A joint venture between Arcadis Australia Pty Ltd and Mott MacDonald Australia Pty Ltd

OSD Detailed SSD DA - WIND ENGINEERING: PUBLIC SAFETY AND COMFORT

Victoria Cross Over Station Development

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Prepared For – Lendlease Building Pty Limited | ABN 97 000 098 162

OSD Detailed SSD DA - WIND ENGINEERING: PUBLIC SAFETY AND COMFORT

Victoria Cross Over Station Development

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Changes made to this document since its last revision, which affect its scope or sense, are marked in the right margin by a vertical bar (|).

Date	Rev	Amendment Description	By
05/06/2019	A	Issued For Information	Neil Mackenzie
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Contents

1. Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) development application (DA) for a commercial mixed-use Over Station Development (OSD) above the new Sydney Metro Victoria Cross Station. The detailed SSD DA is consistent with the Concept Approval (SSD 17_8874) granted for the maximum building envelope on the site, as proposed to be modified.

The Minister for Planning, or their delegate, is the consent authority for the SSD DA and this application is lodged with the NSW Department of Planning, Industry and Environment (NSW DPIE) for assessment.

This report has been prepared in response to the requirements contained within the Secretary's Environmental Assessment Requirements (SEARs) dated 6 May 2019. Specifically, this report has been prepared to respond to the following SEARs:

The EIS shall:

> *'provide wind analysis, including wind tunnel testing, outlining the impacts to existing and proposed public domain areas and any terraces or useable outdoor space within the proposal'*

This report has also been prepared in response to the following condition of consent for the State Significant Development Concept (SSD 8874) for the OSD

Wind Impacts

B6. *The detailed development application shall be accompanied by a Wind Impact Assessment including computer modelling of the detailed building form. Compliance shall be demonstrated with the Lawson wind comfort criteria through the incorporation of mitigation measures within the detailed design.*

The detailed SSD DA seeks development consent for:

- Construction of a new commercial office tower with a maximum building height of RL 230 or 168 metres (approximately 42 storeys).
- The commercial tower includes a maximum GFA of approximately 61,500sqm, excluding floor space approved in the CSSI
- Integration with the approved CSSI proposal including though not limited to:
  - Structures, mechanical and electronic systems, and services; and
  - Vertical transfers;
- Use of spaces within the CSSI 'metro box' building envelope for the purposes of:
  - Retail tenancies;
  - Commercial office lobbies and space;
  - 161 car parking spaces within the basement for the purposes of the commercial office and retail use;
  - End of trip facilities; and
  - Loading and services access.
- Utilities and services provision.

- Signage locations (building identification signs).
- Stratum subdivision (staged).

1.1 The site

The site is generally described as 155-167 Miller Street, 181 Miller Street, 187-189 Miller Street, and part of 65 Berry Street, North Sydney (the site). The site occupies various addresses/allotments and is legally described as follows:

- 155-167 Miller Street (SP 35644) (which incorporates lots 40 and 41 of Strata Plan 81092 and lots 37, 38 and 39 of Strata Plan 79612)
- 181 Miller Street (Lot 15/DP 69345, Lot 1 & 2/DP 123056, Lot 10/DP 70667)
- 187 Miller Street (Lot A/DP 160018)
- 189 Miller Street (Lot 1/DP 633088)
- Formerly part 65 Berry Street (Lot 1/DP 1230458)

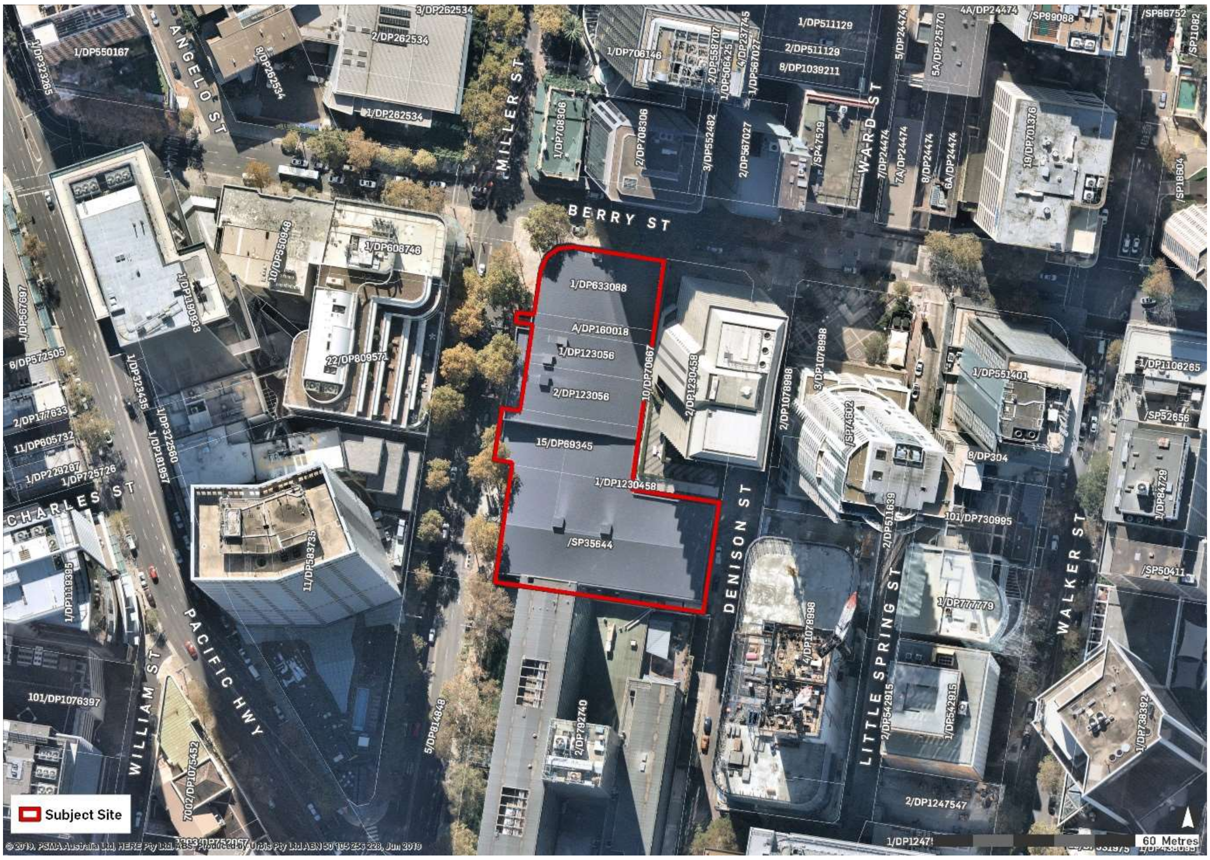


Figure 1 – Site Aerial

1.2 Sydney Metro description

Sydney Metro is Australia's biggest public transport project. Services started in May 2019 in the city's North West with a train every four minutes in the peak. Metro rail will be extended into the CBD and beyond to Bankstown in 2024. There will be new metro railway stations underground at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, Waterloo and new metro platforms under Central.

In 2024, Sydney will have 31 metro railway stations and a 66 km standalone metro railway system – the biggest urban rail project in Australian history. There will be ultimate capacity for a metro train every two minutes in each direction under the Sydney city centre. The Sydney Metro project is illustrated in the Figure below.

On 9 January 2017, the Minister for Planning approved the Sydney Metro City & Southwest - Chatswood to Sydenham project as a Critical State Significant Infrastructure project (reference SSI 15_7400) (CSSI Approval). The terms of the CSSI Approval includes all works required to construct the Sydney Metro Victoria Cross Station, including the demolition of existing buildings and structures on both sites. The CSSI Approval also includes construction of below and above ground improvements with the metro station structure for appropriate integration with the OSD.

With regards to CSSI related works, any changes to the "metro box envelope" and public domain will be pursued in satisfaction of the CSSI conditions of approval and do not form part of the scope of the detailed SSD DA for the OSD.

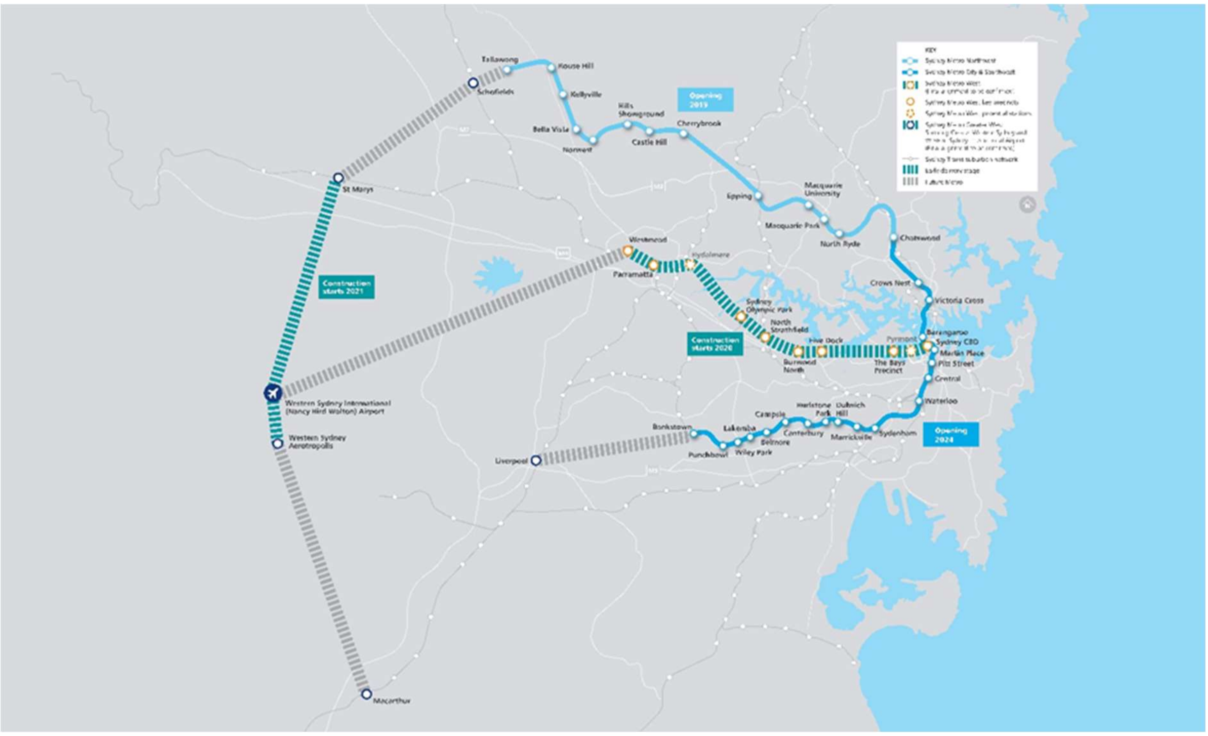


Figure 2 – Sydney Metro Alignment Map. Source: Sydney Metro

2. Assessment Criteria

This report assesses pedestrian safety and comfort at the site against the criteria outlined in this section. These criteria have been developed using the Lawson Criteria and analysis of areas of concern around the site.

2.1 Comfort

The Lawson comfort criteria (Lawson and Penwarden, 1975 amended with input from Isyumov and Davenport, 1975) are often used for wind comfort assessments in outdoor areas and are defined in Table 1. The commonly used Beaufort scale is also provided for comparison in Table 2. The Lawson criteria are used to assess wind force only and do not allow for variations in ambient temperature, solar radiation, and other environmental variables.

The comfort criteria (Lawson, 1978) are based on the exceedance of the threshold wind speeds occurring less than 5% of the time (approximately once per month during daylight hours). The value of 5% has been established as giving a reasonable allowance for extreme and relatively infrequent winds that are tolerable within each category. For example, if the mean hourly wind speed at a particular location is less than 4 m/s for 95% of the time then that location is classified as C4. On the Beaufort scale, 4 m/s is described as a gentle breeze. At the other extreme, if the wind speed exceeds 8 m/s more than 5 % of the time but exceeds 10m/s less than 5% of the time, then category C1 applies and the location would be considered windy though not necessarily unsafe. The Beaufort description of this would be a fresh breeze. A wind speed in excess of 10m/s more than 5% of the time would incur a category of C1+. Note that mean hourly wind speed is in terms of gust equivalent mean (GEM).

Table 1 Pedestrian Wind Comfort Criteria

Comfort rating	Description	Mean hourly wind speed	Appropriate area usage	Description of wind effects
C1+	Uncomfortable for all users	>10m/s	Uncomfortable for all uses	• Umbrellas difficult to use • Hair blown straight
C1	Fast or business walking	10m/s	Areas where people are not expected to linger	• Force of wind felt on body
C2	Leisurely walking	8 m/s	General walking or sightseeing	• Dust and papers raised • Hair disarranged
C3	Short period sitting/standing	6 m/s	Bus stops, building entrances	• Light leaves and twigs in motion • Lightweight flags extend
C4	Long period sitting/standing	4 m/s	Reading a newspaper, eating and drinking	• Light wind felt on face • Leaves rustle

Table 2 Beaufort scale

Beaufort number	Description	Mean hourly wind speed
0	Calm	0.3
1	Light air	0.3–1.5
2	Light breeze	1.6–3.3
3	Gentle breeze	3.4–5.4
4	Moderate breeze	5.5–7.9
5	Fresh breeze	8.0–10.7
6	Strong breeze	10.8–13.8
7	Near gale	13.9–17.1
8	Gale	17.2–20.7
9	Strong gale	20.8–24.4
10	Storm	24.5–28.4
11	Violent storm	28.5–32.6
12	Hurricane	32.7 and over

2.2 Safety

The pedestrian wind safety criteria are based on an exceedance once per annum during daylight hours. A mean hourly wind speed (as GEM) which is greater than 15 m/s but less than 20m/s which occurs once a year is classified as unsuitable for general public, which includes the elderly, cyclists and children. Able bodied users are those determined to experience distress when the wind speed exceeds 20m/s once per year.

Such safety criteria indicate the potential for danger during normal pedestrian activity, for example, a pedestrian crossing on a busy road, where the consequences of being blown over would be very serious. Other examples include access ways to hospitals and schools where the local pedestrian population is unlikely to cope safely with extreme winds.

Referring again to the Beaufort scale, S2 would be classified as gale force, S1 as strong gale force. Note that mean hourly wind speed is in terms of gust equivalent mean (GEM).

Table 3 Pedestrian Wind Safety Criteria

Safety rating	Description	Mean hourly wind speed
S1	Unsuitable for able bodied	20m/s
S2	Unsuitable for general public	15m/s

2.3 Project Specific Criteria

The areas shown in Figure 3 below have been considered relevant to the project site with the required comfort conditions nominated in Table 4. The wind comfort criteria selected for the project site have been proposed based on, similar projects of this nature, local area mapping and requirements, and the various conditions related to the different site uses, with the wind effects at the station entrances at Southern Metro entry and Denison Street concourse complying with the Lawson Comfort Criteria for Business walking criteria (C1).

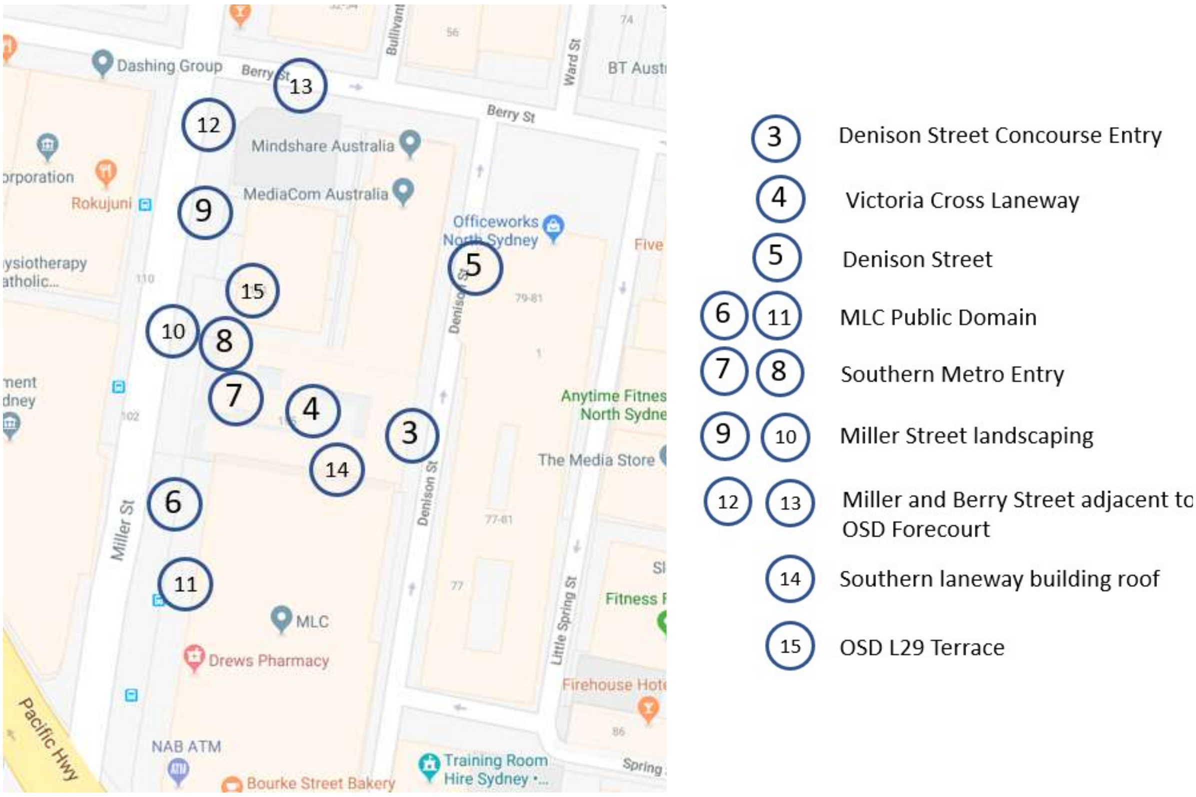


Figure 3 Areas Assessed

Table 4 Assessment Criteria

Location	Description	Criteria	Definition
3	Denison Street Concourse Entry	C1 (<10m/s)	Fast or business walking
4	Victoria Cross Laneway	C2 (<8m/s)	Leisurely walking
5	Denison Street	C1 (<10m/s)	Fast or business walking
6 & 11	MLC Public Domain	C4 (<4 m/s)	Long periods sitting/standing
7 & 8	Southern Metro Entry	C1 (<10m/s)	Fast or business walking
9 & 10	Miller Street	C3 (<6 m/s)	Short periods sitting/standing
12 & 13	Miller and Berry Street adjacent to OSD forecourt	C1 (<10m/s)	Fast or business walking
14	Southern laneway building roof	C4 (<4 m/s)	Long periods sitting/standing
15	OSD L29 Terrace	C3 (<6 m/s)	Short periods sitting/standing

3. Wind Effects

Wind flow patterns around a single wide high-rise building are indicated below in Figure 4.

As the wind flow approaches the building, it gradually diverges. Part of the flow is deviated over the building (1) and part of it flows around the building (2). At the windward facade, a stagnation point with maximum pressure is situated at approximately 70% of the building height. From this point, the flow is deviated to the lower pressure zones of the facade: upwards (3), side-wards (4) and downwards (5).

The considerable amount of air flowing downwards produces a vortex at ground level (6) called standing vortex, frontal vortex or horseshoe vortex. The main flow direction of the standing vortex near ground level is opposite to the direction of the approach flow. Where both flows meet, a stagnation point with low wind speed values is created at the ground in front of the building (7). The standing vortex stretches out sideways and sweeps around the building corners where flow separation occurs and corner streams with high wind speed values are created (8). The corner streams subsequently merge into the general flow around the corners (9).

At the leeward side of the building, an under-pressure zone is created. As a result, backflow or recirculation flow occurs (10,13). A stagnation zone is marked downstream of the building at ground level where the flow directions are opposite and low wind speeds exist (11; end of the recirculation zone). Beyond the stagnation zone, the flow resumes its normal direction but wind speeds stay low for a considerable distance behind the building (i.e. the far wake) (12).

The backflow is also responsible for the creation of slow rotating vortices behind the building (13). Between these vortices and the corner streams (9), a zone with a high velocity gradient exists (the shear layer) that comprises small, fast rotating vortices (16). The shear layers originate at the building corners where flow separation occurs.

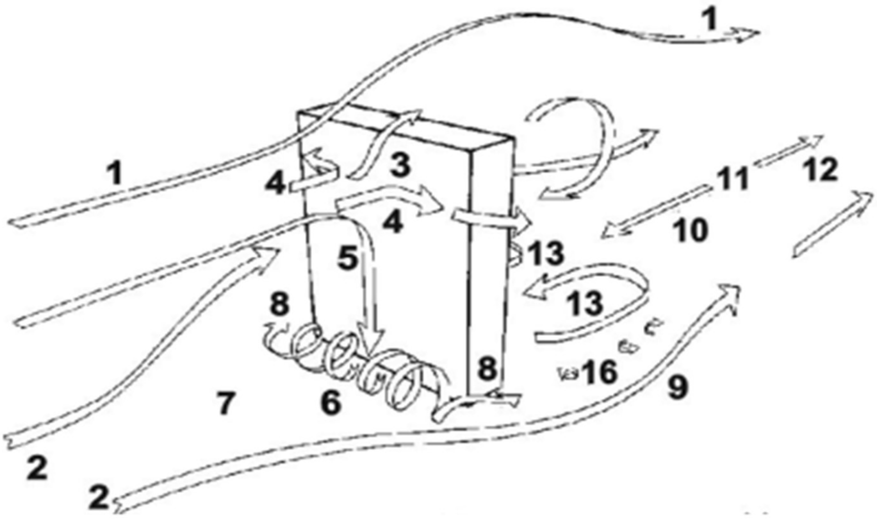


Figure 4 Wind effects around a building

4. Wind Climate

Wind is a highly variable meteorological element, both in speed and direction. It is influenced by a wide range of factors; from large scale pressure patterns to the time of day and the nature of the surrounding terrain. Because the wind is highly variable, it is often studied by means of frequency analyses of data from a particular observation site. Different statistical analysis methods have been used for the different criteria; a Weibull distribution for comfort conditions and Gumbel (with Gringorten correction) Extreme Value distribution for safety.

The wind data used for the assessment was acquired from the the Bureau of Meteorology's automatic weather station at Wedding Cake West, located within Sydney Harbour approximately 5.3km to the east of the site. Data has been scaled to the appropriate terrain category using methods as per AS1170.2:1989.

The wind rose for the Weibull distribution of the Wedding Cake West data is shown below in Figure 5. Winds are predominantly from the west and north, with wind speeds at 10m above ground level approaching 8m/s for 5% (95th percentile).

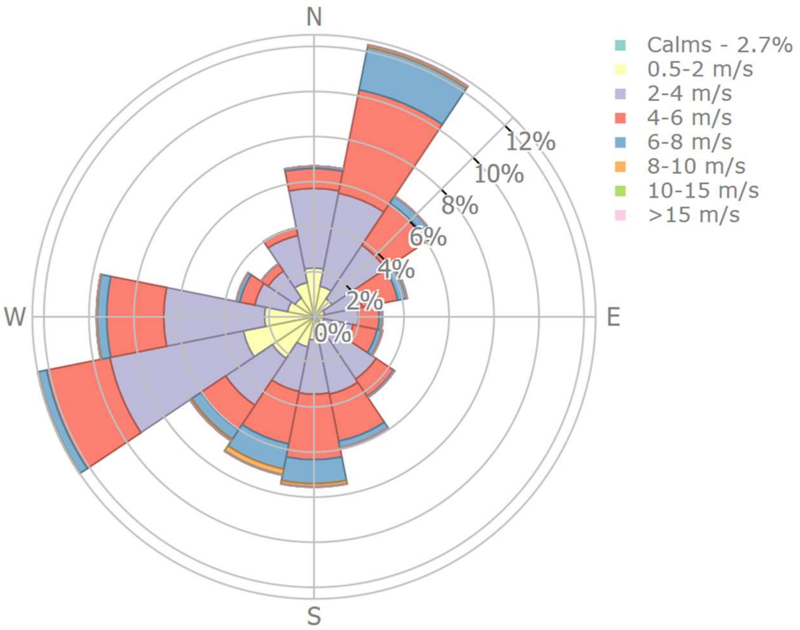


Figure 5 Wind rose for Wedding Cake West observation point

4.1 Weibull distribution

Wind speed probability during comfort conditions is commonly modelled using a Weibull distribution. The relative frequency data of wind speed and wind direction can be represented by a Weibull distribution, where the probability of the wind speed exceeding a speed, V, for any given direction, θ, is given by:

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

where $k(\theta)$ and $C(\theta)$ are Weibull coefficients for the azimuth sector, θ , and $A(\theta)$ is the marginal probability of the wind direction being within the azimuth sector. The following holds true:

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

And therefore the exceedance probability is given by:

$$P(>V) = \sum_{all\,sectors} A(\theta)e^{-[V/C(\theta)]^{k(\theta)}}$$

The Weibull coefficients obtained from the Wedding Cake West weather station data are shown below in Table 5.

4.1 Extreme Value distribution

Extreme Value analyses are used to describe events of infrequently high wind speed for assessment of pedestrian safety. From each of the hourly observations, maximum daily wind speeds were determined and the then daily maximums for each year of data identified to generate coefficients for a type 1 Gumbel (with Gringorten correction) Extreme Value distribution, given by:

$$F\,(V,\theta) = A(\theta)\exp(-\exp[-\frac{V-U(\theta)}{a(\theta)}])$$

Here $U(\theta)$ and $a(\theta)$ are the coefficients for the azimuth sector θ, shown in Table 5.

Table 5 Weibull and Extreme Value Distribution Coefficients

Sector	Weibull		Extreme	
	k(θ)	C(θ)	U(θ)	a(θ)
N	2.315	3.072	5.4495	0.7437
NNE	2.750	4.786	7.7057	0.4957
NE	2.744	4.183	6.2089	0.7845
ENE	2.769	4.606	6.5562	1.031
E	2.691	4.159	5.7893	0.9591
ESE	2.710	4.416	6.2648	0.9311
SE	3.003	3.604	5.1381	0.5227
SSE	2.890	4.170	6.096	0.6826
S	2.597	4.803	7.8211	0.7102
SSW	2.187	4.805	8.0234	0.7653
SW	1.860	3.619	6.9875	0.8429
WSW	2.357	3.525	6.6886	0.6245
W	2.358	3.738	6.8842	0.6188
WNW	2.001	3.416	5.7973	0.8503
NW	2.383	3.011	4.7891	0.4543
NNW	2.374	2.817	4.5282	0.7571

5. Wind and Site Simulation

Wind tunnel simulation of the atmospheric boundary layer requires the basic characteristics of the natural wind to be modeled at a reduced scale. The natural wind at a given site possesses the characteristics of the approach flow, modified by adjacent natural (topographic) and man-made features which give rise to the “near-field” flow. Accurate modelling of the approach flow and near-field flow is therefore required.

5.1 Wind tunnel

Measurements were carried out using the atmospheric boundary layer wind tunnel at The University of Sydney. The tunnel has a test width of 2.5m, a turntable of diameter 2.4m, and a development length of approximately 15-20m. The turbulent boundary layer is established using a trip board, and roughness elements over the development length.

5.2 Modelling of the approach flow

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

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

The mean speed and turbulence intensity in the approach flow shall be modeled to within 10% of their target values. The integral scale shall be within a factor of 3 of the value determined from the chosen geometric scaling ratio (1:400 in this case).

A suitable model of the atmospheric boundary layer is given by Deaves and Harris (1978), which is incorporated in AS1170.2. This model uses a logarithmic law to describe the mean wind speed profile with the roughness length being the main parameter.

AS1170.2 defines the development length for a structure of 150m height as 6000m, with a “lag distance” of 3000m over which the terrain shall be ignored. The terrain categories used to simulate the approach flows were selected using the definitions in Table 6 below. The corresponding directions for each terrain category selected are shown below in Figure 6.

Table 6 Description of terrain categories used to simulate approach flows

Terrain Category (AS 1170.2)	Definition [Roughness Length]
2	Grassland with few, well-scattered obstructions having heights generally from 1.5m to 10m. [0.02 m]
3	Terrain with numerous closely spaced obstructions 3m to 5m high such as areas of suburban housing. [0.2 m]

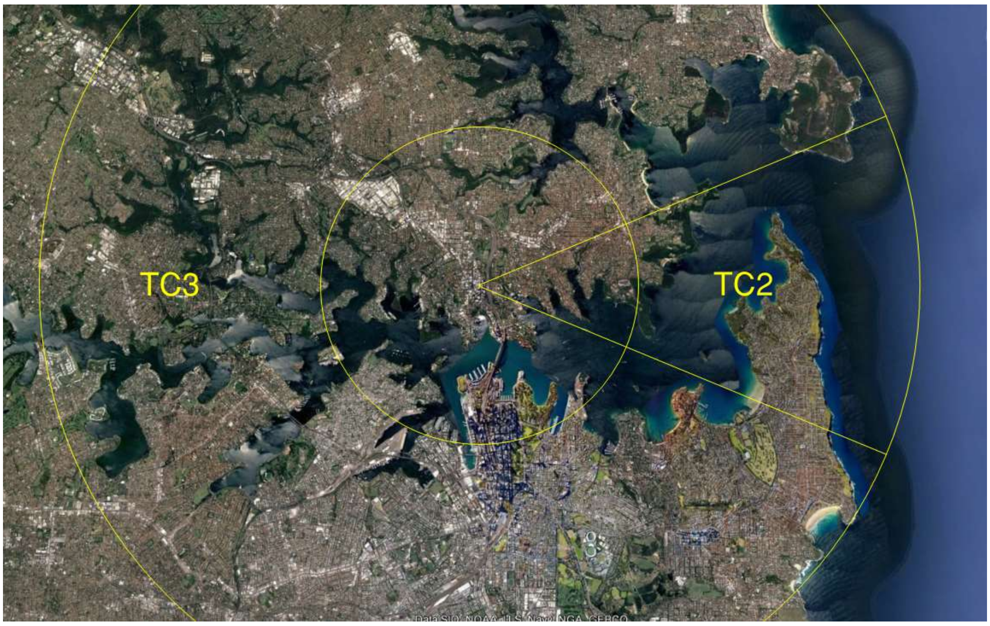


Figure 6 Definition of terrain categories

Confirmation that the wind tunnel adequately models, for each terrain category, the variation of mean wind speed with height and the variation of longitudinal component of turbulence with height is provided in Appendix A.

5.3 Modelling of the near-field flow

Physical features, such as significant buildings, structures or topography, will 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 modeled to the correct scale, to an accuracy of 10% or better.

A survey of the site was carried out to acquire information on the footprint, form and height of all buildings within 400 m of the site. Surrounding physical features within a radius of 450m were then modelled to the required accuracy. The figures overleaf show the wind tunnel model of the site and its and surroundings, which constructed from expanded polystyrene.

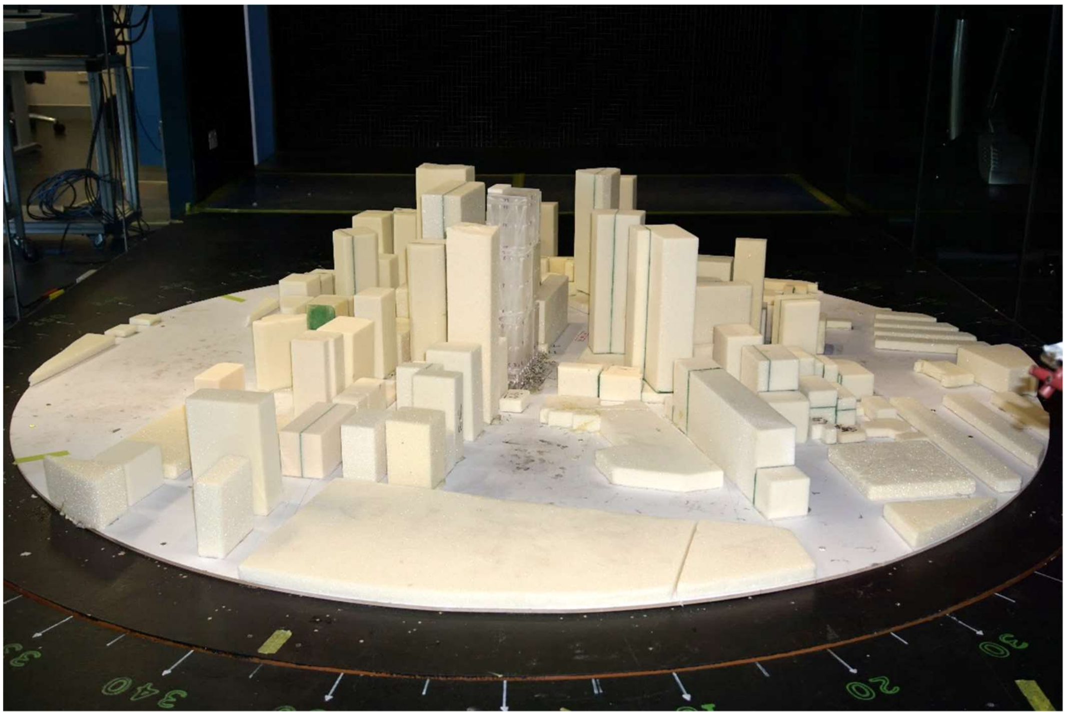


Figure 7 Wind tunnel model north view

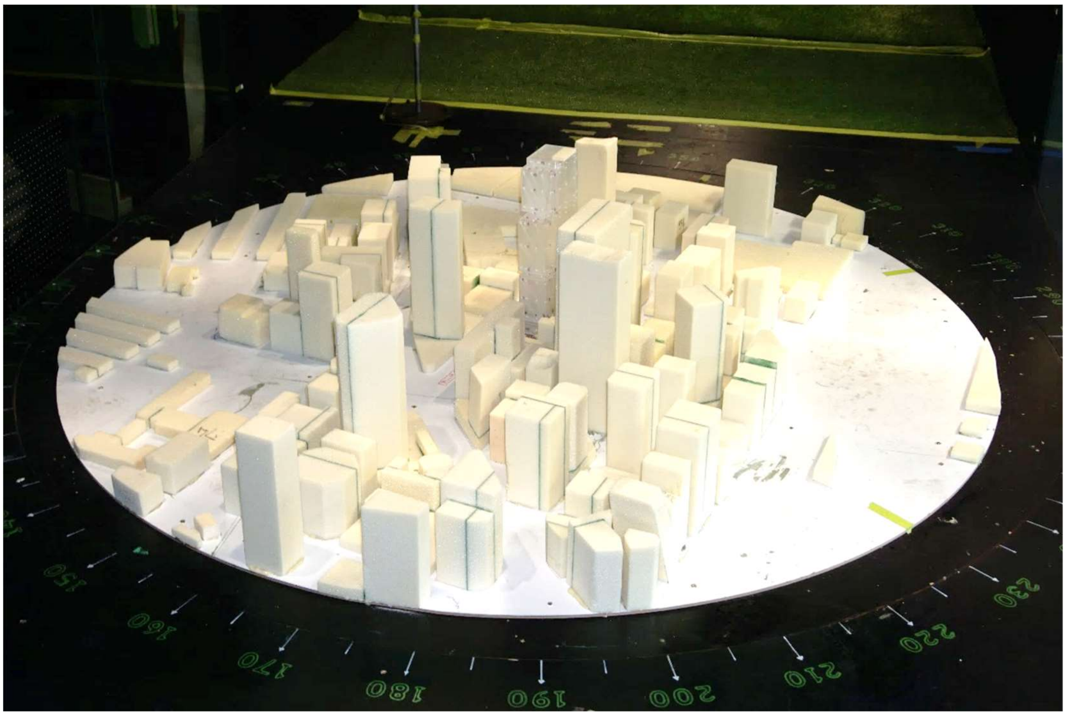


Figure 8 Wind tunnel model south view

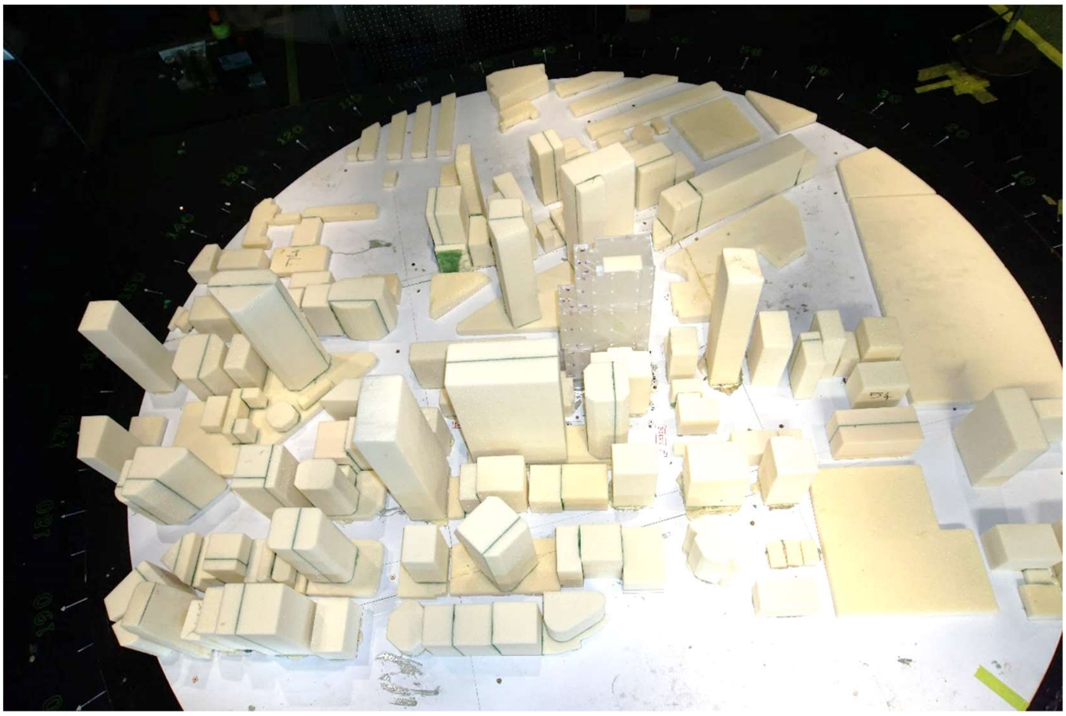


Figure 9 Wind tunnel model east view

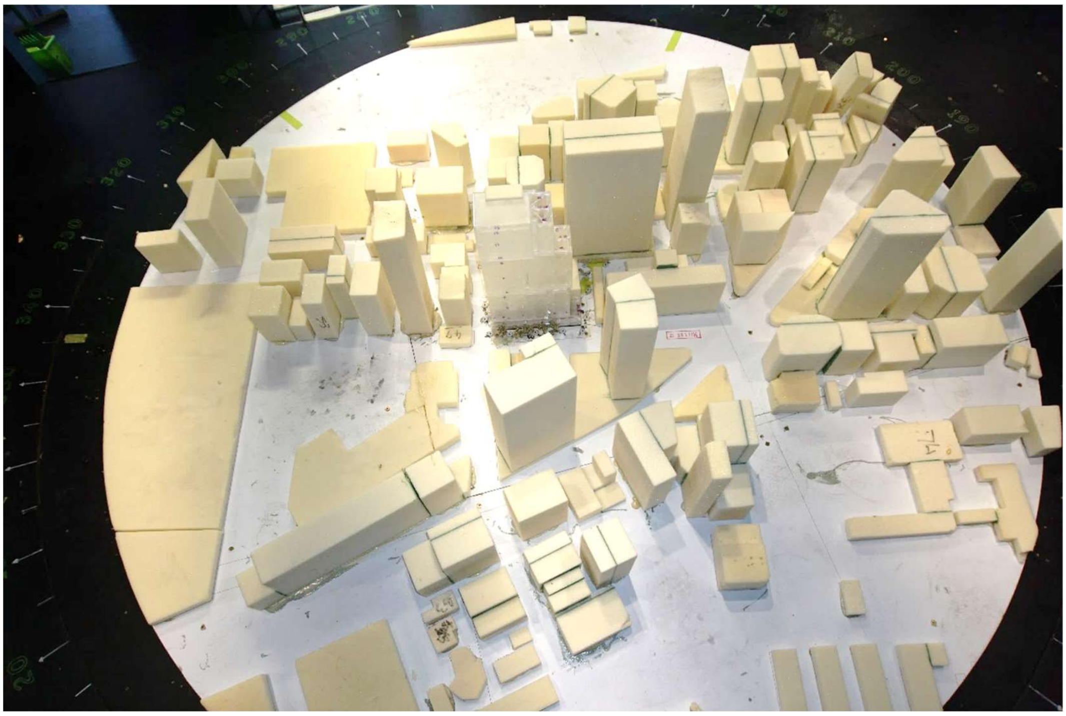


Figure 10 Wind tunnel model west view

Figure 11 Wind tunnel model detail view of Irwin sensors

5.4 Scaling laws

For the atmospheric conditions to be accurately modelled, the modelled conditions must be scaled appropriately. The geometric, velocity, time and frequency scales were determined as follows.

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

$$L = \frac{(z_0)m}{(z_0)p} = \frac{(L_u)m}{(L_u)p} = 1:400$$

- Velocity scale: The wind tunnel reference mean velocity was chosen as approximately 12 m/s to maximise the sensitivity of the measurement instrumentation. The velocity scale for the simulation was (with a design mean wind speed of approximately 24m/s):

$$V = \frac{(V_{ref})m}{(V_{ref})p} = 0.5$$

In addition, the following scales are necessary to determine wind tunnel instrumentation sampling and frequency response characteristics:

- Time scale:

$$T = \frac{\mathrm{L}}{V} = \frac{t_m}{t_p} = 1{:}\,200$$

- Frequency scale:

$$F = \frac{1}{T} = \frac{f_m}{f_p} = 200{:}\,1$$

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

- This rate corresponds to approximately 5 Hz in full-scale, which will allow pressure fluctuations with frequencies up to approximately 2.5 Hz (full-scale) to be determined without distortion or attenuation.

A sampling duration of 60 seconds was used for the following reasons:

- It ensures measured maxima and minima provide representative estimates of peaks encountered during a full-scale interval of over one hour.
- It provides a statistically stable estimate of the mean and RMS pressures (otherwise affected by the turbulence intensity being at approximately 15% at the height of the pitot tube).

6. Method

To measure the ground-level wind speeds across all relevant locations on the site, an array of sensors is used. Consideration must be made when selecting the sensing and logging equipment, sensor locations and ensuring correct calibration in order to obtain accurate measurements.

For the analysis, Irwin sensors were used to obtain measurements at twenty different locations around the site. After applying calibration factors and obtaining the measured wind speeds, statistical methods were used to determine the site ground-level wind speeds at each location for the comfort and safety exceedance probabilities.

6.1 Sensor locations

The location and number of Irwin sensors were selected in order to capture measurements of the flow surrounding the areas of concern defined in Section 2.3. Their locations are shown below in Figure 12.

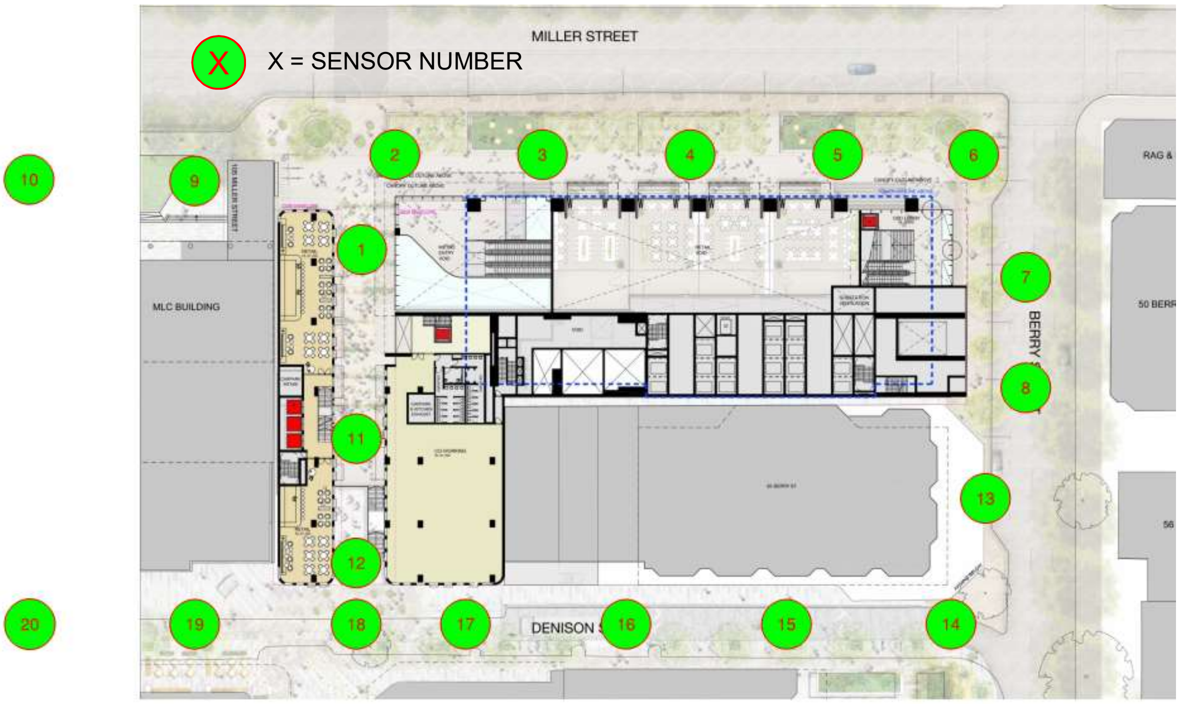


Figure 12 Sensor locations

Figure 13 Irwin sensor locations (clockwise fom top left: cnr Miller St and laneway, cnr Berry St and Miller St, laneway, Denison St)

6.2 Sensor calibration

Sensor calibration was conducted to ensure the accuracy and validity of measurements taken.

All pressure taps were zeroed (calibrated at zero tunnel speed) after at most 30 minutes of tunnel running.

Separate calibration adjustments are also made for each Irwin sensor. The relationship between the actual dynamic pressure and measured dynamic pressure for each sensor is linear. I.e.

$$p_{dyn} = slope \times p_{dyn,measured} + intercept$$

With the calibration slope and intercept known for each sensor, *i*, the velocities were obtained using the equation below:

$$v_i = \sqrt{\frac{2}{\rho}\left(slope_i \times \left(p_{t,i} - p_{s,i}\right) + intercept_i\right)}$$

6.3 Test methodology

Measurements from the sensor array were taken for the full 360° azimuth range at 10° intervals, as required by AWES. 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 and height of 0.5m (200m full-scale) (see Figure 15). 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 pedestrian-level wind speeds. The following method is used for the analysis:

1. Ground-level wind speeds are obtained from the calibrated Irwin sensor data.
2. Mean of these ground-level wind speeds for each 60-second test are calculated.
3. The mean ground-level wind speeds are translated to reference level using the measured speed ratios for each direction.
4. The probability of exceedance of the reference speed is determined for each direction (refer Section 4).
5. The total probability of exceeding a given ground-level wind speed is determined.
6. The ground-level wind speed is varied to achieve an exceedance probability of 5% (comfort) and 0.02% (safety).
7. These speeds are compared to the pedestrian comfort and safety criteria (refer Section 2)

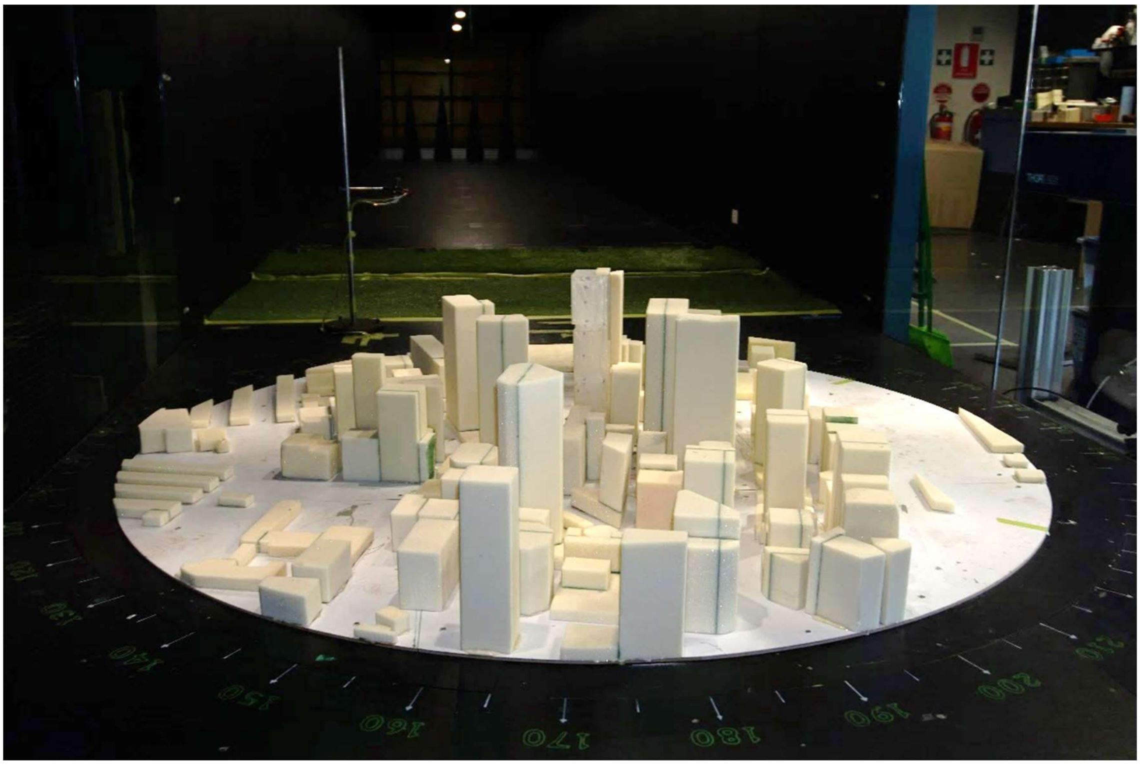


Figure 14 Tunnel setup showing Pitot-static tube for reference velocity measurement

7. Results

Results of the analysis are displayed in the figures and tables below. The wind speeds for both exceedance probabilities (5% for comfort, once in one year for safety) at each location are tabulated in Table 7. Figure 15 shows the test results for the comfort criteria (5% exceedance probability wind speeds against C4 – C1+ criteria) at each of the sensor locations. Figure 16 shows the test results for the safety criteria (once in one year exceedance probability against S1-S2 criteria) at each of the sensor locations.

Table 7 Comfort and Safety values for each sensor location

Sensor number	Comfort wind speed (m/s)	Safety wind speed (m/s)
1	3.9	5.7
2	4.1	5.7
3	3.5	4.9
4	2.2	3.0
5	3.5	4.8
6	4.6	6.1
7	5.8	8.4
8	5.9	8.0
9	3.4	4.8
10	4.5	6.5
11	5.6	8.8
12	8.2	13
13	3.0	4.1
14	5.1	7.9
15	6.8	11
16	6.8	11
17	6.3	9.1
18	4.5	6.0
19	3.5	4.9
20	3.1	4.3

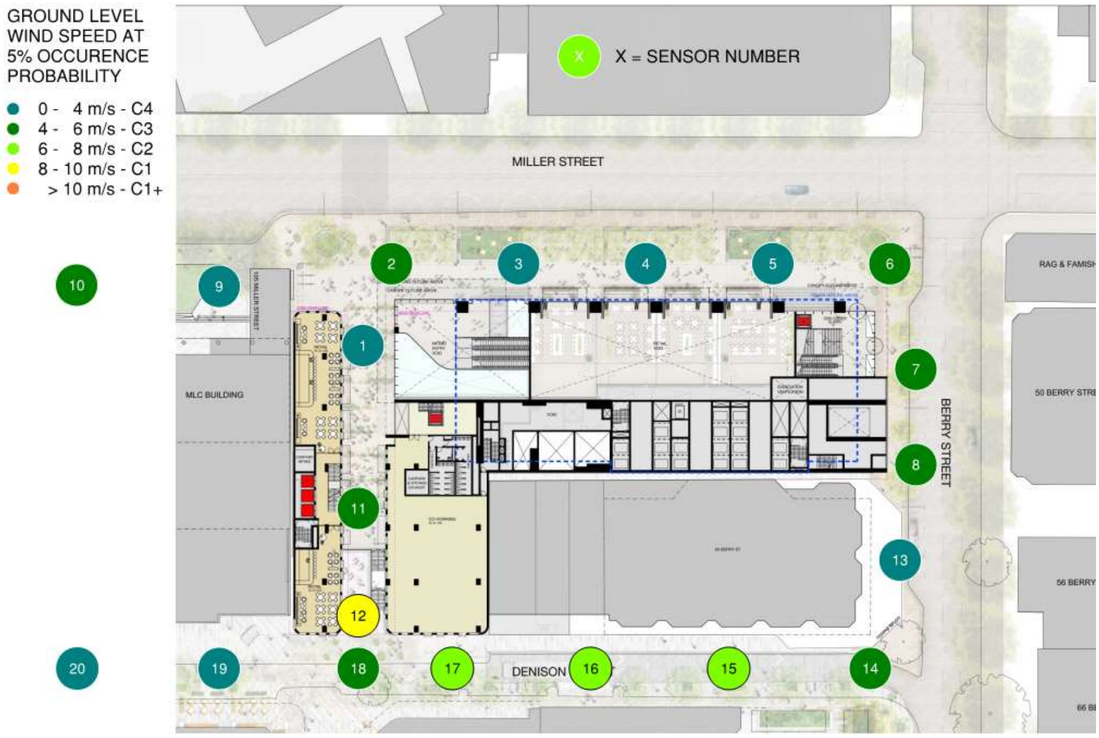


Figure 15 Comfort criteria: ground-level wind speeds, occurrence probability of 5%

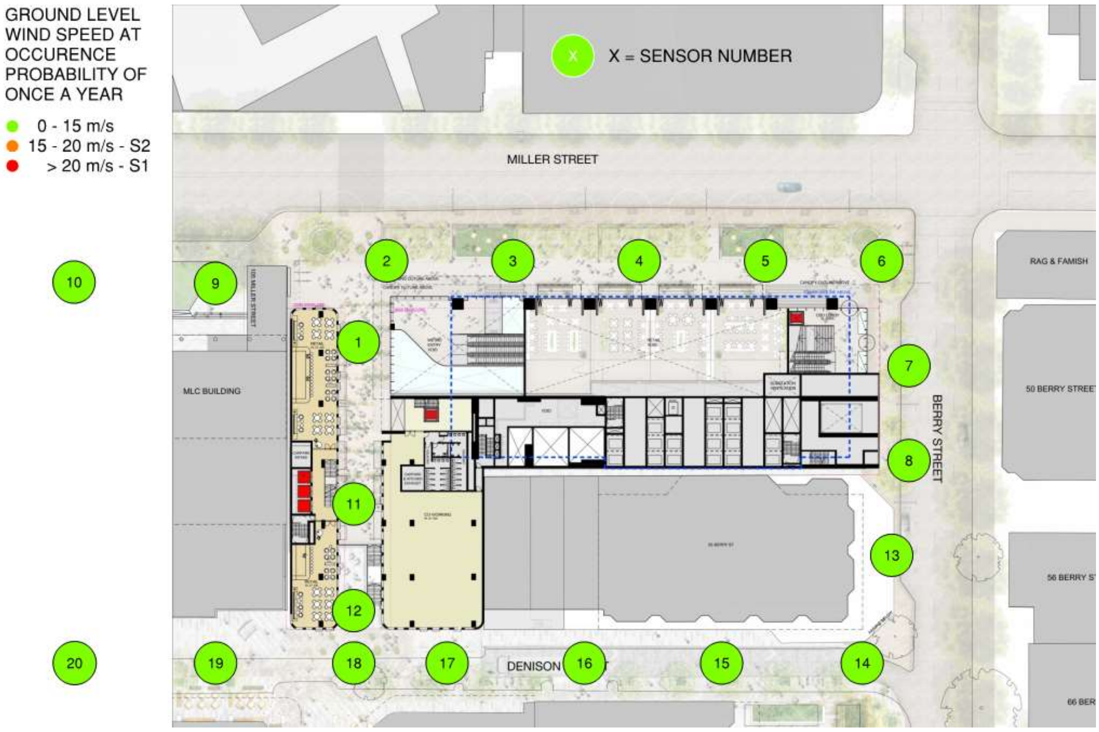


Figure 16 Safety criteria: ground-level wind speeds, occurrence probability of once per year

8. Assessment

From the tables and figures shown in Section 7, the results are assessed against the criteria outlined in Section 2. Comfort wind speeds are compared with the comfort assessment criteria for the areas of concern (refer Table 4) in Table 8. Comfort criteria of C1 or lower (10m/s, acceptable for fast or business walking) are achieved at all locations. Safety wind speeds are below below the S2 safety criteria at all locations, with the highest speed of 13m/s reached at sensor number 12.

Table 8 Comfort Rating

Location	Description	Sensor	Result	Criteria
3	Denison Street Concourse Entry	12	5.6	C1 (<10m/s)
4	Victoria Cross Laneway	11	2.2	C2 (<8m/s)
5	Denison Street	14-20	5.2	C1 (<10m/s)
6 & 11	MLC Public Domain	9,10	3.9	C4 (<4 m/s)
7 & 8	Southern Metro Entry	1,2	4.0	C1 (<10m/s)
9 & 10	Miller Street	3-5	3.0	C3 (<6 m/s)
12 & 13	Miller and Berry Street adjacent to OSD forecourt	6-8	5.4	C1 (<10m/s)
14	Southern laneway building roof	(*)	<2	C4 (<4 m/s)
15	OSD L29 Terrace	(*)	<6	C3 (<6 m/s)

(*) Assessed using Computational Fluid Dynamics (CFD) as noted in "OSD Section 4.55 Modification – wind report"

9. Summary & Conclusion

Wind effects on the public domain and roof terraces have been assessed as a result of the proposed Over Station Development (OSD) at Victoria Cross Station.

A physical scale model of the tower was constructed at 1:400, with the surrounding built environment included in the model to a radius of 500m full-scale. Approach wind profiles were established using roughness elements as required. Irwin sensors were used to measure wind speed at locations of interest relative to a reference point.

Some areas (eg. Roof terraces) were assessed in detail using Computational Fluid Dynamics (CFD) rather than physical modelling.

For each direction tested, measured and predicted wind speeds relative to a reference point were combined with statistics of wind speed and direction for the site. From this analysis, the wind speed exceeded for 5% of the time and annually was determined and compared with appropriate criteria based on intended use.

It was demonstrated that the Proposed Design complies with the criteria appropriate for the intended use at all areas of interest. Compliance is achieved through the use of awnings and landscape features deliberately introduced to mitigate wind effects. No additional mitigation was warranted.

10. References

Australasian Wind Engineering Society, “Wind Engineering Studies of Buildings”, AWES-QAM-1-2001

Bureau of Meteorology, Historical Wind Data, Wedding Cake West (station 066196)

Deaves and Harris, 1978, “A mathematical model of the structure of strong winds”, CIRIA, London

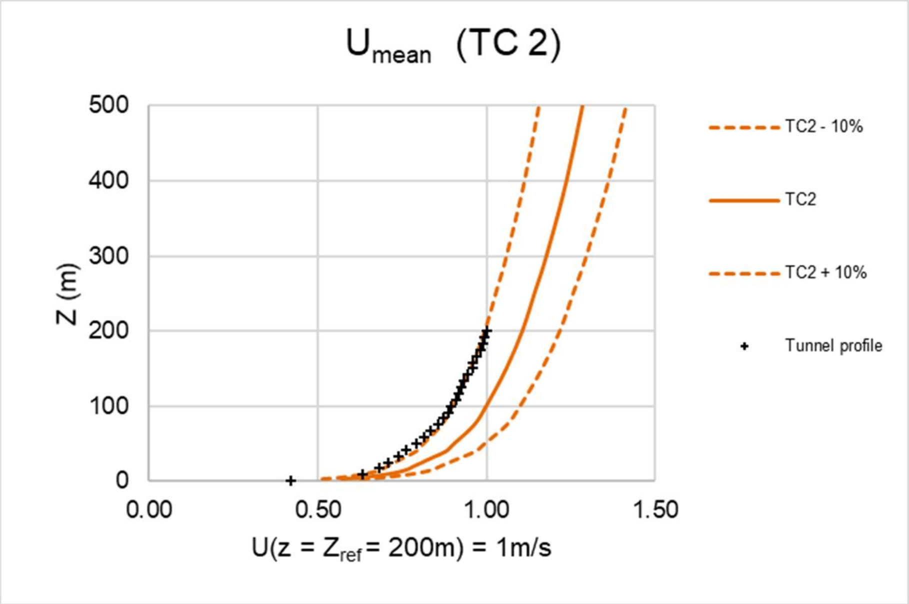
Lawson, T, and Penwarden, A, 1976, "The Effects of Wind on People in the Vicinity of Buildings," Proceedings of the Fourth International Conference on Wind Effects on Buildings and Structures. Cambridge University Press, U.K. pp. 605-622.

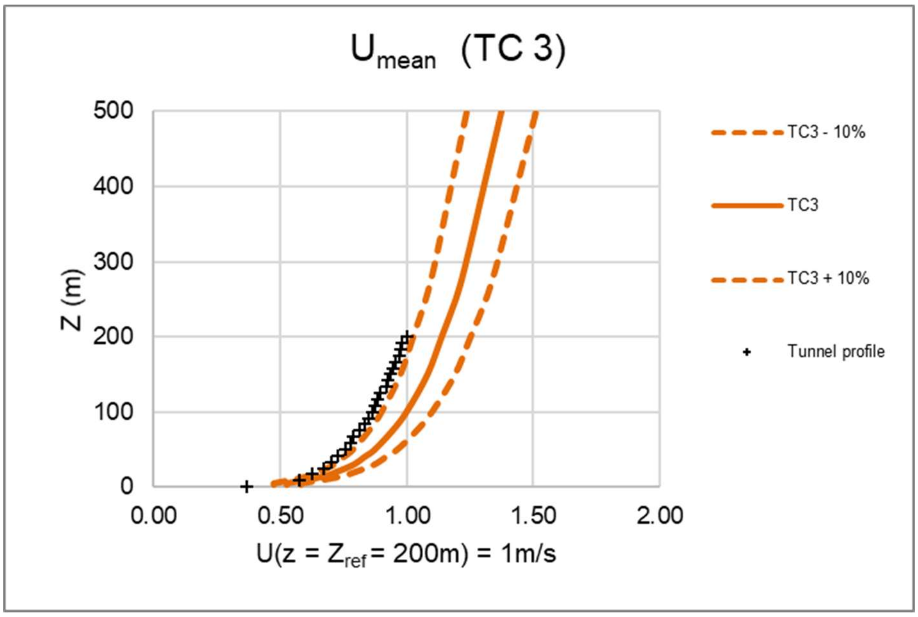
Standards Australia 1989, Minimum design loads on structures (known as the SAA Loading Code), Part 2: Wind Loads, AS 1170.2-1989

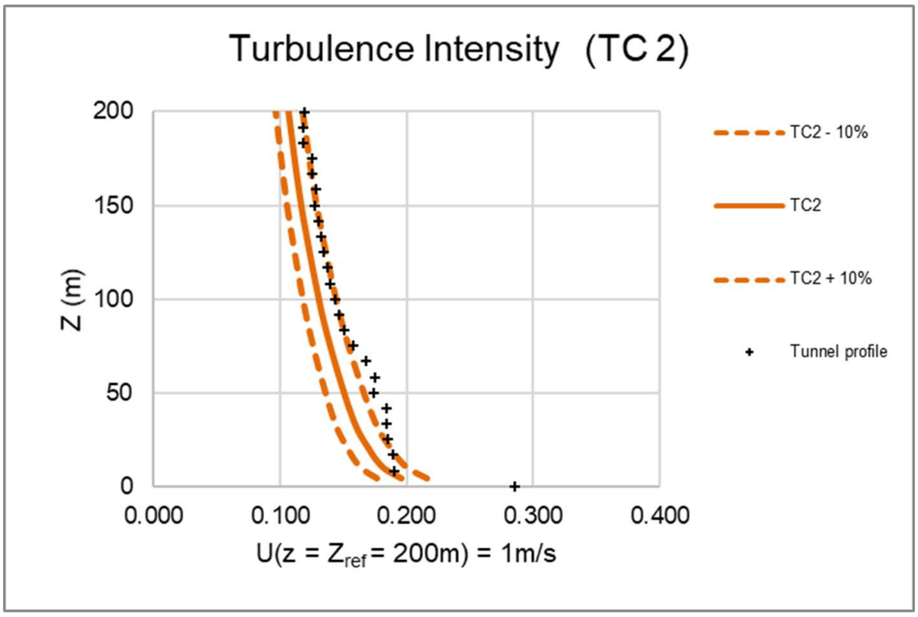
Standards Australia 2011, Structural Design Actions, Part 2: Wind Actions, AS 1170.2:2011

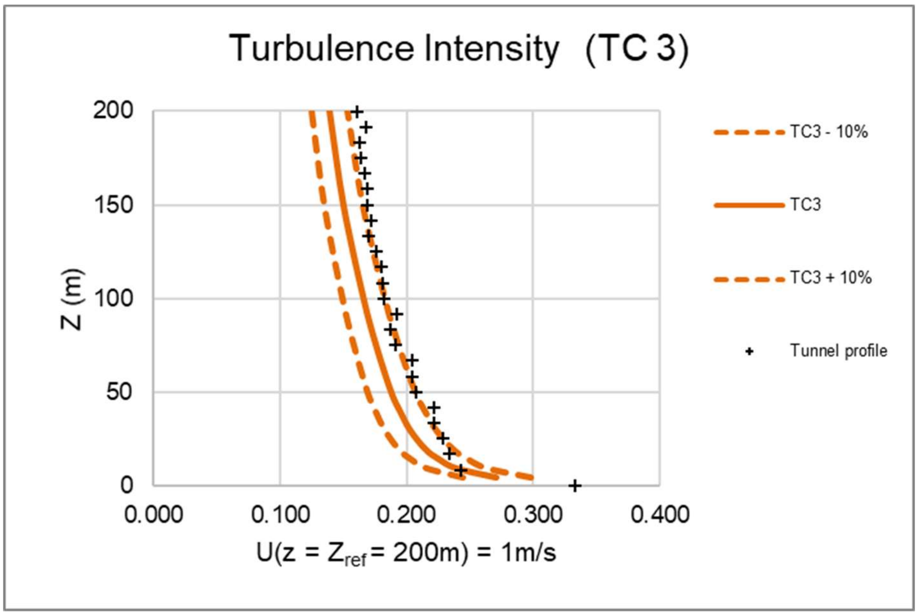
Appendices

A. Wind Tunnel Calibration






Turbulence Intensity (TC 2)
200
150
100
50
0
Z (m)
0.000
0.100
0.200
0.300
0.400
U(z = Z_ref = 200m) = 1m/s
TC2 - 10%
TC2
TC2 + 10%
Tunnel profile


Turbulence Intensity (TC 3)
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150
100
50
0
Z (m)
0.000
0.100
0.200
0.300
0.400
U(z = Z_ref = 200m) = 1m/s
TC3 - 10%
TC3
TC3 + 10%
Tunnel profile