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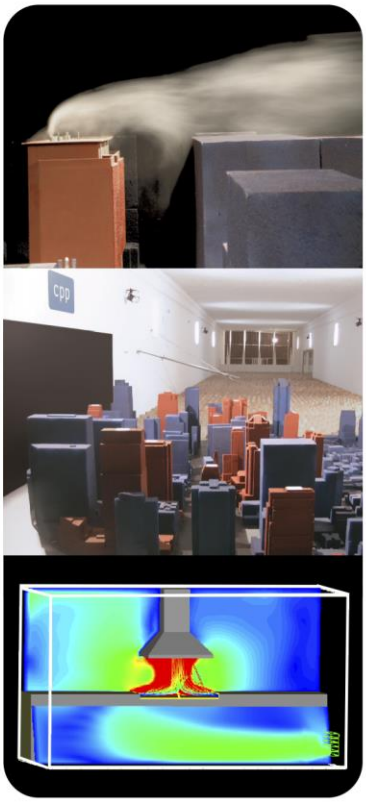
Final Report



Pedestrian Wind Tunnel Tests for:

388 Pitt St

Sydney NSW

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This report supports a Stage Significant Development Application (SSDA) for the mixed use redevelopment of 338 Pitt Street, Sydney, which is submitted to the City of Sydney pursuant to *Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). China Centre Development Pty Ltd is the proponent of the SSDA.*

The site is located at the corner of Pitt Street and Liverpool Street, within the 'Mid Town' precinct of Sydney's Central Business District (CBD). The site is approximately 150m west of Museum Station and Hyde Park, and approximately 350m from Town Hall Station. The site includes several allotments and constitutes nearly one third of the city block between Bathurst Street, Pitt Street and Liverpool Street. The site is an irregular shape and has a combined area of approximately 5,900m².

The proposed development comprises of hotel, residential, commercial and retail uses and will include:

- *demolition of all existing structures;*
- *excavation and site preparation, including any required remediation;*
- *construction and use of a mixed-use development, with an iconic 258m two-tower built form above a podium and internal courtyard;*
- *four (4) basement levels and a lower ground level accommodating residential, retail and hotel car parking, motorcycle parking, bicycle parking, loading dock, storage and relevant building services;*
- *improvements to the public domain, including landscaping, pedestrian thoroughfares/connections, and landscaping; and*
- *augmentation and extension of utilities and services.*

A detailed description of development is provided by Ethos Urban within the EIS.

The following table summarises the requirements of the SEARS relevant to this report:

Key issues	Requirement	Relevant Report Section
1. Statutory and Strategic context	Address the statutory provisions applying to the development contained in all relevant environmental planning instruments, including: Sydney Development Control Plan 2012.	Section 3
5. Amenity	A Wind Impact Assessment, including wind tunnel testing of any wind impacts of the proposal on the public domain and all landscape areas on upper levels (using the assessment criteria for sitting)	Sections 4, 5, and 6

EXECUTIVE SUMMARY

A preliminary wind tunnel study of the proposed 388 Pitt St development to be located in Sydney NSW was conducted to assess the pedestrian wind environment in and around the development site. A model of the project was fabricated to a 1:400 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 570 m radius were constructed and placed on the turntable.

The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. Approach boundary layers, representative of the environment surrounding the proposed development, were established in the test section of the wind tunnel. The approach wind flow had appropriate turbulence characteristics corresponding to a Suburban Approach as defined in Standards Australia (2011).

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 11 locations for 16 wind directions each. These points were tested around the development in the proposed configuration, focusing on access routes and outdoor pedestrian areas. The measurements were combined with site specific wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location. Additional wind tunnel results from the surrounding area were included in the assessment.

The wind conditions around the ground plane of proposed development were found to be generally suitable for pedestrian walking activities from a comfort perspective with reference to the Lawson comfort criteria. All locations on the ground plane passed the Lawson distress criteria.

Wind conditions on the sky bridge were also investigated and were found to be classified as uncomfortable or suitable for business walking only. All sky bridge locations exceeded the distress criterion due to exposed nature of these locations. An assessment of the podium roof terraces was also made based on available data.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
28/01/20	Final Report	JS	AVD	TXE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

D	Characteristic dimension (building height, width, etc.), m
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{rms}/U
U	Local mean velocity, m/s
U_{ref}	Reference mean velocity at reference height z_{ref}, m/s
U_{pk}	Peak wind speed in pedestrian studies, m/s
U_{rms}	Root-mean-square of fluctuating velocity, m/s
z	Height above surface, m
ν	Kinematic viscosity of approach flow, m²/s
$\sigma(\ )$	Standard deviation of $(\ ), = (\ )'_{\mathrm{rms}}$
ρ	Density of approach flow, kg/m³
$(\ )_{\mathrm{max}}$	Maximum value during data record
$(\ )_{\mathrm{min}}$	Minimum value during data record
$(\ )_{\mathrm{mean}}$	Mean value during data record
$(\ )_{\mathrm{rms}}$	Root mean square about the mean

1 INTRODUCTION

Pedestrian acceptability of footpaths, entrances, plazas and terraces is an important design parameter of interest to the building owner and architect. Assessment of the acceptability of the pedestrian level wind environment is desirable during the project design phase so that modifications can be made, if necessary, to create wind conditions suitable for the intended use of the space.

Techniques have been developed which permit boundary layer wind tunnel modelling of buildings to determine wind velocities in pedestrian areas. This report includes wind tunnel test procedures, test results, and discussion of acquired test results. Table 1 summarises the model configurations, test methods, and data acquisition parameters used. All the data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2010). While analytical methods such as computational fluid dynamics (CFD) have some utility in the field of pedestrian wind comfort, they are not yet capable of reliably and accurately predicting gust wind speeds for assessment of wind conditions from a safety perspective.

Table 1: Parameters and configurations for data acquisition.

General Information	
Model scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m AGL
Approach Terrain Category	Suburban Approach (Terrain Category 3)
Testing Configurations	
Configuration	Proposed 388 Pitt St development with existing and approved surrounding buildings, as shown in Figure 3. Pedestrian winds measured at 11 locations for 16 wind directions at 22.5° increments from 0° (north).

2 THE WIND TUNNEL TEST

Modelling of the aerodynamic flow around a structure requires special consideration of flow conditions to obtain similitude between the model and the prototype. A detailed discussion of the similarity requirements and their wind tunnel implementation can be found in Cermak (1971, 1975, 1976). In general, the requirements are that the model and prototype be geometrically similar, that the approach mean velocity and turbulence characteristics at the model building site have a vertical profile shape similar to the full-scale flow, and that the Reynolds number for the model and prototype be equal. Due to modelling constraints, the Reynolds number cannot be made equal and the Australasian Wind Engineering Society Quality Assurance Manual (2001) suggests a minimum Reynolds number of 50,000, based on minimum model width and wind velocity at the top of the model; in this study the modelled Reynolds number was over 50,000.

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 1. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by vorticity generating fence and spires. The spires, barrier, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in Figure 2 and are explained more fully in Section 4.1.1.

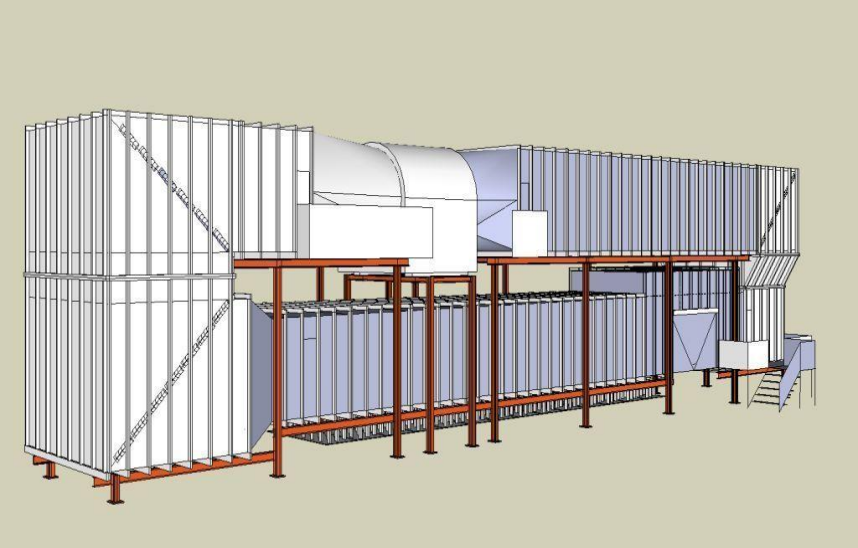

Figure 1: Schematic of the closed-circuit wind tunnel.

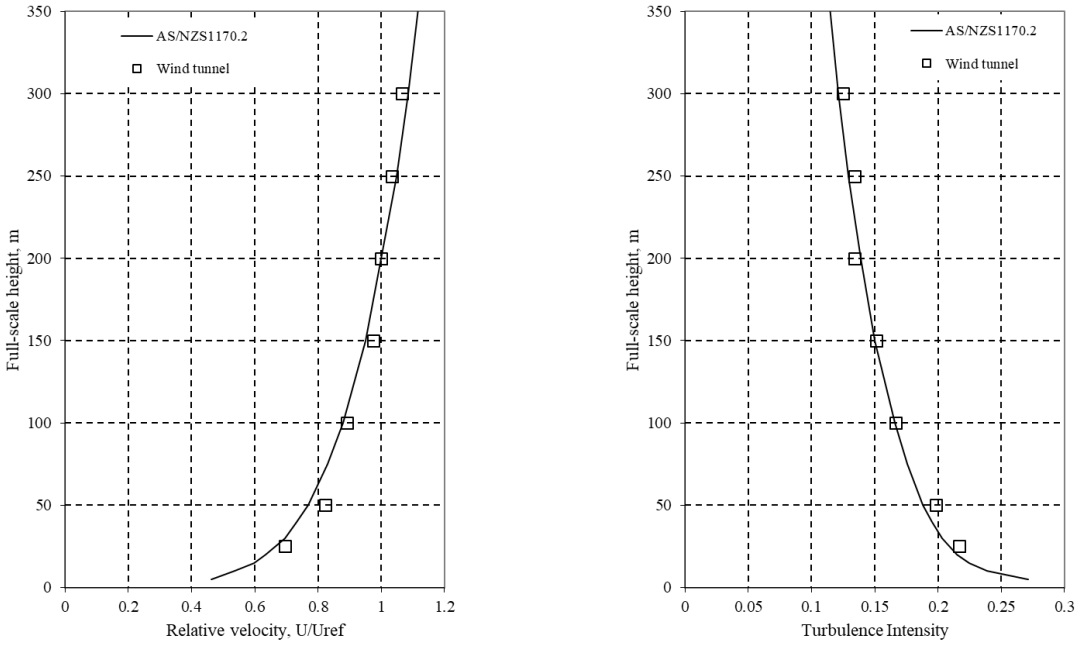

Figure 2: Mean velocity and turbulence profiles (Terrain Category 3) approaching the model.

A model of the proposed development and surrounds to a radius of 570 m was constructed at a scale of 1:400, which was consistent with the modelled atmospheric flow, permitted a reasonable test model size with an adequate portion of the adjoining environment to be included in a proximity model, Figure 3, and was within wind tunnel blockage limitations. Significant variations in the building surface were formed into the model. The models were mounted on the turntable located near the downstream end of the wind tunnel test section, Figure 4. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the test models are included in Appendix 1.

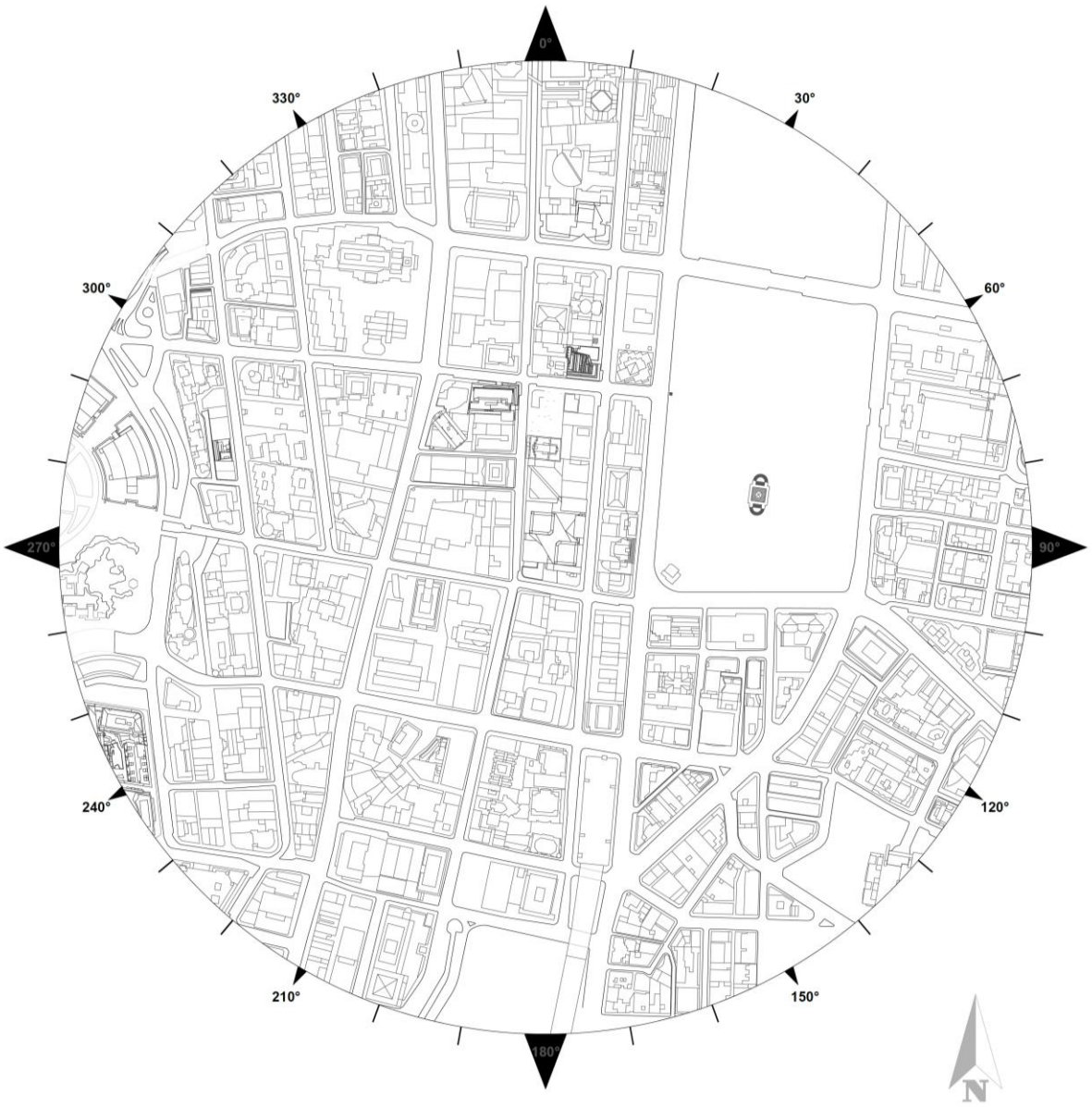

Figure 3: Project location and turntable layout.

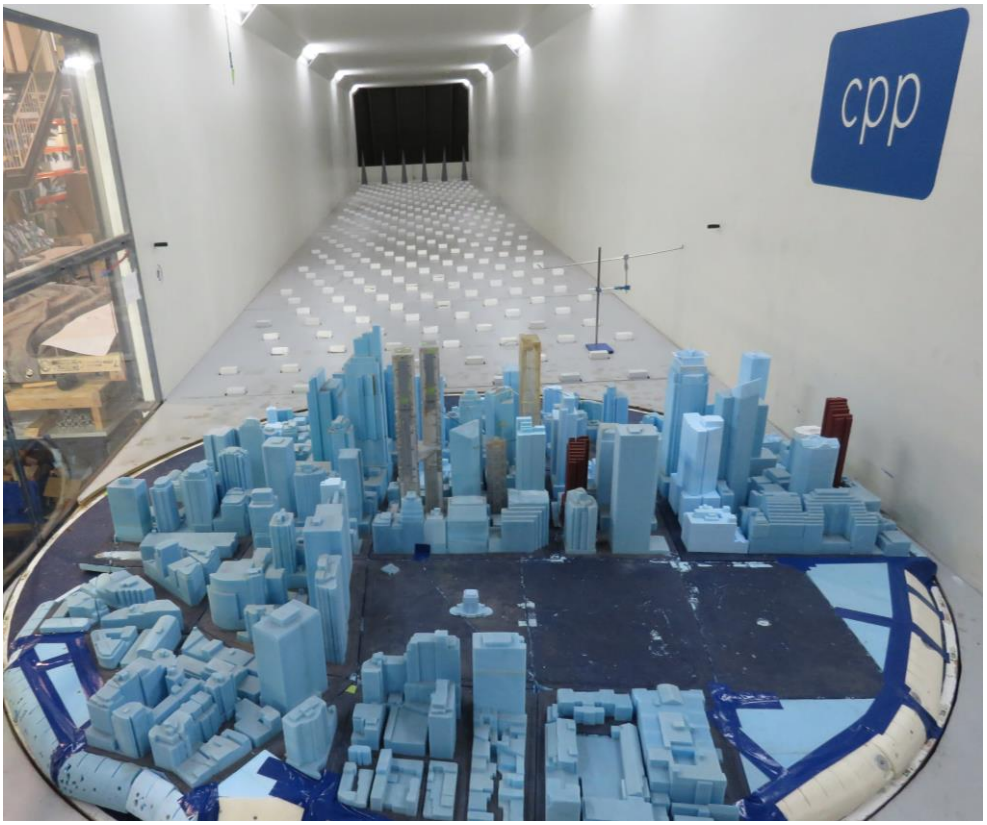

Figure 4: Proposed 388 Pitt St model in the wind tunnel viewed from the east.

3 ENVIRONMENTAL WIND CRITERIA

Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. Because pedestrians will tolerate higher wind speeds for a smaller period of time than for lower wind speeds, these criteria provide a means of evaluating the overall acceptability of a pedestrian location. Also, a location can be evaluated for its intended use, such as for an outdoor café or a footpath. One of the most widely accepted set of criteria was developed by Lawson (1990), which is described in Table 2.

Lawson's criteria have categories for comfort, based on wind speeds exceeded 5% of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "Business Walking" to "Pedestrian sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds[1]. In both cases, the wind speed used is the larger of a mean or gust equivalent-mean (GEM) wind speed. The GEM is defined as the peak gust wind speed divided by 1.85; this is intended to account for locations where the gustiness is the dominant characteristic of the wind. Assessment using the Lawson criteria provides a similar classification as using once per annum gust criteria, but also provides significantly more information regarding the serviceability wind climate.

Table 2: Summary of Lawson criteria.

Comfort (maximum of mean or gust equivalent mean (GEM†,) wind speed exceeded 5% of the time)	
< 4 m/s	Pedestrian Sitting (considered to be of long duration)
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)
6 - 8 m/s	Pedestrian Walking
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)
> 10 m/s	Uncomfortable[1]
Distress (maximum of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access area
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able-bodied people would be expected; frail or cyclists would not be expected

Note: †, The gust equivalent mean (GEM) is the peak 3 s gust wind speed divided by 1.85.

[1] The rating of "uncomfortable" in Table 2 is the word of the acceptance criteria author and may not apply directly to any particular project. High wind areas are certainly not uncomfortable all the time, just on windier days. The word uncomfortable, in our understanding, refers to acceptability of the site by pedestrians for typical pedestrian use; i.e., on the windiest days, pedestrians will not find the areas "acceptable" for walking and will tend to avoid such areas if possible. The distress rating fail indicates some unspecified potential for causing injury to a less stable individual who might be blown over. The likelihood of such events is not well described in the literature and is likely to be strongly affected by individual differences, presence of water, blowing dust or particulates, and other variables in addition to the wind speed.

The current City of Sydney (2012) DCP specifies wind effects not to exceed 16 m/s, and 10 m/s for 'active frontages'. The draft amendments of the DCP require a wind speed of 8 m/s not to be exceeded for more than 5% of the time between 6 am and 10 pm, aligning with the pedestrian walking criterion by Lawson. The safety criterion of the draft amendments requires an annual maximum peak 0.5 second gust wind speed not to be exceeded, which aligns with the Lawson criterion of a GEM wind speed of 15 m/s for a 3 second gust. In the vicinity of 388 Pitt St, Liverpool and Pitt Streets comprise active frontages, while Castlereagh Street and Elizabeth Street are not. There are few locations in Sydney that would meet the current DCP criteria without shielding to improve the wind conditions. From discussions with Council the current DCP criterion wind speed is a once per annum gust wind speed similar to the 2004 DCP, but is meant to be interpreted as a comfort level criterion to promote outdoor café style activities and is not a distress requirement.

The once per annum gust wind speed criterion is based on the work of Melbourne (1978), and the 16 m/s level is classified as acceptable for pedestrian walking along a main accessway, and 10 m/s level is classified as generally acceptable for use for pedestrian sitting. This criterion gives the once per annum (actually 0.1% of the time) gust wind speed, and uses this as an estimator of the general wind conditions at a site. To combat this limitation, this study is based upon the criteria of Lawson (1990), which are described above. Assessment using the Lawson criteria provides a similar comfort classification as using the once per annum gust criteria, which is the basis of the City of Sydney (2012) DCP; however, it also provides significantly more information regarding the serviceability wind climate. The Lawson criteria align with the draft amendments of the City of Sydney DCP. On the basis of these arguments, the Lawson criteria are adopted for the current study.

4 DATA ACQUISITION AND RESULTS

4.1 Velocities

Velocity profile measurements were taken to verify that appropriate boundary layer flow approaching the site was established and to determine the likely pedestrian level wind climate around the test site. Pedestrian wind measurements and analysis are described in Section 4.1.2. All velocity measurements were made with hot-film anemometers, which were calibrated against a Pitot-static tube in the wind tunnel. The calibration data were described by a King's Law relationship (King, 1914).

4.1.1 Velocity Profiles

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in Figure 2. Turbulence intensities are related to the local mean wind speed. These profiles have the form as defined in Standards Australia (2011) and are appropriate for the approach conditions.

4.1.2 Pedestrian Winds

The proposed development is located in the heart of the Sydney CBD. The site is located on the south- west of Liverpool and Pitt St, Figure 3. The development is surrounded by medium to high- rise buildings. Topography surrounding the site is essentially flat from a wind perspective.

CPP has conducted extensive testing throughout the Sydney CBD, and some existing data for nearby areas have been included in this study. For this report, wind speed measurements were recorded at 11 locations, as described in Table 1, to evaluate pedestrian wind comfort and safety in and around the project site shown in Figure 6 to Figure 8. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian wind comfort and safety at building corners where relatively severe conditions are frequently found, near building entrances and passageways, and at upper level outdoor locations.

The hot-film signal was sampled for a period corresponding to one hour in prototype. All velocity data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the minimum size of a gust affecting a pedestrian and is the basis for the various acceptability criteria. These local wind speeds, U, were normalised by the tunnel reference velocity, U_{ref}. Mean and turbulence statistics were calculated and used to calculate the normalised effective peak gust using:

$$\frac{U_{pk}}{U_{ref}} = \frac{U + 3U_{rms}}{U_{ref}}$$

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200 m are plotted in polar form in Appendix 2. The graphs show velocity magnitude and the approach wind direction for which that velocity was measured. The polar

plots aid in visualisation of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust wind speed is of greater importance.

To enable a quantitative assessment of the wind environment in the region, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1995 to 2017, Figure 5.

From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 2; this gives additional information regarding directional sensitivity at each location.

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarised in Figure 5 to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 2. In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has been found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s.

Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in Table 3 including qualitative descriptions of wind effects.

The tables in Appendix 2 additionally provide the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson comfort and distress criteria, and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian wind comfort and safety with respect to the Lawson criteria is presented in Figure 6 to Figure 8 for each test location. The implications of the results are discussed in Section 5.

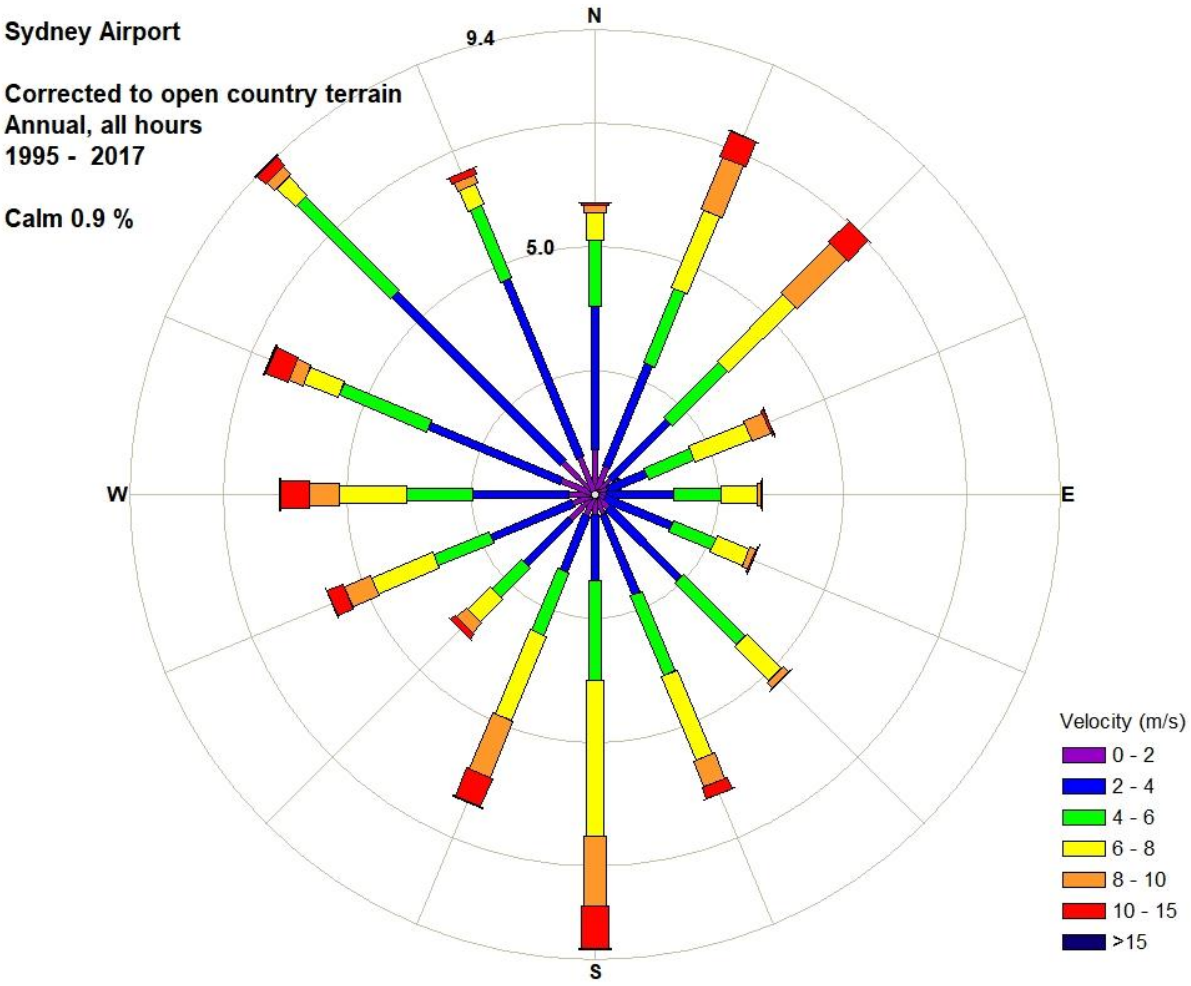

Figure 5: Wind rose for Sydney Airport.

Table 3: Summary of wind effects on people, Penwarden (1973)

Description	Beaufort Number	Speed (m/s)	Effects
Calm, light air	0, 1	0–2	Calm, no noticeable wind.
Light breeze	2	2–3	Wind felt on face.
Gentle breeze	3	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps
Moderate breeze	4	5–8	Raises dust, dry soil, and loose paper. Hair disarranged.
Fresh breeze	5	8–11	Force of wind felt on body. Drifting snow becomes airborne. Limit of agreeable wind on land.
Strong breeze	6	11–14	Umbrellas used with difficulty. Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	7	14–17	Inconvenience felt when walking.
Gale	8	17–21	Generally impedes progress. Great difficulty with balance in gusts.
Strong gale	9	21–24	People blown over by gusts.

5 DISCUSSION

The wind climatology chart of Figure 5 indicates that the most frequent strong winds are from the south, north-east and west quadrants. The locations tested around the development site are susceptible to winds from these directions, depending on the relative position of the location tested to the geometry of the proposed development and surrounds. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the polar plots in Appendix 2. The polar plots show the severity, distribution, and frequency of steady winds and gusts from 16 directions at 22.5° intervals.

A summary of the expected wind rating targets based on the intended use of the space at the investigated locations and the wind tunnel results, including the Lawson comfort and safety ratings, is provided in Table 4.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 6 to Figure 8, which depict the locations selected for investigation along with the Lawson comfort and distress criteria ratings. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes or exceeds the distress criterion, Table 2. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people found in Table 3.

Note that testing was performed without existing and proposed trees, and other plantings or landscape additions to provide a worst-case assessment. Heavy landscape planting typically reduces the wind speeds by less than 10% and in general should not be relied on to provide sufficient shielding from winds that potentially pose a safety risk. Mitigation measures are likely to be required for orange and red locations and may be necessary for other locations depending on the intended use of the space. Although conditions may be classified as acceptable, there may be certain wind directions that cause regular strong events, and these can be determined by an inspection of the polar plots in Appendix 2.

Table 4: Summary of expected wind rating targets versus wind tunnel results.

Description / Location		Target	Wind Tunnel Results – Base case Configuration			Notes
		Comfort rating, 5% exceedance wind speed (m/s)	Comfort rating, 5% exceedance wind speed (m/s)	Meets target Y(es)/N(o)	Safety rating, 0.022% exceedance wind speed (m/s)	
Ground Floor	1	>6 to 8	4.4	Y	8.6	
	2	>6 to 8	5.5	Y	10.4	
	3	>6 to 8	4.4	Y	8.9	
	4	>6 to 8	5.3	Y	10.8	
	5	>6 to 8	5.7	Y	10.8	
	6	>6 to 8	4.3	Y	8.8	
	7	>4 to 6	3.4	Y	6.8	
	8	>6 to 8	4.2	Y	9.6	
	9	>6 to 8	4.4	Y	9.1	
Sky Bridge	10	>4 to 6	12.0	N	25.2	
	11	>4 to 6	9.2	N	17.1	

LEGEND

Comfort Criteria
- Outdoor Dining
- Pedestrian Sitting
- Pedestrian Standing
- Pedestrian Walking
- Business Walking
- Uncomfortable

Safety Criteria
- Passes safety criteria
- Able bodied
- Fails safety criteria

The wind conditions at locations remote to the site are presented in Figure 7. These wind conditions are representative of the general pedestrian wind environment in this area of the Sydney CBD. The majority of the locations are classified as suitable for pedestrian standing, with a few locations being slightly windier and exceeding the standing rating. The block corners adjacent to Hyde Park are subjected to windier conditions and hence tend to fall in the categories of pedestrian walking and business walking, whereas locations nested deeper within the city 'spine' (western side of site) are more sheltered and experience calmer conditions. All locations pass the distress criterion.

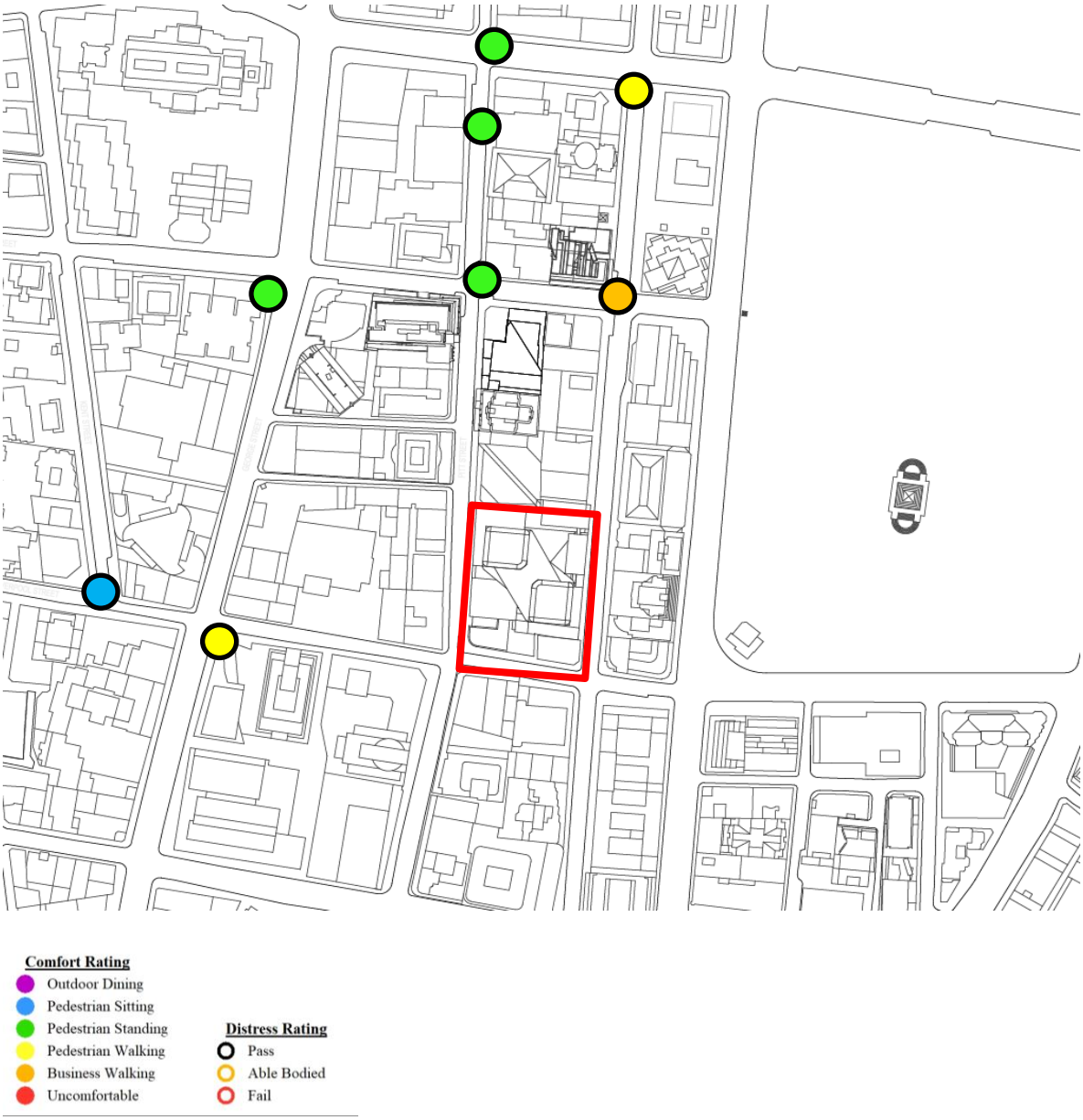

Figure 6: Pedestrian wind speed measurement locations with comfort/distress ratings – Remote locations

The wind conditions on ground level at the site are presented in Figure 8. Wind conditions in the vicinity of the site are mostly classified as suitable for pedestrian standing from a Lawson comfort perspective. The calmest condition was measured in Location 7 at the north- eastern part of the central plaza which is well shielded by the surrounding podium massing. This location is rated as suitable for pedestrian sitting. All locations pass the distress criterion.

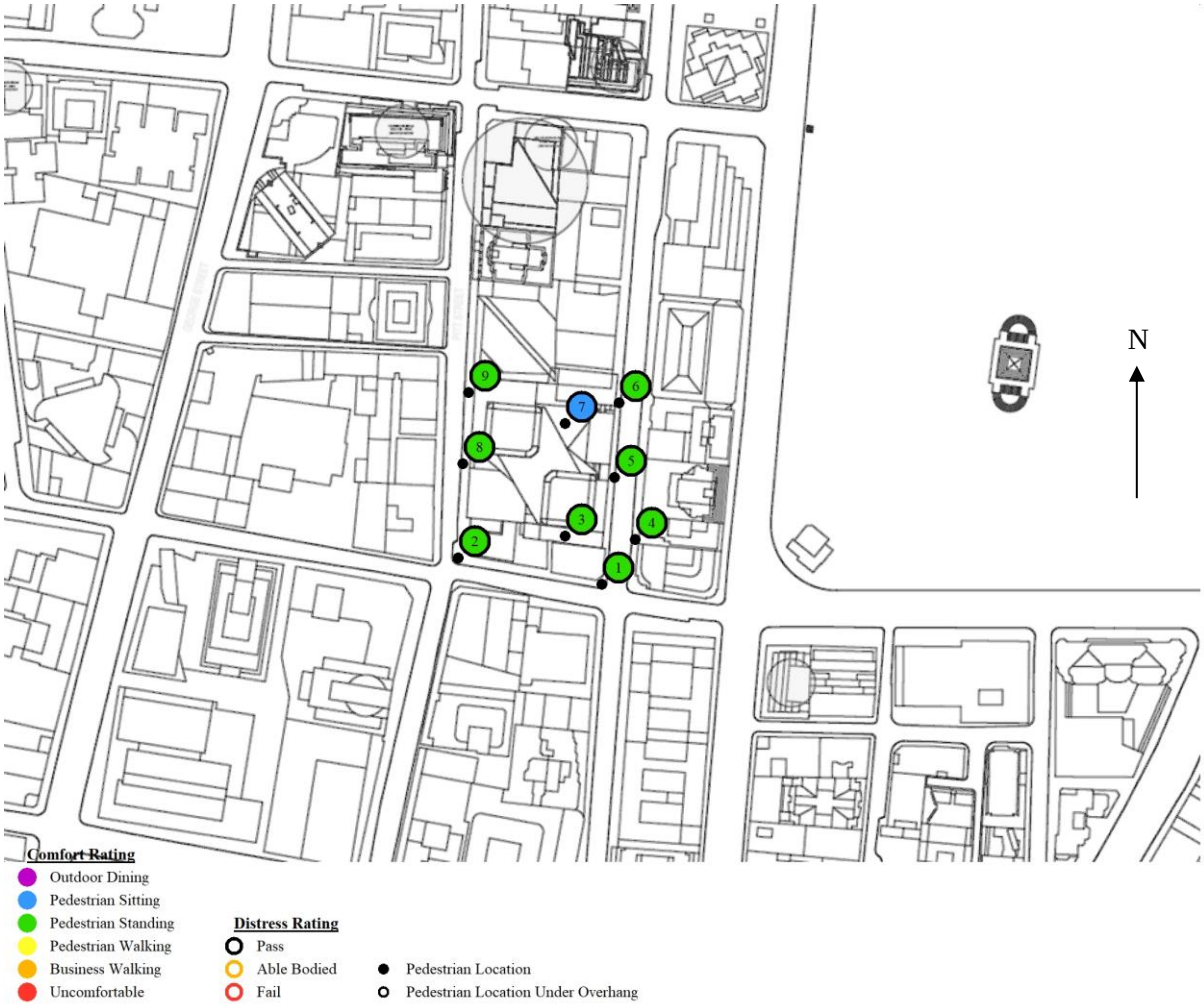

Figure 8: Pedestrian wind speed measurement locations with comfort/distress ratings – Ground Floor.

Due to the exposed nature of the Sky Bridge, Location 10 and 11 are classified as uncomfortable and suitable for business walking respectively, with both locations exceeding the distress criterion. This area is not expected to be suitable for permanent outdoor use without significant mitigation treatments. As per the polar plots in Appendix 2, both locations are subjected to strong unimpeded winds from most directions. It is expected that the detailed design of this area will incorporate elements such as high balustrades or screens, semi-enclosed areas, and localised protection to seating areas. Further wind tunnel testing during detailed design stages could be used to develop and verify the effectiveness of these measures.

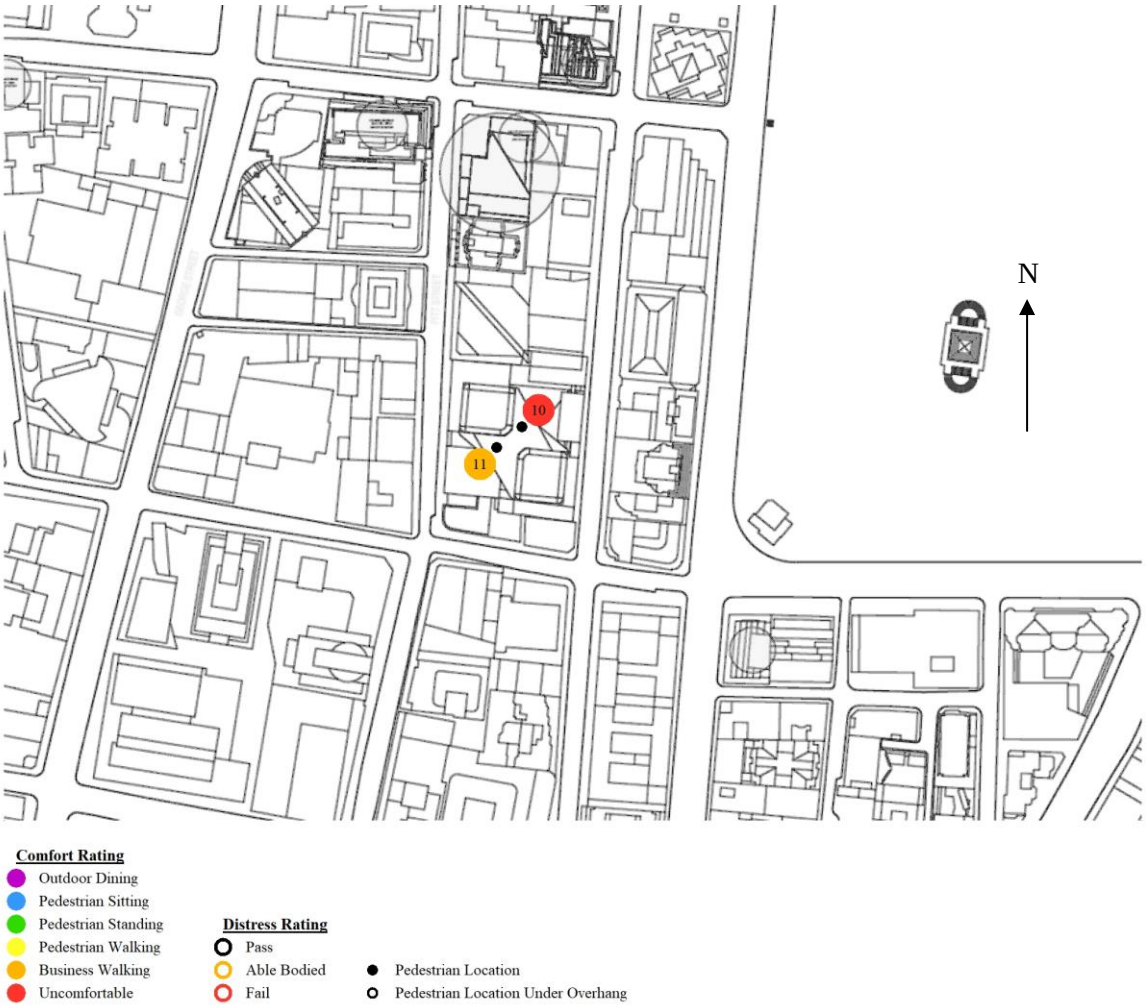

Figure 9: Pedestrian wind speed measurement locations with comfort/distress ratings – Sky Bridge.

6 ASSESSMENT

6.1 Ground Floor

Preliminary wind tunnel test results indicate that the conditions on the ground floor are relatively calm. In particular, the courtyard and pedestrian access routes within the site boundaries are expected to experience mild conditions due to the protection provided by the surrounding podium. In addition, the inclusion of distributed landscaping elements, colonnades and undercrofts as indicated in current drawings (Figure 10) is likely to improve conditions within these spaces. At the exterior of the site, measured conditions are comparable to or better than surrounding areas. As with most locations in Sydney, local treatments to dedicated seating or dining areas would be recommended. These may include awnings or canopies, or vertical screening elements. With the inclusion of such elements where appropriate, all ground plane areas are expected to be suitable for their intended use.

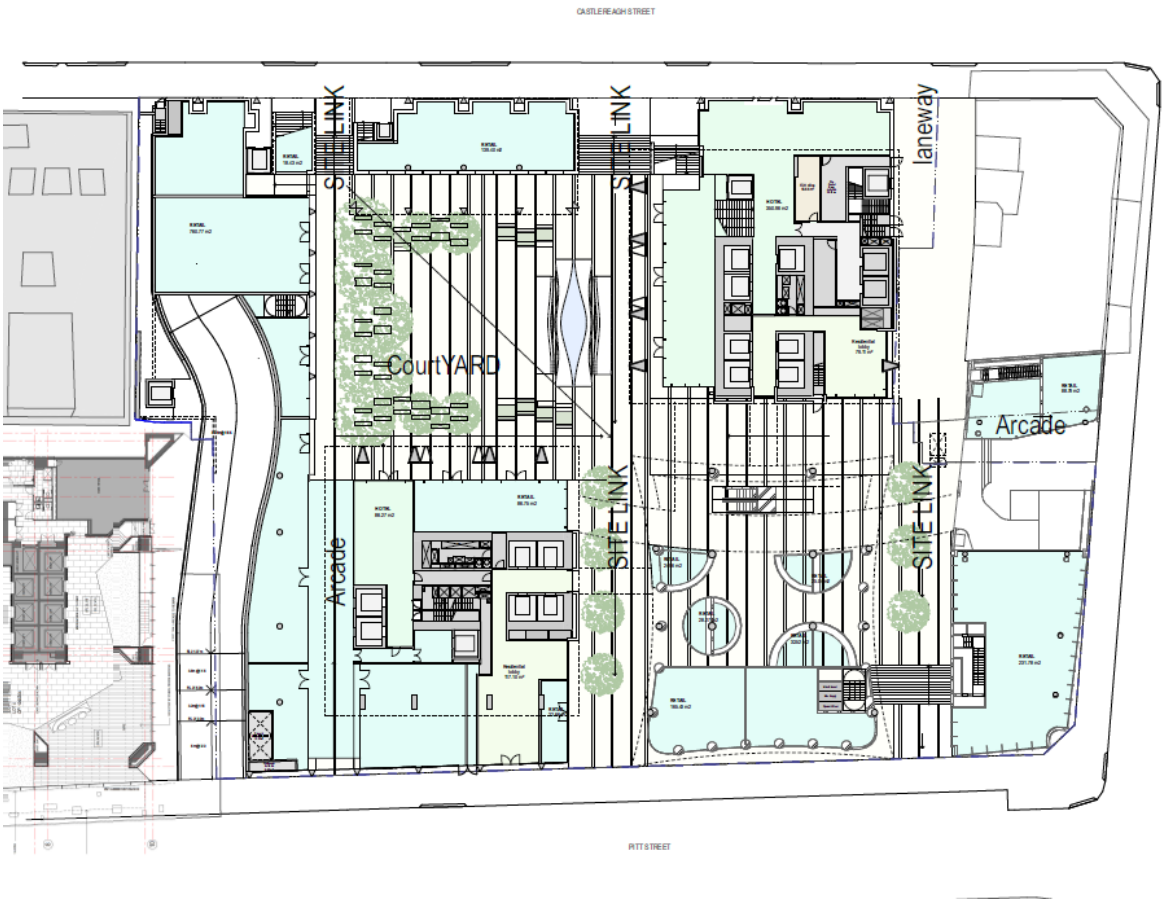

Figure 10: Ground Floor Plan

6.2 Podium Terraces

The current preliminary testing did not include measurements on the podium roof terraces, however conditions may be inferred from existing results. The Level 4 and Level 8 rooftop gardens are somewhat exposed to the effects of westerly and north-easterly winds respectively. These locations receive less shielding than ground level and will be more strongly affected by nearby tall buildings. The Level 4 rooftop garden is anticipated to experience stronger wind condition during westerly winds due to less shielding from neighbour buildings in this direction. The Level 8 Hotel rooftop will be affected by north-easterly winds approaching over the open region of Hyde Park. Areas close to bases of towers will also be exposed to downwash from tower facades, which may degrade conditions. Depending on the prevailing wind direction, some calm areas are likely to exist on both terraces at most times, however overall conditions are likely to be reasonably strong at times.

Figure 11L Level 4 (Top) and Level 8 (Bottom) plans

The proposed perimeter landscaping for Level 8 will encourage improved wind amenity for this space. In addition, the following measures may be incorporated during detailed design with a view to achieving conditions suitable for pedestrian sitting:

- Horizontal awnings or canopies, particularly near tower bases
- Fence-type structure or high balustrade at podium edges
- Vertical screening elements around dedicated seating areas, using a mix of solid and porous media
- Pavilion-type structures to provide localised calm areas

How these elements are incorporated will depend of the final detailed use of outdoor areas and may be adequately addressed during detailed design stages.

6.3 Sky Bridge

Similar to the podium terraces, the outdoor areas on the Sky Bridge will require specific attention during detailed design to achieve wind conditions suitable for its intended use. It is expected these would be developed and verified through further wind tunnel testing.

7 CONCLUSION

Cermak Peterka Petersen Pty. Ltd. has conducted a wind tunnel test concerning the impact of the proposed 388 Pitt St development, Sydney NSW on the local wind environment. Our summary assessment of the proposed development is as follows:

The wind conditions around the ground plane of proposed development were found to be generally suitable for pedestrian walking activities from a comfort perspective with reference to the Lawson comfort criteria. These conditions are similar to or better than surrounding areas. The level of landscaping and small-scale structures indicated in the current design will further improve the wind environment. All locations on the ground plane passed the Lawson distress criteria.

Wind conditions on the sky bridge were also presented and were found to be classified as “uncomfortable” and business walking. Tested locations on the Sky Bridge exceeded the distress criterion due to their exposed nature. Outdoor areas on these levels will require significant mitigation treatments in order to be feasible. While conditions on the podium roof terraces are not expected to be as sever, these will also require specific treatments to ensure a desirable wind environment is achieved. It is expected these may be developed during detailed design and through further wind tunnel testing.

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Appendix 1: Additional photographs of the CPP wind tunnel model

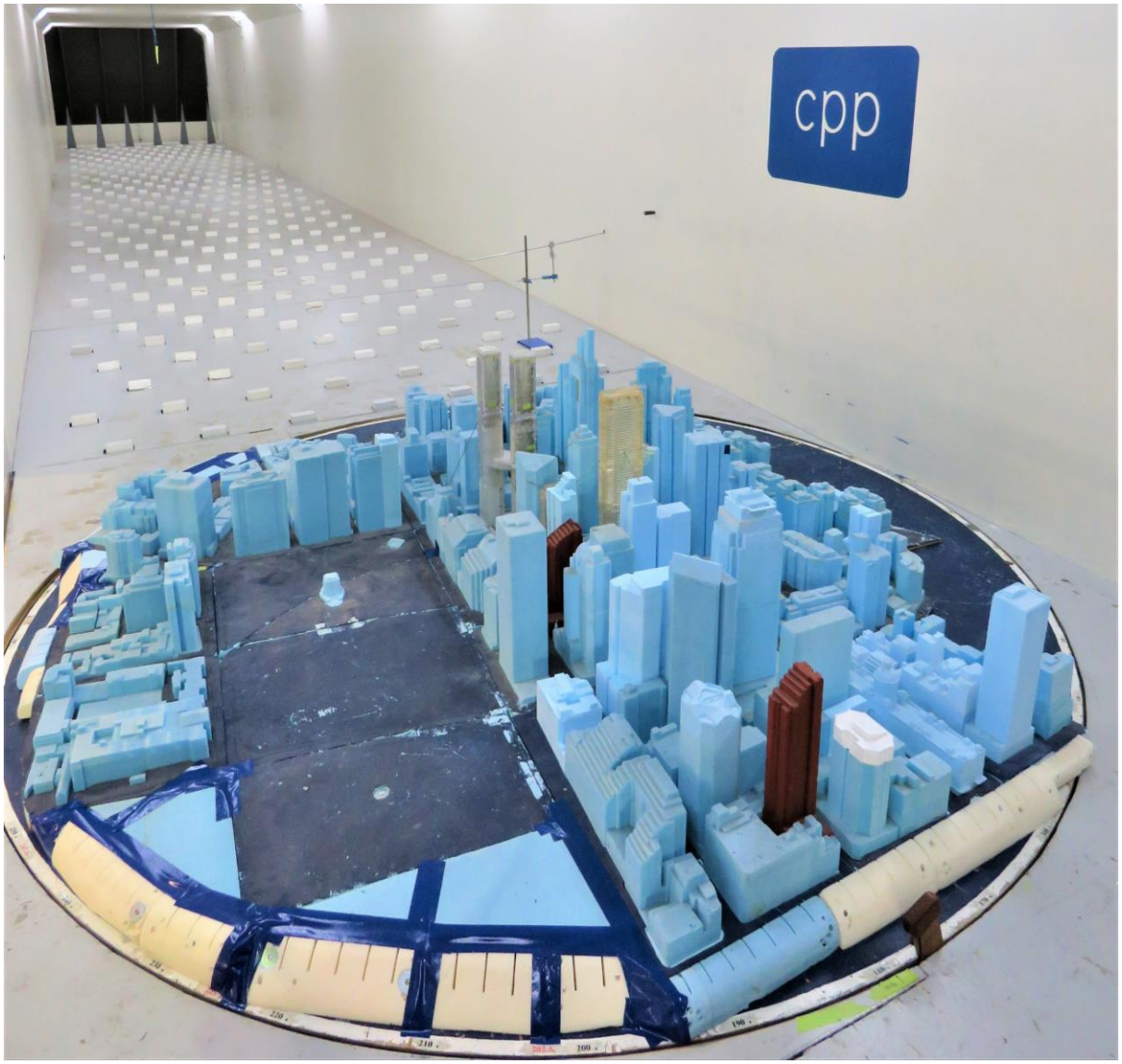


Figure 12: Proposed 388 Pitt St model in the wind tunnel viewed from the north

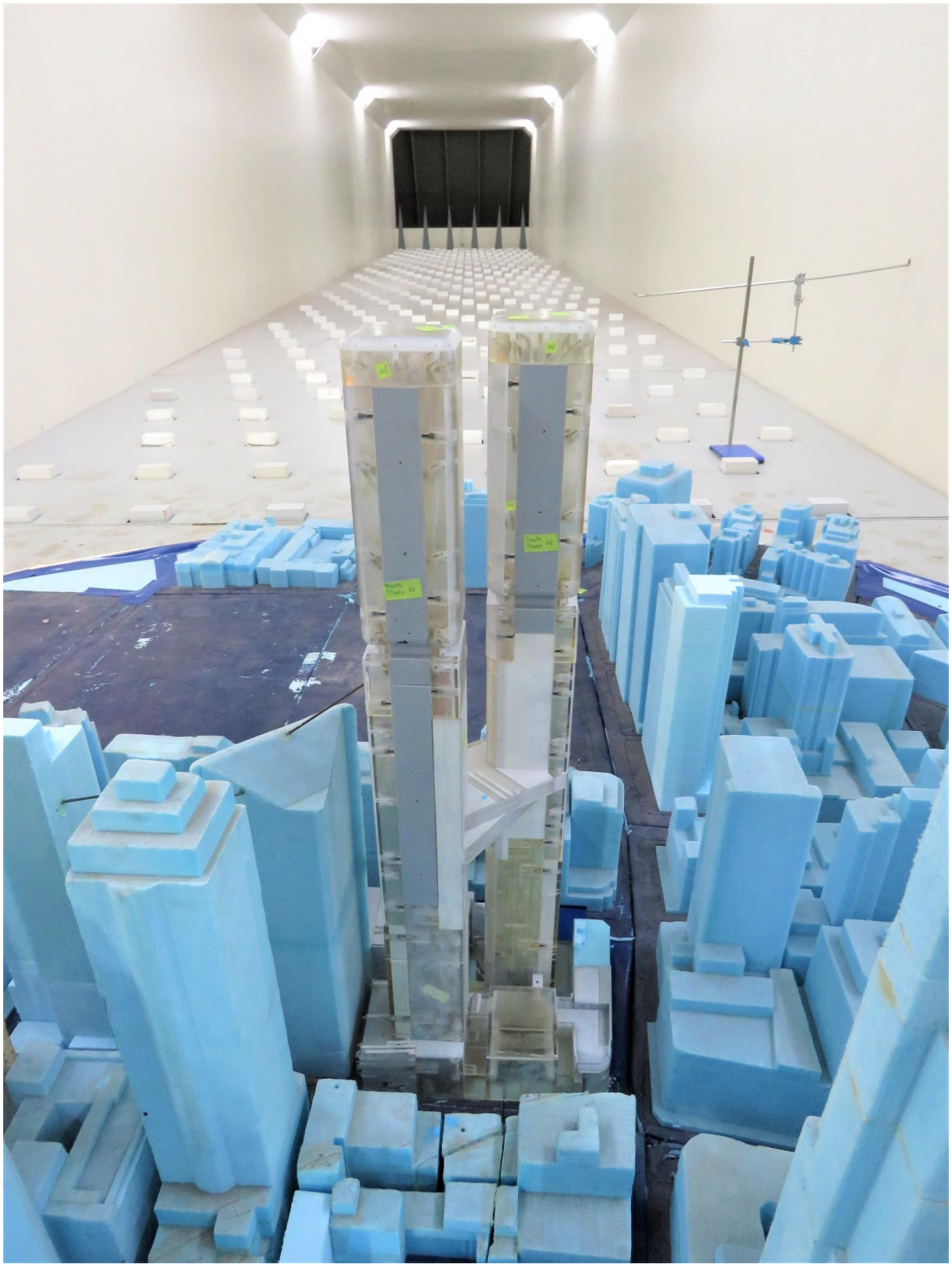
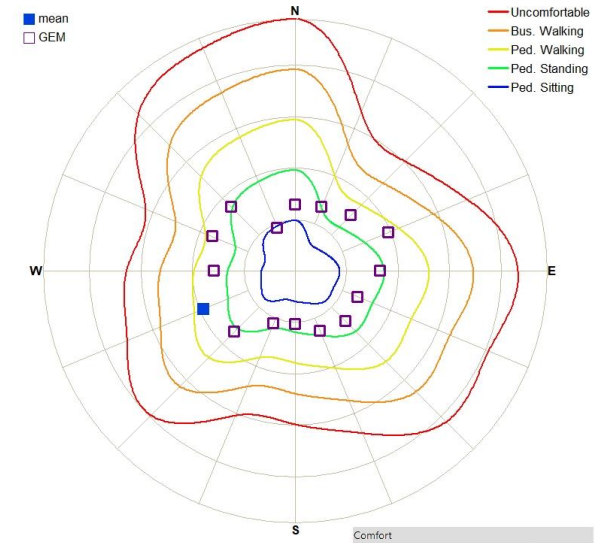


Figure 13: Close-up of the proposed 388 Pitt St model in the wind tunnel viewed from the west

Appendix 2: Directional wind results

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	31.17	46.13	46.48
4	3.25	7.10	7.71
6	0.44	0.63	0.73
8	0.04	0.05	0.05
10	0.00	0.00	0.00

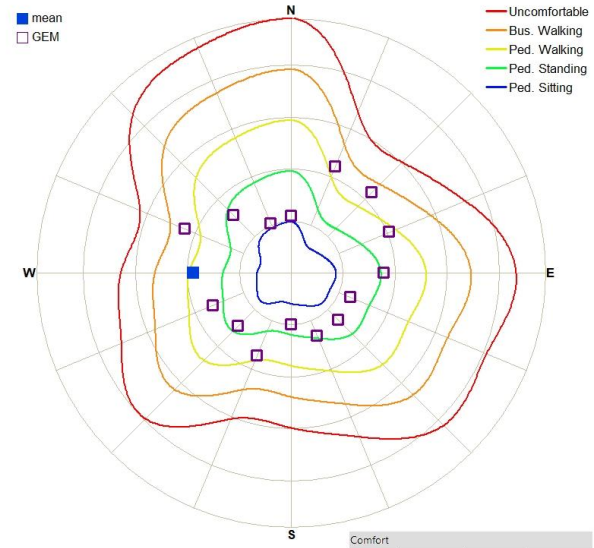
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	4.3	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	8.5	8.6
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	39.20	50.04	50.14
4	9.92	14.68	14.82
6	1.43	3.31	3.36
8	0.22	0.48	0.49
10	0.03	0.05	0.05

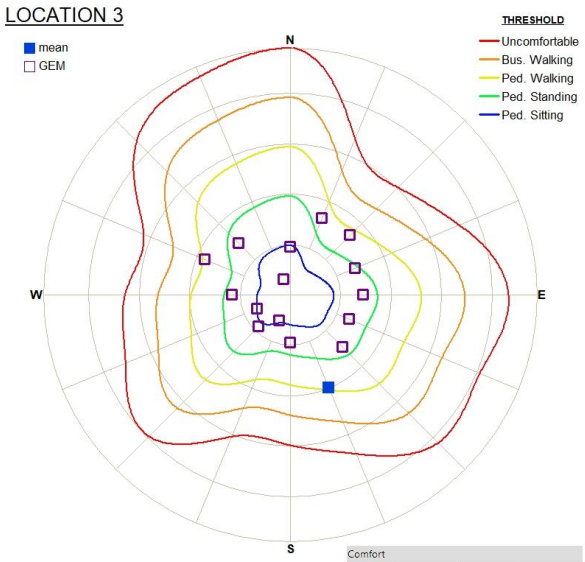
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.5	5.5
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.2	10.4	10.4
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	23.86	35.19	35.84
4	3.74	6.31	7.41
6	0.33	0.70	0.89
8	0.03	0.06	0.09
10	0.00	0.00	0.00

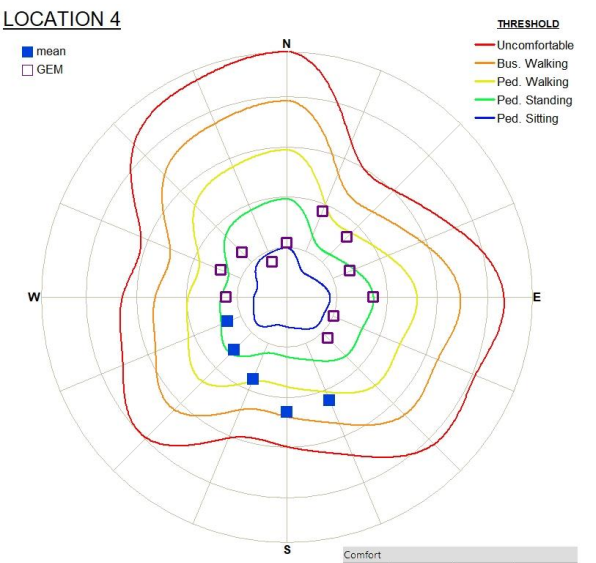
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.2	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	8.6	8.9
Rating	Pass	Pass	Pass

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	40.68	45.84	47.17
4	13.97	12.68	16.27
6	2.59	1.63	2.95
8	0.45	0.11	0.46
10	0.05	0.01	0.05

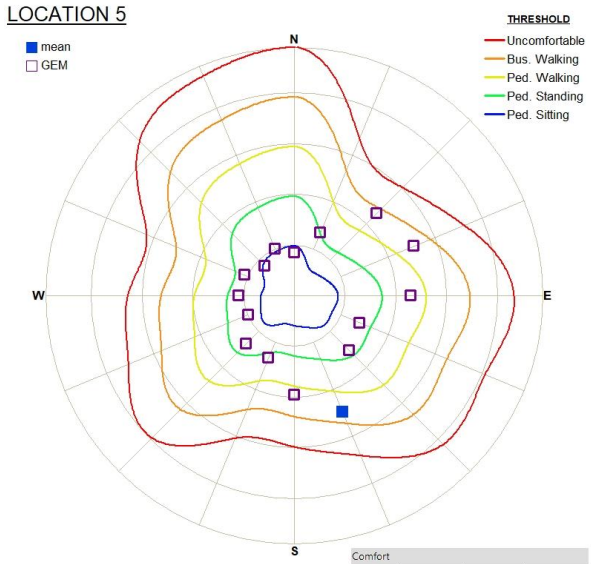
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	4.9	5.3
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.8	9.2	10.8
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	35.33	44.91	45.46
4	10.71	14.76	15.98
6	2.30	3.55	4.12
8	0.30	0.42	0.57
10	0.03	0.04	0.06

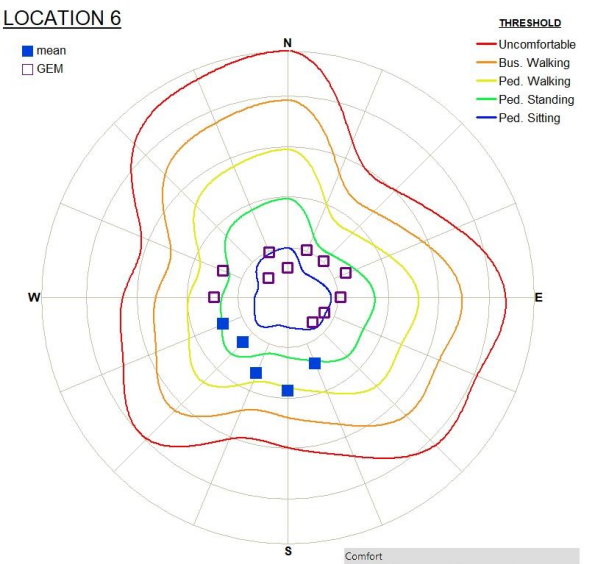
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.5	5.7
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.4	10.3	10.8
Rating	Pass	Pass	Pass

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	26.00	35.33	35.87
4	5.64	6.24	6.75
6	0.75	0.71	0.84
8	0.06	0.05	0.06
10	0.00	0.00	0.00

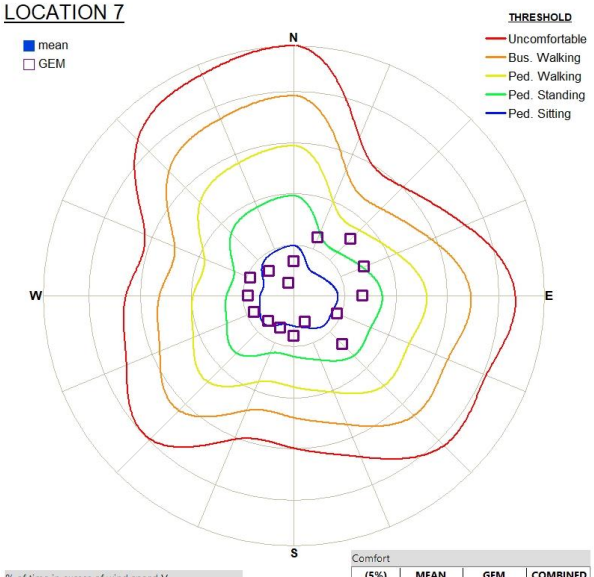
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	4.2	4.3
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.7	8.5	8.8
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	13.16	21.07	21.07
4	1.68	2.38	2.38
6	0.08	0.14	0.14
8	0.00	0.00	0.00
10	0.00	0.00	0.00

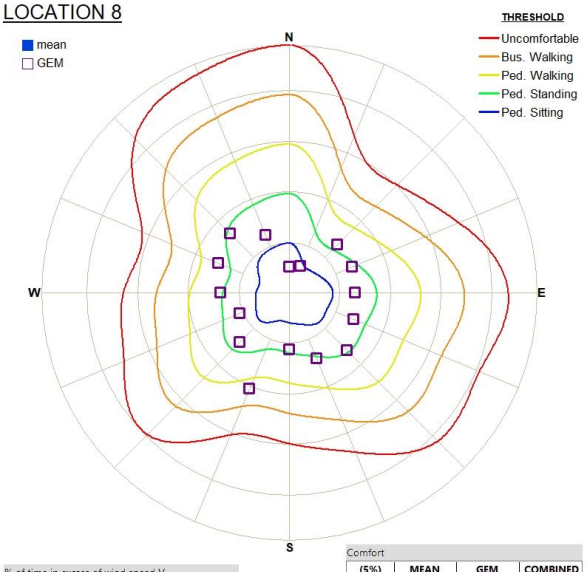
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.0	3.4	3.4
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.5	6.8	6.8
Rating	Pass	Pass	Pass

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	27.76	40.70	40.70
4	3.08	6.57	6.57
6	0.27	0.93	0.93
8	0.02	0.11	0.11
10	0.00	0.01	0.01

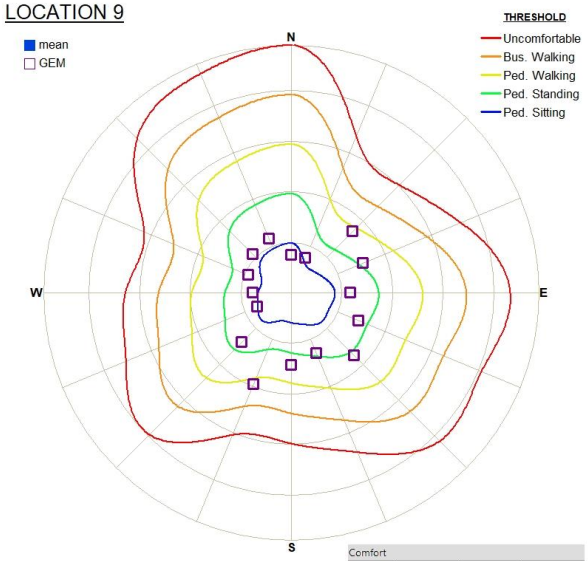
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.7	9.6	9.6
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	26.78	35.78	35.78
4	3.97	7.86	7.86
6	0.35	0.87	0.87
8	0.03	0.07	0.07
10	0.00	0.01	0.01

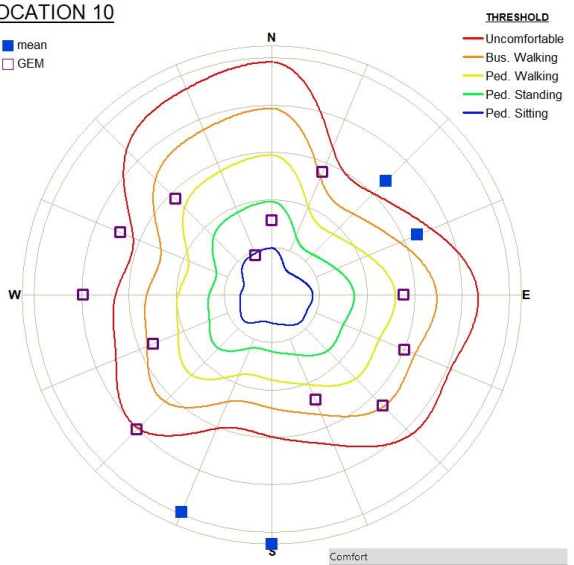
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	9.1	9.1
Rating	Pass	Pass	Pass

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	69.97	78.07	78.61
4	41.15	48.82	50.24
6	25.87	28.01	30.51
8	15.89	14.95	17.84
10	9.11	7.79	10.09

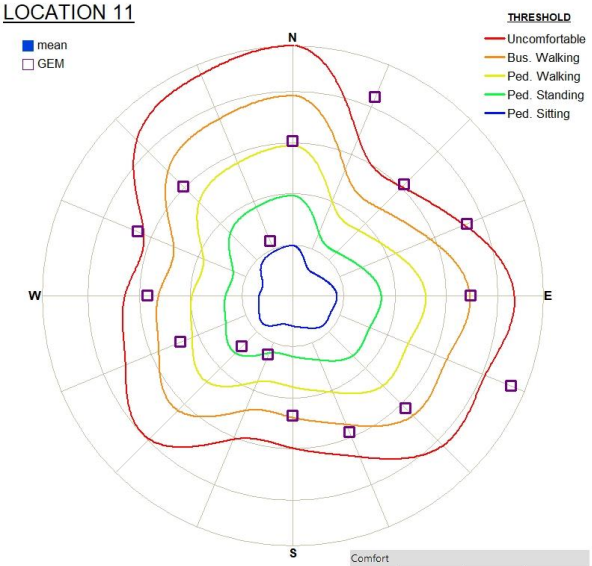
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	11.7	11.2	12.0
Rating	Uncomfortable	Uncomfortable	Uncomfortable

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	25.2	23.5	25.2
Rating	Fail	Fail	Fail

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	62.44	77.26	77.26
4	23.14	44.24	44.24
6	7.19	21.45	21.45
8	2.41	9.44	9.44
10	0.58	3.33	3.33

Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.6	9.2	9.2
Rating	Ped Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.8	17.1	17.1
Rating	Pass	Able Body	Able Body