



WIND ENGINEERING
CONSULTANTS

PEDESTRIAN WIND ASSESSMENT
CPP PROJECT 18682
16 SEPTEMBER 2024

100 Botany Road Development

Alexandria, NSW

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Executive Summary

A wind tunnel study of the 100 Botany Road Development, to be built in Alexandria, NSW was conducted to assess the surrounding pedestrian wind environment. Measurements of winds likely to be experienced by pedestrians were combined with wind statistics and compared to wind comfort and safety criteria.

The wind tunnel testing was performed in a natural boundary layer wind tunnel of CPP. A model of the project was fabricated to a 1:250 length scale and centered on a turntable in the wind tunnel. Replicas of existing and approved surrounding buildings within a 360 m radius were constructed and placed on the turntable. An approach boundary layer representative of the environment surrounding the proposed development was established in the test section of the wind tunnel.

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 33 locations for 16 wind directions each. These points were tested around the development site focusing on pedestrian access routes, entries, and outdoor seating or recreation 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. A subset of 10 locations was tested with the addition of a proposed building at 78-82 Wyndham Street.

The results of the wind assessment can be summarized as follows:

GROUND LEVEL:

The wind environment around the development was found to be generally suitable for Pedestrian Standing style activities from a comfort perspective with reference to the Lawson criteria. A couple of locations were rated as suitable for Pedestrian Sitting activities, which is suitable for the intended use of publicly accessible areas, and some locations further on the northeast side were rated as Pedestrian Walking. These locations were found to satisfy the Lawson safety criterion. One location on the far corner of the southeast side is rated as Business Walking from a comfort perspective with rating of Able-Bodied under the safety criterion. The stronger wind conditions at this location are attributed to the Waterloo Metro Quarter Over Station Development rather than the proposed development.

BALCONIES:

Wind conditions at the balconies were found to be generally suitable for Pedestrian Sitting with reference to the Lawson comfort criteria and is considered suitable for the intended use. Both of the tested locations satisfy the Lawson safety criteria. The mild wind conditions here are a result of the inset nature of the balconies.

TERRACES:

The wind conditions on the terraces were found to be generally suitable for Pedestrian Standing with reference to the Lawson comfort criteria. One location at the lower-level terrace facing the south side were found to be calmer and achieved a Pedestrian Sitting comfort rating. All tested locations were found to satisfy the recommended safety criteria.

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1. Background (client provided)

This Pedestrian Wind Assessment has been prepared on behalf of the Kurraba Group (the Proponent) by CPP Wind Engineering Consultants. It is submitted to the Department of Planning, Housing and Infrastructure (DPHI) in support of a State Significant Development Application (SSDA) SSD-63067458 for the construction of a new health research facility located at 74-108 Botany Road and 86-100 Wyndham Street, Alexandria (herein referred to as 100 Botany Road or the site).

This report sets out an assessment of the anticipated pedestrian wind environment within and surrounding the site.

About Kurraba Group

Kurraba Group (Kurraba) is the Proponent of the SSDA for the proposed new health research facility. Kurraba's sole aim is to be Australia's leading and trusted life science focused developer. Kurraba's investment portfolio focuses on innovation, future focused real estate, as demanded by the health science sector.

Site description

The site is located at 74-108 Botany Road and 86-100 Wyndham Street, Alexandria (commonly referred to as 100 Botany Road). The site is made up of six (6) different allotments and has a total approximate area of 5,350.6m². The following lots make up the site:

- Lot 2 DP 136012
- Lot 11 DP 219505
- Lot 11 DP 135914
- Lot 2 DP 659166
- Lot 1 DP 510091
- Lot 3 DP 1146614

The site has a frontage to Botany Road to the east and Wyndham Street to the west. Part of Wyndham Lane runs through the middle of the site.

The site forms part of the recently rezoned Botany Road Precinct, which will be transformed into a vibrant mixed-use precinct that will accommodate employment growth in the Redfern-Waterloo area. The site is opposite the Waterloo Metro Station and its future over station development which is currently under construction.



Figure 1 Aerial Photograph of Site

Source: Nearmap, Ethos Urban

Proposed development

The proposed development will seek consent for the redevelopment of 100 Botany Road for a new health research facility. Specifically, the SSDA seek approval for:

- Demolition of all existing buildings, site preparation and remediation works.
- Bulk excavation to create two (2) levels of basement with access from Wyndham Street, including allowance for a below ground Proton Therapy Cancer Treatment Centre, car parking, loading and services.
- Construction and use of two (2) new health research buildings. One (1) building is proposed along Botany Road which has a stepped built form between seven (7) storeys to the south and eleven (11) storeys to the north. One (1) building is proposed along Wyndham Street which is five (5) storeys. The two (2) buildings will include the following:
 - Ground floor lobby and retail uses fronting Botany Road and Wyndham Street.
 - Proton Therapy patient lobby from Wyndham Street.
 - Various laboratories, write up areas and office spaces.
 - A series of outdoor landscaped terraces within the Botany Road building.
 - One (1) rooftop plant level on each building.
- Landscaping and public domain works including:
 - Construction and extension of Wyndham Lane as a shared laneway.
 - Construction of a pedestrian network including two (2) pathways from Botany Road and an east-west through-site link.

- Extension and augmentation of services and utilities to the development, as required.

Refer to the Environmental Impact Statement for a detailed description of the proposed development.

Secretary’s Environmental Assessment Requirements

In accordance with section 4.39 of the *Environmental Planning & Assessment Act 1979* (EP&A Act), Secretary’s Environmental Assessment Requirements (SEARs) for SSD-63067458 were issued on 16 January 2024. This report has been prepared to respond to the relevant issued SEARs, as set out in the table below.

SEAR	Response / Location in report
Adress how good internal and external environment amenity is achieved, including access to natural daylight and ventilation, pedestrian movement throughout the site, access to landscape and outdoor spaces.	Section 4 - Discussion
Assess amenity impacts on the surrounding locality, including lighting impacts, solar access, visual privacy, visual amenity, view loss and view sharing, overshadowing and wind impacts. A high level of environmental amenity for any surrounding residential or other sensitive land uses must be demonstrated.	Section 4 - Discussion

Summary of mitigation measures

ID	Mitigation measure
Construction Management	
n/a	
Design and Operation	
D/O1	Local screening or dense landscaping for outdoor retail seating areas if desired.

2. Introduction

GENERAL INFORMATION

Pedestrian wind studies are conducted to investigate pedestrian comfort and safety in and around developments. This assessment of the wind environment around developments can inform designers about the suitability of outdoor areas for their intended uses. Where necessary, design modifications can be made, or intervention measures added to mitigate areas with the potential for excessive wind speeds.

This report contains information regarding the local wind climate analysis, wind tunnel testing and analysis procedures, a discussion of the test results, and recommendations to improve wind conditions in areas where any adverse wind conditions may be identified. The test parameters and configurations are summarised in Table 1.

All data collection was performed in accordance with the guidelines of the Australasian Wind Engineering Society (2019), and the American Society of Civil Engineers (1999, 2021). 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: Wind Tunnel Test Parameters

SUMMARY OF TEST PARAMETERS	
GENERAL INFORMATION	
Model Scale	1:250
Surrounding Model Radius (full scale)	360 m
Approach Terrain Category	Built-up environment approach
ENVIRONMENTAL WINDS STUDY	
Number of test locations	33
Reference height (full scale)	100 m
TEST CONFIGURATION(S)	
Configuration 1	Proposed site buildings with surroundings as they currently exist, and all approved or under construction developments within the modelled test radius as shown in Figure 1.
Configuration 2	As configuration 1 with the addition of the proposed building massing of 78-82 Wyndham Street as shown in Figure 1a and Figure 1b (Bottom).

3. Methodology

WIND TUNNEL MODEL

The anticipated wind conditions around the project site were evaluated through wind tunnel testing of a 1:250 scale model of the development and surrounding area. This scale allowed for an adequate portion of surrounding developments and terrain to be included within an approximately 360 m radius of the site and all the relevant building details to be modeled accurately. The boundary-layer wind conditions beyond the modelled area were also appropriately simulated in one of CPP's wind tunnels (see Appendix A). The models were mounted on the turntable, located near the downstream end of the wind tunnel test section, allowing rotation of the modelled area for examination of wind speeds from any approach wind direction. Photographs of the test and surrounds models installed in the wind tunnel are given in Figure 1.

MEASUREMENT POINTS

For this study, wind speed measurements were recorded at 33 locations to evaluate pedestrian wind comfort and safety in and around the project site. The selected test locations are shown in Figure 4 to Figure 7.

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, at outdoor recreation areas and terraces.

The hot-film signal was sampled for a period corresponding to one hour in full scale. All velocity data were digitally filtered to obtain the two to three second running mean wind speed at each point; this 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 100 m are plotted in polar form in Appendix B. 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.

The measured local wind velocities were combined with wind climate data described in the following section to allow assessment of the pedestrian wind environment.

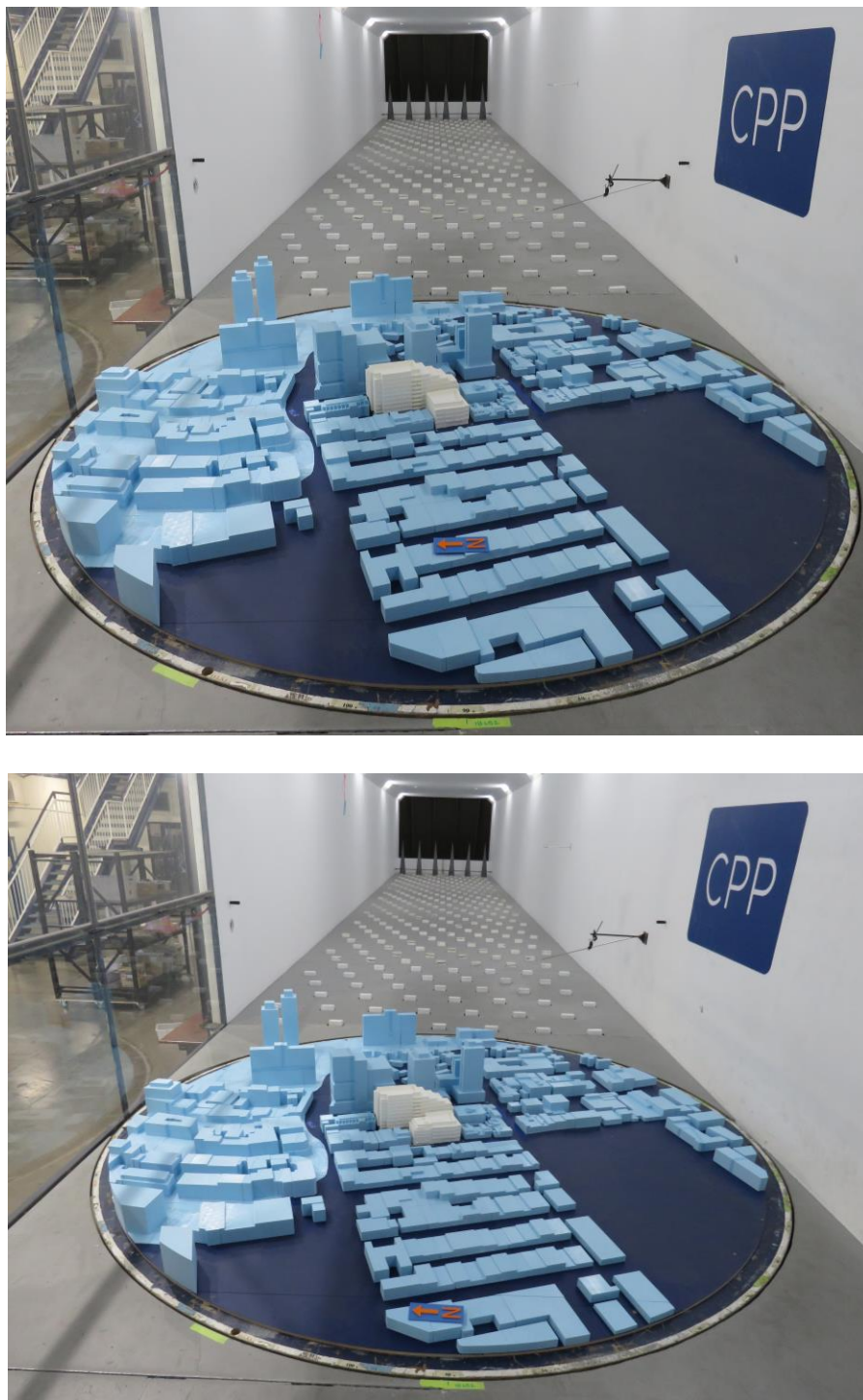


Figure 1a: Photographs of Wind Tunnel Test and Surrounds Model – Configurations A (top) and B (bottom).



Figure 1b: Photographs of Wind Tunnel Test Model, close-up – Configuration 1 (top) and Configuration 2 (bottom).

WIND CLIMATE

The measured velocity data were normalized to an approach reference wind speed and then combined with a climatological model (wind frequency and direction) derived from data measured at a standard height of 10 m at the Sydney International Airport. The project site is located approximately 5 kilometers to the north-east of the airport which provides the best source of historical wind data for the project.

This data is portrayed in the wind rose in Figure 2. The arms of the wind rose point in the direction where the wind is blowing from, the width and color of the arm represent the wind speed, and the length of the arm indicates the percent of the time that the wind blows for that combination of speed and direction. These data were then adjusted to the site location using an analytical method to account for the exposure of the project site for each direction.

The distribution and frequency of winds on an annual basis were analyzed to assess the project with regards to wind comfort and safety. As can be seen from the wind rose in Figure 2, winds from the south and north-east directions are predominant, with secondary winds occurring from the west and south-west directions. The locations tested around the development site may be susceptible to winds from these directions, depending on the relative position of the location tested to the geometry of the proposed development and surrounds.

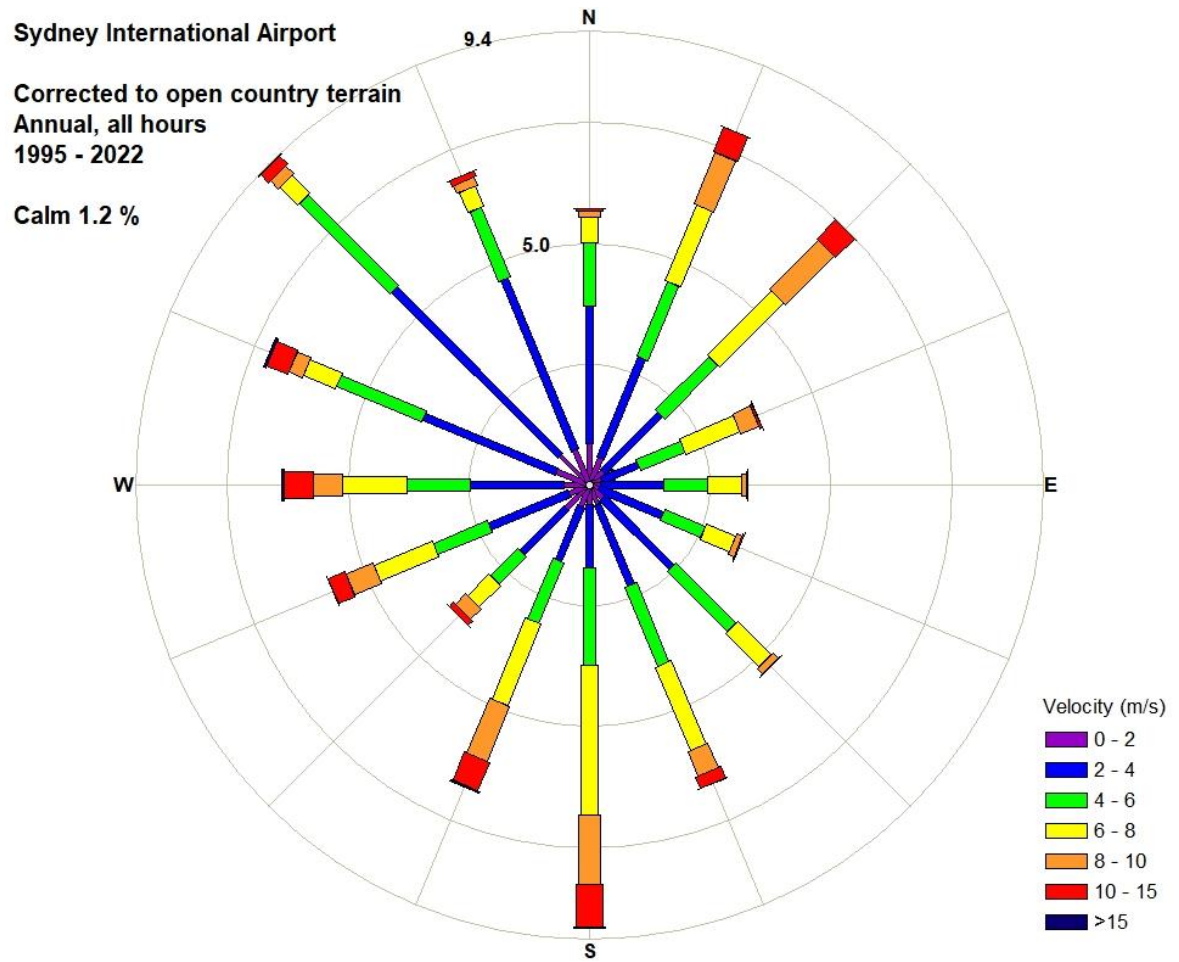


Figure 2: Probability of Wind Speeds by Direction – Sydney International Airport (1995 – 2022, All Hours)

WIND ASSESSMENT CRITERIA

To enable a quantitative assessment of the wind environment, the wind tunnel data and climatological model are combined to calculate wind speeds for comparison with pedestrian wind comfort and safety criteria at each test point.

A number of researchers have suggested quantitative methods for assessing wind comfort and safety based on wind tunnel data and local climate statistics. CPP uses a modified form of the widely-accepted pedestrian-level wind criteria developed by Lawson (1990). Lawson's criteria are divided into separate categories of comfort and distress (safety). The comfort criteria allow planners to assess the usability, with respect to the wind environment, of different locations for various purposes, such as for long-duration activities (e.g., sitting at an outdoor café) or strolling on walkways.

Lawson's criteria are based on wind speeds exceeded 5% of the time, and are described as categories for comfort ranging from 'Pedestrian Sitting' to 'Business Walking', allowing planners to judge the usability of locations for various intended purposes. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds, to identify locations where wind speeds may be hazardous to pedestrians.

The categories and criteria are specified in Table 2.

Table 2: Wind Comfort and Safety criteria (after Lawson, 1990)

COMFORT RATING	U _{EQUIV} *	DESCRIPTION
 Dining**	< 2 m/s	Calm / light breezes suitable for outdoor restaurant uses, seating areas, and other amenities based on CPP experience.
 Sitting	2-4 m/s	Calm or light breezes suitable for long duration seating areas, and other amenities.
 Standing	4-6 m/s	Gentle breezes suitable for sitting for shorter periods, main entrances and bus stops where pedestrians may linger.
 Pedestrian Walking	6-8 m/s	Moderate winds appropriate for window shopping and strolling along a downtown street, or park.
 Business Walking	8-10 m/s	Relatively high speeds that can be tolerated if one's objective is to walk, run, or cycle.
 Uncomfortable	> 10 m/s	Strong winds unacceptable for all pedestrian activities; wind mitigation is typically required.

*U_{Equiv} = Max (U_{Mean}, U_{Gust} / 1.85).

*U_{Equiv} speeds are based on an annual exceedance of 5% (~8 hours / week) assessed over all hours.

** For regular Outdoor Dining, and in semi-enclosed spaces, it has been the experience of CPP that the comfort rating of Sitting may be windier than desired and a comfort criterion of 4 m/s or less may be more applicable.

SAFETY RATING	U_{EQUIV}^*	DESCRIPTION
○ Pass	< 15 m/s	Meets wind safety criterion.
○ Able-Bodied	15-20 m/s	Acceptable where only Able-Bodied people would be expected; not acceptable for frail persons or cyclists
○ Fail	>20 m/s	Excessive wind speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is often required.

* $U_{Equiv} = \text{Max}(U_{Mean}, U_{Gust} / 1.85)$.

* U_{Equiv} speeds are based on an annual exceedance of 0.022% (~2 / year or 1 / season) assessed over all hours.

Pedestrians' perception of wind can often be subjective and vary depending on regional difference in wind climate and thermal conditions, as well as by individual. Calibration to the local wind environment should be taken into account when evaluating predicted wind comfort conditions. Note that the ratings of 'Uncomfortable' and 'Safety' are the words of the published wind criteria and applicability may vary by project and location.

4. Results

A summary of the assessed comfort and safety ratings for each test location is given in Table 3 and Figure 3. The results of the study are graphically presented in Figure 4 to Figure 7 in which measurement locations are displayed on a site plan and color coded to denote the predicted wind comfort and safety rating. 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.

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 B. In addition, the wind speeds corresponding to the 5% (comfort) and 0.022% (safety) thresholds are provided for direct comparison to the criteria. These plots also include directional criterion lines for the Lawson comfort levels to provide additional information regarding directional sensitivity at each location.

In general, wind conditions comfortable for Sitting and Standing are considered appropriate for areas such as entrances where pedestrians are likely to gather for longer durations, while wind conditions comfortable for Casual Walking and Business Walking are more appropriate for sidewalks where pedestrians are actively in transit. Locations rated as Uncomfortable are generally less suitable for most pedestrian activities and wind control solutions are often sought. Whether mitigation is needed at a location depends upon the intended pedestrian use of the location. Although conditions may be classified as acceptable, there may be certain wind directions that cause regular strong events.

Satisfaction of the safety rating is generally required for areas accessible to the general public. A rating of 'Able-Bodied' may be acceptable for areas with managed access or where pedestrians are unlikely to be present under adverse conditions. Mitigation measures are generally required to address any locations deemed to fail the safety assessment.

Table 3a: Summary of wind comfort and safety assessment results – Configuration 1.

Description / Location		Wind Tunnel Results	
		Comfort rating, 5% exceedance wind speed (m/s)	Safety rating, 0.022% exceedance wind speed (m/s)
Ground Level	1	5.4	11.1
	2	4.8	9.1
	3	4.9	9.5
	4	6.0	11.6
	5	5.2	10.5
	6	5.4	11.0
	7	4.9	9.5
	8	3.5	6.6
	9	4.6	9.3
	10	4.0	7.6
	11	4.9	10.4
	12	4.5	10.1
	13	4.5	8.2
	14	7.7	14.6
	15	4.7	10.4
	16	6.3	12.1
	17	5.5	10.0
	18	6.5	13.2
	19	5.2	10.1
	20	4.5	8.4
	21	6.3	12.6
	22	5.8	11.2
	23	8.3	16.4
Balconies	24	3.7	8.6
	25	2.4	4.8
Terraces	26	3.0	6.5
	27	5.5	12.2
	28	4.4	9.1
	29	4.1	8.1
	30	5.2	10.8
	31	4.4	9.2
	32	4.8	9.9
	33	5.3	11.1

LEGEND	
Comfort Criteria	Safety Criteria
 Outdoor Dining	 Passes safety criteria
 Pedestrian Sitting	 Able bodied
 Pedestrian Standing	 Fails safety criteria
 Pedestrian Walking	
 Business Walking	
 Uncomfortable	

Table 3b: Summary of wind comfort and safety assessment results – Configuration 2.

Description / Location		Wind Tunnel Results	
		Comfort rating, 5% exceedance wind speed (m/s)	Safety rating, 0.022% exceedance wind speed (m/s)
Ground Level	1.1	5.3	11.0
	2.1	4.7	9.5
	3.1	4.9	9.8
	4.1	6.1	11.9
	5.1	5.4	11.1
	6.1	4.9	10.1
	7.1	4.8	9.7
	8.1	3.8	7.7
	9.1	3.6	7.7
	10.1	4.1	8.8

LEGEND

Comfort Criteria

	Outdoor Dining
	Pedestrian Sitting
	Pedestrian Standing
	Pedestrian Walking
	Business Walking
	Uncomfortable

Safety Criteria

	Passes safety criteria
	Able bodied
	Fails safety criteria

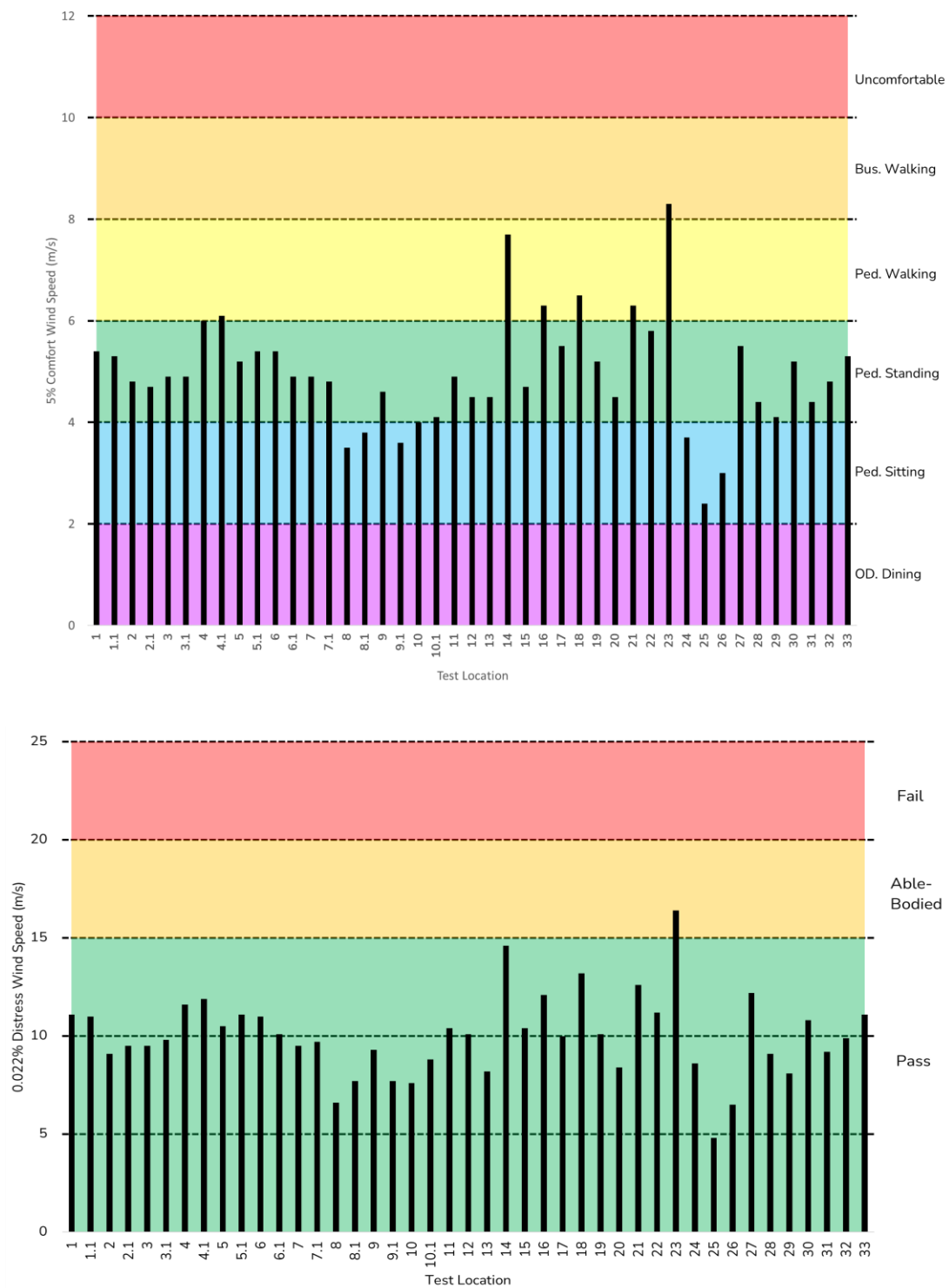


Figure 3: Summary of wind comfort and safety assessment results – Configuration 1.

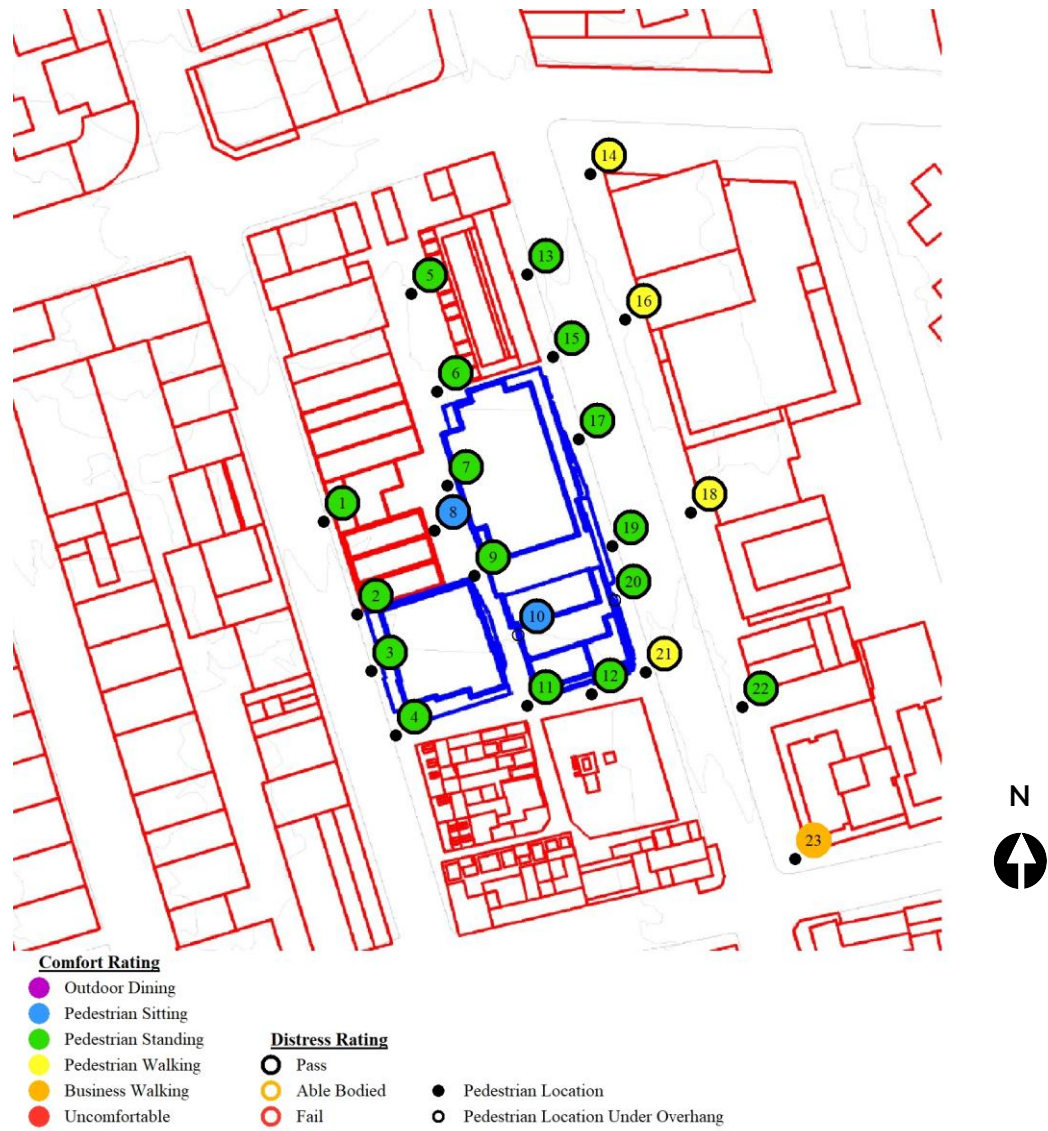
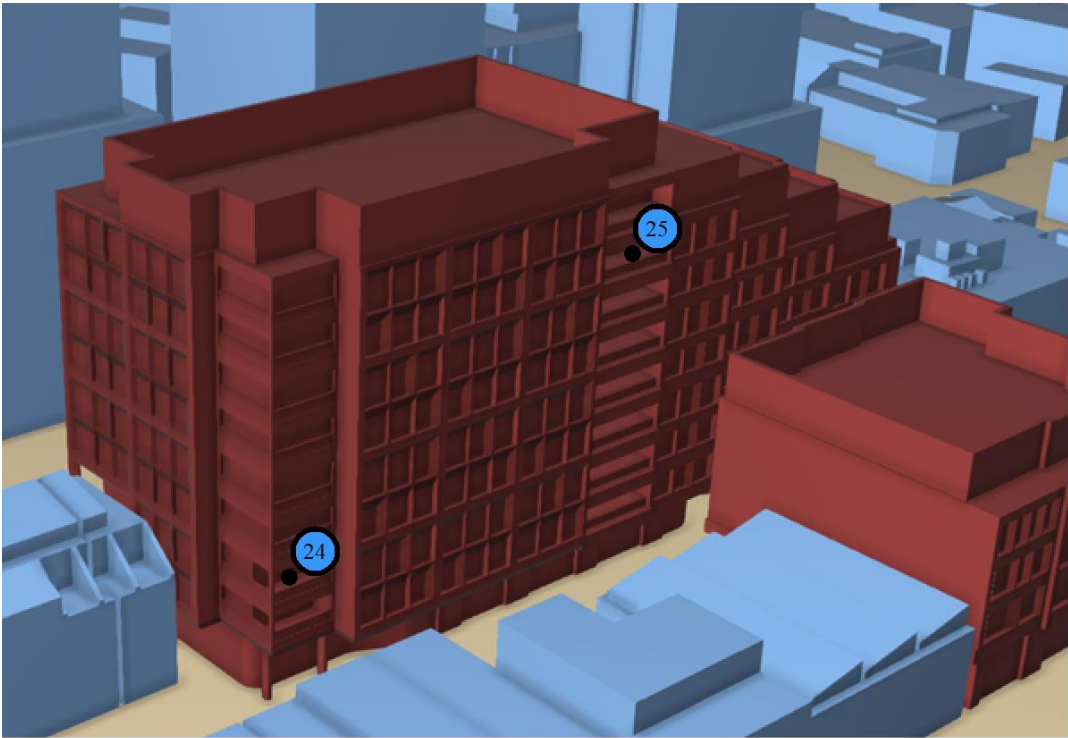


Figure 4: Pedestrian wind speed measurement locations with comfort/safety ratings – Surrounds – Configuration 1.



Figure 5: Pedestrian wind speed measurement locations with comfort/safety ratings – Surrounds – Configuration 2.



Comfort Rating

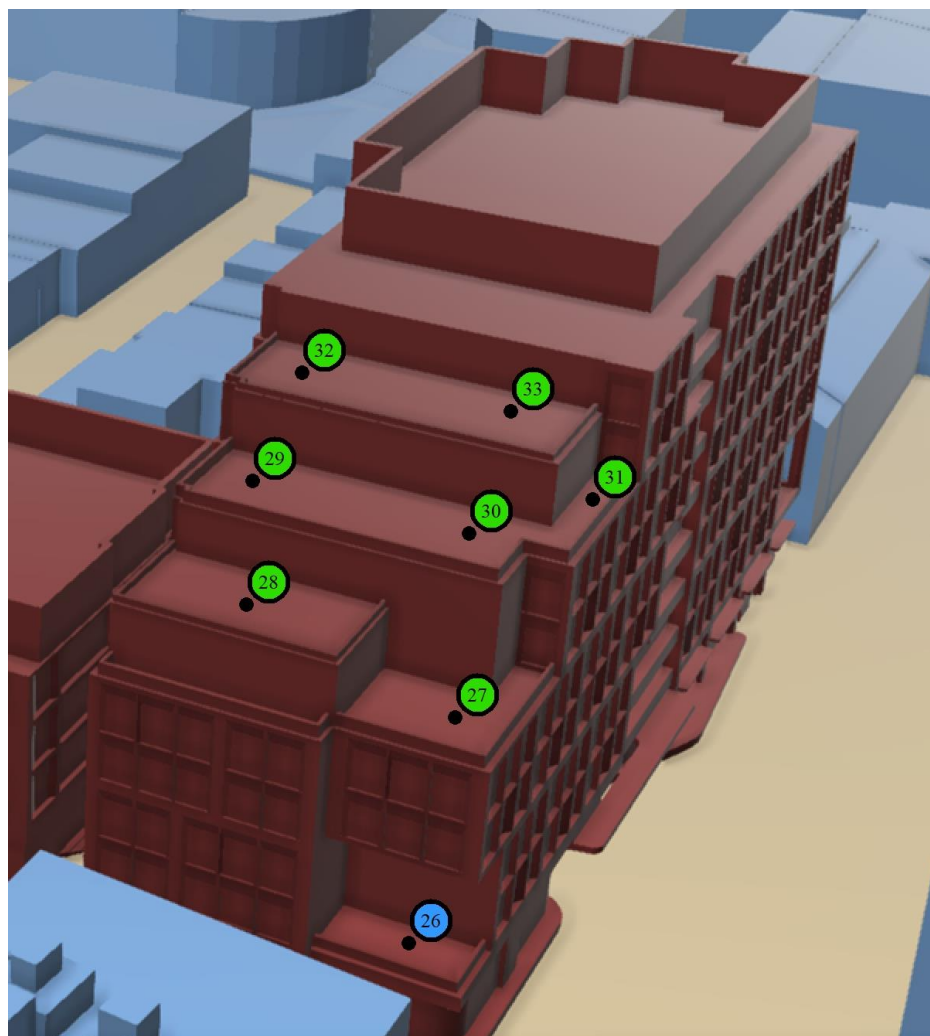
- Outdoor Dining
- Pedestrian Sitting
- Pedestrian Standing
- Pedestrian Walking
- Business Walking
- Uncomfortable

Distress Rating

- Pass
- Able Bodied
- Fail
- Pedestrian Location
- Pedestrian Location Under Overhang



Figure 6: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies



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

Figure 7: Pedestrian wind speed measurement locations with comfort/safety ratings – Terraces

5. Discussion

GENERAL CONDITIONS

In the street-level areas surrounding the development (Figure 4 and 6) the wind conditions are generally in the Pedestrian Standing or Pedestrian Walking comfort categories of the Lawson criteria. Pedestrian level winds tend to be governed by exposure to winds from the south and west quadrants, which are prevalent in Sydney. In general, slightly stronger local winds are found near street block corners, or in more open areas, while milder areas are available where the nearby buildings can provide shielding from these prevailing wind directions.

GROUND LEVEL

The comfort and distress ratings at ground level for the site are tested in two configurations, shown in Figure 4 and Figure 5.

In Configuration 1 (Figure 4) with the existing building at 78-82 Wyndham Street, the measured wind conditions around the ground plane of the development are rated at Pedestrian Standing comfort levels in most locations. Two locations (Locations 8 and 10) in the parallel laneway between Botany Road and Wyndham Street experienced slightly milder wind conditions as these locations are well protected from strong winds originating from most wind directions and are rated as Pedestrian Sitting. If any locations other than these two areas are to be used for long-term stationary type activities such as café-style dining or other hospitality use, mitigation measures such as the additions of small-scale screening structures or raised planters should be considered to provide localised shielding in the intended seating areas. Stronger wind conditions are experienced at the south-east corner of the development site (Location 21), and at the along the eastern side of Botany Road close to the Waterloo Metro Quarter Over Station Development (OSD) (Locations 14, 16, and 18) with a rating of Pedestrian Walking. Location 23 at the corner of Botany Road and Wellington Street experiences stronger wind conditions due to the accelerated flow around the corners of the OSD for winds from the west and south-east quadrants. This location is rated as Business Walking under the comfort criteria and has an Able-Bodied Lawson safety rating. It is noted that the stronger wind conditions along the eastern side of Botany Road are largely driven by the OSD rather than the proposed development.

In Configuration 2 (Figure 5), the proposed building at 78-82 Wyndham Street included in the wind tunnel model and immediately surrounding locations were tested. The wind conditions around this area are largely similar to configuration 1, with most locations in the Pedestrian Standing comfort category. One location (Location 4.1) at the south-west corner of the development site changes comfort rating from Pedestrian Standing to Walking, though the change in 5% exceedance wind speed is negligible between the two test configurations.

BALCONIES

Wind conditions on the balconies are shown in Figure 6 (Locations 24 and 25). Due to their inset nature and their location of the balconies facing only the west side of the building, these locations are well-shielded from wind from most directions. Both balcony test locations were in Pedestrian Sitting comfort category. As such these balconies would be considered suitable for the intended use. These locations pass the Lawson safety criterion.

TERRACES

The main development building on the Botany Roadside features staggered terraces on the southern side. The wind comfort conditions on these terraces are shown in Figure 7. The majority of the terrace area experiences relatively mild wind speeds with a Pedestrian Standing comfort rating. Local mitigation such as porous or non-porous vertical screening, and cabanas may be considered if milder wind are desired in parts of the terraces. The Level 1 terrace at the south-east corner of the building is less exposed than the higher terraces and benefits from the overhang of the upper levels. Furthermore, the neighbouring building located on the east and south side of the development provide some shielding for this terrace resulting in a Pedestrian Sitting comfort rating. All terrace locations satisfy the Lawson safety criterion.

APPLICABILITY

Testing was performed without existing and proposed trees and other plantings to provide a worst-case assessment. Heavy landscape planting typically reduces wind speeds by less than 10% and in general should not be relied upon to mitigate strong winds due to variation in size and foliage and difficulty in accurate modelling. Further, trees or other plantings may pose a safety risk if damaged during high winds.

The results presented within this report are based on the 3D model labelled 240509_Kurraba_100 Botany Rd_Actual Model.3dm received by CPP on 10 May 2024. If significant changes to the design of the development have occurred beyond this date or new information regarding the status of surrounding buildings becomes available, it is recommended that CPP be contacted to evaluate the impact of any changes.

6. Conclusion

CPP has conducted a wind tunnel study to quantify the pedestrian-level wind environment for the proposed 100 Botany Road Development development for two configurations. In general, most pedestrian-accessible areas around the site are assessed as suitable Pedestrian Standing under the Lawson comfort criteria. These conditions are considered typical of the surrounding area and suitable for the intended use of public domain spaces. Stronger wind conditions were observed on the eastern side of Botany Road particularly at the south-west corner of the Waterloo Metro OSD.

Wind conditions on balconies are generally at Pedestrian Sitting levels, which is considered suitable for the intended use. Conditions on the building terraces are generally reasonable, however, local mitigation measures such as raised planters, porous or non-porous vertical screening may be considered if milder conditions are desired. All locations satisfy the safety criterion with the exception of the corner Botany Road and Wellington Street, with a rating of Business Walking and Able-Bodied under the comfort and safety criteria, respectively. The wind conditions in this area are largely driven by the OSD building.

References

American Society of Civil Engineers (2021), *Wind Tunnel Testing for Buildings and Other Structures* (ASCE 49-21).

Lawson, T.V. (1990), "The Determination of the Wind Environment of a Building Complex before Construction" Department of Aerospace Engineering, University of Bristol, Report Number TVL 9025.

Standards Australia (2021), *Australian/New Zealand Standard, Structural Design Actions, Part 2: Wind Actions* (AS/NZS1170.2:2021).

Australasian Wind Engineering Society (2019), *Wind Engineering Studies of Buildings* (AWES-QAM-1-2019).

Appendix A – Wind Tunnel Test Facilities

The wind tunnel testing was performed at the CPP wind engineering laboratory in Sydney, Australia. Specifications for the wind tunnel used for this project are given in Figure A1.

The mean velocity profile approaching the modeled area for each direction has the form:

$$\frac{U}{U_{ref}} = \left(\frac{z}{z_{ref}} \right)^n$$

in which U is the mean velocity at height z , U_{ref} is a reference wind speed at reference height z_{ref} , and n is a constant which depends on the characteristics of the upstream roughness for each direction.

The profiles of longitudinal turbulence intensity in the flow approaching the modeled area are also modeled. The turbulence intensities are appropriate for the approach mean velocity profiles selected.

CPP SYDNEY WIND TUNNELS	
DIMENSIONS	
Test section length	21 m
Test section width	3 m
Ceiling height	2.4 m
DRIVE SPECIFICATIONS	
Total power	110 kW
Type of drive	Single Axle motor/12 blade axial fan
Speed Control	Variable frequency drive
FLOW CHARACTERISTICS	
Mean Velocity	0 to 20 m/s
Boundary-layer thickness*	1.2 m (nominal)
Turbulence	About 2% at entrance to test section
Longitudinal pressure gradient	Zero by blockage tolerant roof

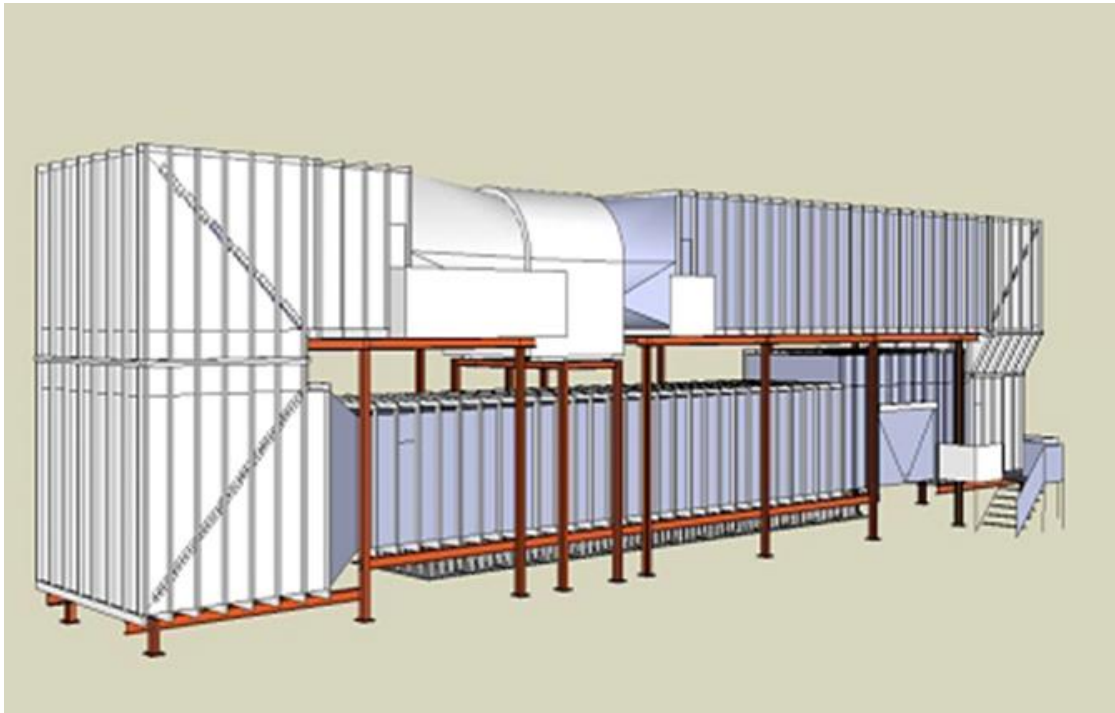
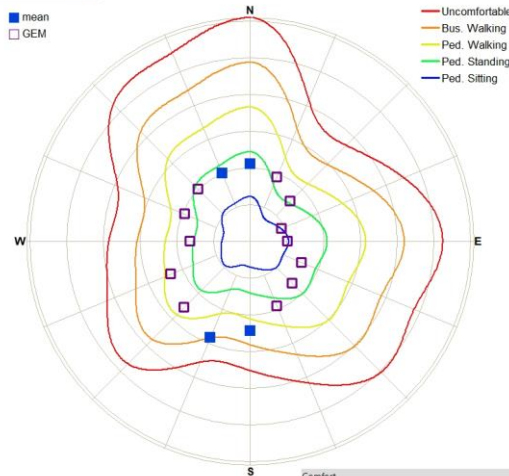


Figure A1: CPP Wind Tunnel - Sydney, Australia

Appendix B - Directional wind results

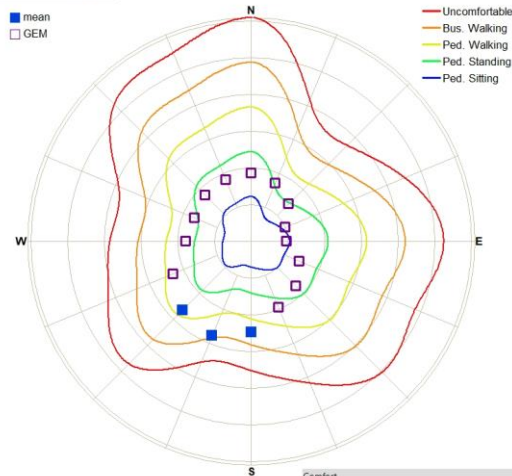
LOCATION 1



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.98	49.01	48.54
4	11.39	13.42	14.43
6	2.78	2.50	3.18
8	0.47	0.29	0.49
10	0.07	0.04	0.07

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.2	5.4
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.1	10.3	11.1
Rating	Pass	Pass	Pass

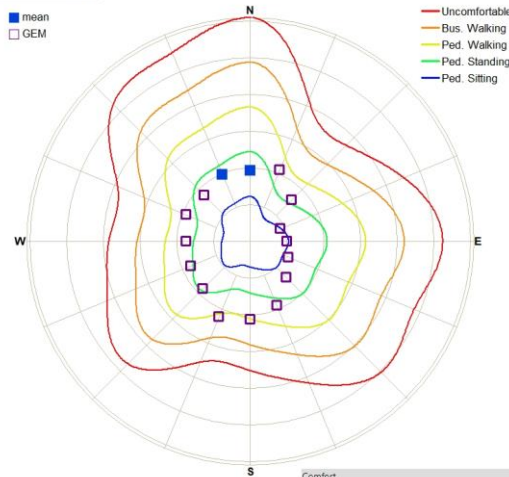
LOCATION 1.1



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	35.52	46.08	46.57
4	10.67	11.99	13.78
6	2.81	2.04	3.08
8	0.47	0.21	0.48
10	0.07	0.02	0.07

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.0	5.3
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.0	10.0	11.0
Rating	Pass	Pass	Pass

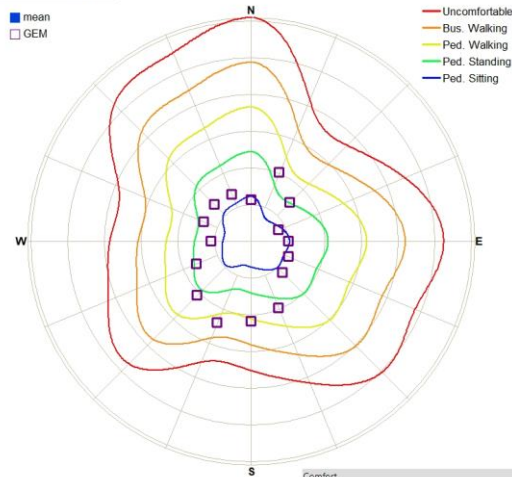
LOCATION 2



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	36.63	44.36	44.77
4	7.60	10.69	10.75
6	0.86	1.26	1.26
8	0.07	0.09	0.09
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.4	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.9	9.1	9.1
Rating	Pass	Pass	Pass

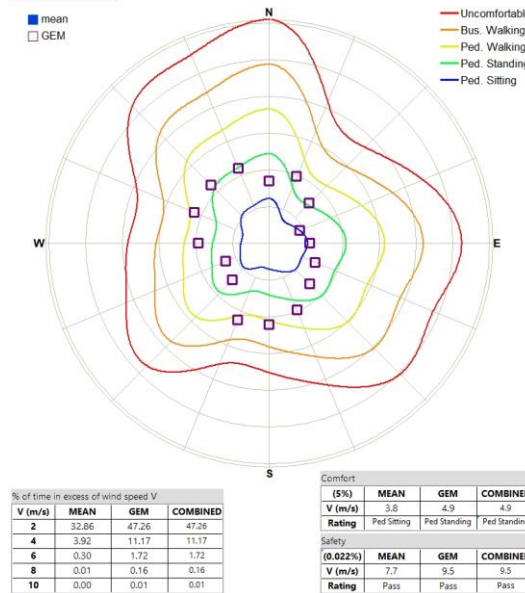
LOCATION 2.1



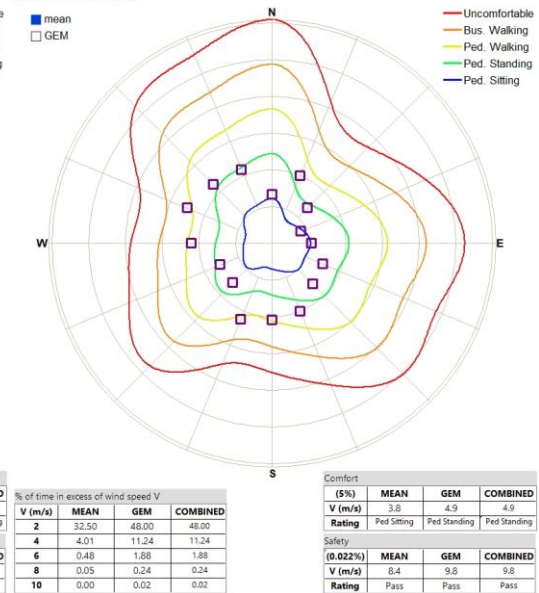
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	23.28	37.03	37.03
4	4.77	9.50	9.50
6	0.60	1.34	1.34
8	0.05	0.14	0.14
10	0.00	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.7	4.7
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.6	9.5	9.5
Rating	Pass	Pass	Pass

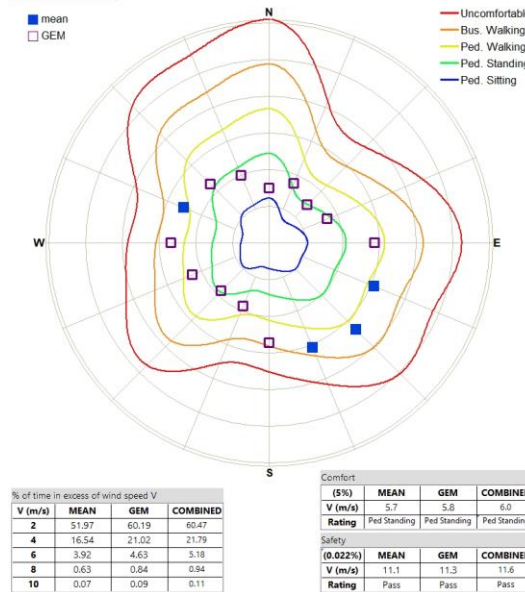
LOCATION 3



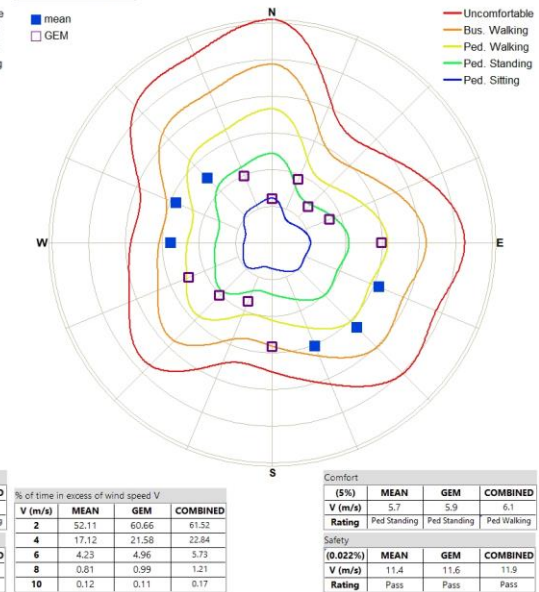
LOCATION 3.1



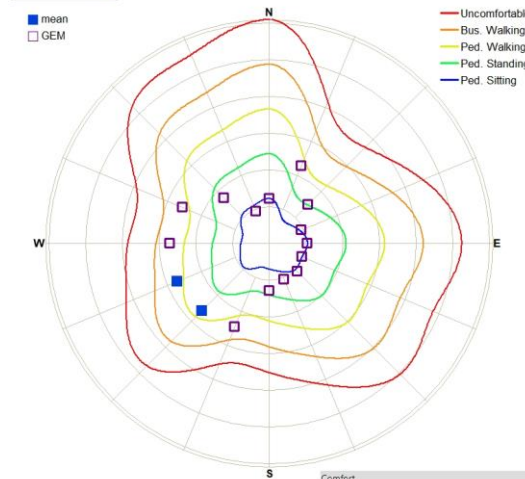
LOCATION 4



LOCATION 4.1



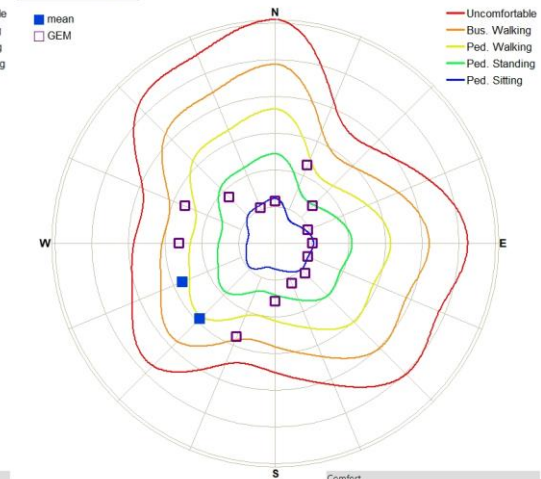
LOCATION 5



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	26.23	39.77	40.09
4	8.27	11.92	12.34
6	1.81	2.62	2.78
8	0.20	0.42	0.44
10	0.02	0.04	0.05

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.1	5.2
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	10.4	10.5
Rating	Pass	Pass	Pass

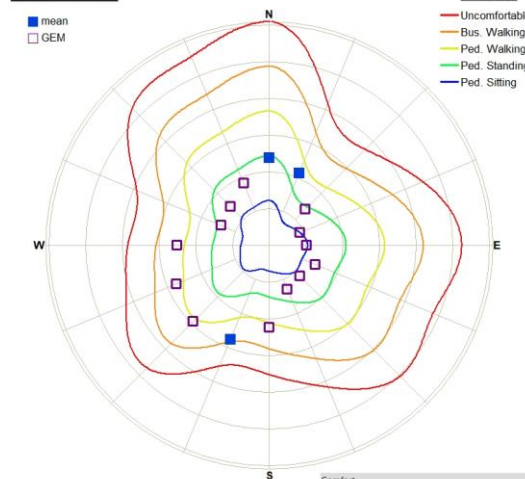
LOCATION 5.1



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.24	42.56	42.84
4	9.36	13.38	13.79
6	2.39	3.38	3.55
8	0.36	0.59	0.63
10	0.03	0.08	0.08

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.3	5.4
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.3	11.1	11.1
Rating	Pass	Pass	Pass

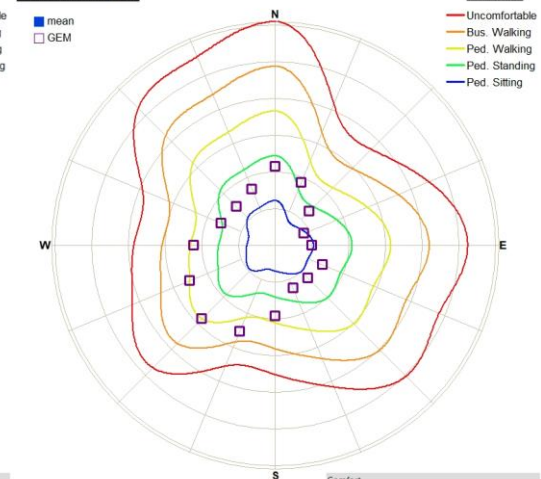
LOCATION 6



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	36.66	44.34	44.78
4	12.46	14.37	14.77
6	2.70	3.12	3.41
8	0.38	0.40	0.49
10	0.05	0.05	0.07

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	5.4	5.4
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	10.6	11.0
Rating	Pass	Pass	Pass

LOCATION 6.1

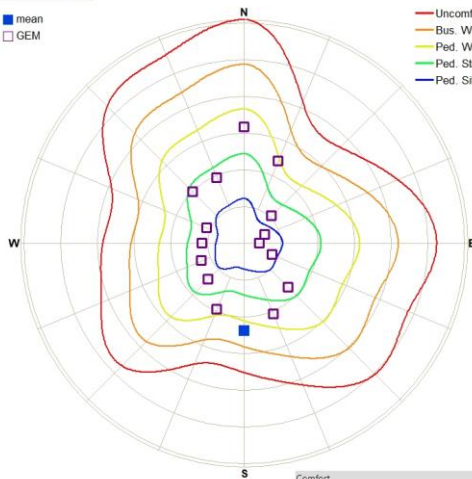


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	32.64	42.06	42.06
4	9.15	11.19	11.19
6	1.54	1.98	1.98
8	0.19	0.23	0.23
10	0.02	0.03	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	4.9	4.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.0	10.1	10.1
Rating	Pass	Pass	Pass

LOCATION 7

■ mean
□ GEM

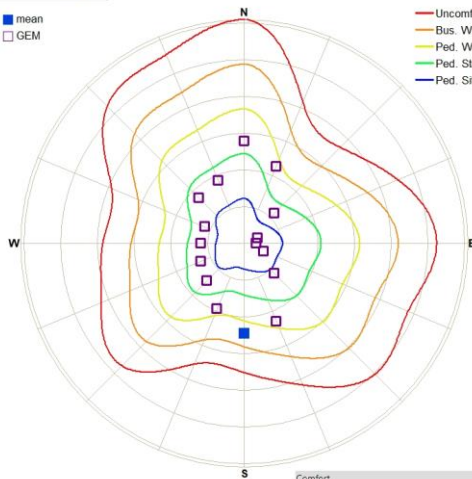


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.50	40.91	40.93
4	6.17	10.81	10.90
6	1.03	1.66	1.69
8	0.11	0.15	0.15
10	0.01	0.01	0.01

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.8	4.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.3	9.4	9.5
Rating	Pass	Pass	Pass

LOCATION 7.1

■ mean
□ GEM

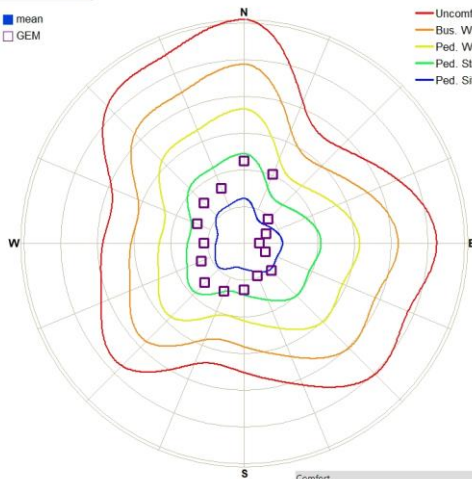


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	27.09	38.79	38.95
4	6.45	10.23	11.02
6	1.15	1.41	1.71
8	0.15	0.11	0.18
10	0.01	0.01	0.02

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.7	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.6	9.2	9.7
Rating	Pass	Pass	Pass

LOCATION 8

■ mean
□ GEM

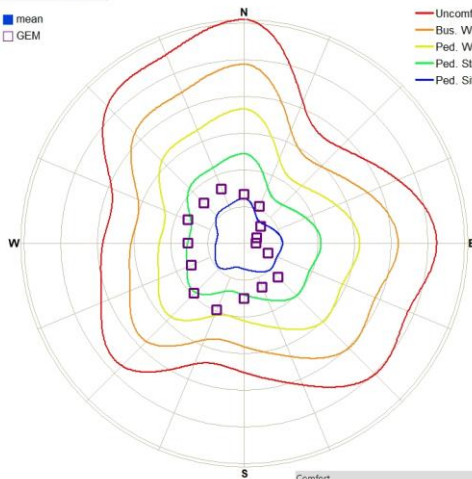


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	13.02	25.92	25.92
4	0.46	2.52	2.52
6	0.00	0.06	0.06
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	2.7	3.5	3.5
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.2	6.6	6.6
Rating	Pass	Pass	Pass

LOCATION 8.1

■ mean
□ GEM

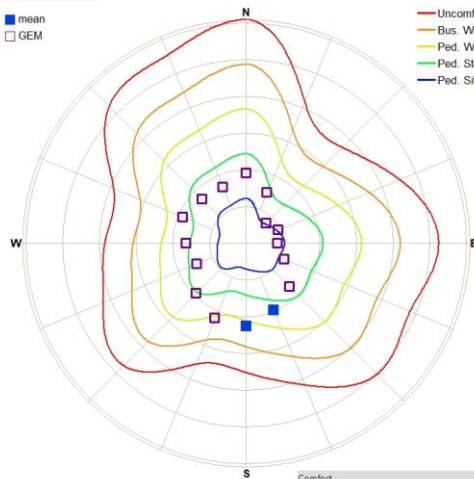


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	14.07	28.45	28.45
4	0.84	3.95	3.95
6	0.02	0.27	0.27
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	2.8	3.8	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.9	7.7	7.7
Rating	Pass	Pass	Pass

LOCATION 9

■ mean
□ GEM

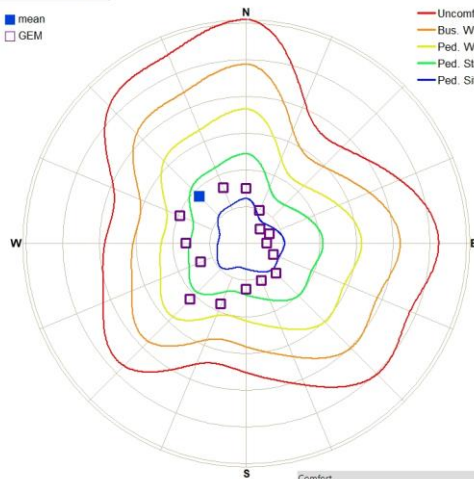


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	30.90	38.12	38.36
4	7.44	8.52	8.81
6	1.13	1.25	1.34
8	0.08	0.10	0.10
10	0.00	0.00	0.01

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	4.4	4.6	4.6
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	9.2	9.3
Rating	Pass	Pass	Pass

LOCATION 9.1

■ mean
□ GEM

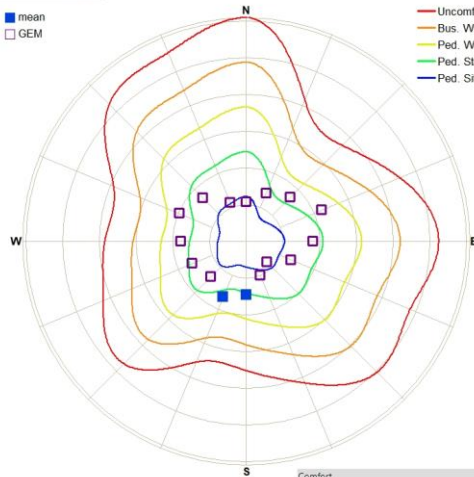


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	19.03	26.17	26.44
4	1.75	3.50	3.52
6	0.20	0.32	0.32
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	3.1	3.6	3.6
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.4	7.7	7.7
Rating	Pass	Pass	Pass

LOCATION 10

■ mean
□ GEM

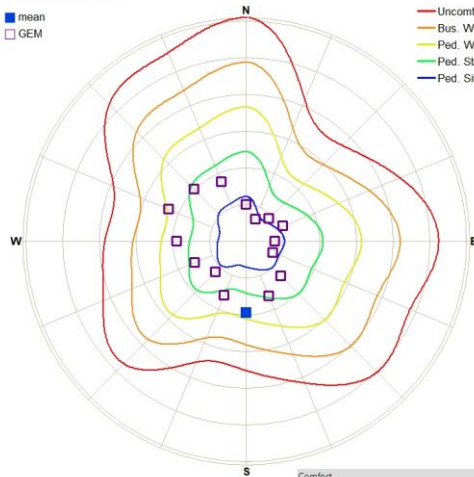


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	25.09	36.47	36.86
4	2.34	4.81	5.18
6	0.09	0.29	0.32
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	3.5	3.9	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.6	7.6	7.6
Rating	Pass	Pass	Pass

LOCATION 10.1

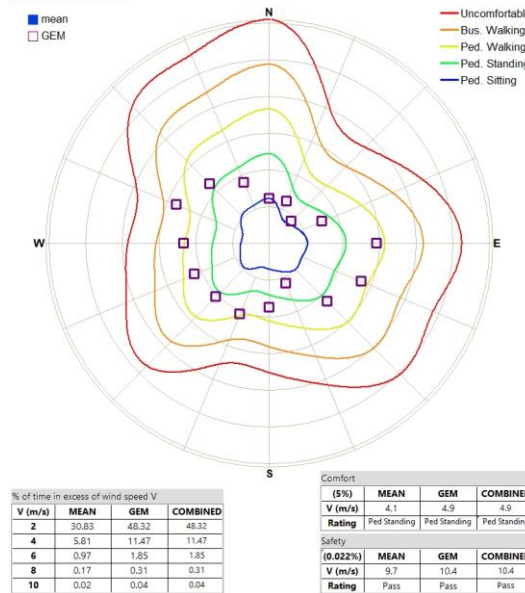
■ mean
□ GEM



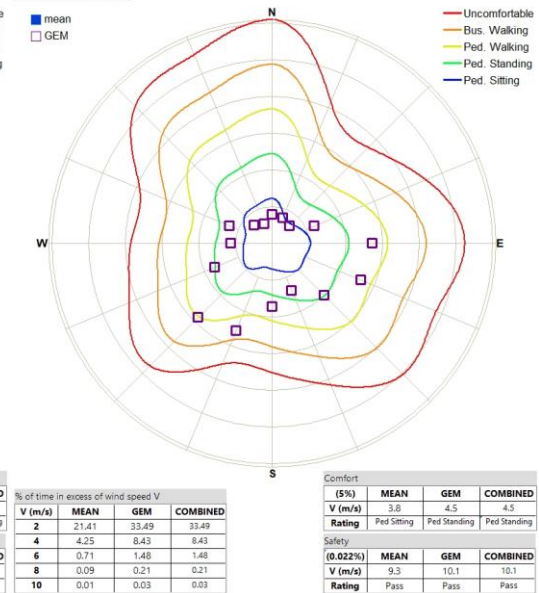
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	25.31	32.96	33.31
4	4.32	5.02	5.64
6	0.52	0.60	0.74
8	0.03	0.06	0.08
10	0.00	0.00	0.00

Comfort			
(%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.0	4.1
Rating	Ped Sitting	Ped Sitting	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.2	8.7	8.8
Rating	Pass	Pass	Pass

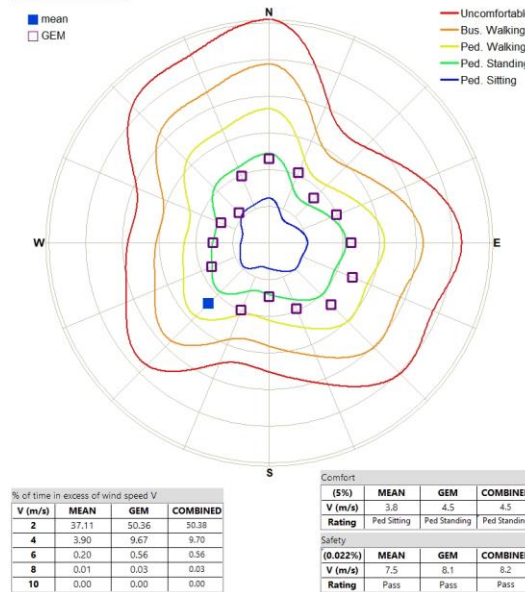
LOCATION 11



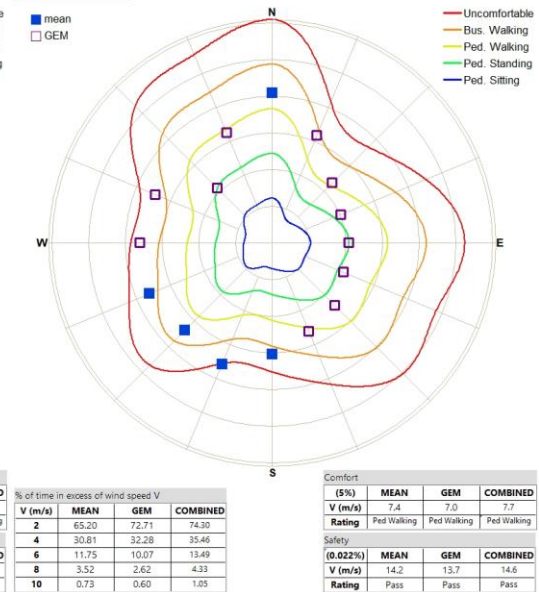
LOCATION 12



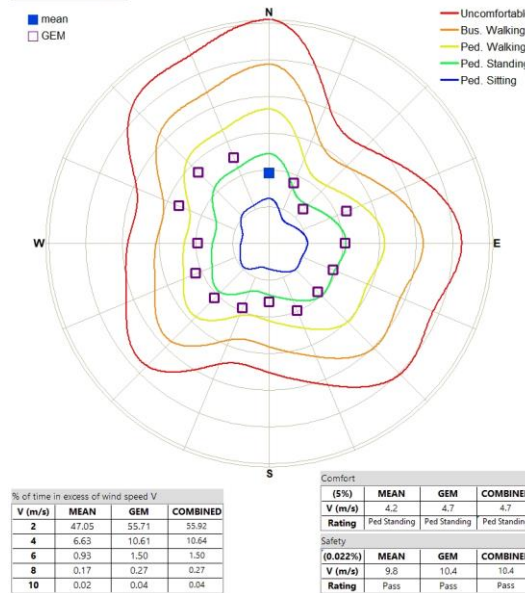
LOCATION 13



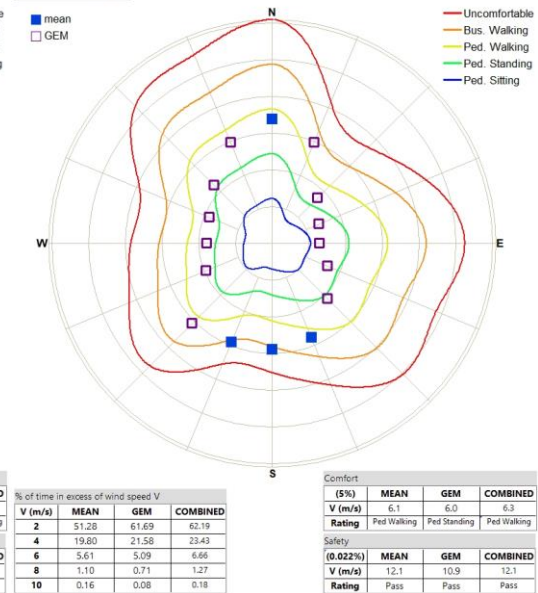
LOCATION 14



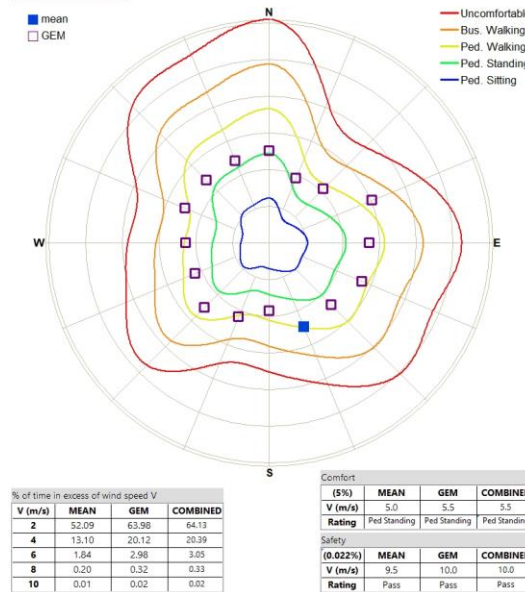
LOCATION 15



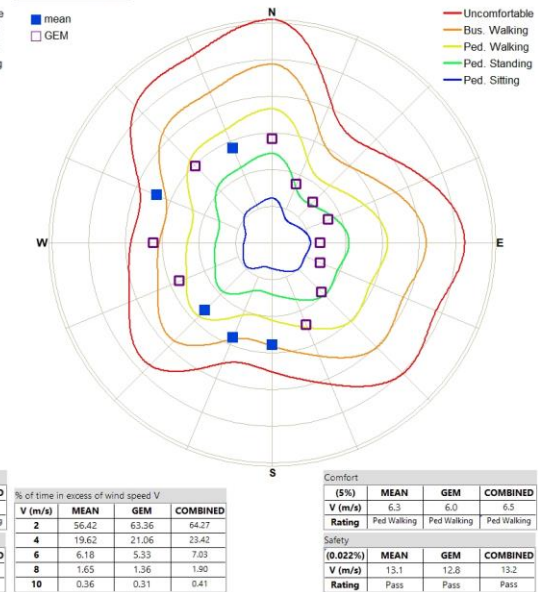
LOCATION 16



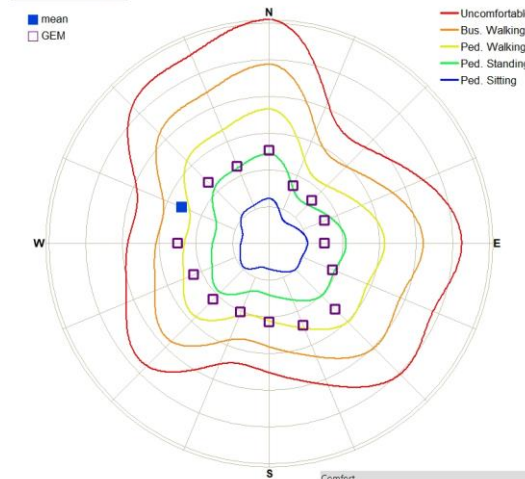
LOCATION 17



LOCATION 18



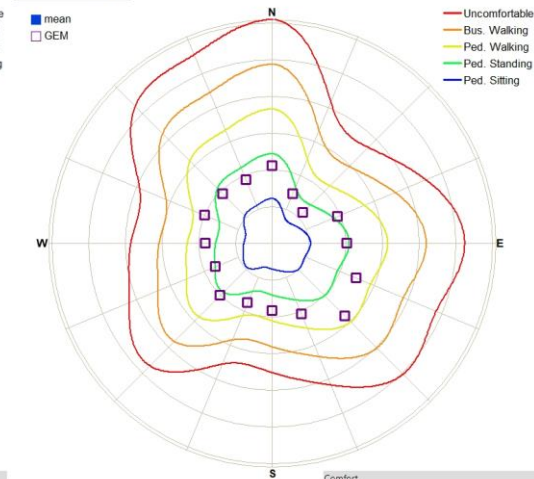
LOCATION 19



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	45.62	59.10	59.33
4	8.97	15.31	15.48
6	1.49	2.41	2.32
8	0.23	0.29	0.33
10	0.02	0.02	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.2	5.2
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.9	9.8	10.1
Rating	Pass	Pass	Pass

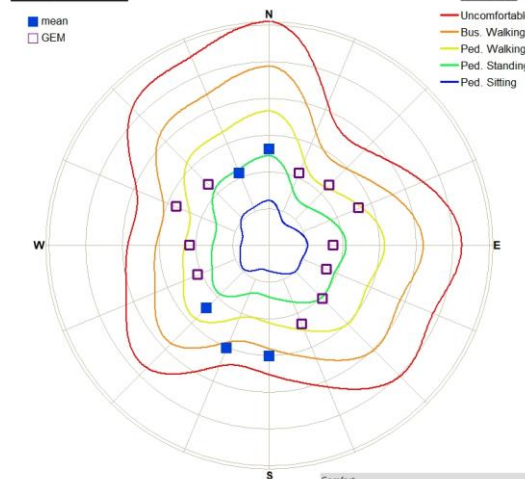
LOCATION 20



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	34.18	51.76	51.76
4	3.83	9.56	9.56
6	0.16	0.81	0.81
8	0.00	0.05	0.05
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.5	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.1	8.4	8.4
Rating	Pass	Pass	Pass

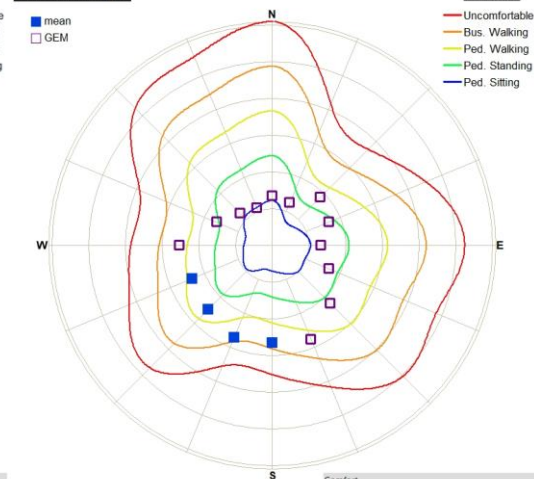
LOCATION 21



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	53.95	61.89	62.70
4	18.20	23.03	24.36
6	5.47	5.01	6.59
8	1.38	0.85	1.32
10	0.24	0.11	0.27

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.1	6.0	6.3
Rating	Ped Walking	Ped Standing	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.6	11.3	12.6
Rating	Pass	Pass	Pass

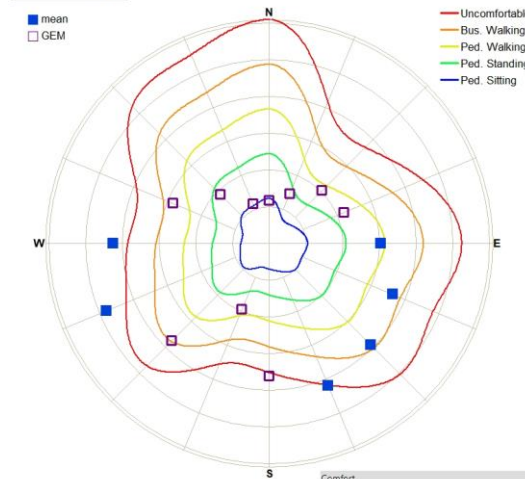
LOCATION 22



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.41	48.94	48.49
4	15.09	16.91	16.77
6	3.68	3.26	4.37
8	0.60	0.41	0.70
10	0.08	0.04	0.09

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.5	5.5	5.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.1	10.5	11.2
Rating	Pass	Pass	Pass

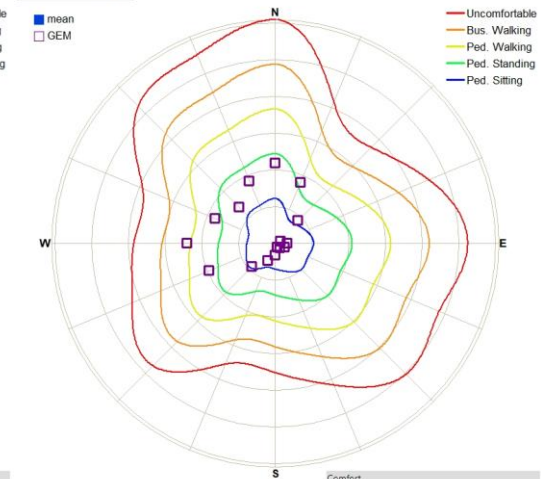
LOCATION 23



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	54.19	63.02	64.24
4	26.50	31.05	33.48
6	12.55	12.45	15.97
8	4.55	4.00	6.06
10	1.54	1.17	2.89

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.8	7.5	8.3
Rating	Ped Walking	Ped Walking	Bus Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	16.3	14.9	16.4
Rating	Able Body	Pass	Able Body

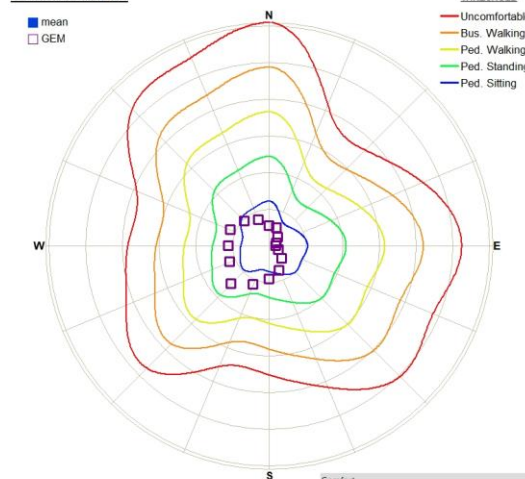
LOCATION 24



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	8.60	19.75	19.75
4	0.51	3.85	3.85
6	0.01	0.54	0.54
8	0.00	0.05	0.05
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.4	3.7	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.8	8.6	8.6
Rating	Pass	Pass	Pass

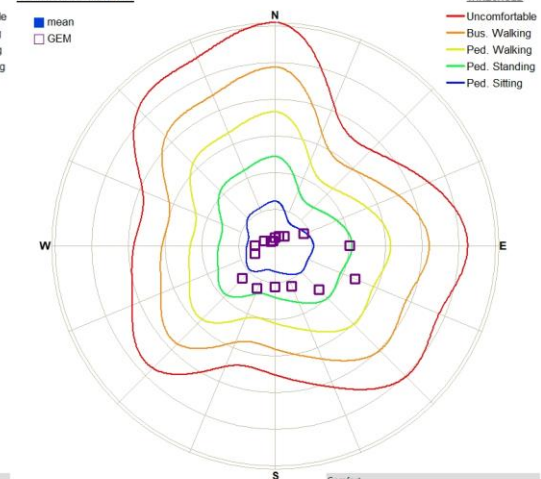
LOCATION 25



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	2.33	9.57	9.57
4	0.00	0.19	0.19
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	1.7	2.4	2.4
Rating	Outdoor Dining	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	3.4	4.8	4.8
Rating	Pass	Pass	Pass

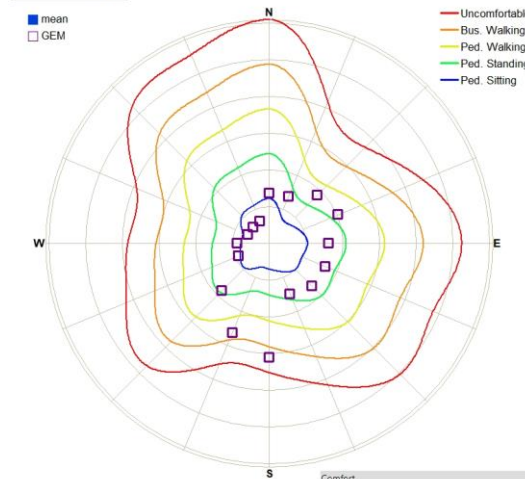
LOCATION 26



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	7.54	16.24	16.24
4	0.10	1.00	1.00
6	0.00	0.05	0.05
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.2	3.0	3.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.6	6.5	6.5
Rating	Pass	Pass	Pass

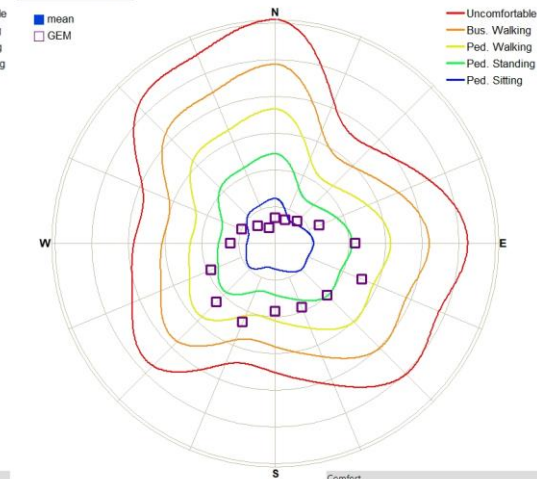
LOCATION 27



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.05	36.75	36.75
4	7.53	12.59	12.59
6	1.70	3.98	3.98
8	0.22	1.01	1.01
10	0.02	0.20	0.20

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.5	5.5
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.0	12.2	12.2
Rating	Pass	Pass	Pass

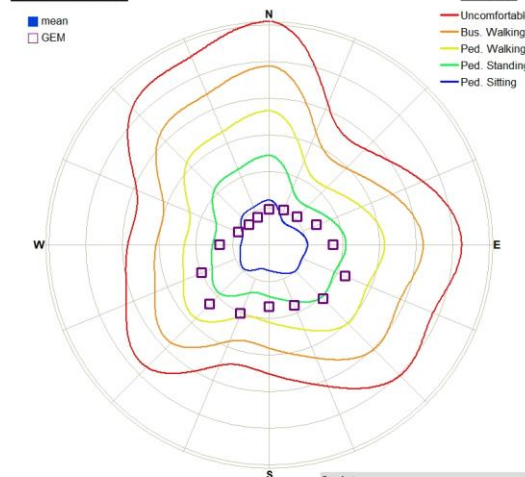
LOCATION 28



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	25.10	34.95	34.95
4	4.04	7.66	7.66
6	0.48	0.92	0.92
8	0.05	0.09	0.09
10	0.00	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.7	9.1	9.1
Rating	Pass	Pass	Pass

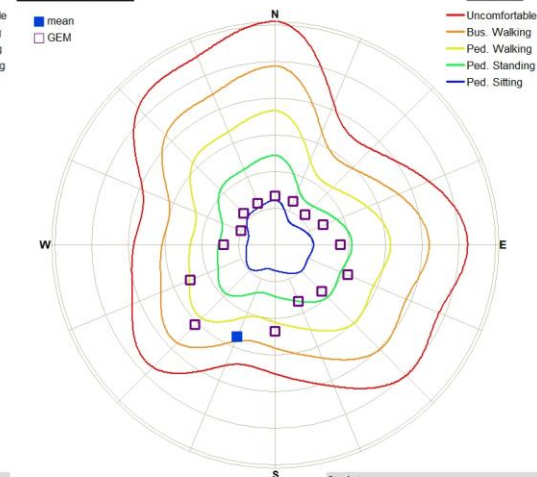
LOCATION 29



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.23	37.19	37.19
4	2.50	5.70	5.70
6	0.12	0.44	0.44
8	0.00	0.03	0.03
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.4	4.1	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.1	8.1	8.1
Rating	Pass	Pass	Pass

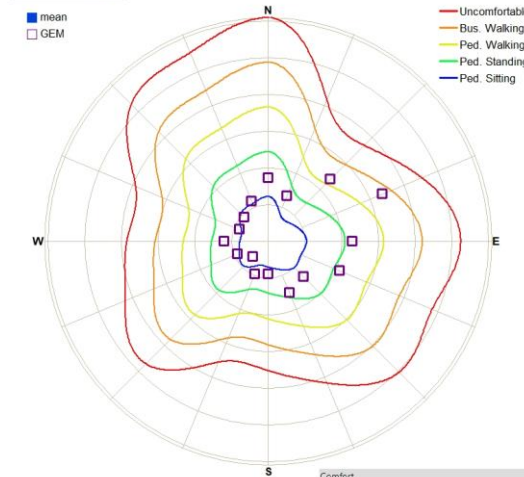
LOCATION 30



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	27.63	42.62	42.64
4	8.39	11.55	11.62
6	2.15	2.78	2.87
8	0.33	0.40	0.43
10	0.05	0.05	0.06

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.2	5.2
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	10.7	10.8
Rating	Pass	Pass	Pass

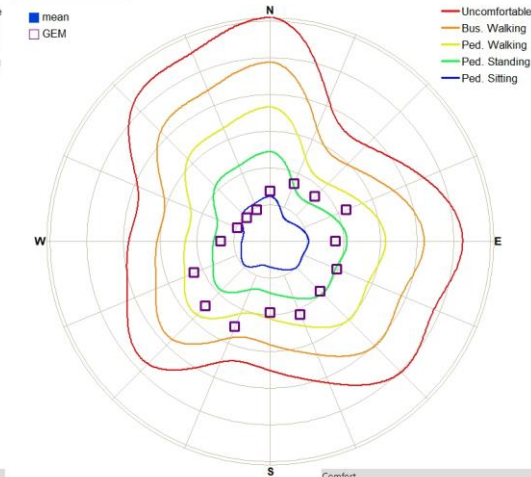
LOCATION 31



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	14.61	29.08	29.08
4	3.24	6.53	6.53
6	0.43	1.59	1.59
8	0.02	0.14	0.14
10	0.00	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	4.4	4.4
Rating	Ped. Sitting	Ped. Standing	Ped. Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.9	9.2	9.2
Rating	Pass	Pass	Pass

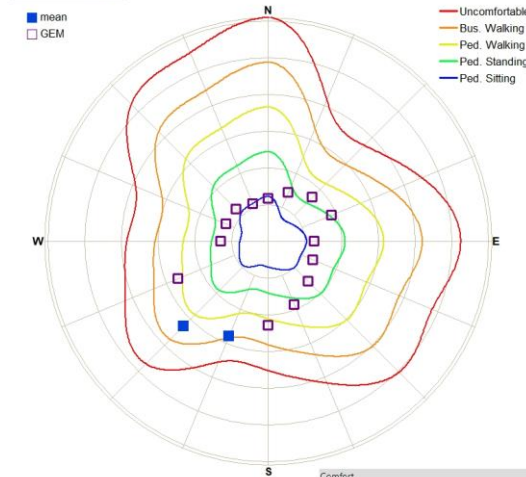
LOCATION 32



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	33.34	45.17	45.17
4	5.55	11.50	11.50
6	0.94	1.57	1.57
8	0.12	0.17	0.17
10	0.01	0.02	0.02

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	4.8	4.8
Rating	Ped. Standing	Ped. Standing	Ped. Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.6	9.9	9.9
Rating	Pass	Pass	Pass

LOCATION 33



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	29.97	43.02	43.10
4	8.71	12.68	12.85
6	2.41	2.91	3.11
8	0.41	0.41	0.48
10	0.06	0.06	0.07

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.2	5.3
Rating	Ped. Standing	Ped. Standing	Ped. Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.0	10.8	11.1
Rating	Pass	Pass	Pass