	Sitting	8.9	Not exceeded
51	Walking	1.9	Sitting	5.9	Not exceeded
52	Walking	3.1	Sitting	9.5	Not exceeded
53	Walking	2.8	Sitting	8.5	Not exceeded
54	Walking	2.7	Sitting	8.0	Not exceeded

4.3 Discussion

The results of the assessment indicate that wind speeds are generally compliant with the intended usage of each area of the proposed development. All the locations fall below the safety criteria outlined by the City of Sydney but there is one location (location 35) that exceeds the prescribed comfort rating. This location is at the northern end of the Richard Johnson Square and therefore it was assumed that seating would be available for pedestrians. However, the proposed development reduces the predicted wind speed at this location, when compared to the baseline investigations (reduction of 0.2 m/s), and therefore it is deemed to be acceptable. This location will be further investigated in a future Detailed SSD.

5 Conclusion

A wind tunnel study was conducted to provide assessment of wind conditions at the site and nearby surrounding environment. Wind speeds around the development have been assessed against the Sydney Development Control Plan wind criteria to ensure compliance with local requirements. The development, surrounding terrain, local built environment and approach flow were modelled at the necessary accuracy to satisfy the AWES-QAM-1-2019. Atmospheric wind was simulated according to AS/NZS 1170.2:2011 profiles and the local wind environment modelled via statistical analysis of Bureau of Meteorology historical weather data.

The results of the assessment indicate that wind speeds are generally compliant with the intended usage of each area of the proposed development. All the locations fall below the safety criteria outline by the City of Sydney but there is one location (location 35) that exceeds the prescribed comfort rating. This location is at the northern end of the Richard Johnson Square where seating is currently available for pedestrians. This means that the wind speed at the seating locations is higher than the City of Sydney prescribed comfort level, but the wind tunnel test has shown that the proposed development improves the comfort level (by reducing the wind speed) at this location. Therefore, it is deemed to be acceptable and the no further mitigation measures are required.

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Appendix A Statistical analysis of meteorological data

A.1 Scaling methods

Modelling of local wind effects requires accurate representation of the surrounding terrain and built environment. The influence of terrain and built environment over the development length is incorporated into AS/NZS 1170.2:2021 as different terrain categories. Based on the terrain category, a suitable model of the atmospheric boundary layer (change in velocity and turbulence intensity with height) is given, which accounts for nearby structures and terrain (roughness). This model uses a logarithmic law to describe the mean wind speed profile in terms of roughness length.

Wind data from Sydney Airport was corrected to open terrain (category 2) using methods outlined in Holmes, 2021. To scale to the terrain roughness surrounding the site (e.g. category 3), scaling was applied using mean wind speed terrain/height multipliers from AS/NZS 1170.2:1989; i.e., multiplying by 0.44/0.6 = 0.733.

A.2 Weibull analysis

To accurately account for the relative contributions of wind events from different directions, comfort exceedance probabilities were defined using a Weibull distribution. The probability of the wind speed at a certain location, U_i, exceeding a speed, V, for any given direction, θ, is given by:

$$p(U_i > V, \theta) = A(\theta)e^{\left[-\left(\frac{V}{C(\theta)}\right)^{k(\theta)}\right]}$$

Here *k (θ)* and *C(θ)* are Weibull coefficients for the azimuth sector, *θ*, and *A (θ)* is the marginal probability of the wind direction being within the azimuth sector. Therefore, the sum of all the marginal probabilities will be equal to one and the following will hold true:

$$\sum_{all\ sectors} A(\theta) = 1$$

Consequently, the exceedance probability is given by:

$$p(U_i > V) = \sum_{all\ sectors} A(\theta)e^{\left[-\left(\frac{V}{C(\theta)}\right)^{k(\theta)}\right]}$$

The Weibull coefficients obtained from the Sydney Airport BoM data, for the Sydney DCP (2012) assessment hours, are shown below in Table A-1.

Table A-1 Weibull coefficients for all 36 assessment directions

Direction	A	C	k
0	0.019	3.90	2.41
10	0.015	3.55	2.44
20	0.024	4.55	2.36
30	0.049	6.14	2.80
40	0.046	9.29	3.10
50	0.036	8.66	3.12
60	0.022	8.81	3.51
70	0.020	8.47	3.45
80	0.019	7.03	3.31
90	0.016	6.48	3.23
100	0.014	6.46	2.74
110	0.016	6.29	2.94
120	0.018	6.95	2.85
130	0.028	7.49	3.17
140	0.028	7.70	3.12
150	0.024	7.95	2.84
160	0.032	8.90	2.69
170	0.049	7.96	2.96
180	0.048	8.44	2.92
190	0.039	8.66	2.93
200	0.034	8.31	2.85
210	0.023	8.04	2.44
220	0.014	6.37	2.18
230	0.013	5.51	2.33
240	0.015	4.76	2.39
250	0.024	5.49	2.51
260	0.030	5.81	2.58
270	0.027	5.81	2.29
280	0.025	5.30	2.10
290	0.029	4.98	1.96
300	0.036	4.54	1.95
310	0.045	4.07	2.16
320	0.044	3.80	2.37
330	0.032	3.94	2.30
340	0.022	4.14	2.16
350	0.019	4.51	2.25

A.3 Extreme Value analysis

For analyses involving high return periods, infrequent wind events of high wind speed are considered. Such wind events have been described using a Type 1 Extreme Value Distribution (or Gumbel Distribution) with Gringorten's modification, which models infrequent events more accurately than the Weibull distribution. The probability of the wind speed at a given location, U_i, exceeding a speed, V, for any given direction, θ, is given by:

$$p(U_i > V, \theta) = 1 - e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}$$

Where u *(θ)* and *a (θ)* are the calculated coefficients for each azimuth sector. The return period for exceedance velocity, V, for each sector is the inverse of the exceedance probability, i.e.:

$$R_\theta = \frac{1}{p(U_i > V, \theta)}$$

The overall exceedance probability for all wind directions is given by:

$$1 - \frac{1}{R} = \prod_\theta \left(1 - \frac{1}{R_\theta}\right)$$

$$1 - \frac{1}{R} = \prod_\theta e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}$$

Therefore, the return period for winds from all directions is:

$$R = \frac{1}{1 - \prod_\theta e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}}$$

The Extreme Value coefficients obtained from the Sydney Airport BoM data, for all hours, are shown below in Table A-2.

Table A-2 Extreme value coefficients for all 36 assessment directions

Direction	A	u	a
0	0.023	7.12	0.75
10	0.019	6.68	0.79
20	0.029	8.03	0.91
30	0.045	9.78	0.64
40	0.037	12.97	0.83
50	0.029	12.14	1.02
60	0.017	11.30	0.96
70	0.016	10.78	1.30
80	0.015	10.66	1.67
90	0.013	9.86	1.33
100	0.011	10.25	1.89
110	0.013	10.19	1.07
120	0.015	11.01	1.62

Direction	A	u	a
130	0.022	11.52	1.87
140	0.024	12.50	1.61
150	0.021	12.43	1.91
160	0.028	14.50	1.89
170	0.041	12.64	1.19
180	0.039	14.22	1.25
190	0.036	14.08	0.96
200	0.032	12.63	1.52
210	0.023	12.69	1.42
220	0.015	10.96	1.47
230	0.016	9.79	1.17
240	0.018	8.53	0.58
250	0.027	9.46	0.97
260	0.031	9.71	0.96
270	0.027	10.22	1.08
280	0.027	10.46	0.84
290	0.029	10.21	0.71
300	0.035	10.04	0.77
310	0.043	9.46	1.18
320	0.046	8.73	1.63
330	0.039	8.56	0.99
340	0.030	8.03	0.93
350	0.026	7.68	0.99

Appendix B Wind tunnel calibration

B.1 Scaling laws

The fundamental concept is that the model of the structure and that the wind should be at approximately the same scale.

- Geometric Scale: The geometric scale was at 1:400, and affects the ratio of roughness length and integral scales of longitudinal turbulence:

$$L = \frac{(z_o)m}{(z_o)p} = \frac{(L_u)m}{(L_u)p} = 1:400$$

- Velocity Scale: The wind tunnel reference mean velocity was chosen as about 10 m/s to maximise the sensitivity of the measurement instrumentation. The velocity sale for the simulation was (with a design mean speed of about 26 m/s):

$$V = \frac{(V_{ref})m}{(V_{ref})p} = 0.38$$

- In addition, the following scales are necessary to determine wind tunnel instrumentation sampling and frequency response characteristics:
- Time Scale: $T = \frac{L}{V} = \frac{t_m}{t_p} = 1:150$
- Frequency Scale: $F = \frac{1}{T} = \frac{f_m}{f_p} = 150:1$

A sampling rate of 1000 Hz was used for the following reasons (consistent with the Australasian Wind Engineering Society Quality Assurance Manual):

- The rate corresponds to about 6.67 Hz in full-scale, which will allow pressure fluctuations with frequencies up to about 2.53 Hz (full-scale) to be determined without distortion or attenuation.

A sampling duration of 40 seconds was used as it ensures measured maximum and minimum wind speeds provide representative estimates of peaks encountered during a full-scale interval of just above 1.6 hrs, and a statistically stable estimate of the mean and RMS wind speeds.

B.2 Wind tunnel calibration

The wind tunnel approach flow was calibrated to match the AS 1170.2:2011 terrain category 1 and 3 approach flow (depending on the approach sector), within a margin of 10% as per the Australasian Wind Engineering Society Quality Assurance Manual. The approach flow was normalised against a height of 600 m. The normalised approach flow and turbulence intensity are shown in Figure B- to Figure B-, respectively.

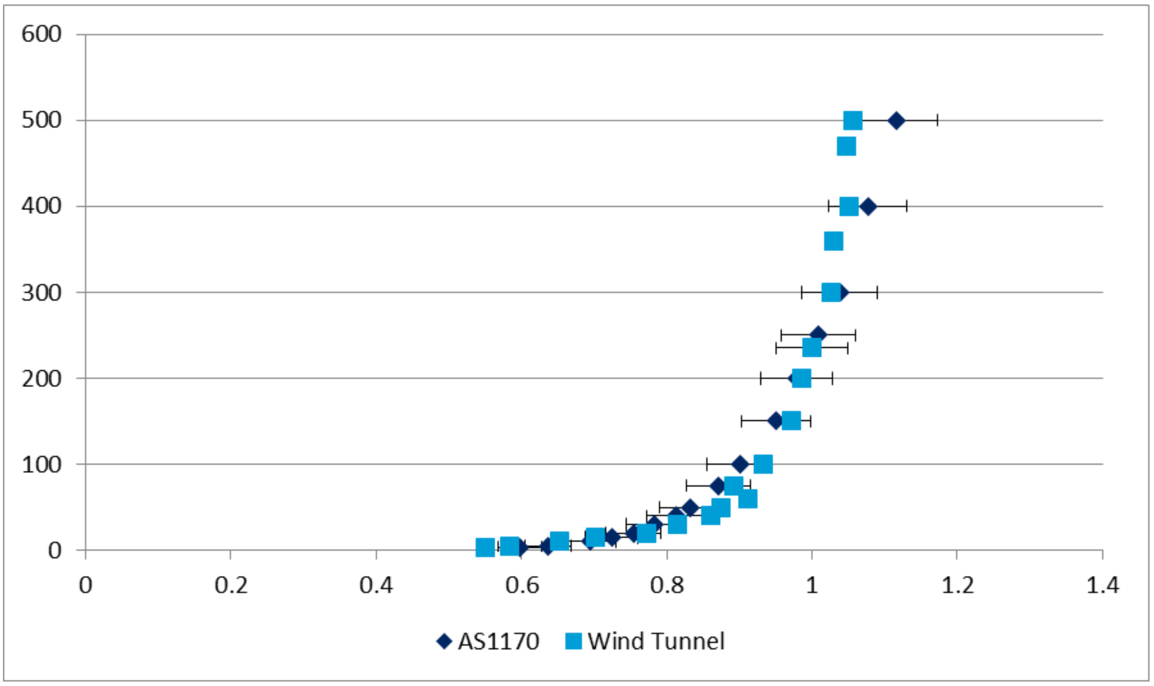

Figure B-2 Mean velocity profile for terrain category 1 comparison with AS1170.2:2011

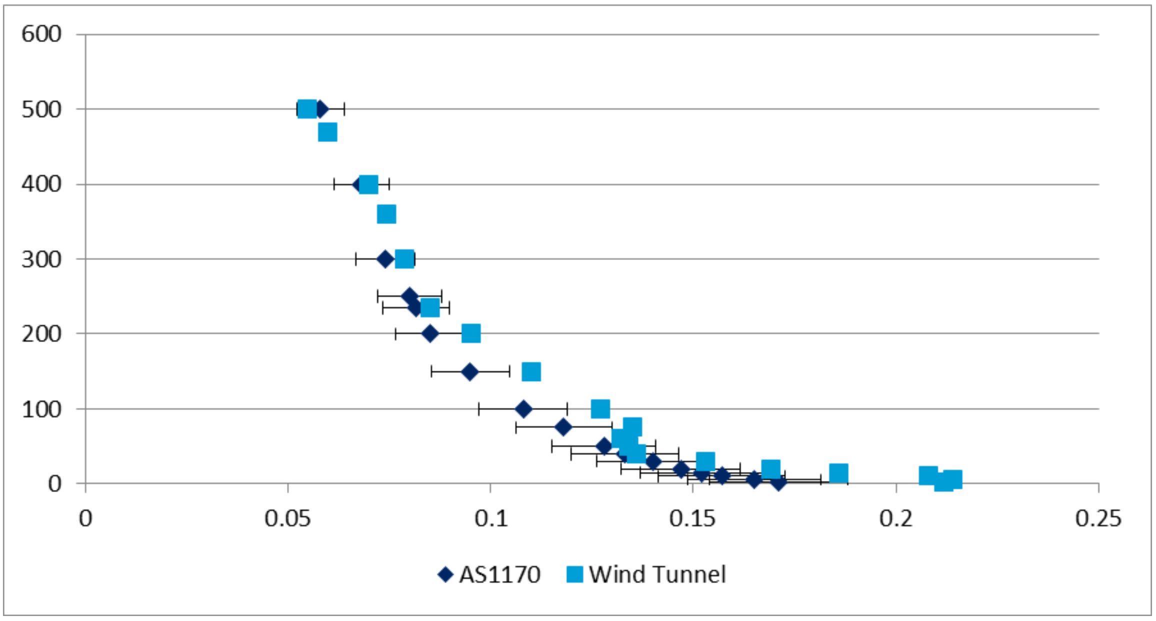

Figure B-2 Turbulence intensity profile for terrain category 1 comparison with AS1170.2:2011

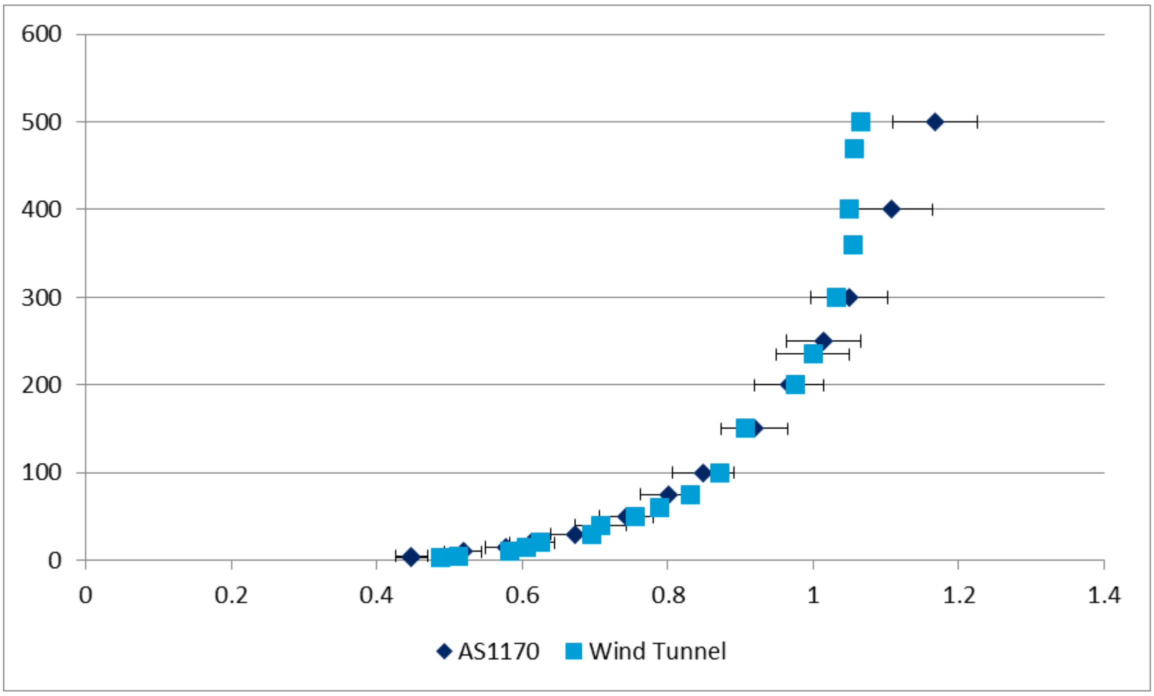

Figure B-3 Mean velocity profile for terrain category 3 comparison with AS1170.2:2011

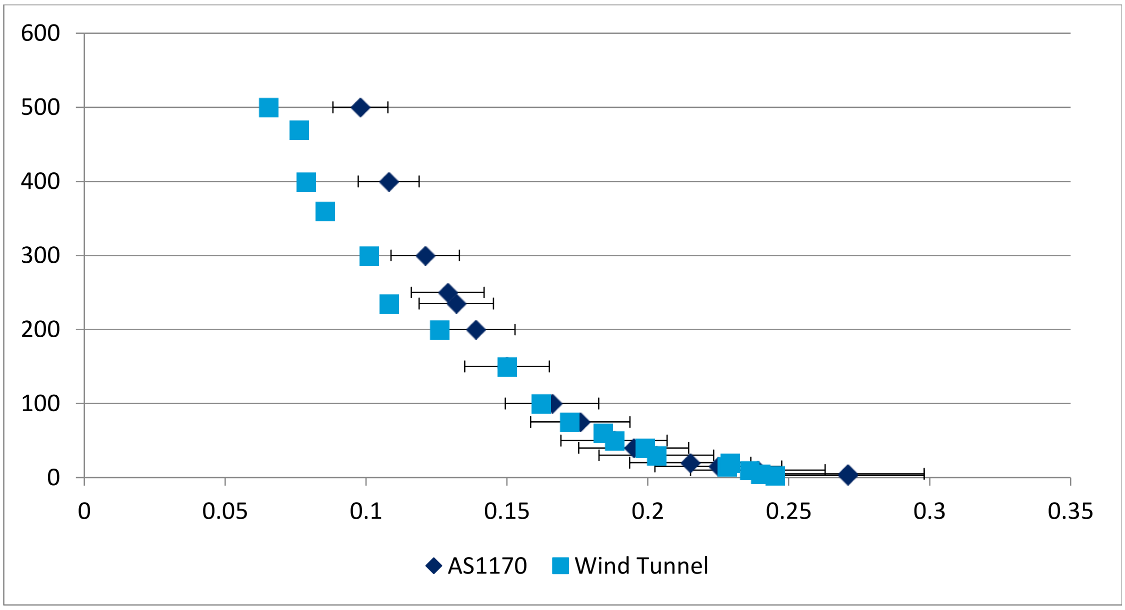

Figure B-4 Turbulence intensity profile for terrain category 3 comparison with AS1170.2:2011

B.3 Sensor calibration

Irwin sensors were used at various locations to determine the ground level wind speeds. These sensors were calibrated prior to their use in accordance with Irwin's 1980 paper, "A Simple Omnidirectional Sensor for Wind Tunnel Studies of Pedestrian Level Winds". The below equation describes the relationship between the measured pressure difference between the two parts of the sensor and the Reynolds number (Re) at the desired height (1.5 m). The velocity can then be calculated from the Reynolds number.

$$Re_{height} = A + B * \left(\frac{\Delta p h^2}{\rho v^2}\right)^C$$

where:

- ***A*** is a constant, taken as 85
- ***B*** is a constant, taken as 1.74
- ***C*** is a constant, taken as 0.5
- Δ***p*** is the difference in static pressures at the two measurement locations on each sensor
- ***h*** is the height of the probe, 1.8 mm
- ***ρ*** is the density of air, taken as 1.2 kg/m^3
- ***v*** is the kinematic viscosity, taken as $1.57x10^{-5}$ m^2/s.

The constants of the curve were found by fitting a power curve to the mean of the individual probe curves which were within 2% (in terms of static pressure) of each other. Probes that were outside this range but within 5% of the mean were kept and probes with responses outside 5% were not used.