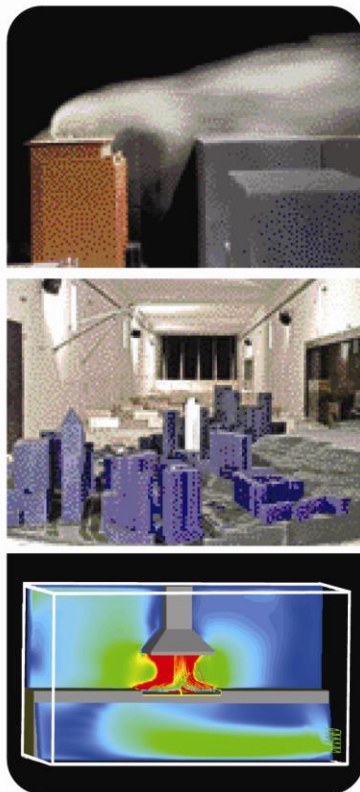




CERMAK
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WIND ENGINEERING AND AIR QUALITY CONSULTANTS

FINAL REPORT



Wind Tunnel Tests for:

SITE 9, SYDNEY OLYMPIC PARK

Sydney Olympic Park, NSW 2127

Australia

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EXECUTIVE SUMMARY

This report provides an opinion based qualitative assessment of the impact of the proposed Site 9, Sydney Olympic Park on the local pedestrian-level wind environment in and around the development. This assessment is based on wind-tunnel testing of the proposed development combined with site specific wind climate data.

A model of the project was fabricated to a 1:300 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 450 m radius were constructed and placed on the turntable. The existing site conditions were tested, and compared with the expected wind environment with the proposed development.

The proposed development is relatively isolated from a wind perspective. The environmental wind conditions around the proposed development are generally expected to be suitable for pedestrian standing from a comfort perspective, with locations on the corners being slightly windier and classified as suitable for pedestrian walking with reference to the Lawson comfort criterion. All location passed the distress criterion with reference to Lawson pedestrian wind acceptability criterion. The site location, massing, large podium to the north, and orientation relative to the prevailing wind directions reduces the amount of downwash reaching street level.

Windier locations around the development are due to flow accelerating around the building corners. The through-site link is suitable for pedestrian standing activities similar to the exterior. Comparison with the existing wind conditions shows that the proposed development will have minimal impact on the wind conditions. As the proposed development will have a noticeable, but acceptable, impact on the ground level pedestrian wind environment close to the site, no additional amelioration measures are considered necessary.

Wind conditions on the north podium are generally classified as suitable for pedestrian sitting activities, largely due to the presence of significant landscaping.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
04/04/2016	Final Report	KF	GSW	GSW

TABLE OF CONTENTS

EXECUTIVE SUMMARY	ii
TABLE OF CONTENTS.....	iii
LIST OF FIGURES.....	iii
LIST OF TABLES	iii
LIST OF SYMBOLS.....	iv
1. INTRODUCTION.....	1
2. THE WIND TUNNEL TEST	2
3. ENVIRONMENTAL WIND CRITERIA	5
4. DATA ACQUISITION AND RESULTS	6
4.1. Velocities.....	6
4.1.1. Velocity Profiles.....	6
4.1.2. Pedestrian Winds	6
5. DISCUSSION.....	9
REFERENCES.....	14
Appendix 1: Additional photographs of the CPP wind tunnel model.....	15
Appendix 2: Directional Wind Results	17

LIST OF FIGURES

Figure 1: Schematic of the closed circuit wind tunnel.....	2
Figure 2: Mean velocity and turbulence profiles.....	3
Figure 3: Project location and turntable layout	4
Figure 4: Proposed Site 9, Sydney Olympic Park model in the wind tunnel viewed from the east	4
Figure 5: Wind rose for Bankstown Airport	8
Figure 6: Pedestrian wind speed measurement locations with comfort/distress ratings – site plan of existing configuration	10
Figure 7: Pedestrian wind speed measurement locations with comfort/distress ratings – Site plan of proposed configuration	10
Figure 8: Pedestrian wind speed measurement locations with comfort/distress ratings – Ground floor of proposed configuration	12
Figure 9: Pedestrian wind speed measurement locations with comfort/distress ratings – Podium levels of proposed configuration	13
Figure 10: Existing development viewed from the south-west.....	15
Figure 11: Proposed development viewed from the south-west	15
Figure 12: Close up of the north podium viewed from the south-west	16

LIST OF TABLES

Table 1: Configurations for data acquisition.....	1
Table 2: Summary of Lawson criteria	5
Table 3: Summary of wind effects on people, Penwarden (1973)	8

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 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, m ² /s
$\sigma()$	Standard deviation of $()$, $\sigma() = ()'_{rms}$
ρ	Density of approach flow, kg/m ³
$()_{max}$	Maximum value during data record
$()_{min}$	Minimum value during data record
$()_{mean}$	Mean value during data record
$()_{rms}$	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.

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

Table 1: Configurations for data acquisition

<i>General Information</i>	
Model length scale	1:300
Surrounding model radius (full-scale)	450 m
Reference height (full-scale)	200 m AGL
Approach Terrain Category	Terrain Category 3
<i>Testing Configuration(s)</i>	
Proposed Configuration	Proposed Site 9, Sydney Olympic Park development with surrounding buildings, as shown in Figure 3. Pedestrian winds measured at 25 locations for 16 wind directions at 22.5° increments from 0° (north)
Existing Configuration	Existing conditions with surrounding buildings as shown in Figure 10 in Appendix 1. Pedestrian winds measured at 5 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 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 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

A model of the proposed development and surrounds to a radius of 450 m was constructed at a scale of 1:300, 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 testing are included in Appendix 1.

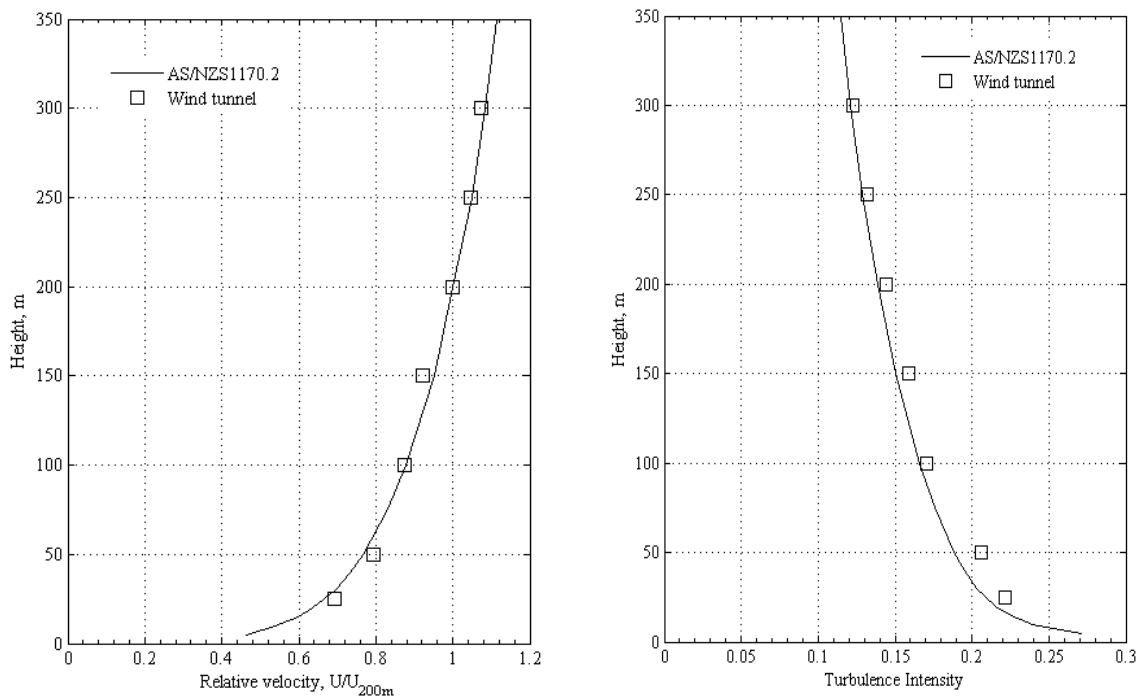


Figure 2: Mean velocity and turbulence profiles

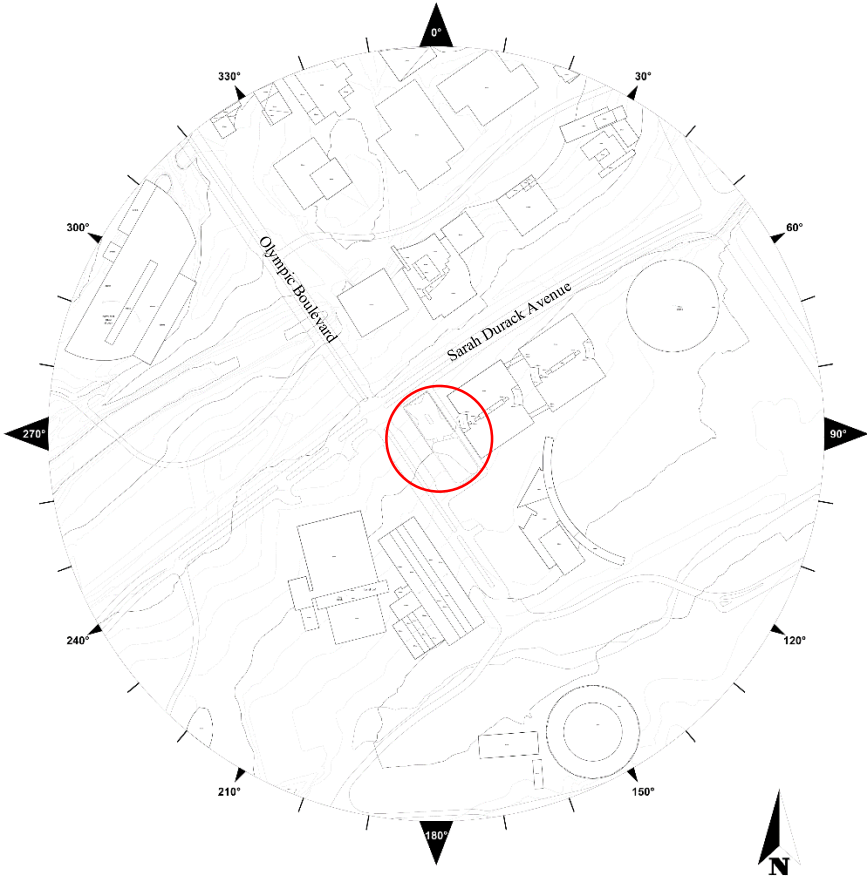


Figure 3: Project location and turntable layout



Figure 4: Proposed Site 9, Sydney Olympic Park 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. The Sydney Olympic Park Authority has no specific wind assessment criteria.

Lawson’s criteria have categories for comfort, 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 speeds¹. 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. Assessment using the Lawson criteria provides a similar classification as using once per annum gust criteria, however 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
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.

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 Sydney Olympic Park about 13 km to the west of Sydney CBD. The site is located on the south-east corner of Olympic Boulevard and Sarah Durack Avenue, Figure 3. The development is in the vicinity of various stadia used in the 2000 Sydney Olympics.

For this report, wind speed measurements were recorded at 25 locations to evaluate pedestrian comfort in and around the project site, Figure 6 to Figure 9. All points tested were for the configurations described in Table 1. 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 primarily for pedestrian safety around the development, at building corners where relatively severe conditions are frequently found, near building entrances, and at outdoor recreational areas. 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, 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 Bankstown Airport from 1993 to 2014, 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 comfort and safety with respect to the Lawson criteria is presented in, Figure 6 to Figure 9, for each test location. The implications of the results are discussed in Section 5.

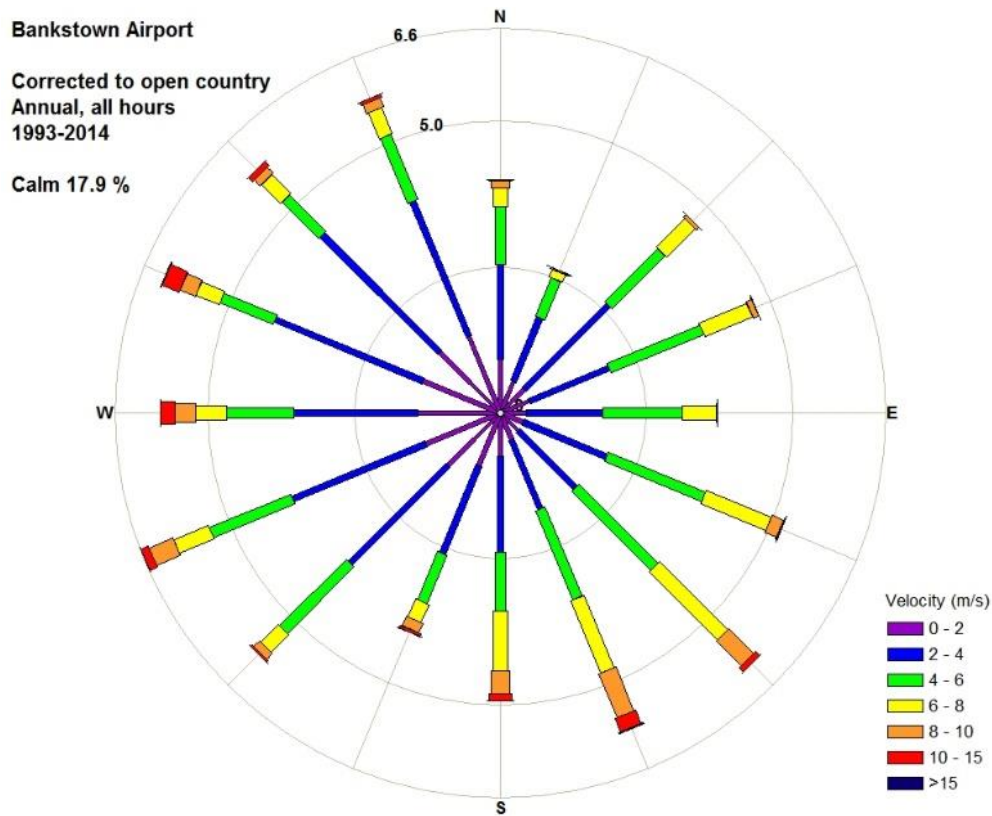


Figure 5: Wind rose for Bankstown Airport

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-east, south-west, and north-west quadrants. The locations tested around the development site are susceptible to winds from the different directions, depending on the relative location of the point 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 wind gusts from various directions.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 6 to Figure 9, which depict the locations selected for investigation of pedestrian wind comfort along with the Lawson criteria rating for both comfort and distress. Note that testing was performed without all the planned trees and other plantings to provide a worst case assessment; heavy landscape planting typically reduces the wind speeds by less than 10%. The dense tree planting along Sydney Olympic Boulevard was included in the model. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes the distress criterion. 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 plots in Appendix 2.

Wind conditions at locations around the existing configuration are classified as suitable for pedestrian standing or sitting activities, Figure 6. These results will be used as a comparison to determine the effect that the proposed development will have on the pedestrian wind environment.

The wind environment at ground level locations close to the proposed development are presented in Figure 7. It is evident that all locations are classified as suitable for pedestrian standing or sitting. All locations pass the distress criterion. Comparison of Locations 1 and 3 in the proposed configuration with 1.1 and 3.1 of the existing configuration shows the extent to which the proposed development affects the pedestrian level wind conditions in the north-east vicinity of the site. In the existing configuration, Locations 1.1 and 3.1 were classified as suitable for pedestrian sitting activities.

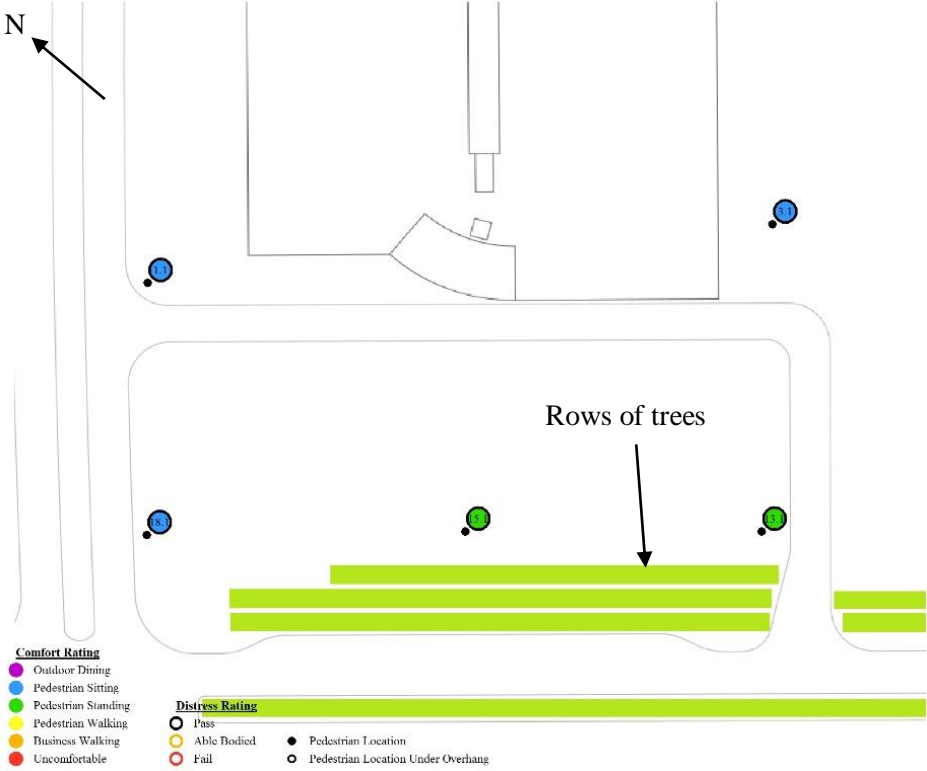


Figure 6: Pedestrian wind speed measurement locations with comfort/distress ratings – site plan of existing configuration

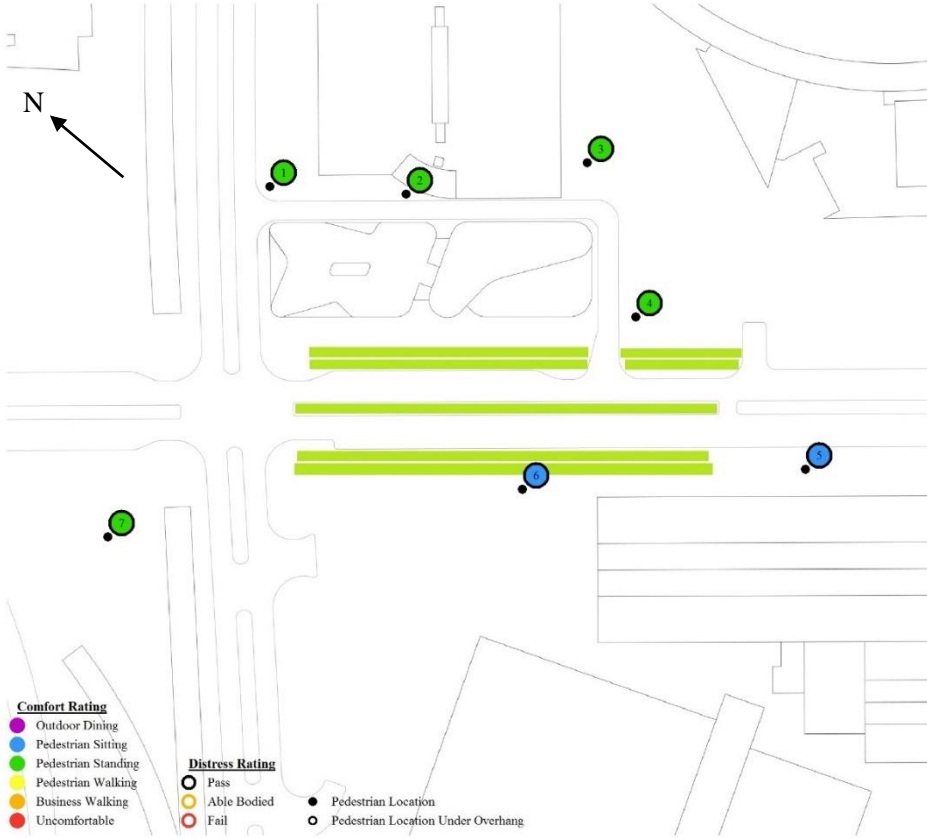


Figure 7: Pedestrian wind speed measurement locations with comfort/distress ratings – Site plan of proposed configuration

The wind environment at ground level locations within the proposed development is presented in Figure 8. The podium appears to have mitigated a significant portion of the downwash, which is beneficial for the ground level wind conditions. All locations pass the distress criterion. The majority of all locations are classified as suitable for pedestrian standing or sitting. Locations 12, 13, and 18, on the building corners, are classified as suitable for pedestrian walking and are expected to be windy for certain wind conditions. Analysis of the polar plots Appendix 2 reveals that the building corners are susceptible to winds from the south-west quadrant, and would be suitable for the wind speed associated with upper bound of the pedestrian walking criterion for around 97% of the time. This is considered acceptable for use as a pedestrian thoroughfare.

Locations around the development and outside main entrances are classified as suitable for pedestrian standing activities, which is considered acceptable for the intended use of the space. Any future café-style seating around the development should be situated away from the building corners, with localised screening to create calmer conditions if necessary.

Wind conditions at either end of the through-site link, Locations 10 and 15, are suitable for the wind speed associated with the pedestrian standing criterion for more than 95% of the time, Figure 8. The wind speeds in the through-site like are developed by pressure driven flow and are expected to be similar to the wind conditions at either end of the passageway. These wind speeds are considered acceptable given its intended use as a pedestrian thoroughfare. Wind conditions through the pedestrian link will be steady as they are driven by the pressure differential at either end of the link.

Comparing Locations 13.1, 15.1, and 18.1 of the existing configuration with Locations 13, 15, and 18 of the proposed configuration, it is evident that the proposed development will adversely alter the ground level wind conditions primarily around the building corners. This is as expected due to the inclusion of a large isolated development. However, the resulting wind conditions are considered acceptable given the intended use of these areas. All locations pass the distress criterion, and no amelioration measures are considered necessary.



Figure 8: Pedestrian wind speed measurement locations with comfort/distress ratings – Ground floor of proposed configuration

The wind environment on the private north and south podium of the proposed development is presented in Figure 9. Significant landscaping was incorporated into the north podium of the model using evergreen trees, Figure 12 in Appendix 1. Wind conditions on the north podium roof are relatively calm, due to the amount of landscaping around the raised central atrium, and the presence of a 1.2 m high balustrade around the perimeter of the podium. Location 20 is close to the podium edge and experiences downwash flows from the south tower for winds from the south-east and north-west quadrants. The classification of the north podium roof as suitable for pedestrian standing is acceptable and the wind conditions are relatively mild for such a space. All locations pass the distress criterion.

The south podium is non-trafficable to residents, and the wind conditions here were simply included to determine the magnitude of the downwash off the south tower. The wind conditions on the south podium are windier than on the north podium due to the proximity to the tower. It should be noted that the primary purpose of a podium is to protect the ground plane from strong downwash winds, and so are inherently windy. Windy conditions in this area are largely attributed to winds from the south-east and south-west producing downwash from the tower.

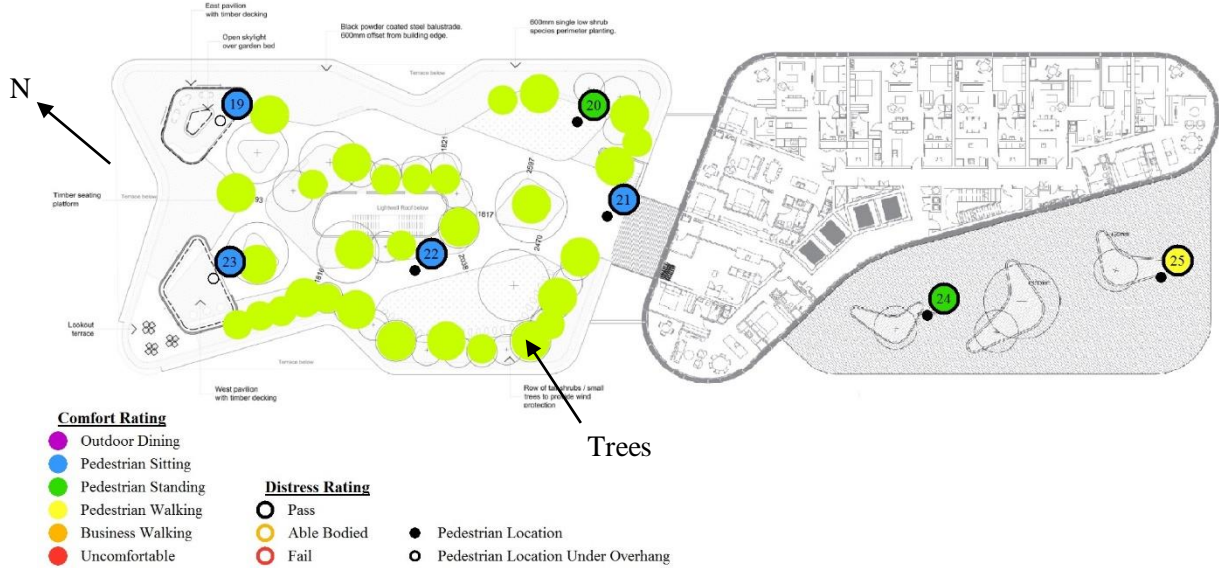


Figure 9: Pedestrian wind speed measurement locations with comfort/distress ratings – Podium levels of proposed configuration

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Appendix 1: Additional photographs of the CPP wind tunnel model



Figure 10: Existing development viewed from the south-west

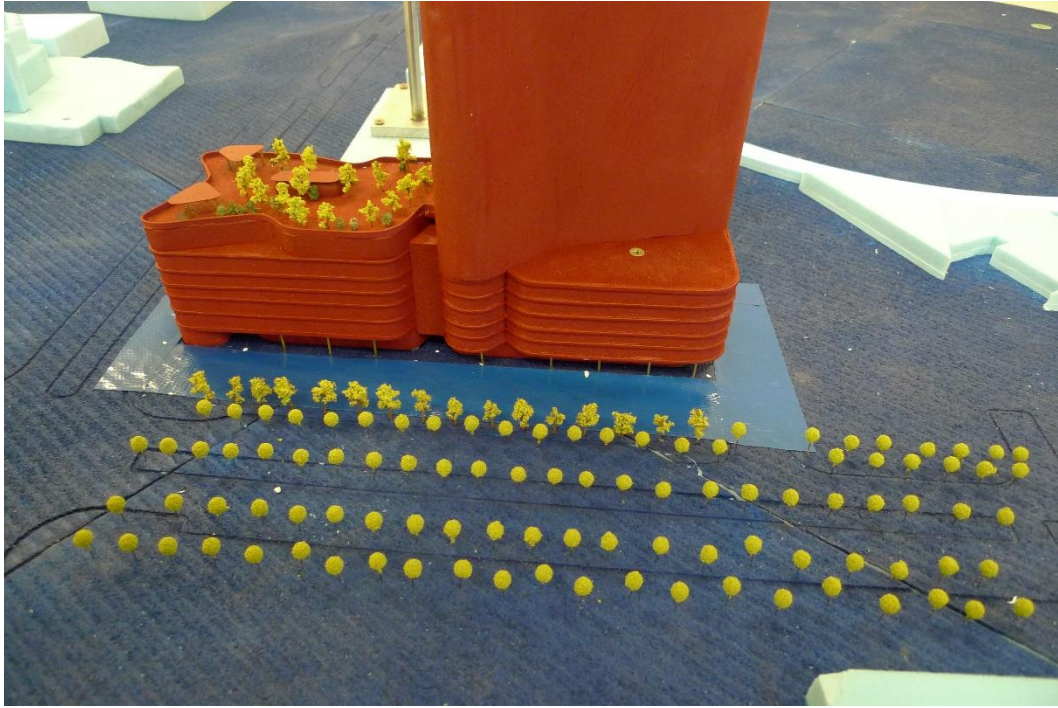


Figure 11: Proposed development viewed from the south-west

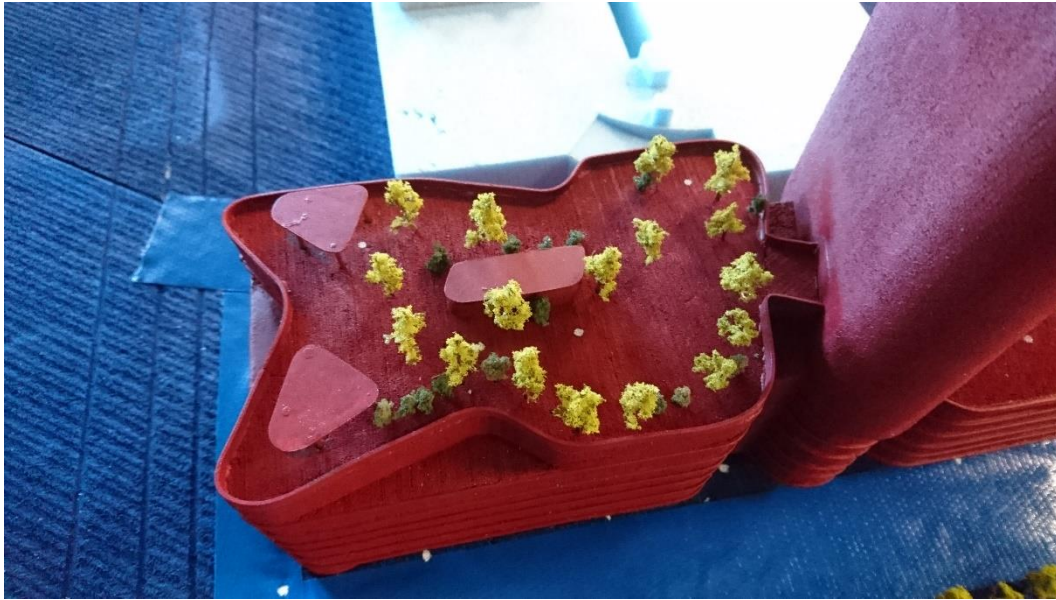
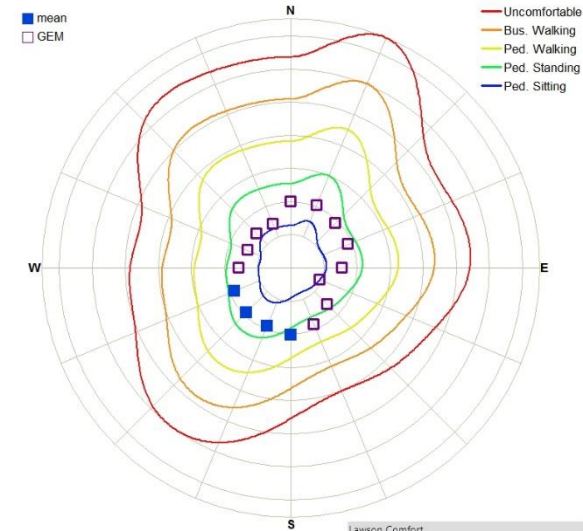


Figure 12: Close up of the north podium viewed from the south-west

Appendix 2: Directional Wind Results

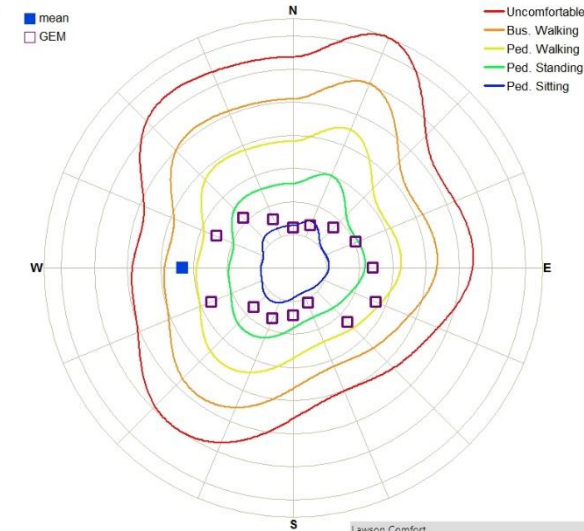
LOCATION 1.1



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	22.24	26.74	27.85	
4	1.60	1.82	2.29	
6	0.05	0.05	0.07	
8	0.00	0.00	0.00	
10	0.00	0.00	0.00	

Lawson Comfort				
(5%)	MEAN	GEM	COMBINED	
V (m/s)	3.2	3.4	3.5	
Rating	Ped Sitting	Ped Sitting	Ped Sitting	
Lawson Safety				
(0.022%)	MEAN	GEM	COMBINED	
V (m/s)	6.5	6.4	6.6	
Rating	Pass	Pass	Pass	

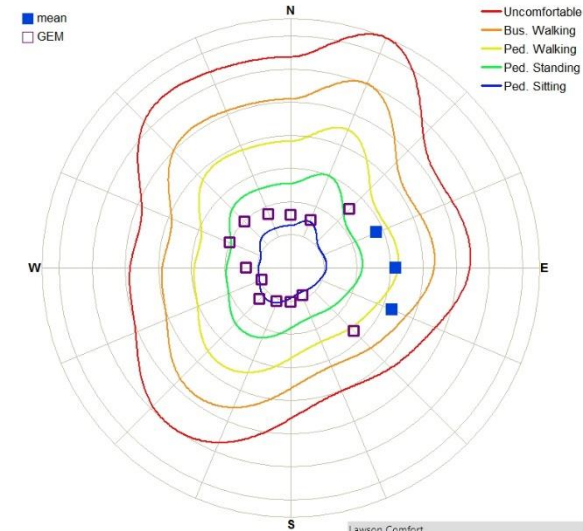
LOCATION 1



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	26.62	34.89	35.67	
4	5.80	8.21	8.71	
6	1.18	1.15	1.55	
8	0.24	0.12	0.26	
10	0.04	0.01	0.04	

Lawson Comfort				
(5%)	MEAN	GEM	COMBINED	
V (m/s)	4.1	4.5	4.6	
Rating	Ped Standing	Ped Standing	Ped Standing	
Lawson Safety				
(0.022%)	MEAN	GEM	COMBINED	
V (m/s)	10.6	9.5	10.7	
Rating	Pass	Pass	Pass	

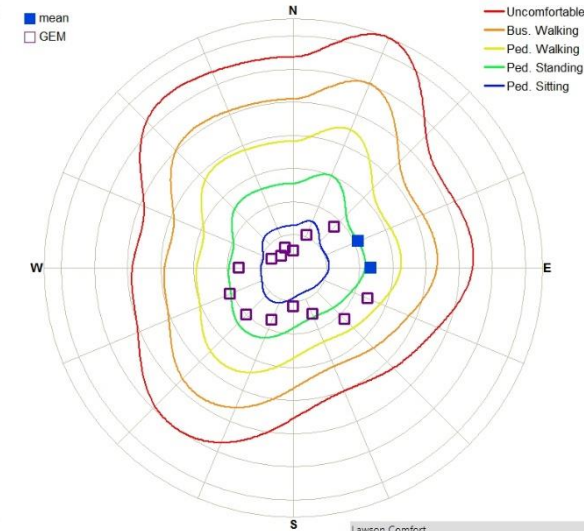
LOCATION 2



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	22.73	27.45	27.86	
4	8.84	8.77	9.77	
6	1.37	0.98	1.57	
8	0.08	0.04	0.09	
10	0.00	0.00	0.01	

Lawson Comfort				
(5%)	MEAN	GEM	COMBINED	
V (m/s)	4.7	4.6	4.9	
Rating	Ped Standing	Ped Standing	Ped Standing	
Lawson Safety				
(0.022%)	MEAN	GEM	COMBINED	
V (m/s)	8.8	8.4	8.9	
Rating	Pass	Pass	Pass	

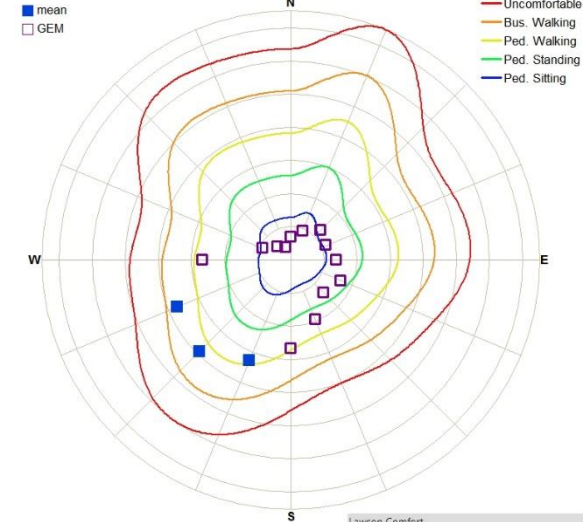
LOCATION 3.1



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	21.72	27.08	27.40	
4	2.77	4.11	4.44	
6	0.06	0.15	0.15	
8	0.00	0.01	0.01	
10	0.00	0.00	0.00	

Lawson Comfort				
(5%)	MEAN	GEM	COMBINED	
V (m/s)	3.6	3.8	3.9	
Rating	Ped Sitting	Ped Sitting	Ped Sitting	
Lawson Safety				
(0.022%)	MEAN	GEM	COMBINED	
V (m/s)	6.4	7.0	7.0	
Rating	Pass	Pass	Pass	

LOCATION 3

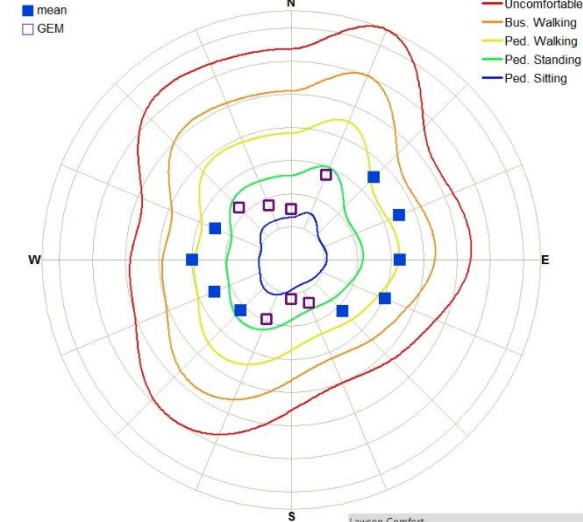


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.16	30.43	31.46
4	7.07	7.82	8.89
6	1.90	1.63	2.30
8	0.39	0.20	0.43
10	0.06	0.02	0.07

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	4.6	4.8
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	9.9	11.0
Rating	Pass	Pass	Pass

LOCATION 4

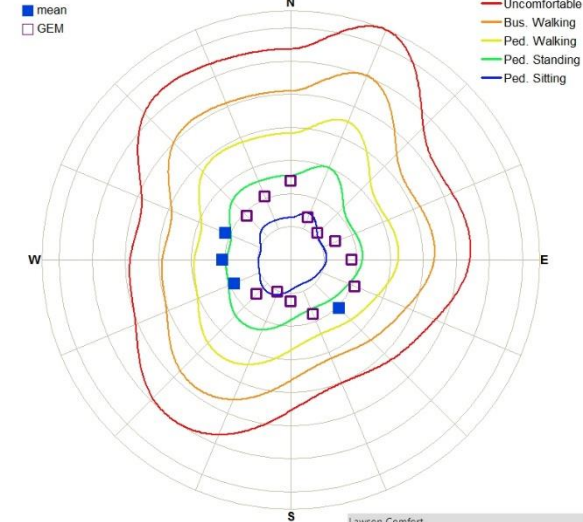


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	36.47	38.87	41.58
4	13.65	10.55	13.99
6	2.73	1.03	2.75
8	0.19	0.05	0.19
10	0.02	0.01	0.02

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.3	4.8	5.3
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.8	8.7	9.8
Rating	Pass	Pass	Pass

LOCATION 5

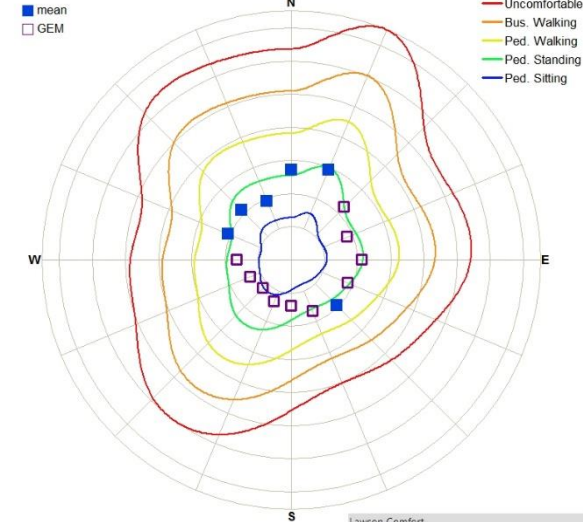


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.34	28.73	29.87
4	3.29	3.29	4.09
6	0.15	0.10	0.18
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	3.7	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.2	6.8	7.3
Rating	Pass	Pass	Pass

LOCATION 6

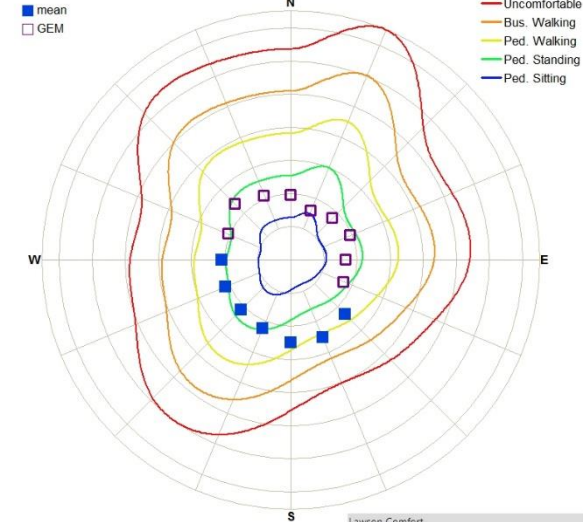


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.32	31.95	33.12
4	2.64	2.76	3.37
6	0.12	0.08	0.13
8	0.01	0.00	0.01
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	3.6	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.0	6.7	7.1
Rating	Pass	Pass	Pass

LOCATION 7

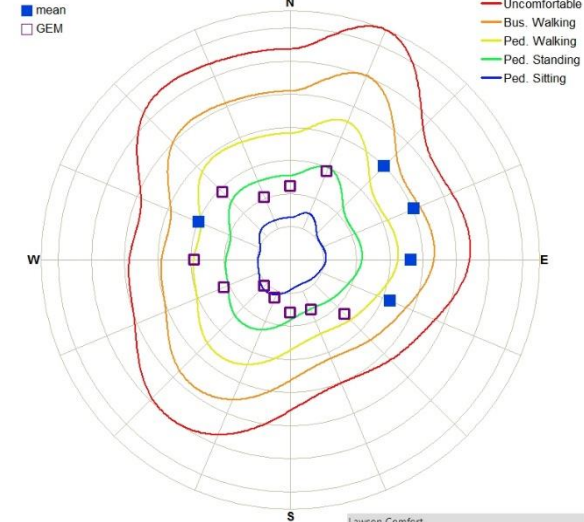


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	33.56	36.33	38.28
4	7.52	6.24	8.13
6	0.85	0.41	0.88
8	0.06	0.02	0.06
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.4	4.2	4.5
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.6	7.9	8.7
Rating	Pass	Pass	Pass

LOCATION 8

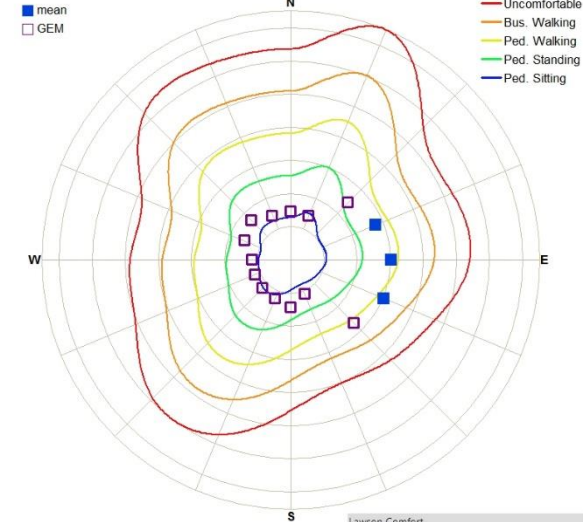


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	35.53	43.02	44.79
4	14.05	12.89	16.35
6	4.26	1.70	4.55
8	0.46	0.15	0.51
10	0.02	0.02	0.03

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.7	5.0	3.8
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.0	9.7	10.2
Rating	Pass	Pass	Pass

LOCATION 9

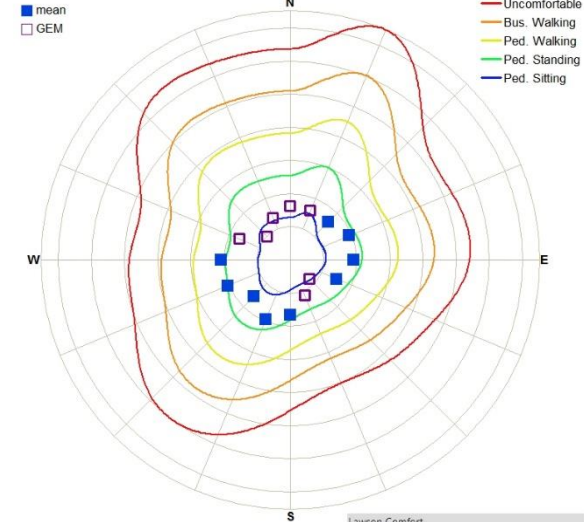


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	21.64	27.68	28.22
4	7.33	7.33	8.75
6	0.81	0.67	1.16
8	0.03	0.03	0.05
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.4	4.4	4.7
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.1	8.1	8.5
Rating	Pass	Pass	Pass

LOCATION 10

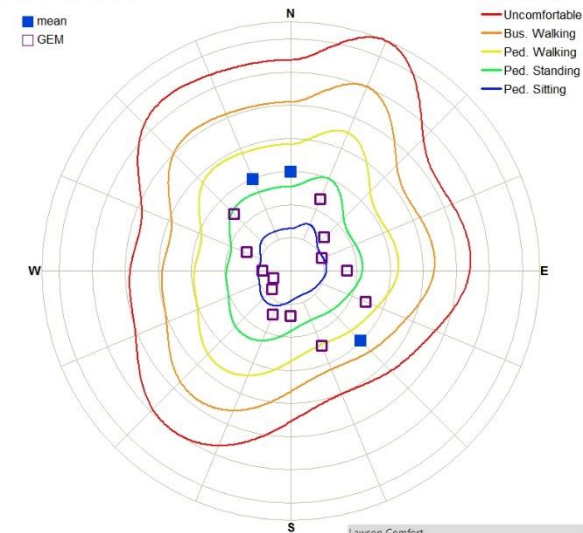


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	21.61	22.19	24.30
4	1.62	1.38	1.77
6	0.08	0.05	0.09
8	0.01	0.00	0.01
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	3.1	3.3
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.9	6.6	6.9
Rating	Pass	Pass	Pass

LOCATION 11

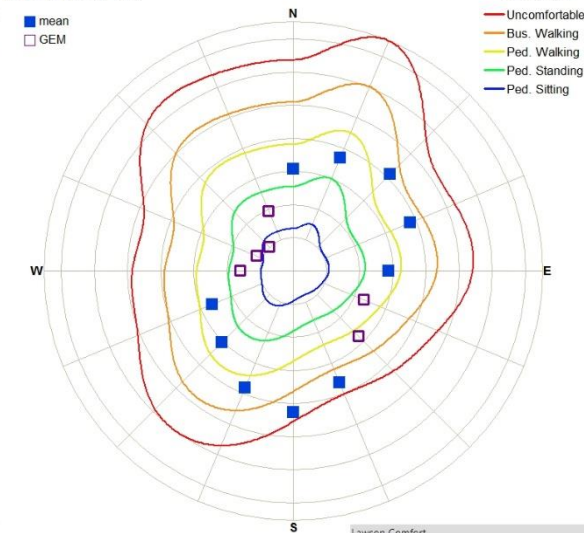


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	23.49	28.12	28.94
4	5.74	7.46	8.02
6	1.09	1.11	1.46
8	0.09	0.08	0.11
10	0.01	0.01	0.01

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	4.5	4.6
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	8.9	9.3
Rating	Pass	Pass	Pass

LOCATION 12

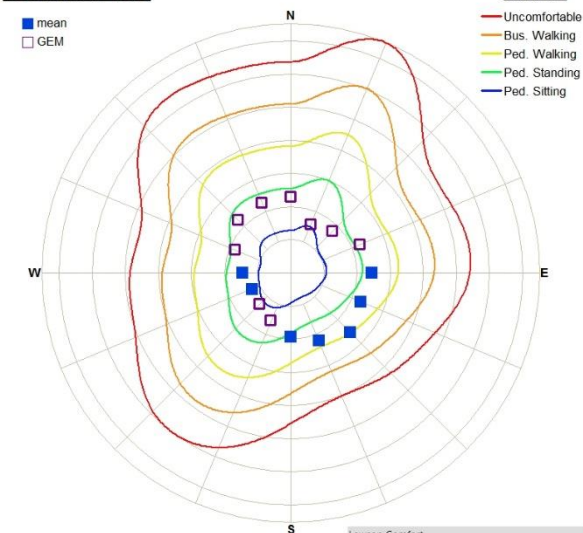


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	44.95	44.88	48.46
4	19.18	17.33	21.85
6	6.91	3.96	7.46
8	1.82	0.67	1.86
10	0.41	0.09	0.41

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.5	5.7	6.6
Rating	Ped Walking	Ped Standing	Ped Walking

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.4	11.4	13.4
Rating	Pass	Pass	Pass

LOCATION 13.1

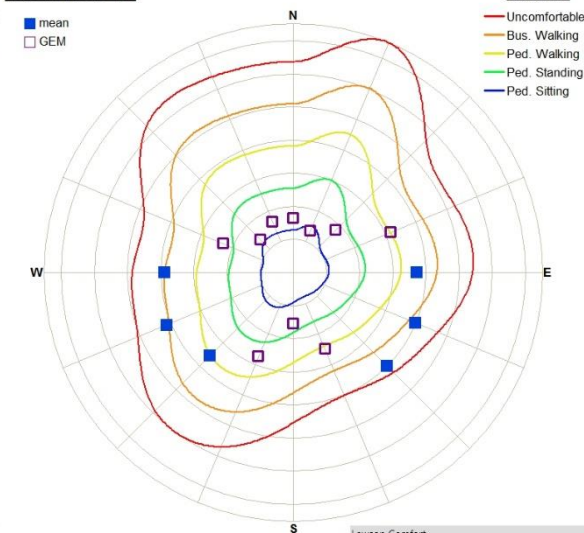


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	33.05	34.06	34.97
4	7.14	6.10	7.47
6	0.47	0.27	0.49
8	0.02	0.01	0.02
10	0.00	0.00	0.00

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

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.9	7.5	8.0
Rating	Pass	Pass	Pass

LOCATION 13

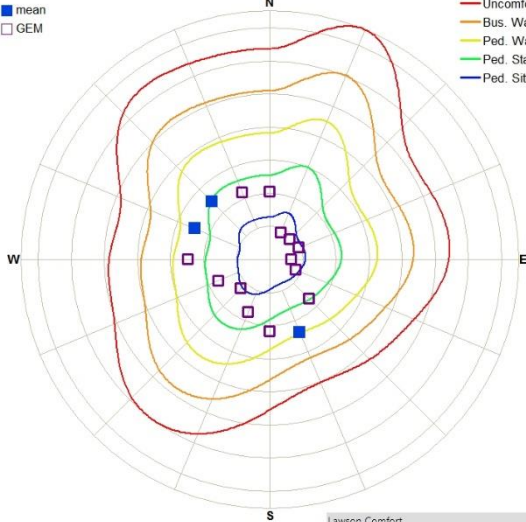


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	42.64	44.80	47.09
4	20.37	18.48	21.94
6	8.17	5.08	8.60
8	2.37	0.83	2.40
10	0.45	0.10	0.46

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.8	6.0	6.8
Rating	Ped Walking	Ped Standing	Ped Walking

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.4	11.6	13.5
Rating	Pass	Pass	Pass

LOCATION 14

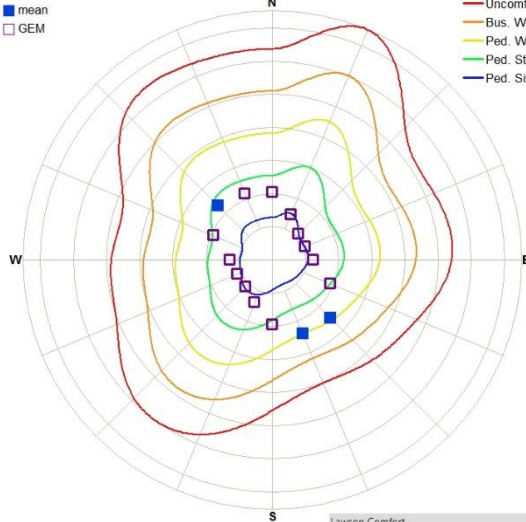


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	21.90	25.47	25.88
4	5.17	5.35	5.79
6	0.72	0.61	0.75
8	0.05	0.04	0.05
10	0.01	0.01	0.01

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	4.0	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.6	8.4	8.6
Rating	Pass	Pass	Pass

LOCATION 15.1

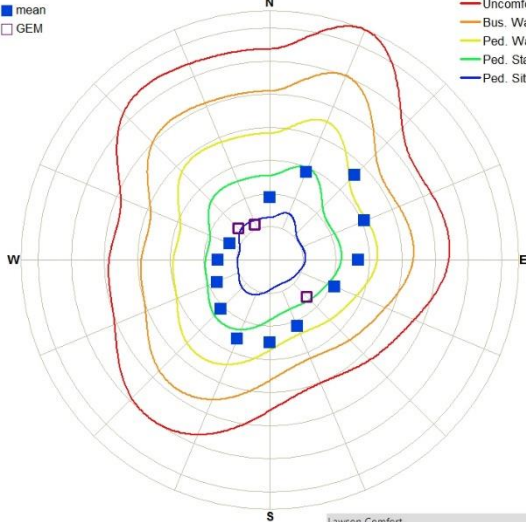


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	22.27	25.94	26.13
4	4.99	5.29	5.73
6	0.54	0.42	0.58
8	0.03	0.02	0.03
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.0	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.2	7.9	8.2
Rating	Pass	Pass	Pass

LOCATION 15

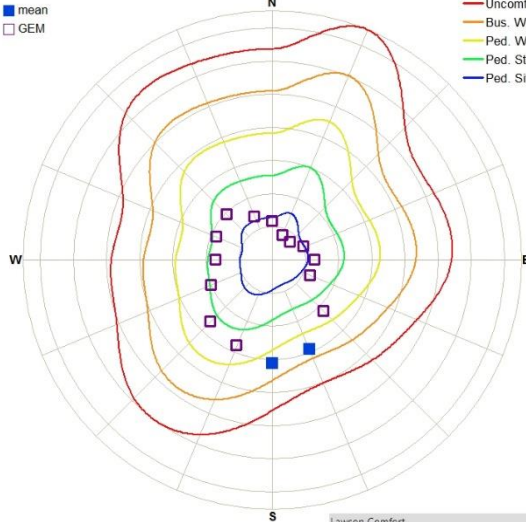


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	35.42	33.57	37.35
4	9.41	5.18	9.57
6	0.97	0.16	0.97
8	0.04	0.01	0.04
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.6	4.0	4.6
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	7.1	8.3
Rating	Pass	Pass	Pass

LOCATION 16

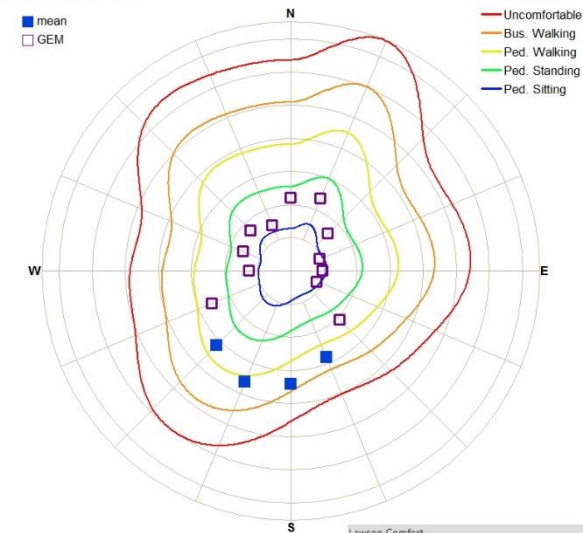


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	23.65	28.52	28.75
4	6.79	8.37	8.86
6	1.82	1.52	1.94
8	0.27	0.17	0.28
10	0.03	0.01	0.03

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	4.6	4.8
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.1	9.6	10.1
Rating	Pass	Pass	Pass

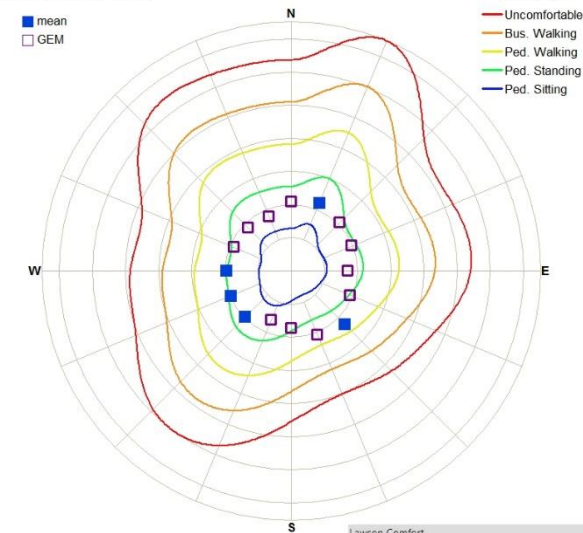
LOCATION 17



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	25.99	30.56	31.24
4	8.45	9.05	10.22
6	2.46	1.71	2.62
8	0.45	0.20	0.46
10	0.06	0.02	0.06

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	4.7	5.0
Rating	Ped Standing	Ped Standing	Ped Standing
Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	9.8	10.9
Rating	Pass	Pass	Pass

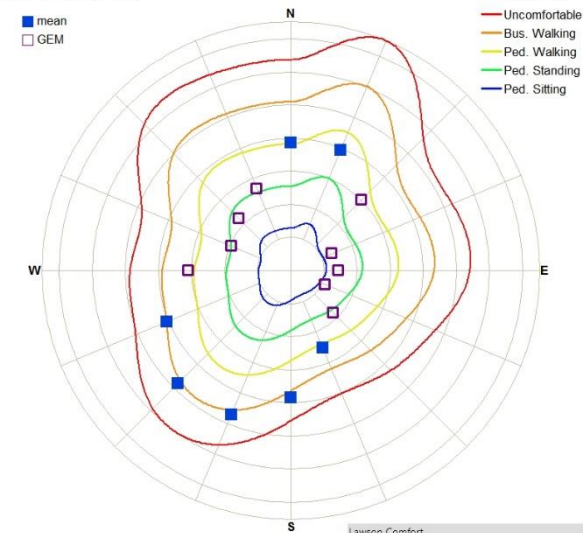
LOCATION 18.1



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	31.17	34.42	35.14
4	4.07	4.83	5.17
6	0.20	0.22	0.25
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.0	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.3	7.5	7.5
Rating	Pass	Pass	Pass

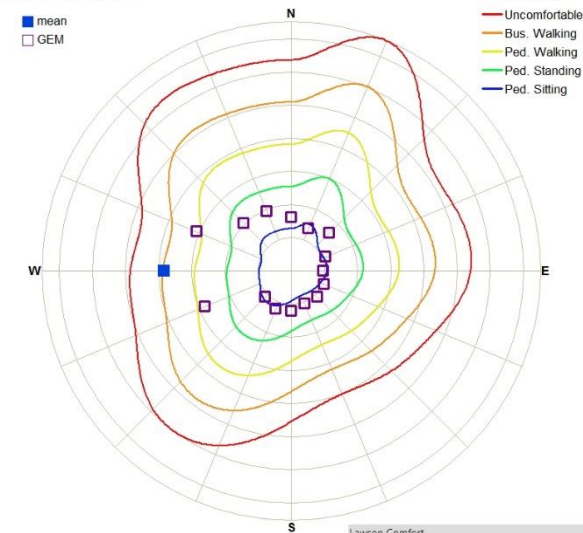
LOCATION 18



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	40.52	47.00	48.62
4	15.81	15.51	18.47
6	5.66	4.16	6.27
8	1.68	0.79	1.81
10	0.39	0.11	0.41

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.1	5.7	6.3
Rating	Ped Walking	Ped Standing	Ped Walking
Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.4	11.6	13.4
Rating	Pass	Pass	Pass

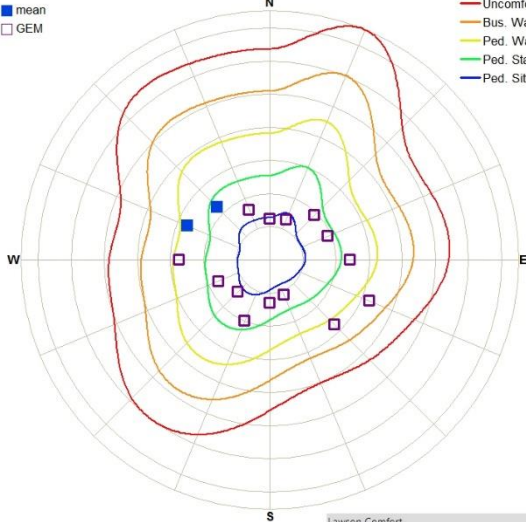
LOCATION 19



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	14.08	23.50	23.73
4	3.65	4.95	5.17
6	1.56	1.80	1.99
8	0.52	0.49	0.62
10	0.14	0.10	0.15

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	3.9	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.2	11.6	12.3
Rating	Pass	Pass	Pass

LOCATION 20

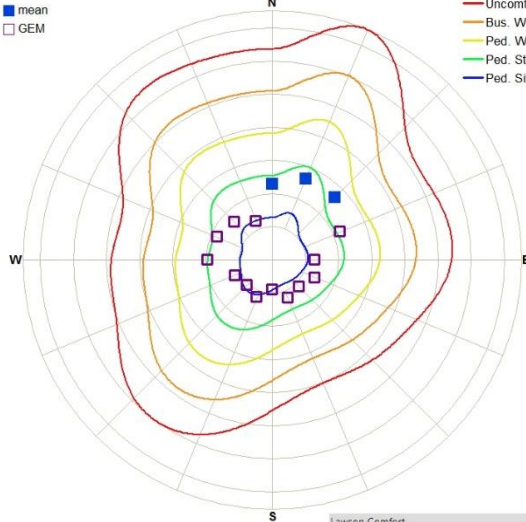


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	23.11	33.27	33.56
4	4.75	8.92	9.01
6	0.62	1.89	1.95
8	0.06	0.16	0.17
10	0.01	0.01	0.01

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.8	4.8
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	9.4	9.5
Rating	Pass	Pass	Pass

LOCATION 21

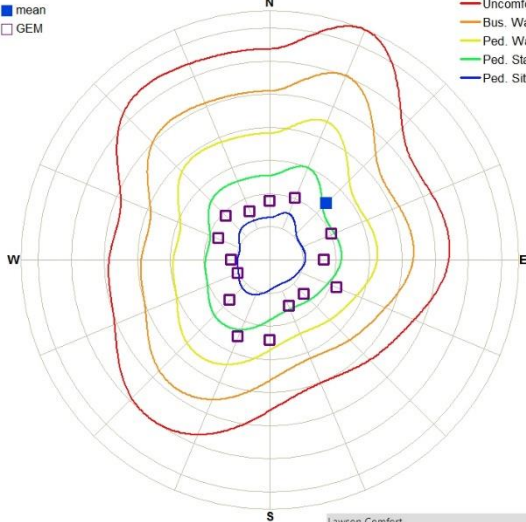


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	14.36	22.22	22.55
4	1.26	2.13	2.21
6	0.03	0.06	0.06
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	3.3	3.3
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.0	6.5	6.5
Rating	Pass	Pass	Pass

LOCATION 22

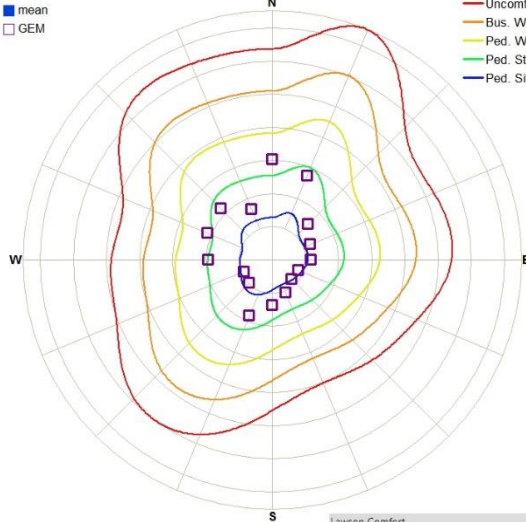


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	19.26	30.29	30.53
4	0.89	3.58	3.74
6	0.01	0.23	0.23
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.0	3.7	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.7	7.7	7.7
Rating	Pass	Pass	Pass

LOCATION 23



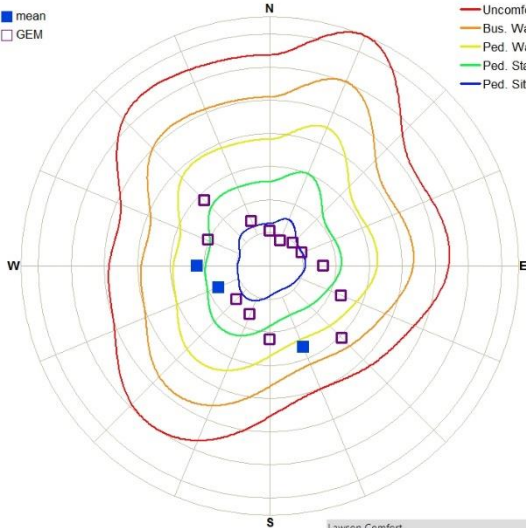
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	10.61	18.97	18.97
4	1.05	2.08	2.08
6	0.06	0.19	0.19
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.6	7.4	7.4
Rating	Pass	Pass	Pass

LOCATION 24

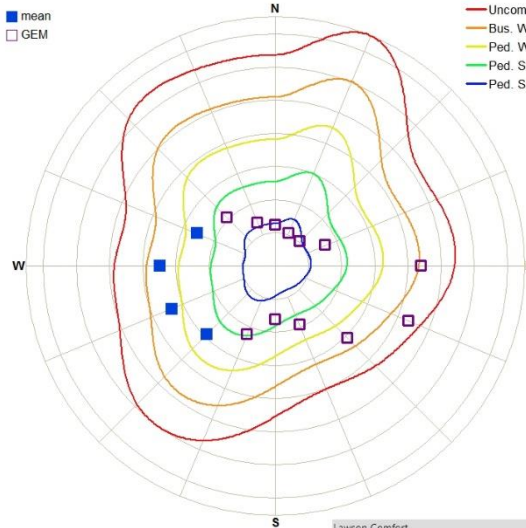
■ mean
□ GEM



THRESHOLD
 — Uncomfortable
 — Bus. Walking
 — Ped. Walking
 — Ped. Standing
 — Ped. Sitting

LOCATION 25

■ mean
□ GEM



THRESHOLD
 — Uncomfortable
 — Bus. Walking
 — Ped. Walking
 — Ped. Standing
 — Ped. Sitting

% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.08	30.33	30.46
4	7.51	9.49	9.62
6	1.44	1.85	1.90
8	0.12	0.19	0.20
10	0.01	0.01	0.01

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.3	9.6	9.7
Rating	Pass	Pass	Pass

% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	34.94	39.40	41.61
4	13.04	15.39	16.85
6	3.94	5.86	6.87
8	0.82	1.34	1.65
10	0.11	0.17	0.24

Lawson Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.6	6.2	6.5
Rating	Ped Standing	Ped Walking	Ped Walking
Lawson Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.5	11.6	12.2
Rating	Pass	Pass	Pass