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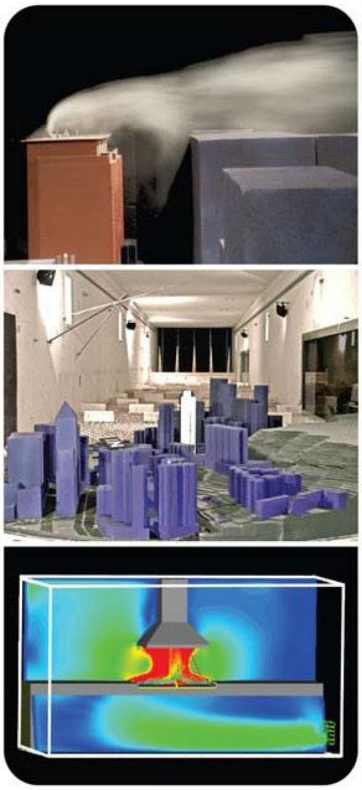
Final Report



Wind Tunnel Tests for:

UTS BROADWAY BUILDING

Sydney, NSW, Australia

Prepared for:

University of Technology, Sydney

15 Broadway

Ultimo

NSW 2007

Australia

CPP Project 5614

CPP
Unit 2, 500 Princes Highway
St. Peters, NSW 2044, Australia
info-syd@cppwind.com
www.cppwind.com

FINAL REPORT

WIND TUNNEL TESTS—UTS BROADWAY BUILDING
Sydney, NSW, Australia

CPP Project 5614

February 2011

Prepared by:

Mick Chay, Ph.D., Senior Engineer
Graeme Wood, Ph.D., Director

Cermak Peterka Petersen Pty. Ltd.
Wind Engineering Consultants
Unit 2, 500 Princes Highway
St. Peters, NSW 2044, Australia
ABN 30 125 146 072

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EXECUTIVE SUMMARY

A wind tunnel study of the proposed UTS Broadway building, to be located in Sydney, NSW, Australia, was conducted to assess pedestrian wind comfort. Based on Denton Corker Marshall drawings of May 2010, a model of the project was fabricated to a 1:400 scale and centred on a turntable in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd (CPP) in St. Peters. Replicas of surrounding buildings within a 600 m radius were constructed and placed on the turntable. 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 Terrain Category 3 as defined in AS/NZ1170.2.

Measurements of winds were made with a hot-film anemometer at 16 locations for 16 wind directions each. These measurements were combined with wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location. Wind conditions at ground level met the comfort criterion for use as a main public accessway, and all locations passed the distress criterion. With regard to the DGR key assessment requirement 4, no locations require amelioration measures.

Wind conditions on the pedestrian walkway around the roof of the development were found to be effectively shielded by the binary screen providing a relatively calm working environment.

Subsequent to the wind tunnel testing, which was based on the May 2010 drawings, there have been a number of minor architectural changes to the geometry of the binary screen and its relation to pedestrian level. These changes, up to January 2011, have been reviewed are not expected to change the measured wind environment around the proposed development presented herein.

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LIST OF SYMBOLS

D	Characteristic dimension (building height, width, etc.)
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{rms}/U
U	Local mean velocity
U_{ref}	Reference velocity at reference height z_{ref}
U_{pk}	Peak wind speed in pedestrian studies
U_{rms}	Root-mean-square of fluctuating velocity
z	Height above surface
ν	Kinematic viscosity of approach flow
$\sigma(\ )$	Standard deviation of $(\ ), = (\ )'_{\mathrm{rms}}$
ρ	Density of approach flow
$(\ )_{\mathrm{max}}$	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 sidewalks, entrances, plazas, and terraces is often 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 improve areas found to be excessively windy.

Analytical methods such as computational fluid dynamics (CFD) are not capable, except in very simple geometries, to estimate wind pressures, frame loads, or wind speeds in pedestrian areas.

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 a discussion of test results obtained. Table 1 summarizes 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, 2006).

Configuration A	
Geometry:	Proposed UTS Broadway building with a model of the proposed Frasers Broadway site, as shown in Figure 4.
Pedestrian Velocities:	Pedestrian winds measured at 16 locations for 16 wind directions in 22.5° increments from 0° (north).

Table 1: Configurations for data acquisition

2. THE WIND TUNNEL TEST

Modelling of the aerodynamic loading on 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 16 m long test section, the floor of which is covered with roughness elements, preceded by a 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.

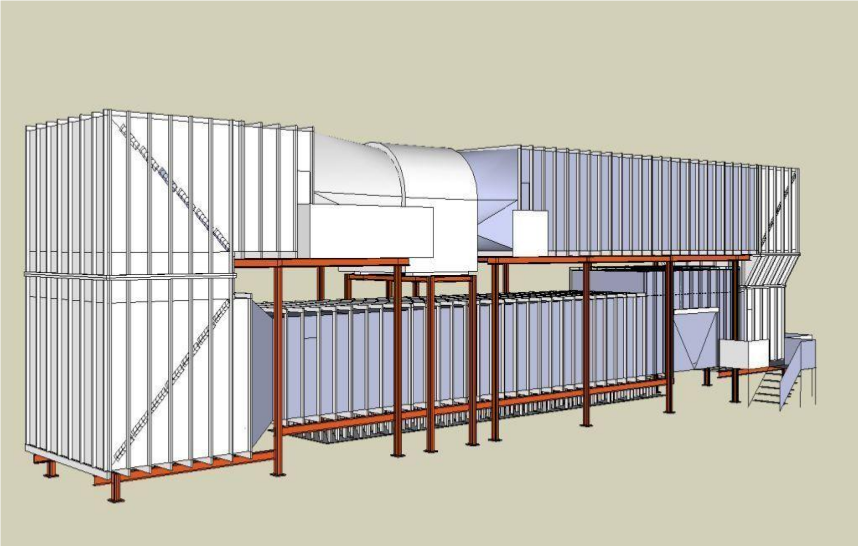

Figure 1: Schematic of the closed circuit wind tunnel

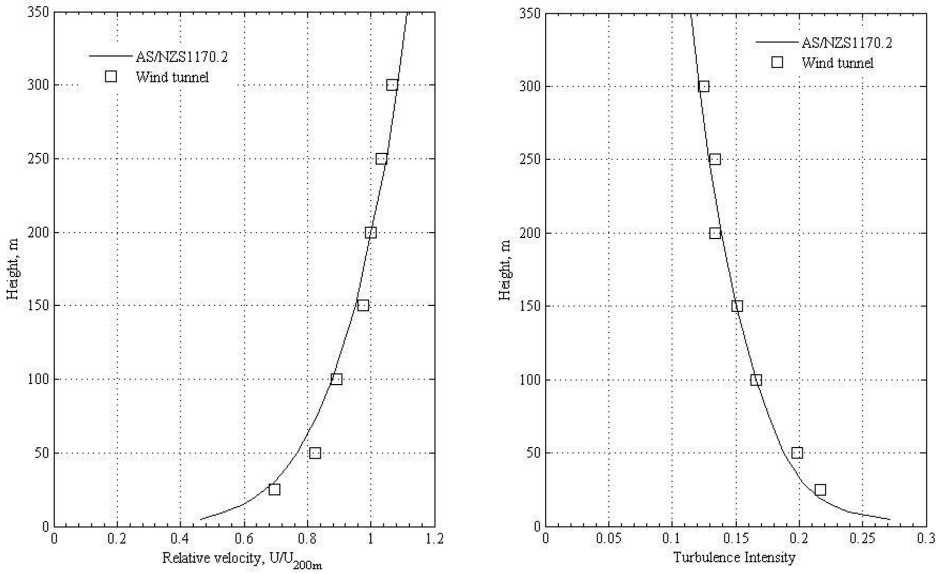

Figure 2: Mean velocity and turbulence profiles approaching the model for Terrain Category 3

A model of the proposed development and surrounds to a radius of 600 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, 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 3. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the testing are in Appendix 1.

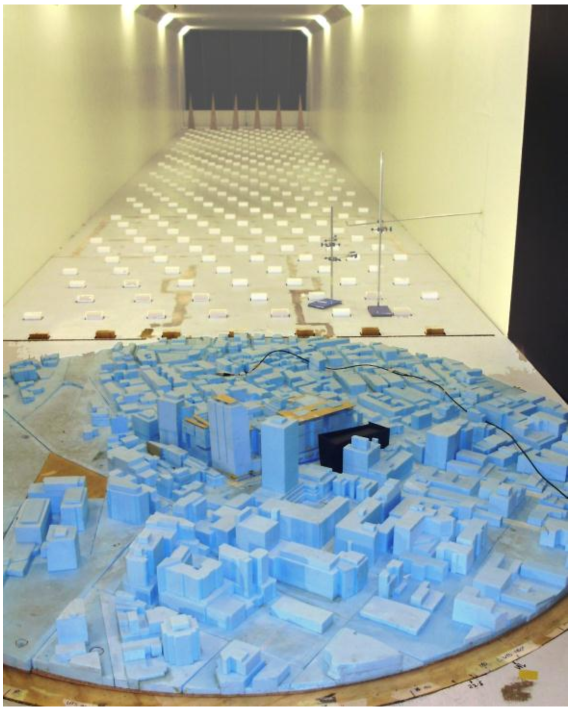

Figure 3: Photograph of the model in the CPP wind tunnel

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 discomfort, based on wind speeds exceeded five percent 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†. In both cases, the wind speed used 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.

Comfort (maximum of mean or gust equivalent mean (GEM[1.]) 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
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: [1.] The gust equivalent mean (GEM) is the peak 3 s gust wind speed divided by 1.85.

Table 2: Summary of Lawson criteria

Compared with the criteria outlined in the City of Sydney DCP (City of Sydney, 2001), the output from the Lawson criteria has been found to result in a similar classification for the intended use of a space, yet is more useful from a planning and assessment perspective.

† 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.

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 anemometer, 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 (2002) and are appropriate for the approach conditions.

4.1.2 Pedestrian Winds The proposed UTS Broadway building is located to the south-west of Sydney CBD, bounded by Broadway, and Jones and Wattle Streets. The topography rises relatively steeply to the west and south. Wind speed measurements were recorded at 16 locations around the single building to evaluate pedestrian comfort at ground level in and around the site, Figure 4 and Figure 5. 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 comfort at the building corners where relatively severe conditions frequently are found, near building entrances, on adjacent sidewalks with heavy pedestrian traffic, and in open plaza areas. Three comparative pedestrian positions, located in a familiar or relatively undisturbed area near the project site, were also tested for reference purposes.

The hot-wire 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. These local wind speeds, U, were normalized by the tunnel reference velocity U_{ref}. Mean and turbulence statistics were calculated and used to estimate the normalised effective peak gust using $\frac{U_{pk}}{U_{ref}} = \frac{U + 3U_{rms}}{U_{ref}}$.

Turntable radius 570 m
Building heights in metres above maximum local ground level

0 m 100 m 200 m 300 m

● Pedestrian location
○ Pedestrian location under overhang

Distress Rating
- Pass
- Able Bodied
- Fail

Comfort Rating
- Outdoor dining
- Pedestrian sitting
- Pedestrian standing
- Pedestrian walking
- Business walking
- Uncomfortable

Figure 4: Remote pedestrian wind speed measurement locations with comfort/distress ratings

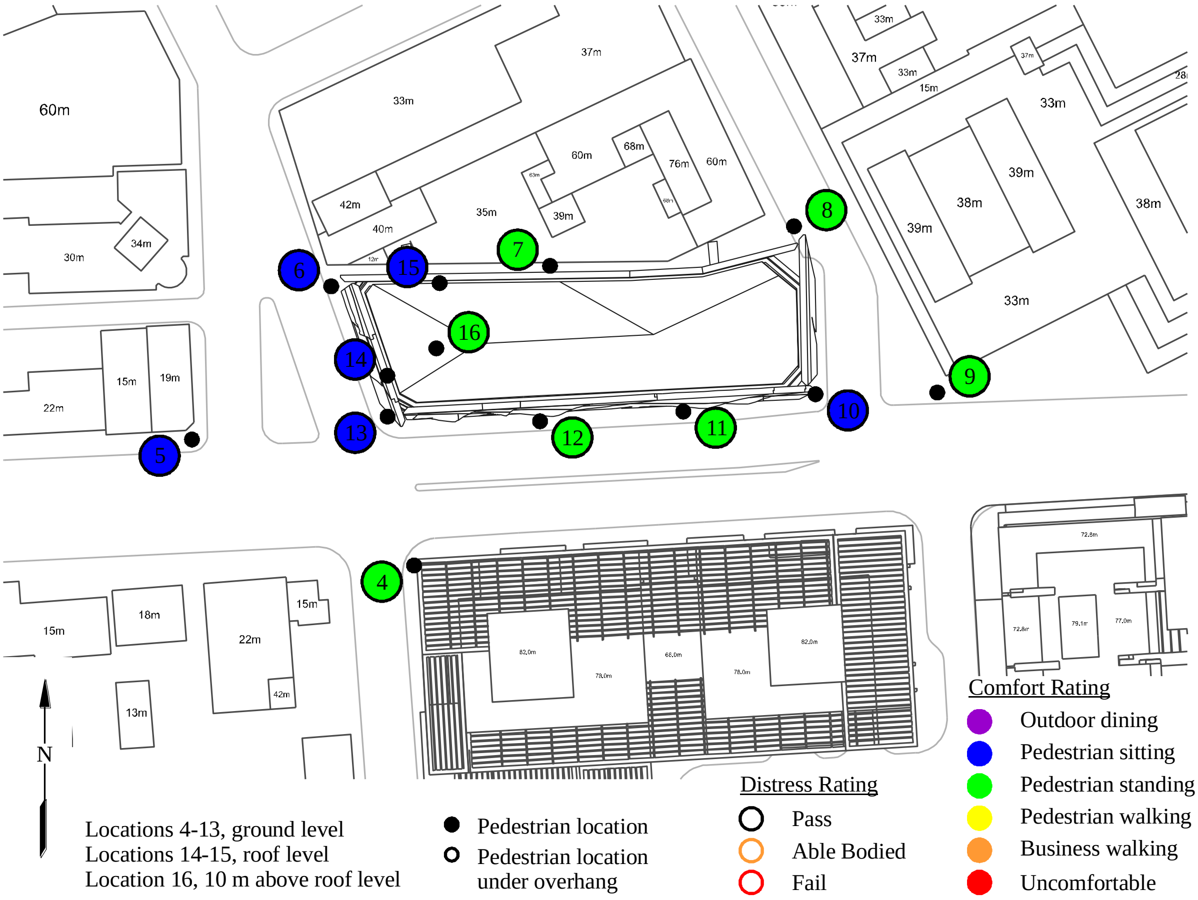

Figure 5: Pedestrian wind speed measurement locations with comfort/distress ratings

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 visualization of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust is of greater importance.

To enable a quantitative assessment of the wind environment, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a height of 10 m at Sydney Airport from 1986 to 2007, Figure 6. 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 criterion lines represent the 5% probability of winds being exceeded from a specific direction.

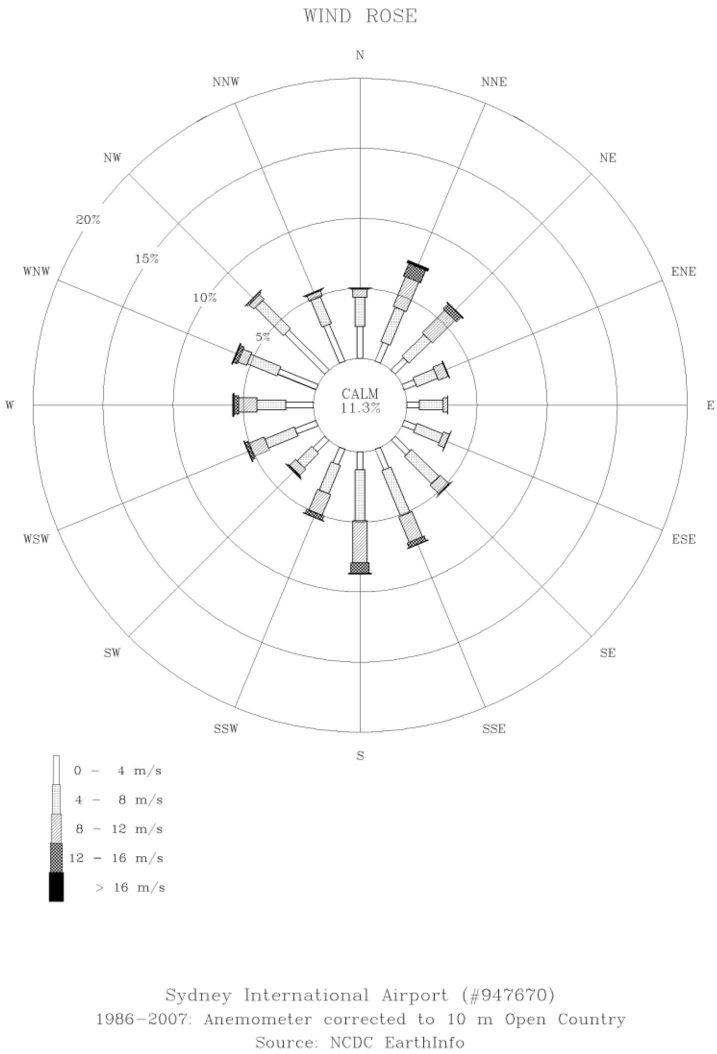

Figure 6: Wind rose of direction and speed for Sydney Airport

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 6 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 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 under the polar plots give the wind speed exceeded 5% and 0.022% for direct comparison with the Lawson criteria and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian comfort and safety with respect to the Lawson criteria is presented in Figure 4 and Figure 5 for each test location. Because some pedestrian wind measurement positions are purposely chosen at sites where large velocities of small spatial extent may exist, the general wind environment about the development may be less severe than one might infer from an analysis only of Figure 4 and Figure 5. The implications of the results are discussed in Section 5.

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.

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

5. DISCUSSION

The wind climatology chart of Figure 6 indicates that the most frequent strong winds are from the north-east, south, and west quadrants. Locations such as point 2, which are sensitive to these directions, Appendix 2, will be more likely to experience higher speeds more often, and thus develop a reputation for being windy. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the graphs in Appendix 2.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded image of Figure 4 and Figure 5, which depict the locations selected for investigation of pedestrian wind comfort around the site along with the Lawson criteria rating for both comfort and distress. Note that testing was performed without planned trees or other plantings to provide a worst case assessment; heavy streetscape planting typically reduces the wind speeds by less than 10%. The central and outer ring colours indicate the comfort and distress rating respectively for each location. Mitigation measures are likely to be required for red locations, and may be necessary for other locations depending on the intended use of the space. Although conditions may be classified acceptable there may be certain wind directions that cause regular strong events, these can be determined by an inspection of the plots in Appendix 2 where calmer conditions occur closer to the centre of the plot.

It is evident from Figure 5 that the wind environment around the proposed development is generally satisfactory for the intended use of the space and all areas are acceptable for pedestrian walking with no distress criteria exceeded. The general wind amenity of the site is typically comparable to wind conditions remote from the site (locations 1 to 3, Figure 4). These surrounding locations give a general indication of the surrounding wind climate and can be used for comparison with the measured wind environment around the development.

Wind conditions are reasonably uniform across the site and with respect to the Lawson criteria are generally fit for purpose. The wind conditions in this area will be dominated by the proposed Frasers Broadway development. Several locations have been tested in the existing conditions without the UTS Broadway or Frasers Broadway developments and are presented in Appendix 3. The results show a similar wind environment across the site. This occurs because the large building massing of the Frasers development creates sheltered conditions for some wind directions, but accelerated channelled flow conditions from other directions resulting in a similar level of wind climate when integrated around all wind directions. The severity of these effects can be ascertained from inspection of the directional data in Appendix 2 and Appendix 3.

All wind conditions at ground level, locations 4-13 Figure 5, are acceptable for use as a main public accessway in satisfying the walking criterion. No uncomfortable locations were recorded across the site. Location 7 in the laneway to the north of the site is classified as acceptable for pedestrian standing, if this area is to be used for outdoor café style activities, local temporary screening would be recommended. For some points certain wind directions will create local windy conditions, such as winds from the south-west quadrant at locations 11 and 12 along Broadway. Wind conditions in the walkway behind the binary screen are expected to be calmer than along Broadway, due to the wind conditions at locations 10 and 13, which will dictate the flow through the walkway.

Locations 14 and 15 on the walkway behind the cantilevered sections of the binary screen experience slightly windy conditions for some wind directions, and are classified for pedestrian sitting. The low once per annum gust wind speeds predicted ensure that this area should be acceptable for student site visits and maintenance throughout the year.

Location 16 is measured approximately 10 m above the roof top for the potential provision of a wind turbine. Despite being windier than other locations around the site, with the wind speed exceeding 4 m/s only 5% of the time, it would be stationary for a large portion of time and would not generate a significant amount of energy. However, from an educational perspective, it would be an exceptionally effective teaching aid for a broad cross-section of students attending courses in the building.

Subsequent to the wind tunnel testing there have been minor architectural changes to the geometry of the binary screen and its relation to pedestrian level. These changes have been reviewed are not expected to significantly change the measured wind environment around the proposed development.

6. CONCLUSION

Wind conditions at ground level met the comfort criterion for use as a main public accessway, and all locations passed the distress criterion. With regard to the DGR key assessment requirement 4, no locations require amelioration measures.

Wind conditions on the pedestrian walkway around the roof of the development were found to be effectively shielded by the binary screen providing a relatively calm working environment.

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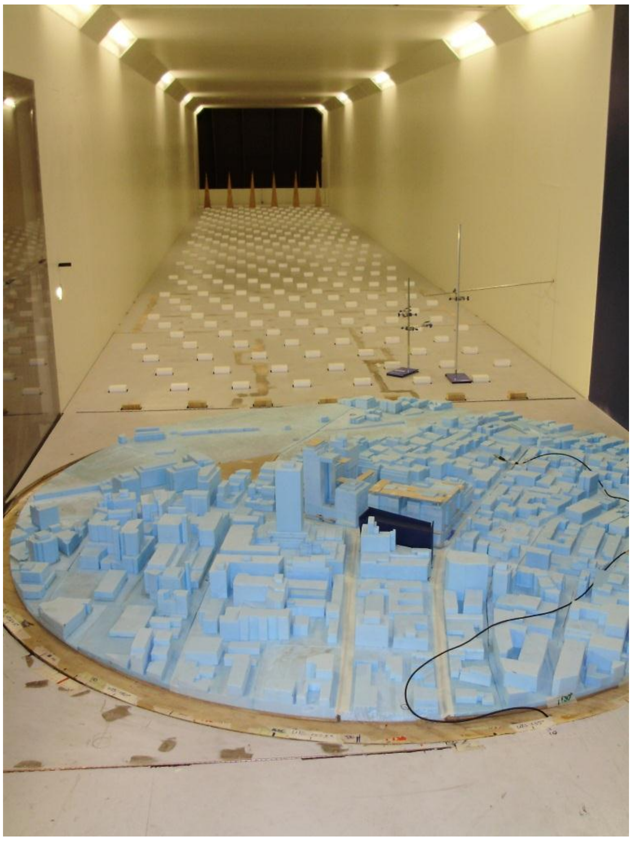
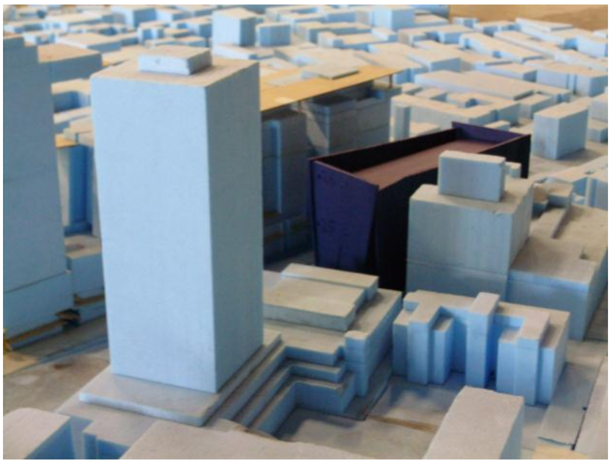
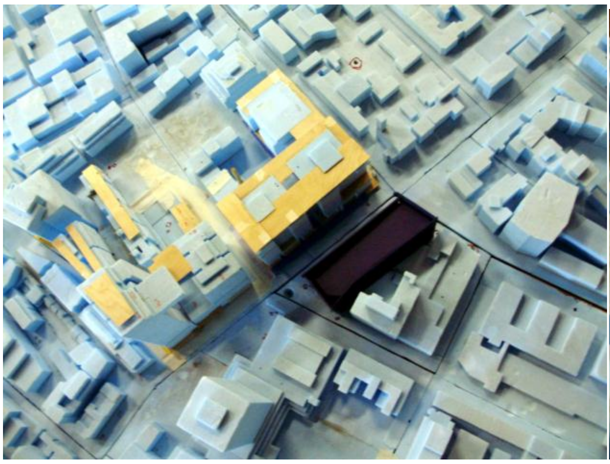
Appendix 1: Additional photographs of the wind tunnel model

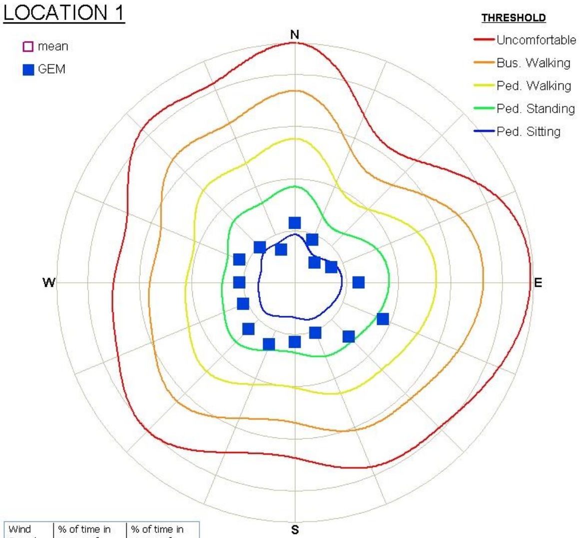






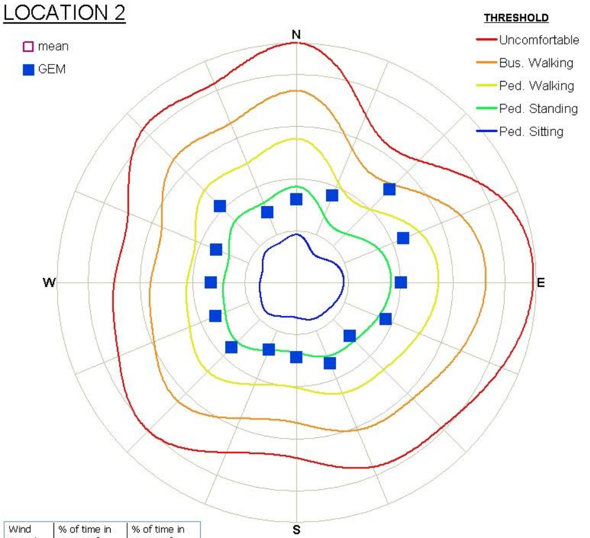
Appendix 2: Directional Wind Results

LOCATION 1



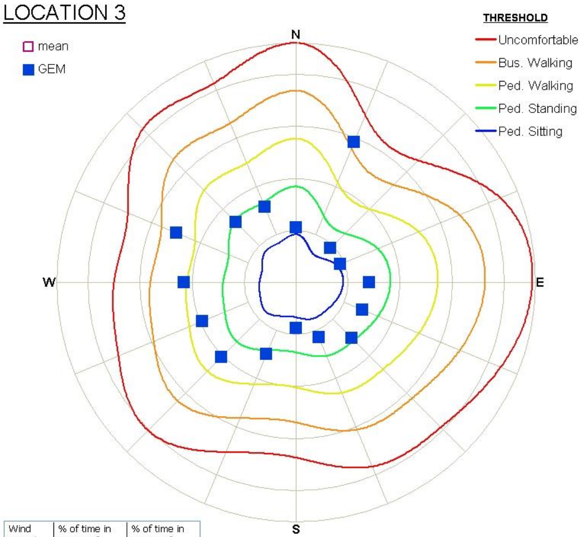
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	8.5	17.5
4.0	0.3	1.4
6.0	0.0	0.1
8.0	0.0	0.0
10.0	0.0	0.0
2.3	**5.0**	Ped Sitting
6.0	**0.022**	Pass
3.0	Ped Sitting	**5.0**
6.9	Pass	**0.022**

LOCATION 2



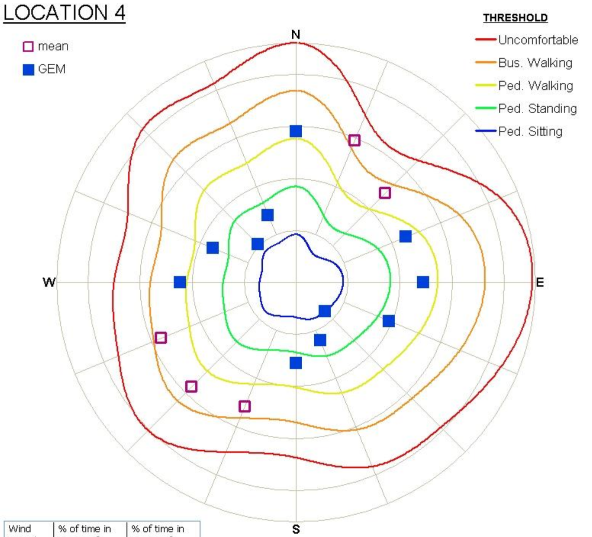
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	25.4	37.1
4.0	4.6	9.7
6.0	1.0	2.1
8.0	0.2	0.4
10.0	0.0	0.1
3.9	**5.0**	Ped Sitting
9.7	**0.022**	Pass
4.8	Ped Standing	**5.0**
10.8	Pass	**0.022**

LOCATION 3



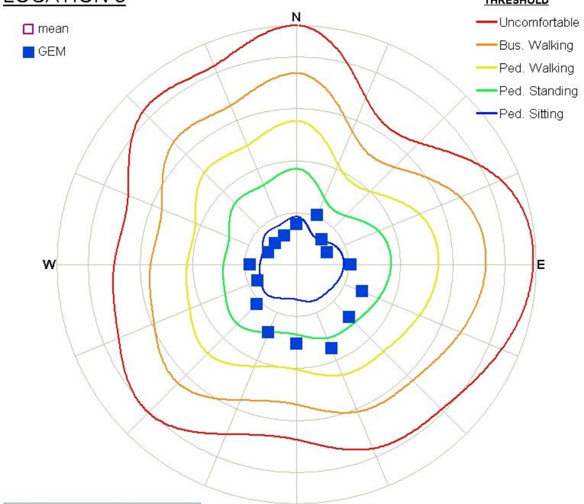
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	18.0	27.9
4.0	4.7	7.0
6.0	1.4	2.0
8.0	0.3	0.6
10.0	0.0	0.1
3.8	**5.0**	Ped Sitting
10.5	**0.022**	Pass
4.5	Ped Standing	**5.0**
11.7	Pass	**0.022**

LOCATION 4



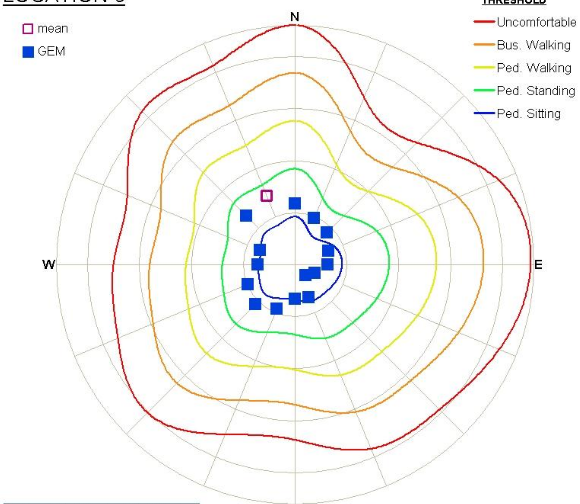
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	33.8	37.4
4.0	13.2	13.8
6.0	4.4	4.1
8.0	1.2	0.9
10.0	0.3	0.2
5.7	**5.0**	Ped Standing
12.7	**0.022**	Pass
5.6	Ped Standing	**5.0**
11.9	Pass	**0.022**

LOCATION 5



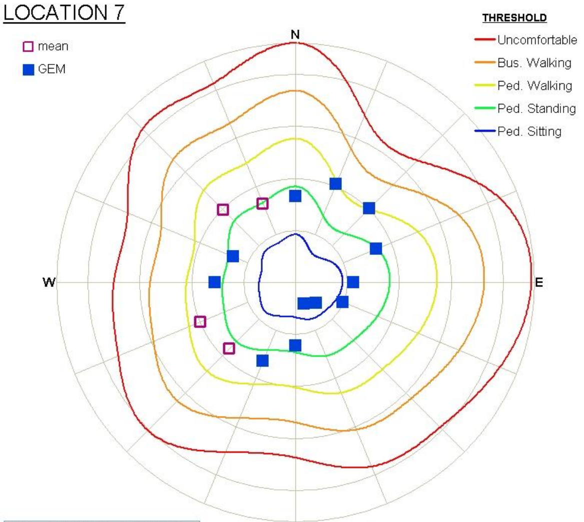
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	9.8	17.9
4.0	0.9	2.2
6.0	0.0	0.2
8.0	0.0	0.0
10.0	0.0	0.0
2.6	**5.0**	Ped Sitting
6.3	**0.022**	Pass
3.2	Ped Sitting	**5.0**
7.5	Pass	**0.022**

LOCATION 6



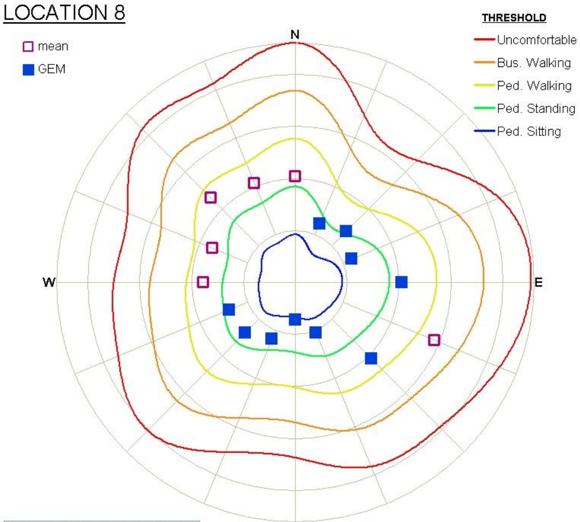
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	5.3	8.2
4.0	0.3	0.3
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
2.0	**5.0**	Ped Sitting
5.5	**0.022**	Pass
2.3	Ped Sitting	**5.0**
5.5	Pass	**0.022**

LOCATION 7



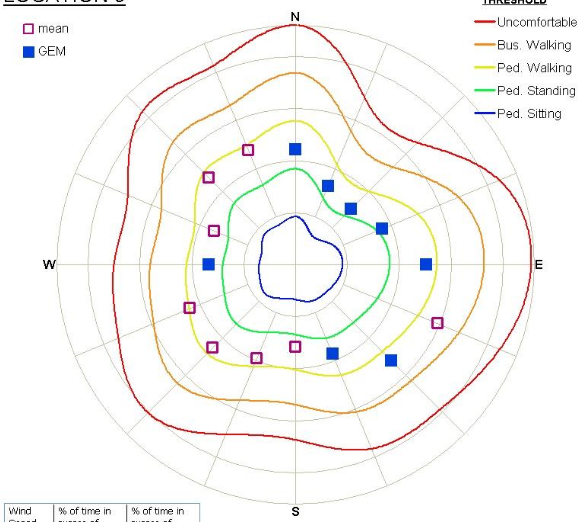
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	22.9	26.7
4.0	4.9	6.7
6.0	0.7	1.1
8.0	0.1	0.1
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
8.7	**0.022**	Pass
4.3	Ped Standing	**5.0**
9.1	Pass	**0.022**

LOCATION 8



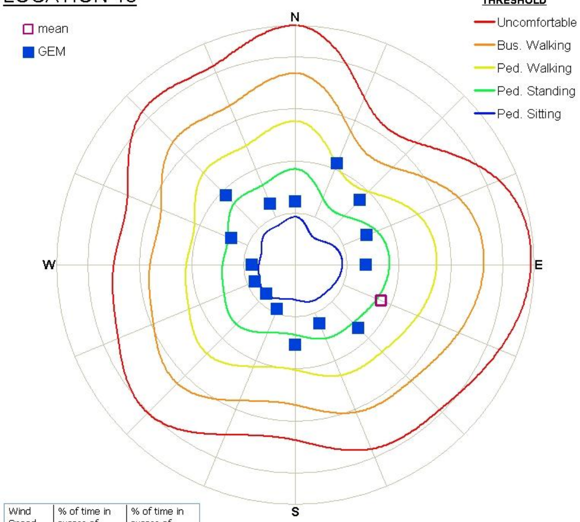
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	23.1	28.9
4.0	5.2	6.7
6.0	1.1	1.1
8.0	0.2	0.2
10.0	0.0	0.0
4.0	**5.0**	Ped Sitting
10.6	**0.022**	Pass
4.3	Ped Standing	**5.0**
10.6	Pass	**0.022**

LOCATION 9



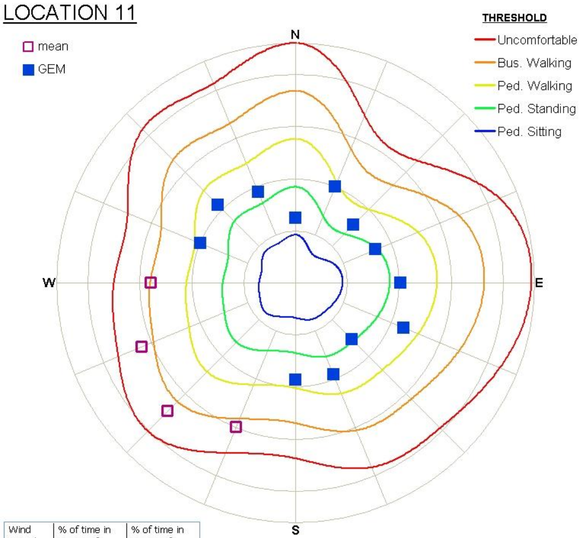
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	38.6	40.7
4.0	11.6	12.7
6.0	2.6	2.5
8.0	0.5	0.4
10.0	0.1	0.1
5.1	**5.0**	Ped Standing
12.0	**0.022**	Pass
5.1	Ped Standing	**5.0**
11.7	Pass	**0.022**

LOCATION 10



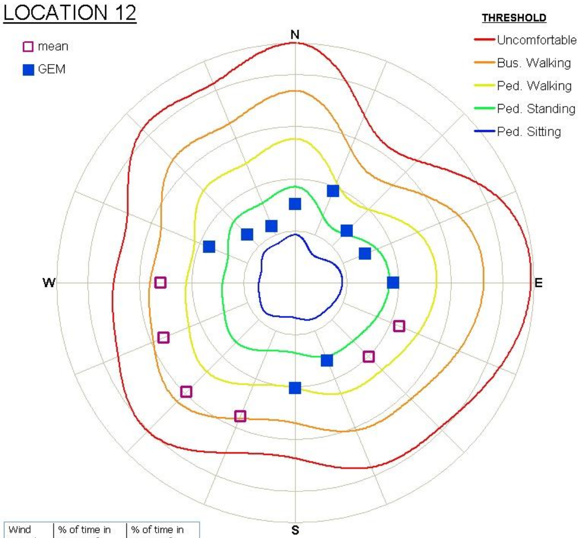
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	21.4	26.6
4.0	3.4	5.2
6.0	0.4	0.7
8.0	0.0	0.1
10.0	0.0	0.0
3.6	**5.0**	Ped Sitting
8.1	**0.022**	Pass
4.0	Ped Sitting	**5.0**
8.7	Pass	**0.022**

LOCATION 11



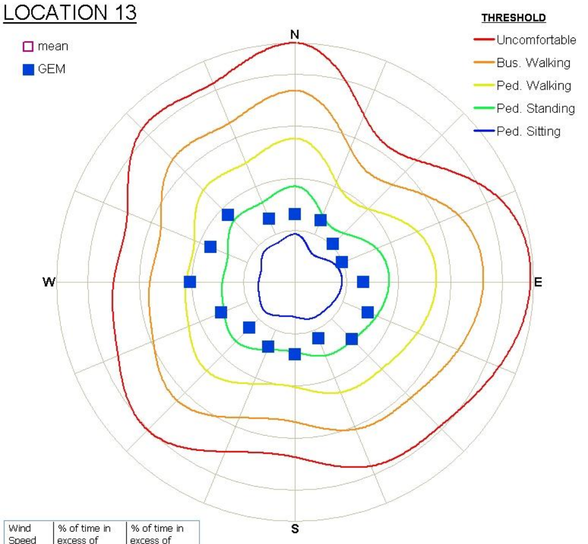
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	36.7	42.0
4.0	12.8	15.1
6.0	4.6	4.4
8.0	1.7	1.1
10.0	0.5	0.3
5.8	**5.0**	Ped Standing
14.7	**0.022**	Pass
5.7	Ped Standing	**5.0**
13.2	Pass	**0.022**

LOCATION 12



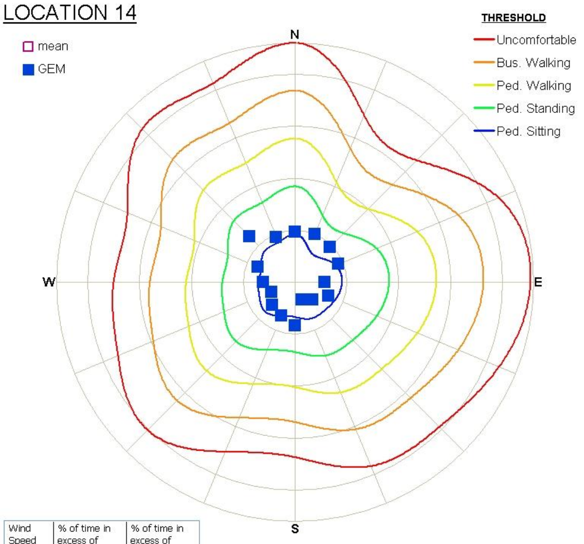
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	34.5	38.8
4.0	11.1	12.6
6.0	3.4	3.0
8.0	1.0	0.6
10.0	0.2	0.1
5.2	**5.0**	Ped Standing
13.0	**0.022**	Pass
5.2	Ped Standing	**5.0**
11.6	Pass	**0.022**

LOCATION 13



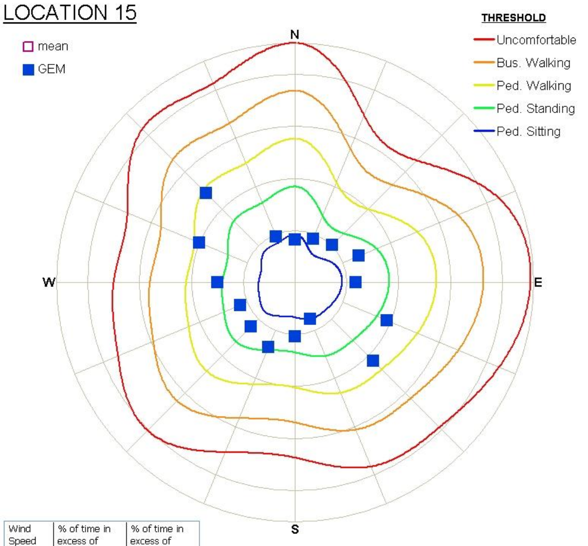
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	18.4	28.0
4.0	2.3	4.7
6.0	0.2	0.7
8.0	0.0	0.1
10.0	0.0	0.0
3.3	**5.0**	Ped Sitting
7.3	**0.022**	Pass
3.9	Ped Sitting	**5.0**
9.1	Pass	**0.022**

LOCATION 14



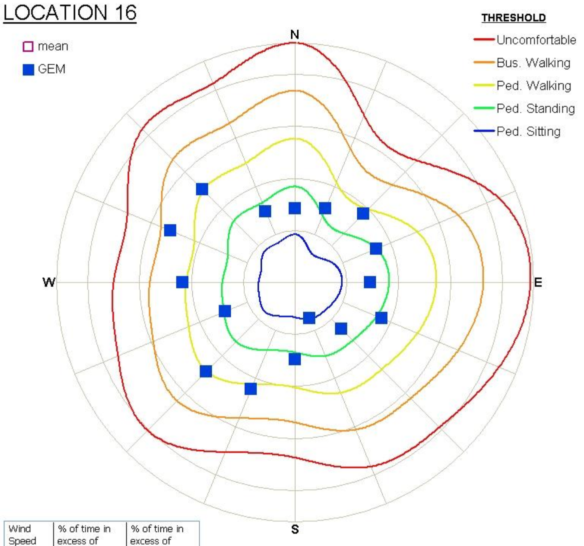
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	3.0	6.7
4.0	0.0	0.2
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
1.7	**5.0**	Outdoor Dinin
4.1	**0.022**	Pass
2.2	Ped Sitting	**5.0**
5.0	Pass	**0.022**

LOCATION 15



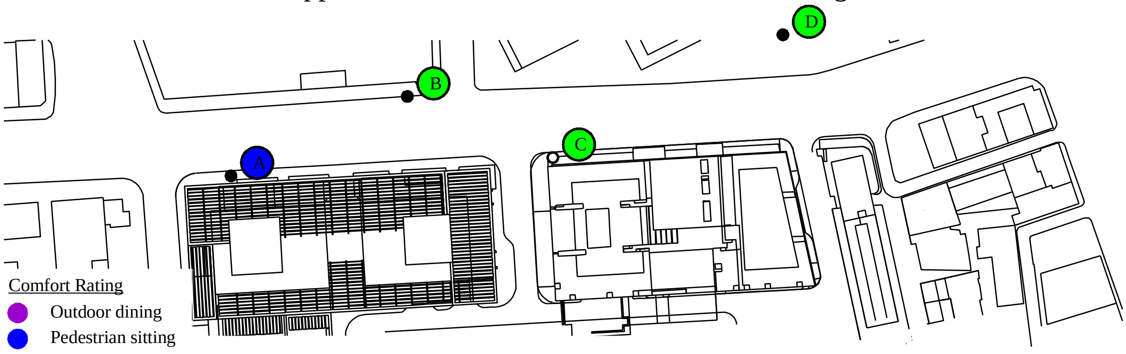
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	16.6	24.5
4.0	2.2	4.6
6.0	0.4	0.9
8.0	0.0	0.2
10.0	0.0	0.0
3.1	**5.0**	Ped Sitting
8.4	**0.022**	Pass
3.8	Ped Sitting	**5.0**
10.1	Pass	**0.022**

LOCATION 16



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.7	35.0
4.0	5.9	9.9
6.0	1.2	2.6
8.0	0.3	0.6
10.0	0.0	0.1
4.2	**5.0**	Ped Standing
10.5	**0.022**	Pass
5.0	Ped Standing	**5.0**
11.6	Pass	**0.022**

Appendix 3: Directional Wind Results – existing condition

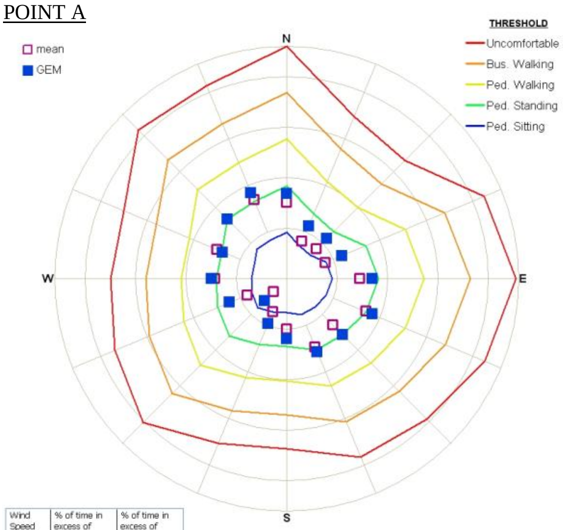


Comfort Rating
- Outdoor dining
- Pedestrian sitting
- Pedestrian standing
- Pedestrian walking
- Business walking
- Uncomfortable

Distress Rating
- Pass
- Able Bodied
- Fail

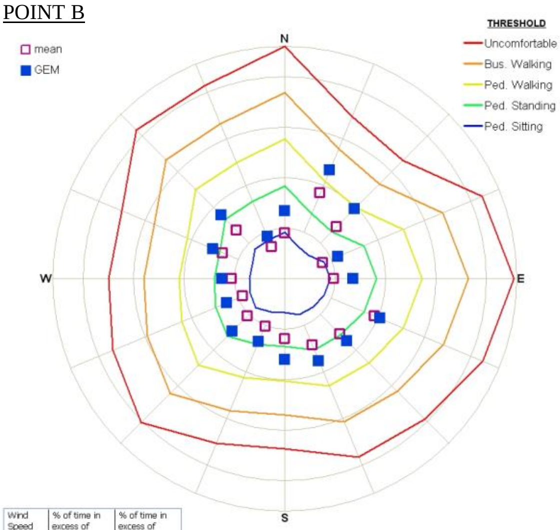
- Pedestrian location
- Pedestrian location under overhang

POINT A



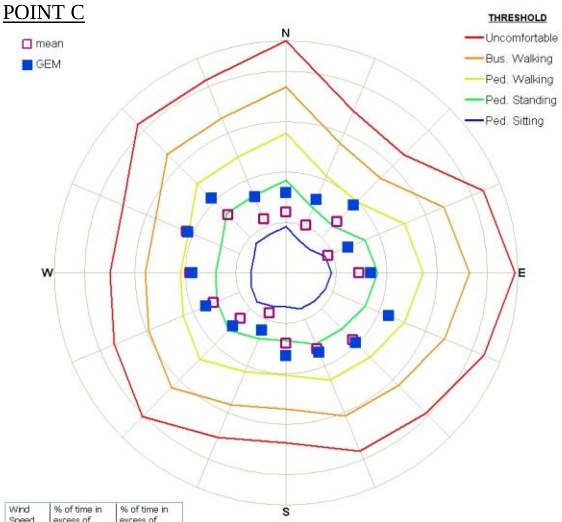
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	19.9	26.2
4.0	2.2	3.5
6.0	0.2	0.3
8.0	0.0	0.0
10.0	0.0	0.0
3.3	**5.0**	Ped Sitting
7.7	**0.022**	Pass
3.7	Ped Sitting	**5.0**
8.2	Pass	**0.022**

POINT B



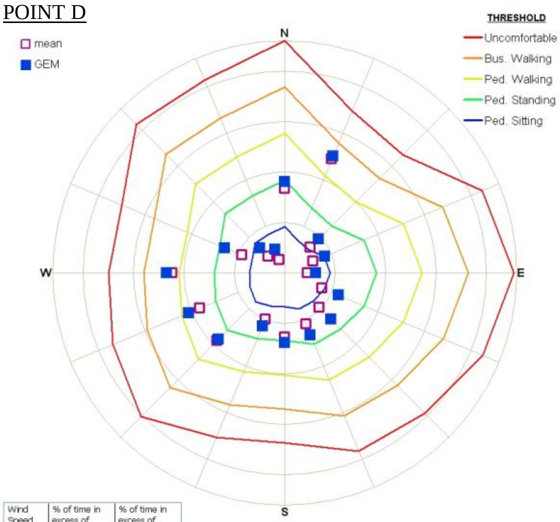
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	22.2	32.7
4.0	3.1	7.5
6.0	0.3	1.2
8.0	0.0	0.2
10.0	0.0	0.0
3.5	**5.0**	Ped Sitting
7.8	**0.022**	Pass
4.4	Ped Standing	**5.0**
9.5	Pass	**0.022**

POINT C



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	30.2	37.1
4.0	6.3	9.5
6.0	0.9	1.6
8.0	0.1	0.2
10.0	0.0	0.0
4.2	**5.0**	Ped Standing
9.7	**0.022**	Pass
4.7	Ped Standing	**5.0**
9.9	Pass	**0.022**

POINT D



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	19.5	25.5
4.0	4.7	6.0
6.0	1.2	1.5
8.0	0.2	0.3
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
10.2	**0.022**	Pass
4.2	Ped Standing	**5.0**
10.7	Pass	**0.022**