



WIND ENGINEERING
CONSULTANTS

QUALITATIVE WIND ASSESSMENT
CPP PROJECT 17939
12 APRIL 2024

Altis Bankstown

Bankstown, NSW

CPP Wind Engineering
Consultants
2/500 Princes Highway
St Peters NSW 2044
Info-syd@cppwind.com

cppwind.com

PREPARED FOR:

Essence

Level 8, 68 Pitt St
Sydney, NSW 2000

Craig Sanders
+61 427 558 761
csanders@essencepm.com.au

PREPARED BY:

Jordan Black
Project Engineer
jblack@cppwind.com

Adam van Duijneveldt
Senior Engineer
avd@cppwind.com

Joe Paetzold, PhD
Engineering Manager
jpaetzold@cppwind.com

Executive Summary

A qualitative assessment of the Altis Bankstown development to be built in Bankstown, NSW was conducted to provide an initial assessment of the surrounding pedestrian wind environment. The assessment was based on the local wind climate, CPP's experience in the region and on comparable projects, and the characteristics of the proposed development.

The wind environment around the development is likely to be generally suitable for Pedestrian Standing to Walking style activities from a comfort perspective with reference to the Lawson criteria. No major adverse impacts to pedestrian comfort or amenity are foreseen as a result of the proposed development. Areas intended for long term stationary activity such as seating and dining may require treatment to ensure they are suitable for their intended use. All areas in the public domain in the vicinity of the subject site are expected to satisfy the relevant wind safety criterion.

Slightly stronger wind conditions are expected to occur through the ground level arcade and on the podium rooftop terrace during higher wind speeds. Mitigation is recommended for areas that will be used for medium to long term stationary occupation within these spaces, and some suggested strategies are provided.

Windier conditions are often found on residential balconies for developments of this type, particularly on exposed corner balconies due to cross flow. The proposed residential balconies, at the tower corners, may occasionally experience strong wind conditions. The proposed balconies situated away from the tower corners are well located and sized from a wind comfort perspective.

This report is a high-level qualitative assessment based on basic features of the local wind climate and proposed built environment. Wind tunnel testing would be suggested should quantification of conditions be required and/or for development of specific mitigation measures.

Document Tracking and Version Control

REVISION	RELEVANT INFORMATION	
R00	Date Issued:	10/04/2024
	Prepared by:	JB
	Reviewed by:	JP
	Approved by:	AVD
	Document Name:	CPP17939_Altis Bankstown_REP_DS_PW_R00.pdf
R01	Date Issued:	12/04/2024
	Prepared by:	JB
	Reviewed by:	JP
	Approved by:	AVD
	Document Name:	CPP17939_Altis Bankstown_REP_DS_PW_R01.pdf

Contents

	1
Executive Summary	2
Document Tracking and Version Control	3
1. Introduction	5
General information	5
2. Wind Climate	7
3. Wind Assessment Criteria	9
3. Assessment	11
Site Description	11
Winds from the west	13
Winds from the South-east	14
Summary – Public Domain	15
Wind conditions within the development	16
4. Conclusion	19
References	20
Appendix A – Wind Flow Mechanisms	21
Appendix B - Wind Impact Planning Guidelines	23

1. Introduction

GENERAL INFORMATION

The assessment of the wind environment around developments can ensure adverse impacts are minimized and 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.

The proposed development is located in the Bankstown CBD, approximately 100 meters to the north of Bankstown station. The surrounding terrain is comprised primarily of low-rise suburban development, with some larger commercial towers, Figure 1.

The proposed development is comprised of three prismatic towers set back over a shared podium, reaching a maximum height of about 85 m above ground level, Figure 2. As it is slightly larger than most of the surrounding structures, the addition of the proposed development is expected to have some impact on the local wind conditions, and the extents are broadly discussed in this report.

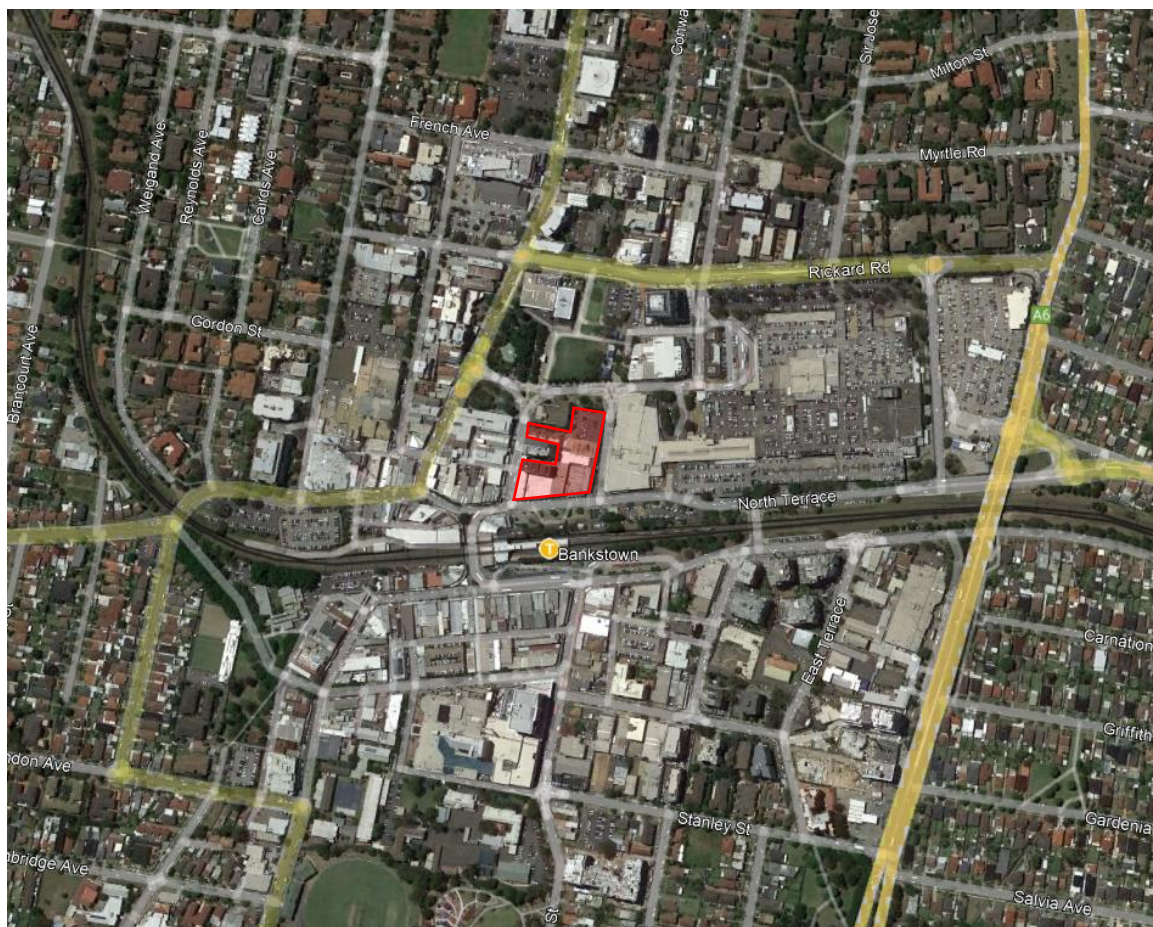


Figure 1: Aerial view of proposed development site (Google Earth, 2023)

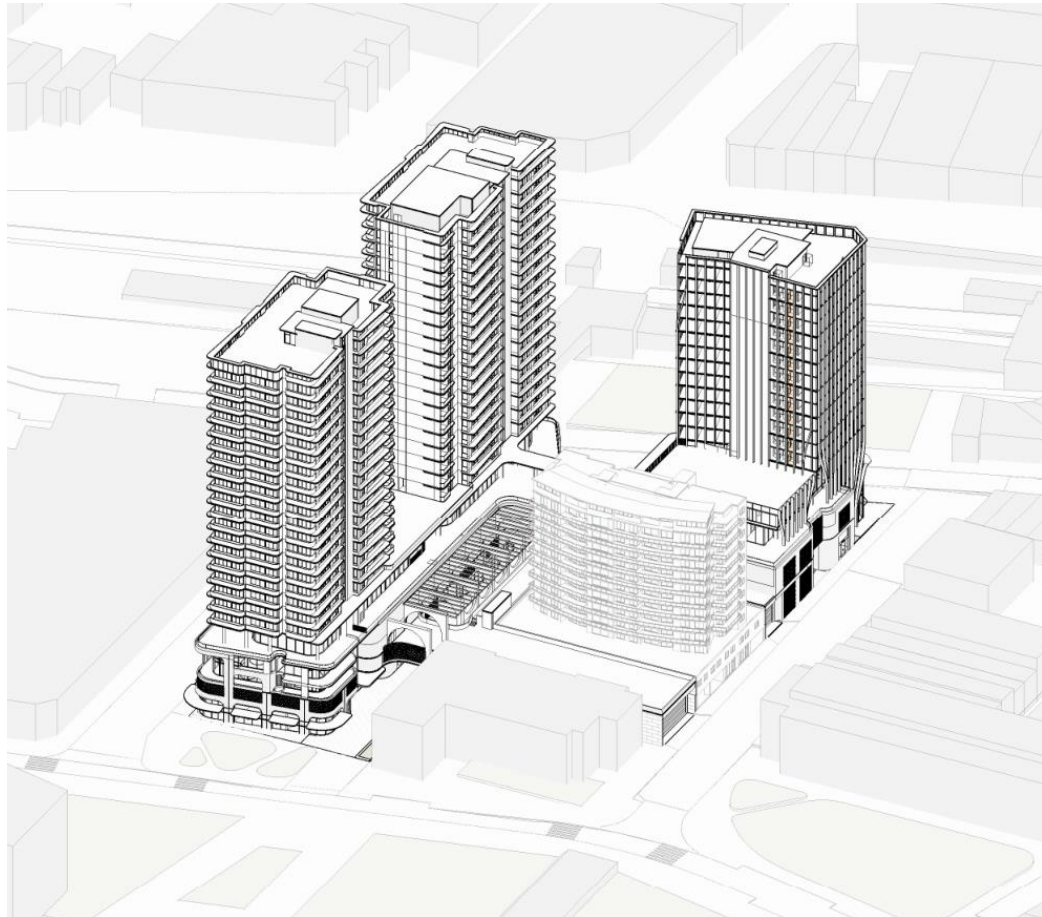


Figure 2: 3D render viewed from the north-west (top) and west Elevation of proposed development

2. Wind Climate

The proposed development lies approximately 4 km to the east of the Bankstown Airport Bureau of Meteorology anemometer, which provides the best source of historical wind data for the project. To enable a qualitative assessment of the wind environment, the wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m from 1995 – 2022 have been used in this analysis.

The wind rose for Bankstown Airport is shown in Figure 3. The arms of the wind roses point in the direction from where the wind is blowing, 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.

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 3, winds from the west and south-east directions are predominant. This wind assessment is structured around these prevailing wind directions.

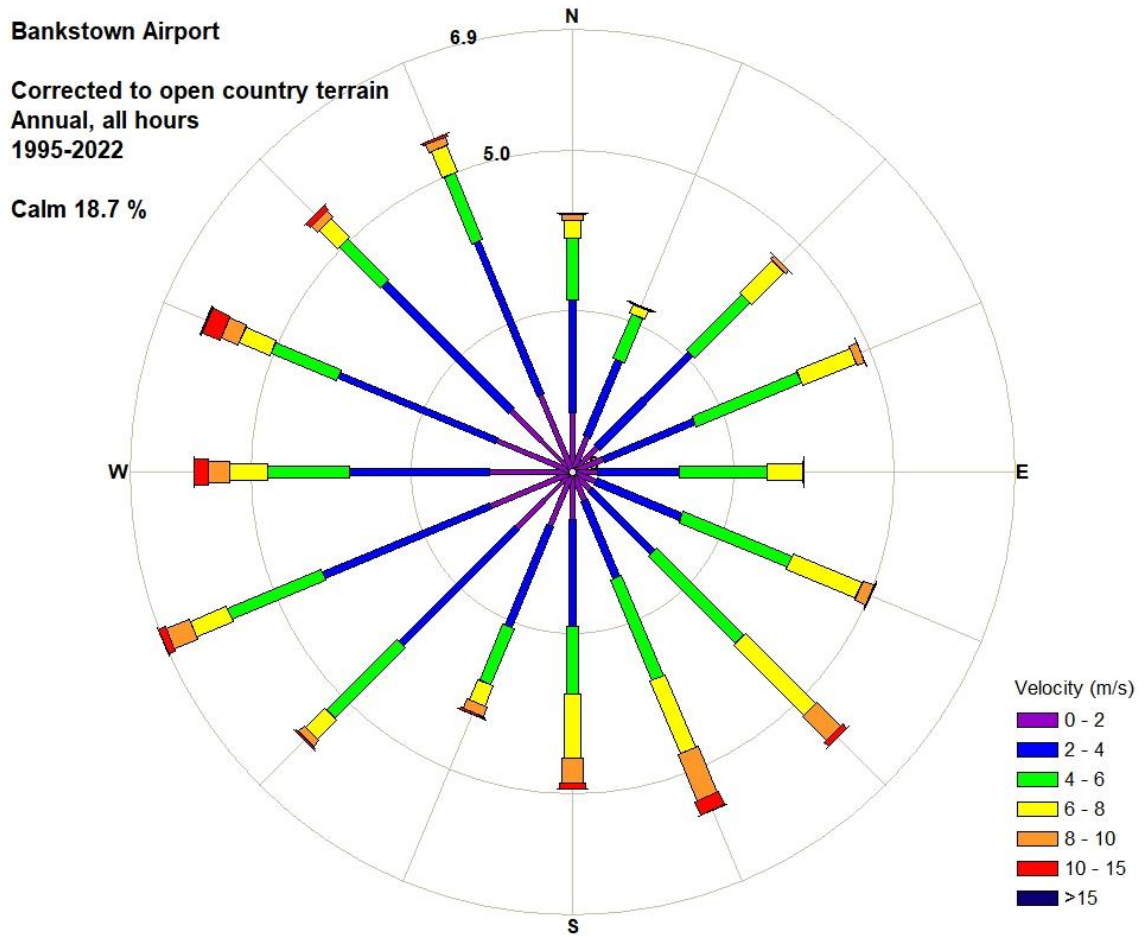


Figure 3: Probability of Wind Speeds by Direction Bankstown Airport –(1995 – 2022, All Hours)

3. Wind Assessment Criteria

A number of researchers have suggested quantitative methods for assessing wind comfort and safety based on estimated wind speeds and local climate statistics. These criteria provide a means of evaluating the wind amenity of location based on the frequency of threshold wind speeds, noting that pedestrians will tolerate higher wind speeds for a shorter time period than lower speeds. The comfort criteria also allow planners to assess the usability, with respect to the wind environment, of different locations for various purposes.

The Canterbury-Bankstown Development Control Plan does not specify a method of assessing wind comfort or safety for this site (City of Canterbury-Bankstown 2023). 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).

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 1. 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.

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.

Assessment using the Lawson criteria is preferred to methods based on once per annum gust speeds such as Melbourne (1978) as it is based on more regularly occurring wind speeds relevant to perception by pedestrians and uses a combined probability integrated over all directions. In addition, it is less susceptible to variations in turbulence levels in urban environments while still considering the impact of short-duration gusts.

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.

Table 1: 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.

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

* 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.

3. Assessment

SITE DESCRIPTION

The development site is surrounded in most directions by low-rise buildings. A region of parkland lies to the north and on the southern side, the site is bordered by railway lines. Topography surrounding the site is relatively flat from a wind perspective and unlikely to significantly affect the wind climate at the site. Winds in such surrounds tend to experience less channelling than areas with many tall structures, with local effects instead being dictated by exposed buildings and their relation to prevailing strong wind directions. Several wind flow mechanisms such as downwash and channelling flow are described in Appendix A and the effectiveness of some common wind mitigation measures are described in Appendix B.

The subject site is located on a block bounded by North Terrace to the south, The Appian Way to the east, The Mall to the north and Fetherstone Street to the west. The proposed development consists of three prismatic towers with rectangular planforms over a shared podium structure with ground-floor retail tenancies and pedestrian communal spaces. A ground floor plan and podium rooftop plan are shown in Figure 4 and Figure 5, respectively.



Figure 4: Ground floor plan of proposed development.



Figure 5: Podium terrace plans of proposed development – Level 4 (top) and Level 5 (bottom)

WINDS FROM THE WEST

Winds from the north-west to south-west will approach the site over a region of suburban development. Winds from this region are relatively unimpeded approaching the development due to the absence of tall buildings or obstacles. Pedestrian areas along the southern and western boundaries of the development may be affected by stronger breezes as the proposed development massing directs wind flow along North Terrace and Fetherstone Street.

As the towers are taller than the upwind surrounds, some incoming winds from the west are likely to be directed toward the ground in the form of downwash. The setback of Towers B and C from the podium edge will reduce the impact of such flows on ground level by redirecting them horizontally, however windier conditions may arise on the podium rooftop level. As the setback of Tower A is limited to the northern side of the building, relatively high wind speeds would still be expected on ground level near to the south-west windward corner of the building during winds from the west.

Relatively high wind speeds would be expected on the podium roof near to the windward corners of the towers during winds from the west. The tower setback from the podium edge may concentrate the impact of downwash from the towers onto the podium roof. Furthermore, increased wind speeds may occur in the undercut areas at the Level 4 south-west corners of Buildings A and B, as downwash flow accelerates around these corners. Due to the orientation and massing of the towers, winds from the west may be channelled through the gap on the podium roof between Towers A and B and Towers B and C creating windier conditions between the towers. The podium roof is to be activated for pedestrian use, therefore amelioration measures that incorporate horizontal and vertical elements are recommended, particularly near entries at the tower bases or proposed seating areas. Such measures are proposed in the form of awnings, pavilion areas and landscaping features. This will help to create areas of calm and increase wind amenity on the podium level and will be necessary for the success of this area. The proposed canopy between Buildings A and B and Buildings B and C, as well as the perimeter landscaping at Level 4 will help to reduce the impact of wind on the Level 4 terrace and are recommended to be retained. However, higher wind speeds are expected to occur in the Level 5 Communal Open Space.

The ground level arcade connects a positive pressure region on the windward side with a negative pressure region on the lee side. This will result in flow through the opening with breezy conditions present at constrictions in the cross-sectional area. As a result, during winds from the west, conditions in the Featherstone Walk through site link are likely to experience some accelerated wind flow. This flow mechanism may also occur through the open western façade of the Compass Way Canopy at Level 4, potentially leading to stronger breezes developing through the ground level arcade between Buildings B and C. If long term stationary activity such as sitting or dining is desired in this area, the addition of vertical screening elements such as raised planter or booth style seating is recommended.

Public domain locations on the eastern side of the development are expected to remain reasonably mild. Overall, for winds from this quadrant, conditions at most public domain locations around the site are expected to remain similar to the existing wind conditions and satisfy the Lawson safety/distress criterion.

WINDS FROM THE SOUTH-EAST

Winds from the south quadrant will approach over a large region of low-rise suburban development and closer to the site, a sector of medium rise buildings and railway lines. Winds from this region are relatively unimpeded approaching the development. Pedestrian areas along the southern and eastern boundaries of the development may be affected by stronger breezes as the proposed development massing directs wind flow along North Terrace and The Appian Way.

As the towers are taller than the upwind surrounds, some incoming winds from the south-east are likely to be directed toward the ground in the form of downwash. The orientation of the Towers relative to winds from the south-east would minimise downwash effects from the tower facades due to the oblique approach angle of the wind. Furthermore, the positioning all three towers, away from the podium edge, will lessen the impact of such flow on the ground level. However, windier conditions may occur on the podium rooftop.

It is expected that the ground level arcade will experience breezy conditions for winds originating from the south-east, particularly near the arcade entries, due to the pressure differential between the southern, northern, eastern, and western sides of the site, as mentioned above. This flow mechanism may also occur between the ground level arcade and the void to the podium, which may introduce unwanted flows through pedestrian spaces. The void is open to ambient conditions at podium level to the south, west and north, and is therefore susceptible to flow through the opening from multiple directions. In order to reduce the likelihood of unwanted flow through the ground level arcade, it is advisable that the void canopy incorporates a façade that is predominantly solid, accounting for at least 70% of its composition. This will enable an expanded cross-sectional area within the arcade, thereby diminishing wind speeds in this area. This would be recommended if comfortable conditions for outdoor seating or dining are required on windier days. Furthermore, the addition of vertical screening elements such as raised planters and booth style seating is recommended at designated seating areas within the arcade.

The podium roof is susceptible to relatively high wind speeds, particularly near the windward corners of the towers during south-east winds. The setback of the towers from the podium edge may intensify the impact of downwash onto the podium roof. Additionally, elevated wind speeds might be experienced at the Level 4 undercut areas at the southern corners of Buildings A and B, where downwash flow accelerates around these corners. The orientation and massing of the towers could funnel south-east winds through the gap on the podium roof between towers A and B, resulting in windier conditions between the two towers. The orientation of the towers relative to south-easterly winds will reduce the impact of downwash on the podium roof. However, given the intended pedestrian use of the podium roof, it may be worth considering the incorporation of wind mitigation measures at key locations such as entrances and designated seating areas. Potential features could be in the form of awnings, pavilion spaces and landscaping features.

During winds from the south-east conditions at public domain locations on the northern and western sides of the development are expected to remain reasonably calm. Overall, for winds from this quadrant, conditions at most public domain locations around the site are expected to remain similar to the existing wind conditions and satisfy the Lawson safety/distress criterion.

SUMMARY – PUBLIC DOMAIN

The addition of the proposed development may cause wind speeds in some areas to increase, while creating calmer conditions in others. On average and for the majority of locations in the vicinity, the pedestrian level wind environment is expected to remain similar to the existing. From a pedestrian comfort perspective, the wind environment around the proposed development site is likely to be classified as acceptable for Pedestrian Standing or Walking under Lawson. These pedestrian comfort levels would be suitable for public accessways, and for stationary short-term exposure activities. Localised amelioration measures would be suggested if calmer areas are desired for particular locations. The necessity of such measures will depend on the required level of wind amenity and the intended use of specific areas as noted in the preceding sections. All locations in the public domain would be expected to satisfy the safety/distress criterion.

WIND CONDITIONS WITHIN THE DEVELOPMENT

GROUND LEVEL

Strong ground level winds may develop through the arcade. As noted, the arcade effectively connects a positive pressure region on the windward side with a negative pressure region on the lee side; regular breezes may arise in the arcade volume as a result. Conditions are likely to remain acceptable for pedestrian access and thoroughfare, however may become undesirably windy for a semi-internal space on high wind days. The incorporation of vertical screens, raised planters and booth type seating may be used to manage conditions in the arcade and would be recommended if this space is to be used for seated dining or similar.

PODIUM TERRACE

As with most outdoor areas at height and in proximity to taller buildings, the podium terrace is relatively exposed from a wind perspective and may experience higher winds, particularly near to the tower bases and in the space between the towers. As noted in previous sections, the use of awnings around the tower bases, particularly near entries or proposed seating areas, will reduce the impact of downwash generated off the tower facades and create protected areas with reasonable conditions for occupants.

Winds may be accelerated between the space between the towers. Localised amelioration in the form of vertical screens, raised planter boxes and booth style seating or cabanas may be used where required to ensure areas of relative calm suitable for their intended uses. Winds are generally accelerated around building corners and undercut areas. Partial enclosure and vertical screening elements will reduce the impact of wind acceleration at the building corners.

BALCONIES

Windier conditions are often found on residential balconies for developments of this type, particularly on exposed corner balconies. Corner balconies open to more than one side can experience strong cross flow for some wind directions. Balconies that are recessed into the façade and situated away from tower corners are generally better protected and experience calmer conditions.

The balconies as proposed are generally well designed and located from a wind perspective, representing relatively small volumes and recessed within the floor plate (Figure 6).

Conditions are expected to be typical of similar residential balconies in this part of Sydney, and no issues are foreseen for normal discretionary use.

ROOF TERRACES

Tower A's rooftop includes an outdoor bar area, while the rooftops of Tower B and C feature communal open spaces (Figure 7). Such spaces may be subject to strong winds due to their elevation and exposure to multiple prevailing wind directions. To ensure a level of amenity suitable for longer term stationary activity, high perimeter balustrades (at least 1.8m in height) as well as partial enclosure of portions of these terraces may be considered. The massing of the plant/overrun levels may be leveraged in combination with overhead canopies or awnings to create calmer areas. Where possible, a vertical enclosure on one side of such an area (by joining the canopy to the balustrade or wall) is suggested. Elsewhere, local treatments such as sunken or booth-style seating, screening, landscaped zones may be considered.



2 TYPICAL BUILDING B L06-L23
1: 150 @A1



2 TYPICAL BUILDING C L06-L18
1: 150

Figure 6: Typical Building B (top) and C (bottom) plans of proposed development.



Figure 7: Building A (top), Building B (bottom-left) and C (bottom-right) proposed roof plans.

4. Conclusion

Cermak Peterka Petersen Pty. Ltd. has provided a qualitative assessment of the impact of the proposed Altis Bankstown project on the local wind environment in and around the development site. Being slightly larger than most surrounding structures, the proposed development will have some effect on the local wind environment, though any changes are not expected to be significant from the perspective of pedestrian comfort or safety. Wind conditions around the development are expected to be classified as acceptable for Pedestrian Standing or Walking from a Lawson comfort perspective and pass the distress/safety criterion. Local amelioration may be advised for areas intended for long-term stationary or outdoor dining activities.

References

City of Canterbury-Bankstown (2023), *Canterbury-Bankstown Development Control Plan*

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.

Melbourne, W.H., 1978, Criteria for Environmental Wind Conditions, *Journal of Wind Engineering and Industrial Aerodynamics*, Vol.3, No.2-3, pp.241-249.

Appendix A – Wind Flow Mechanisms

When the wind hits a large isolated building, the wind is accelerated down and around the windward corners, Figure A1 this flow mechanism is called downwash and causes the windiest conditions at ground level on the windward corners and sides of the building. In Figure A1 smoke is being released into the wind flow to allow the wind speed, turbulence, and direction to be visualised. The image on the left shows smoke being released across the windward face, and the image on the right shows smoke being released into the flow at about third height in the centre of the face.

Techniques to mitigate the effects of downwash winds on pedestrians include the provision of horizontal elements, the most effective being a podium to divert the flow away from pavements and building entrances. Awnings along street frontages perform a similar function, and the larger the horizontal element, the more effective it will be in diverting the flow.

Channelling occurs when the wind is accelerated between two buildings or along straight streets with buildings on either side.

Figure A2 shows the wind at mid and upper levels on a building being accelerated substantially around the corners of the building. When balconies are located on these corners, they are likely to be breezy, and will be used less by the owner due to the regularity of stronger winds. Owners quickly become familiar with when and how to use their balconies. If the corner balconies are deep enough, articulated, or have regular partition privacy fins, then local calmer conditions can exist.

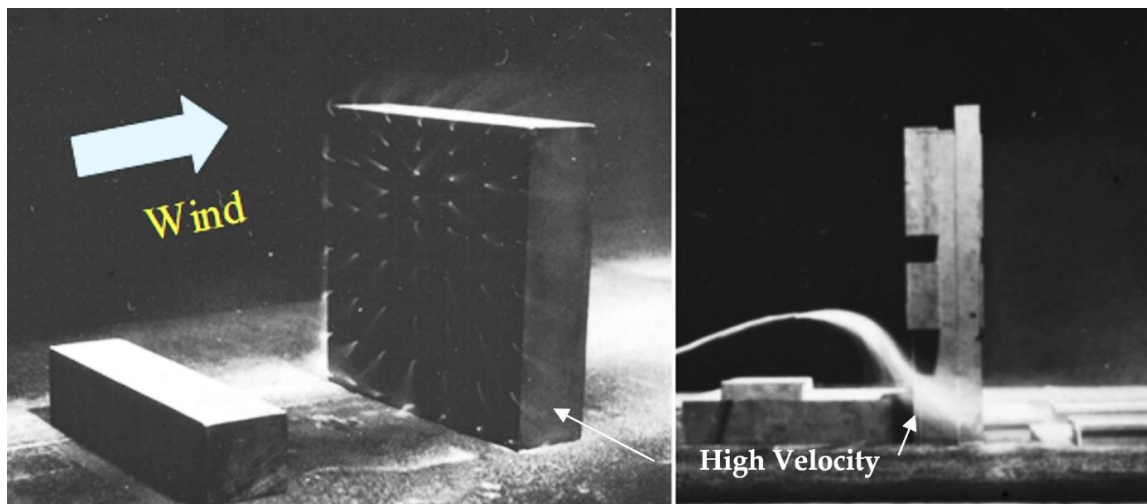


Figure A1: Flow visualisation around a tall building.



Figure A2: Channelling between buildings (L) and visualisation through corner balconies (R).

Appendix B - Wind Impact Planning Guidelines

It is well known that the design of a building will influence the quality of the ambient wind environment at its base. Below are some suggested wind mitigation strategies that should be adopted into precinct planning guidelines and controls (see also Cochran, 2004).

Building form – Canopies

A large canopy may interrupt the flow as it moves down the windward face of the building. This will protect the entrances and sidewalk area by deflecting the downwash at the second storey level, Figure B1. However, this approach may have the effect of transferring the breezy conditions to the other side of the street. Large canopies are a common feature near the main entrances of large office buildings.

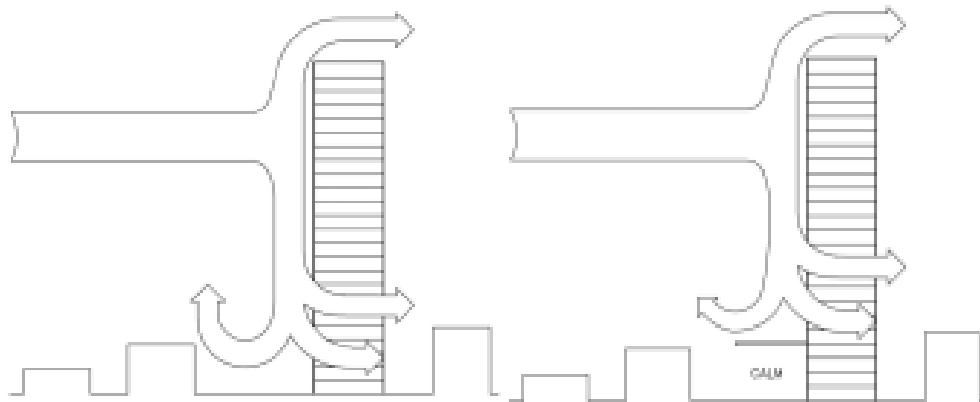


Figure B1: Canopy Windbreak Treatment. (L) Downwash to street level may generate windy conditions for pedestrians. (R) A large canopy is a common solution to this pedestrian-wind problem at street level.

Building form – Podiums

The architect may elect to use an extensive podium for the same purpose, Figure B2, if it complies with the design mandate. This is a common architectural feature for many major projects, but it may be counterproductive if the architect wishes to use the podium roof for long-term pedestrian activities, such as a pool or tennis court.

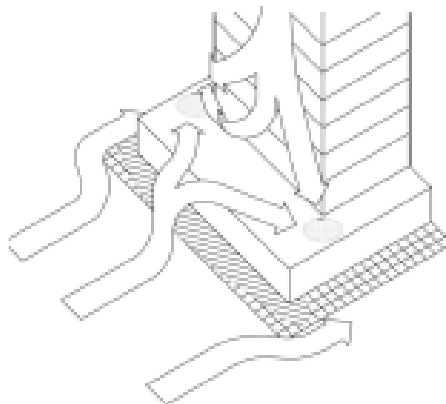


Figure B2: The tower-on-podium massing often results in reasonable conditions at ground level, but the podium may not be useable.

Building form – Arcades

Another massing issue, which may be a cause of strong ground-level winds, is an arcade or thoroughfare opening from one side of the building to the other. This effectively connects a positive pressure region on the windward side with a negative pressure region on the lee side; a strong flow through the opening often results, Figure B3. The uninvitingly windy nature of these open areas is a contributing reason behind the use of arcade airlock entrances (revolving or double sliding doors).

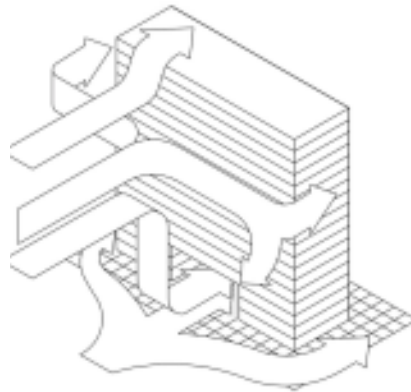


Figure B3: An arcade or open column plaza under a building frequently generates strong pedestrian wind condition.

Building form – Alcove

An entrance alcove behind the building line will generally produce a calmer entrance area at a mid-building location, Figure B4(L). In some cases, a canopy may not be necessary with this scenario, depending on the local geometry and directional wind characteristics. The same undercut design at a building corner is usually quite unsuccessful, Figure B4 (R), due to the accelerated flow mechanism described in Figure B1 and the ambient directional wind statistics. If there is a strong directional wind preference, and the corner door is shielded from those common stronger winds, then the corner entrance may work. However, it is more common for a corner entrance to be adversely impacted by this local building geometry. The result can range from simply unpleasant conditions to a frequent inability to open the doors.

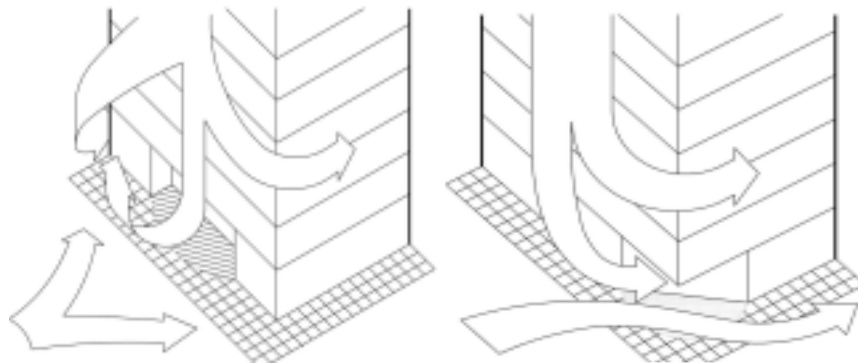


Figure B4: Alcove Windbreak Treatment. (L) A mid-building alcove entrance usually results in an inviting and calm location. (R) Accelerated corner flow from downwash often yields an unpleasant entrance area.

Building form – Façade profile and balconies

The way in which a building's vertical line is broken up may also have an impact. For example, if the floor plans have a decreasing area with increased height the flow down the stepped windward face may be greatly diminished. To a lesser extent the presence of many balconies can have a similar impact on ground level winds, although this is far less certain and more geometry dependent. Apartment designs with many elevated balconies and terrace areas near building ends or corners often attract a windy environment to those locations. Mid-building balconies, on the broad face, are usually a lot calmer, especially if they are recessed. Corner balconies are generally a lot windier and so the owner is likely to be selective about when the balcony is used or endeavours to find a protected portion of the balcony that allows more frequent use, even when the wind is blowing.

Use of canopies, trellises, and high canopy foliage

Downwash Mitigation – As noted earlier, downwash off a tower may be deflected away from ground-level pedestrian areas by large canopies or podium blocks. The downwash then effectively impacts the canopy or podium roof rather than the public areas at the base of the tower, Figure B2. Provided that the podium roof area is not intended for long-term recreational use (e.g. swimming pool or tennis court), this massing method is typically quite successful. However, some large recreational areas may need the wind to be deflected away without blocking the sun (e.g. a pool deck), and so a large canopy is not an option. Downwash deflected over expansive decks like these may often be improved by installing elevated trellis structures or a dense network of trees to create a high, bushy canopy over the long-term recreational areas. Various architecturally acceptable ideas may be explored in the wind tunnel prior to any major financial commitment on the project site.

Horizontally accelerated flows between two tall towers may cause an unpleasant, windy, ground-level pedestrian environment, which could also be locally aggravated by ground topography. Horizontally accelerated flows that create a windy environment are best dealt with by using vertical porous screens or substantial landscaping. Large hedges, bushes or other porous media serve to retard the flow and absorb the energy produced by the wind. A solidity ratio (i.e. proportion of solid area to total area) of about 60-70% has been shown to be most effective in reducing the flow's momentum. These physical changes to the pedestrian areas are most easily evaluated by a model study in a boundary-layer wind tunnel.

References

Cochran L., (2004) Design Features to Change and/or Ameliorate Pedestrian Wind Conditions, Proceedings of the ASCE Structures Congress, Nashville, Tennessee, May 2004.



WIND ENGINEERING
CONSULTANTS

PEDESTRIAN WIND ASSESSMENT
CPP PROJECT 17939
9 MAY 2024

Compass Centre Bankstown

Bankstown, NSW

CPP Wind Engineering
Consultants
2/500 Princes Highway
St Peters NSW 2044,
Australia
Info-syd@cppwind.com
cppwind.com

PREPARED FOR:

Essence

Level 8, 68 Pitt St
Sydney, NSW 2000

Craig Sanders
+61 427 558 761
csanders@essencepm.com.au

PREPARED BY:

Jordan Black
Project Engineer
jblack@cppwind.com

Joe Paetzold, PhD
Engineering Manager
jpaetzold@cppwind.com

Executive Summary

A wind tunnel study of the Compass Centre Bankstown development, to be built in Bankstown, 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 1:300 length scale and centred on a turntable in the wind tunnel. Replicas of existing and approved surrounding buildings within a 430 m radius were constructed and placed on the turntable. Approach boundary layers 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 49 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.

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 to Walking style activities with calmer conditions in alcove areas, which were classified as suitable for Pedestrian Sitting. These conditions are considered suitable for the intended use of public domain spaces. No adverse wind conditions as a result of the proposed development are foreseen. All tested locations satisfy the Lawson safety criteria.

PODIUM TERRACE:

Wind comfort conditions were found to be generally suitable for Pedestrian Standing and Pedestrian Walking. These conditions align with the intended purpose of public domain spaces. Local mitigation measures would be recommended at undercut corner areas if longer term stationary activity such as sitting is desired. There are no significant adverse wind conditions anticipated due to the proposed development. All tested locations meet the safety criteria.

BALCONIES:

Conditions were found to be generally suitable for Pedestrian Sitting and Standing with reference to the Lawson comfort criteria. Balconies on the western sides of Towers B and C were found to be calmer and achieved an Outdoor Dining comfort rating. All tested locations were found to satisfy the recommended safety criteria.

ROOF TERRACES:

The wind environment on the roof terraces within the development were found to be suitable for Pedestrian Sitting and Pedestrian Standing style activities from a comfort perspective with reference to the Lawson criteria. These conditions are suitable for their intended use.

Document Tracking and Version Control

REVISION	RELEVANT INFORMATION
R00	Date Issued: 9 May 2024
	Prepared by: Jordan Black
	Reviewed by: Joe Paetzold, PhD
	Approved by: Joe Paetzold, PhD
	Document Name: CPP17939_Compass Centre Bankstown_REP_PW_R00.pdf

Contents

Executive Summary	1
Document Tracking and Version Control	3
1. Introduction	5
General information	5
2. Methodology	6
Wind Tunnel Model	6
Wind Climate	9
Wind Assessment Criteria	11
3. Results	13
4. Discussion	24
Ground Level	24
Podium Terrace	25
Balconies	26
Roof Terraces	26
Applicability	27
5. Conclusion	28
References	29
Appendix A – Wind Tunnel Test Facilities	30
Appendix B - Directional wind results	32

1. 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	1:300
Surrounding Model Radius (full scale)	430 m
Approach Terrain Category	Built-up environment approach
ENVIRONMENTAL WINDS STUDY	
Number of test locations	49
Reference height (full scale)	100 m
TEST CONFIGURATION(S)	
Configuration A	Site and surroundings as they currently exist and all approved or under construction developments within the modelled test radius as shown in Figure 1.

2. Methodology

WIND TUNNEL MODEL

The anticipated wind conditions around the project site were evaluated through wind tunnel testing of a 1:300 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 430 m radius of the site and all the relevant building details to be modelled 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 49 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 11.

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



Figure 1b: Photographs of Wind Tunnel Test Model – Close up

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 Bankstown Airport. The project site is located approximately 4 kilometres to the east of the airport which provides the best source of historical wind data for the project.

This data is portrayed in the wind roses in Figure 2. The arms of the wind roses point in the direction where the wind is blowing from, the width and colour 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 analysed 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 west and south-east directions are predominant, with secondary winds occurring from the north-east 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.

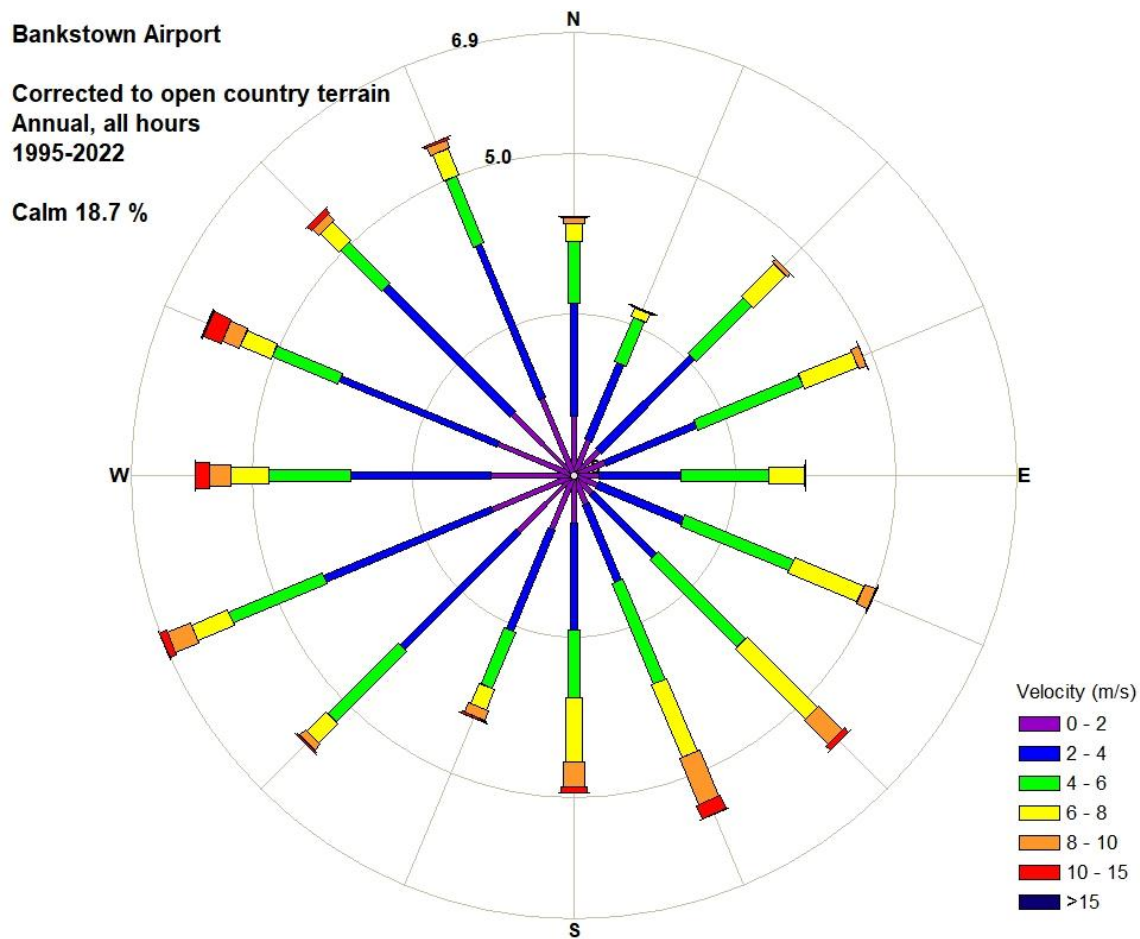


Figure 2: Probability of Wind Speeds by Direction – Bankstown Airport (1995 – 2022, All Hours)

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.

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.

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.

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

* 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 2 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.

3. 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 colour 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 3: Summary of wind comfort and safety assessment results

Description / Location		Wind Tunnel Results	
		Comfort rating, 5% exceedance wind speed (m/s)	Safety rating, 0.022% exceedance wind speed (m/s)
Ground	1	5.9	11.2
	2	5.7	10.9
	3	4.3	8.1
	4	5.8	10.8
	5	5.9	11.1
	6	4.9	9.6
	7	3.0	6.7
	8	3.8	9.5
	9	4.0	7.7
	10	5.5	10.3
	11	5.7	10.8
	12	4.3	8.1
	13	4.8	10.4
	14	4.7	10.6
	15	4.8	10.2
	16	7.4	13.9
	17	5.6	11.8
	18	4.2	7.5
	19	3.7	7.4
	20	5.8	10.7
	21	4.7	9.8
	22	4.8	11.1
	23	4.9	10.2
	24	7.2	14.5
Podium	25	4.4	8.5
	26	5.9	12.7
	27	3.1	6.8
	28	4.5	9.1
	29	6.5	13.7
	30	7.1	12.9
	31	7.7	14.9
	32	6.2	12.0
	33	7.0	13.1
	34	5.6	13.5
	35	2.5	6.4
	36	4.1	9.2
	37	4.4	11.4
	38	3.6	7.2
Balconies	39	2.5	5.0
	40	4.2	11.3
	41	3.7	7.2
	42	3.1	6.8
	43	2.9	7.2
	44	4.6	11.9
	45	1.5	4.6
	46	1.2	3.1
Roof Terrace	47	3.9	9.1
	48	4.0	9.6
	49	2.7	6.2

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

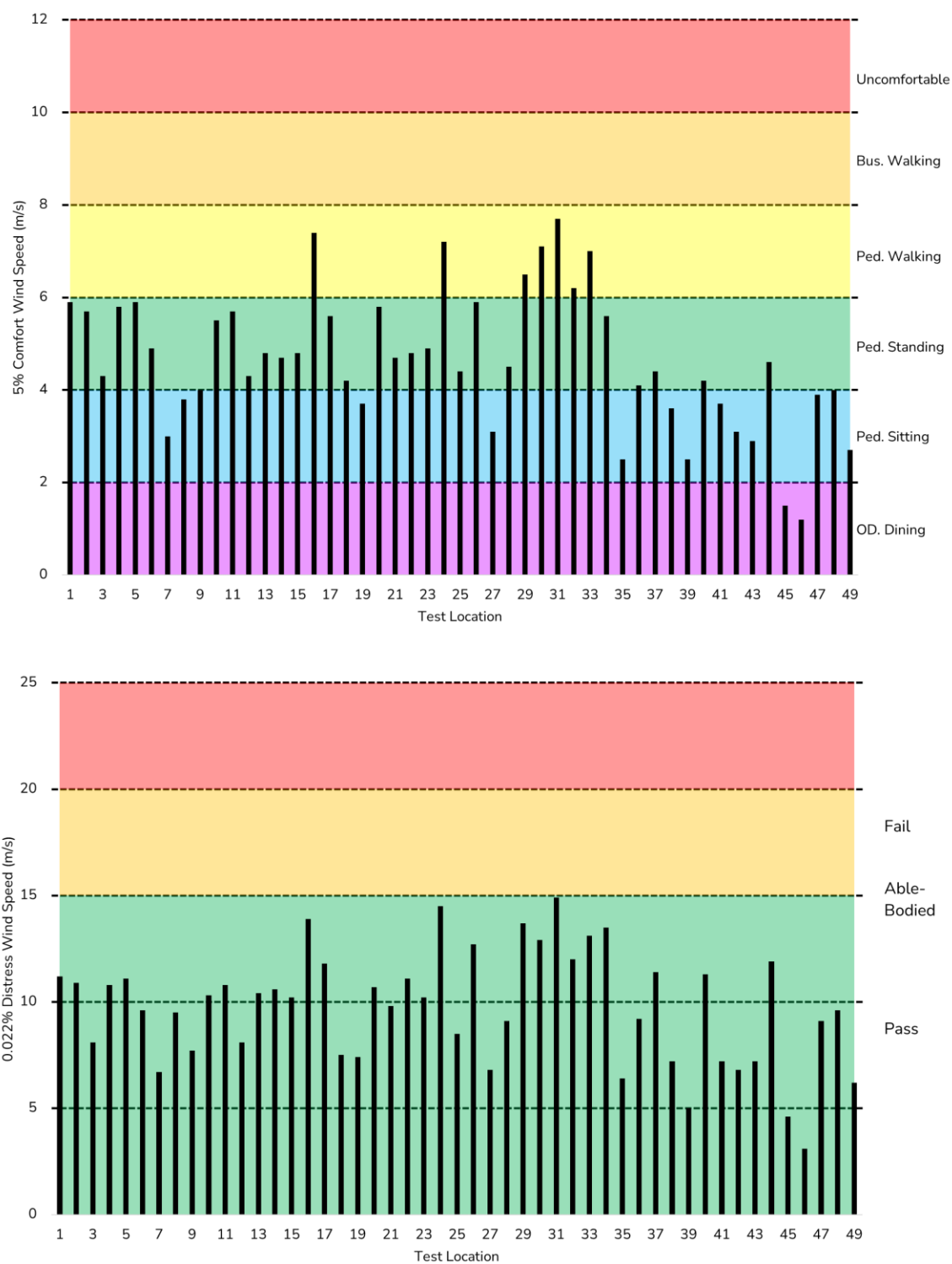


Figure 3: Summary of wind comfort and safety assessment results.

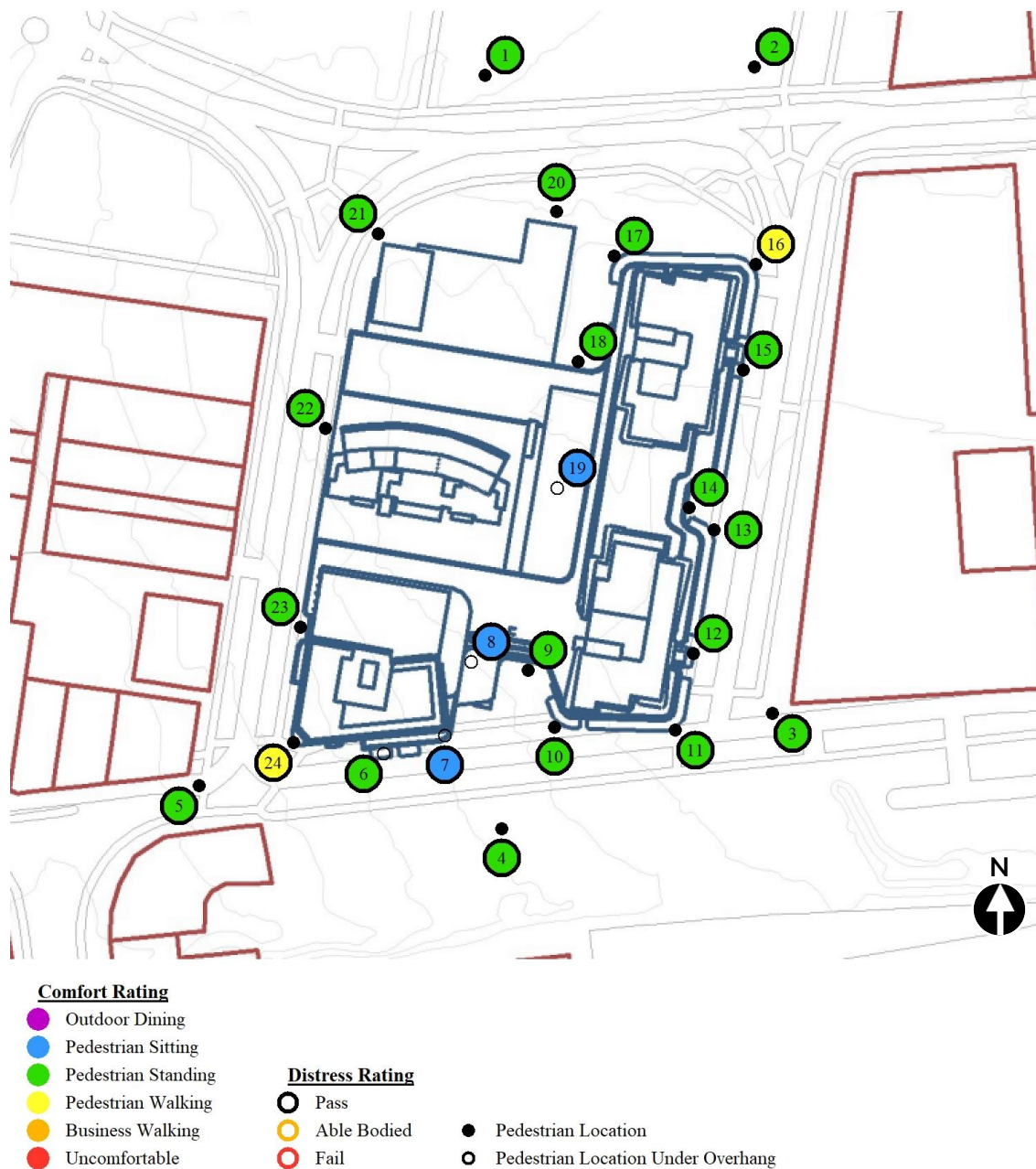


Figure 4: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground – Plan View

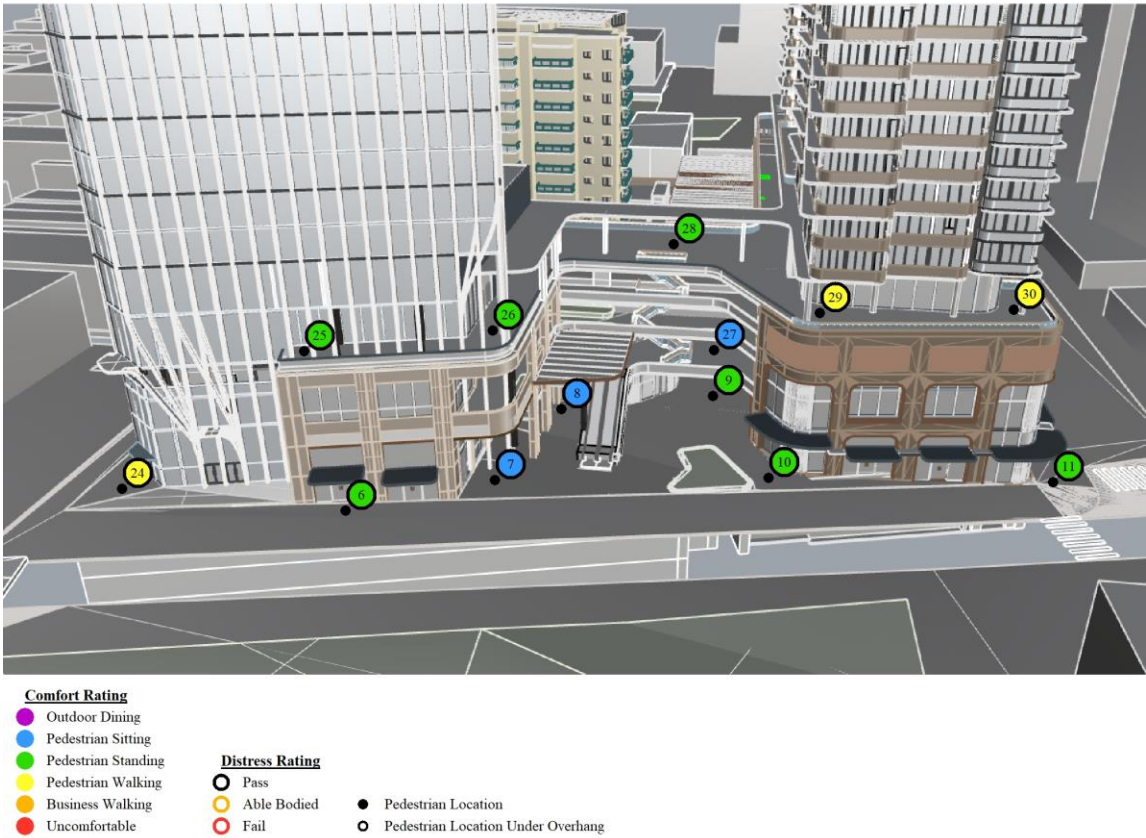


Figure 5: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – South Isometric view.

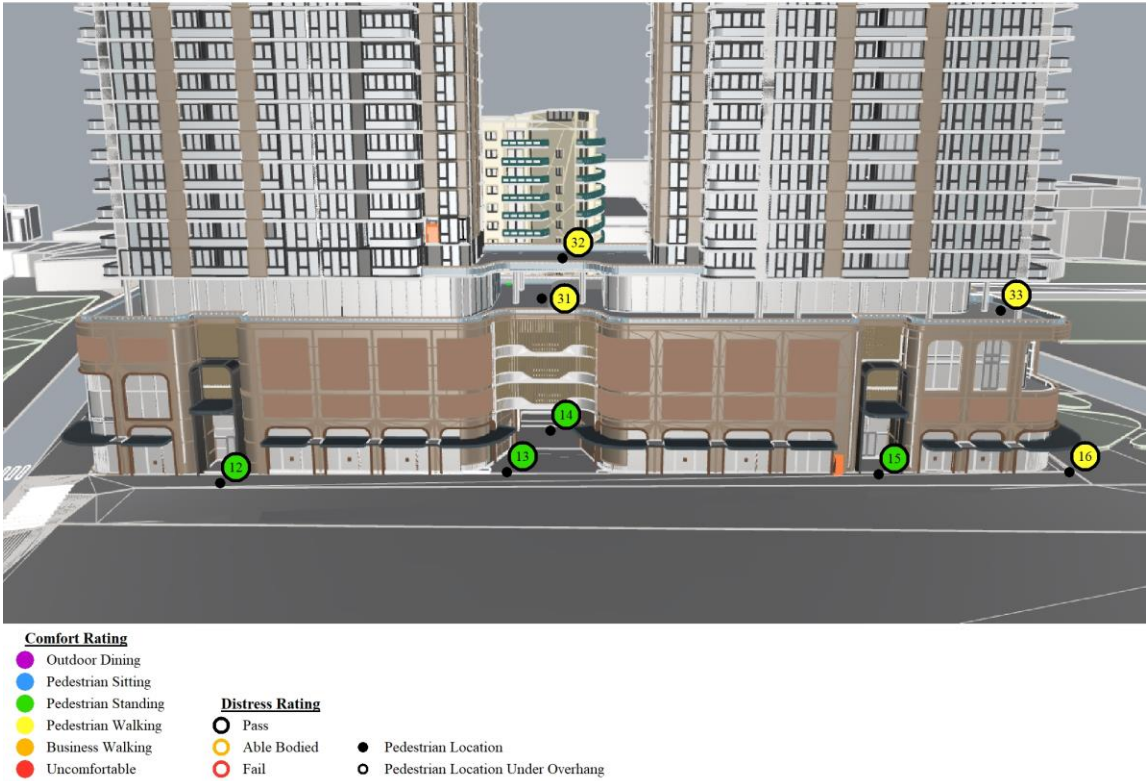


Figure 6: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – East Isometric view.

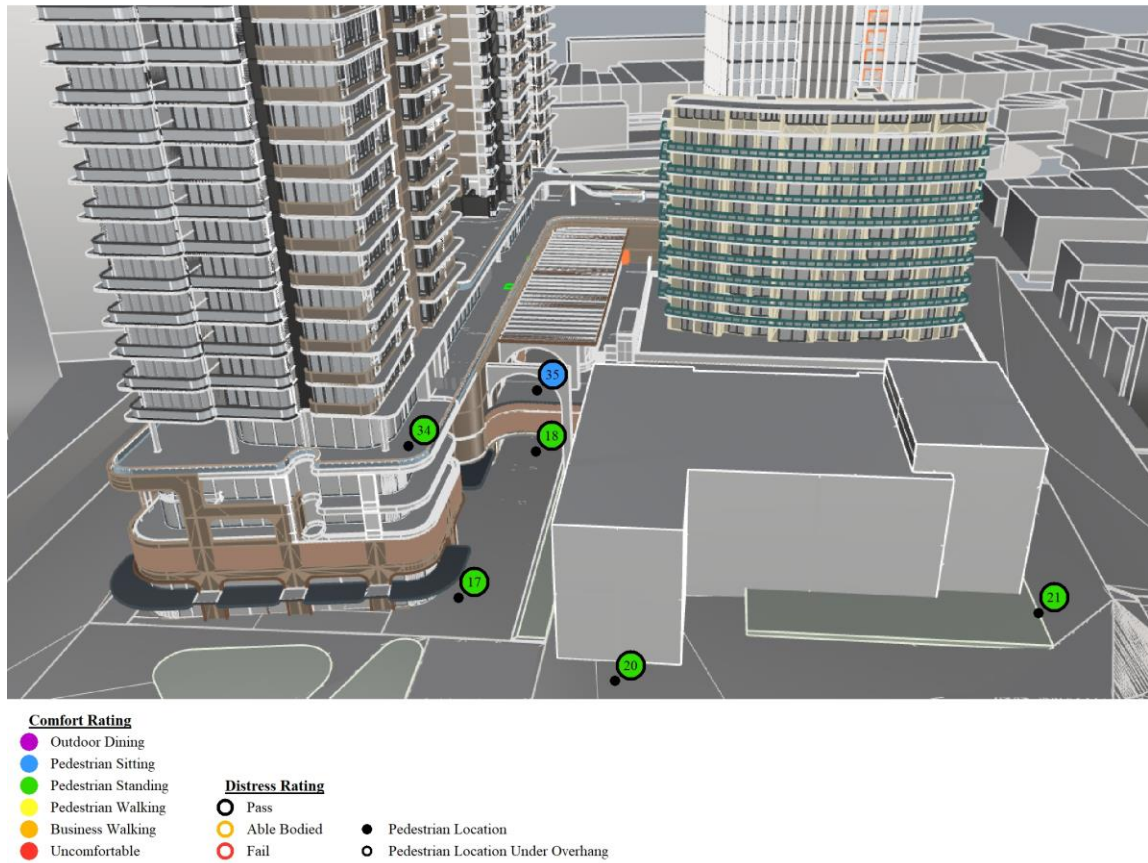


Figure 7: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – North Isometric view.

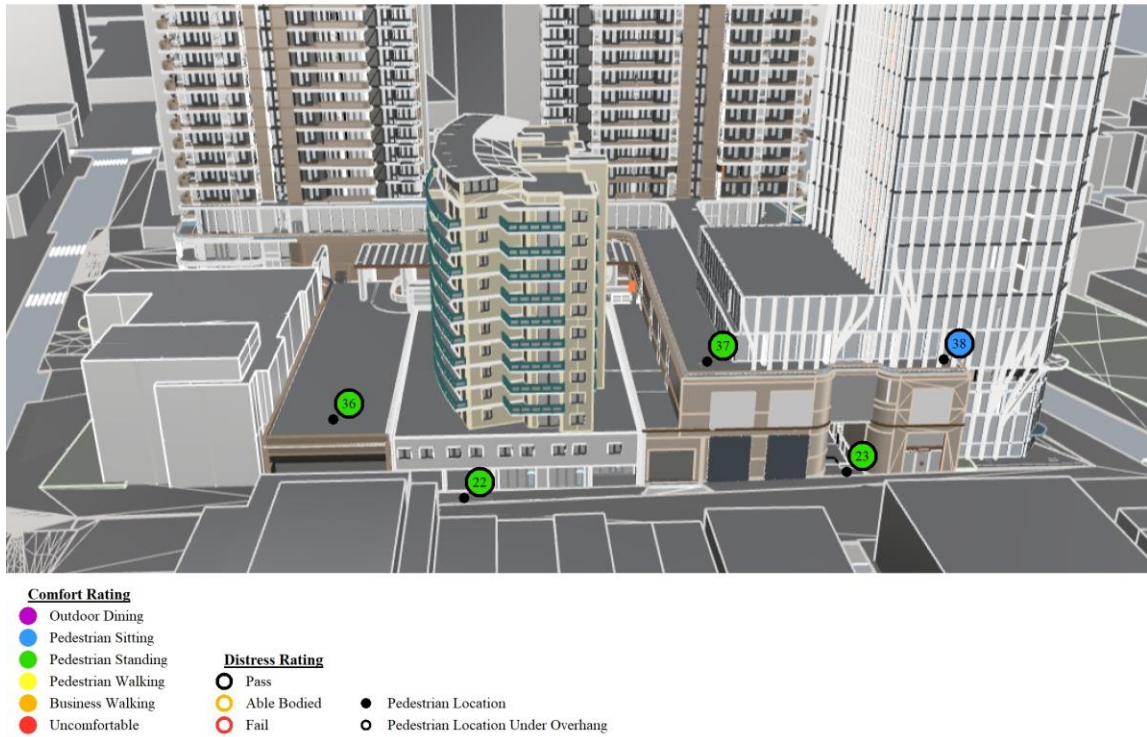


Figure 8: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – West Isometric view.

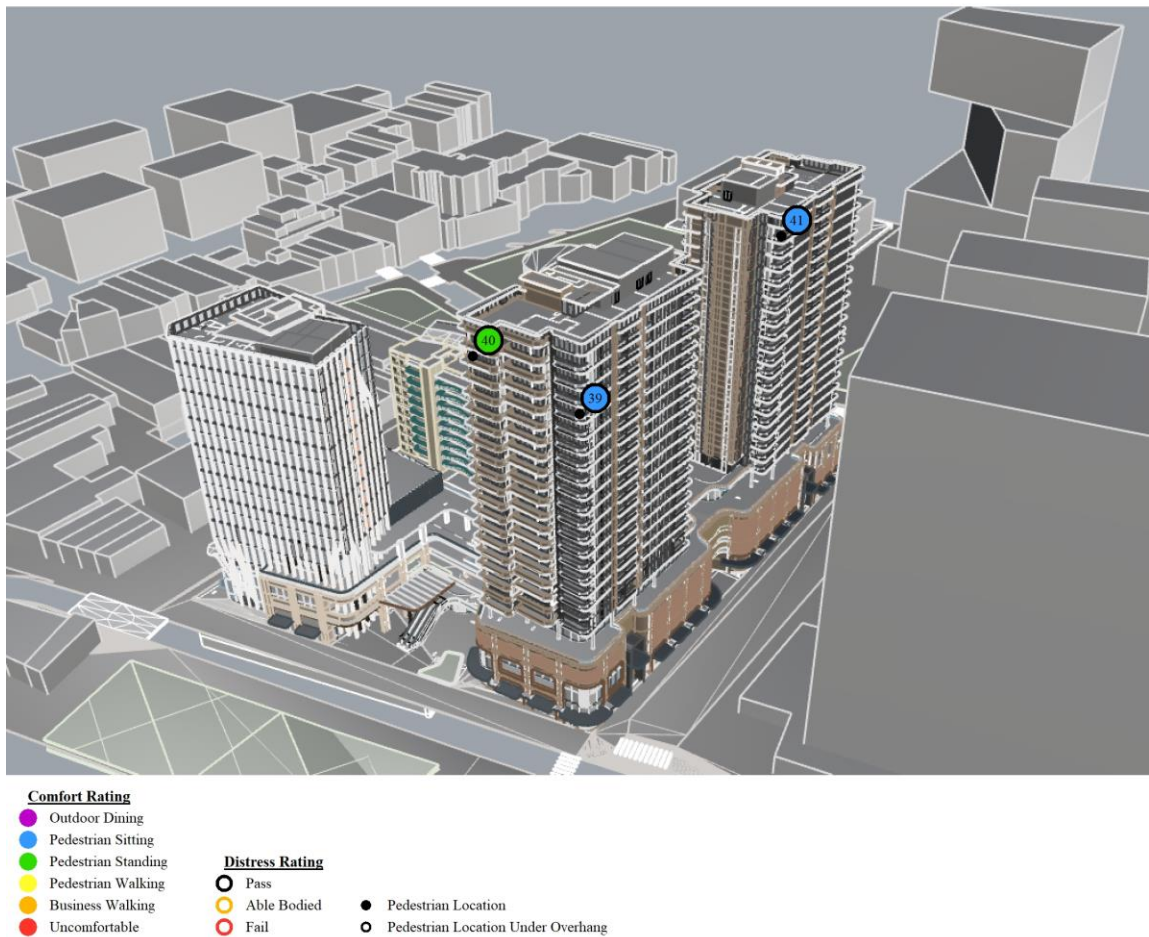


Figure 9: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies – South-east Isometric view

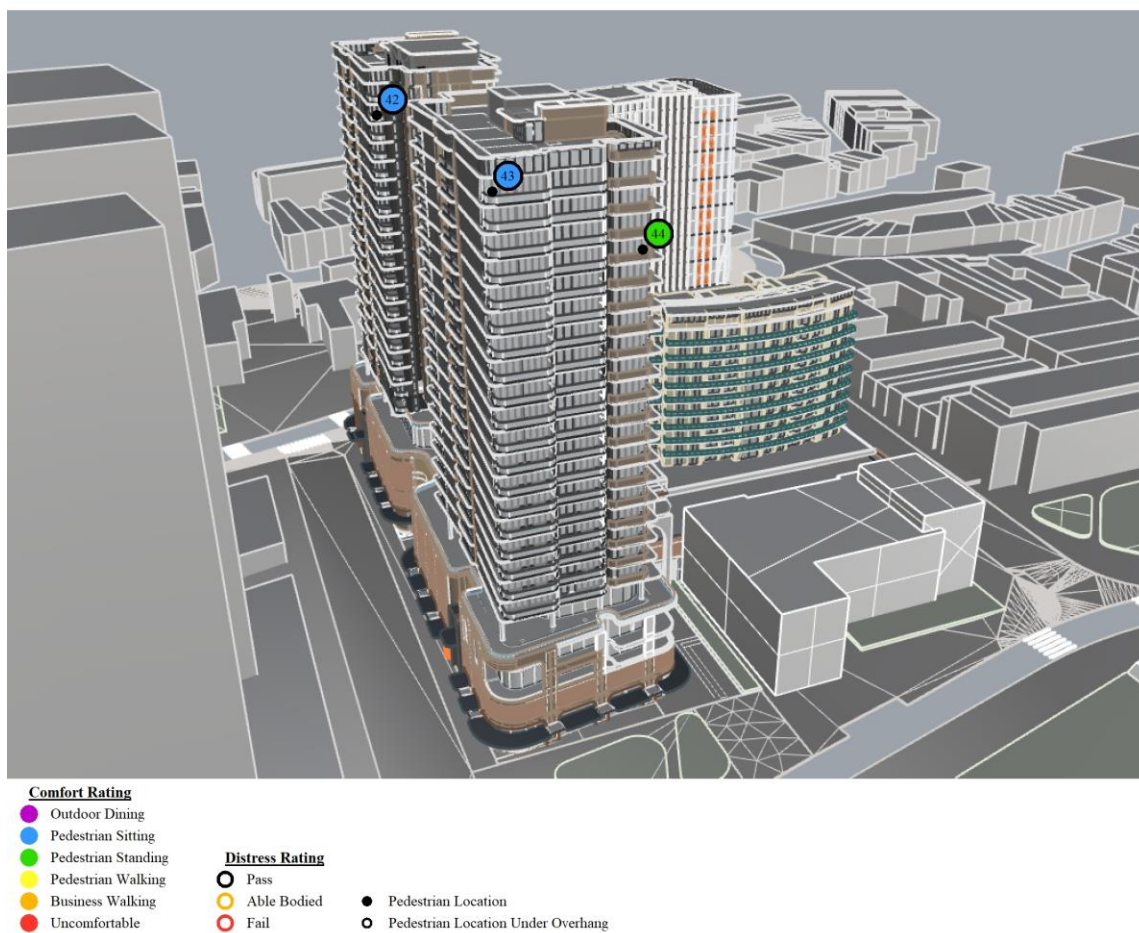


Figure 10: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies – North-east Isometric view.

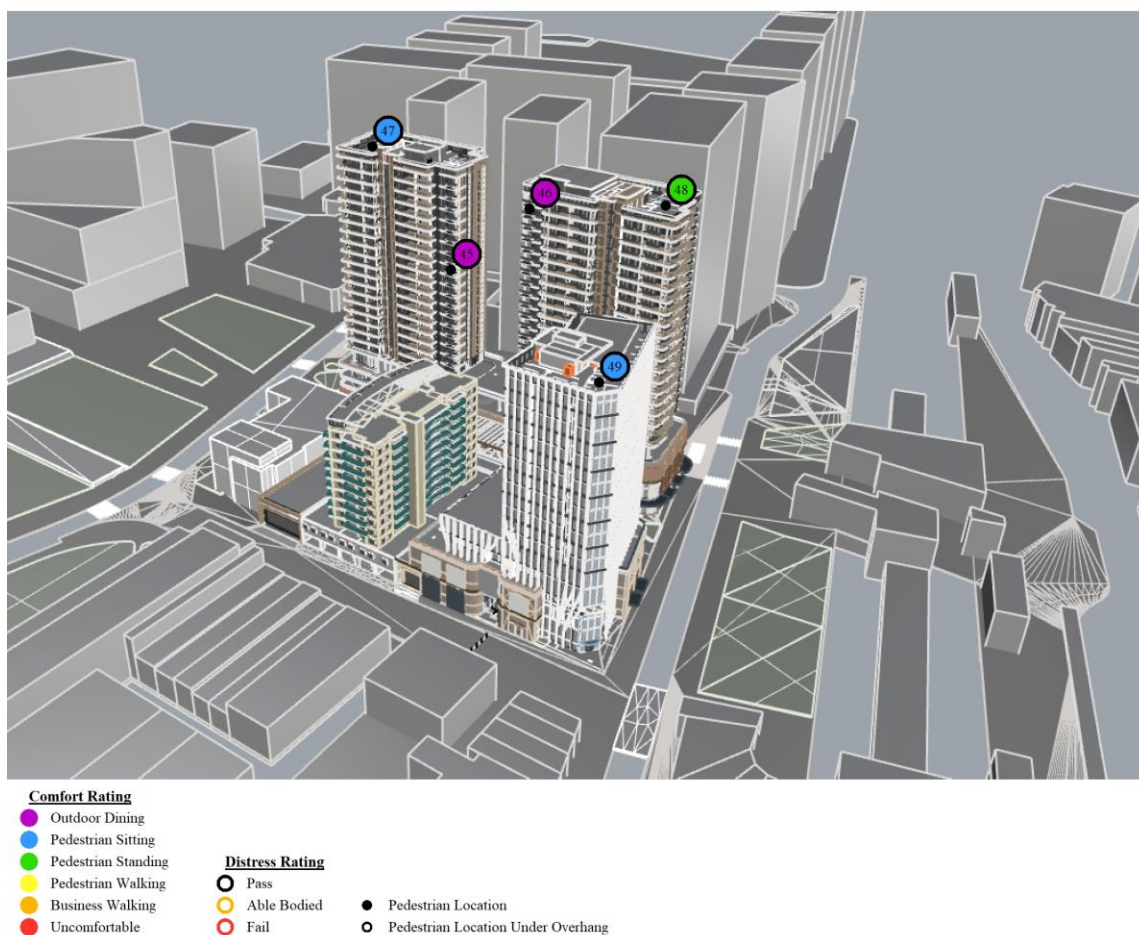


Figure 11: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies and Roof Terraces – South-west Isometric view.

4. Discussion

GROUND LEVEL

The comfort and distress ratings at ground level for the site are shown in Figure 4 to Figure 8. In general, most tested areas are in the Pedestrian Standing comfort category.

On the southern side of the site (Locations 4, 6, 9-11), conditions are typically rated Pedestrian Standing (Figure 4 and Figure 5). The strongest winds in this region generally come from the south-east quadrant. Slightly milder conditions were measured under the awnings at the south-eastern side of Tower A, where Locations 7 and 8 are rated Pedestrian Sitting. The highest wind speeds for Location 8, towards the eastern end of Featherstone Walk, come from the west and are due to pressure driven flow along the enclosed walkway. The windiest location in the southern plaza region, at the junction of Featherstone Walk and Compass Way, meets the wind speed associated with the Outdoor Dining classification for about 70% of the time. If comfortable conditions for outdoor dining are required on windier days, the addition of vertical screening elements such as raised planters and booth style seating is recommended.

The wind conditions along the eastern (Appian Way) side of the site (Locations 12-15) exhibit comparable conditions, with tested locations typically rated in the Pedestrian Standing comfort category (Figure 4 and Figure 6). The highest wind speeds for Locations 13 and 14, at the eastern end of the pedestrian link to the Compass Way arcade, come from the west and is likely due to pressure-driven flow through the enclosed corridor. At the centre of the Compass Way arcade (Location 19), conditions are slightly calmer and rated Pedestrian Sitting. Location 19 meets the wind speed associated with the Outdoor Dining classification for about 70% of the time. As mentioned previously, to increase the percentage of time suitable for Outdoor Dining, vertical screening elements such as raised planters and booth style seating may be used where necessary.

On the northern side of the site (Locations 1, 2, 17, 18, 20, 21), wind conditions are generally rated Pedestrian Standing (Figure 4 and Figure 7). Near the north-eastern corner of Tower C, wind speeds are higher, with Location 16 rated Pedestrian Walking. The higher wind speed at this location is a result of downwash generated off Tower C directing winds from the east and north quadrants to ground level, which are then accelerated around the tower corner. It is noted that calmer conditions are likely to be available closer to the tower and under the protection of the proposed awning that wraps around the north-eastern corner of Tower C. It is recommended that this feature be retained.

Comparable wind conditions are evident on the western side of the site, along Featherstone Street (Locations 5, 22, 23), with typical comfort ratings in the Pedestrian Standing category (Figure 4 and Figure 8). Higher winds speeds are noted at the south-western corner of Tower A, where location 24 is rated Pedestrian Walking. Downwash generated off Tower A directs winds from the west and south to ground level, accelerating flow around the tower corner.

The results indicate wind conditions in most pedestrian accessible areas around the site and near the site entries are acceptable for medium term stationary occupation, waiting (such as for transport), and sitting. Stronger wind conditions at the north-eastern and south-eastern corners of the development area suitable for general pedestrian access and thoroughfare. For areas intended for longer-term stationary occupation such as outdoor dining, the inclusion of vertical screening elements such as raised planters or booth style seating may be used to increase wind amenity. All areas pass the Lawson Safety criterion.

PODIUM TERRACE

Wind conditions on the podium terrace are shown in Figure 5 to Figure 8 and are generally rated Pedestrian Standing or Pedestrian Walking.

In the southern region of the podium terrace, conditions are predominately governed by exposure to winds from the south (Figure 5). From a comfort perspective, Locations 25, 26 and 28 are rated Pedestrian Standing, while Locations 29 and 30 are rated Pedestrian Walking. The increased wind speeds at locations 29 and 30 occur as downwash from Tower B directs flow toward the podium terrace, which accelerates through the undercut sections. Locations 29 and 30 meet the wind speed associated with Pedestrian Sitting for 80% and 75% of the time respectively. The addition of an awning that extends around the southern edge of Tower B will help to increase wind amenity in these areas if milder wind conditions are desired for this space. Relatively mild conditions are indicated for Location 27, in the southern region of the Level 1 terrace, with a comfort rating of Pedestrian Sitting.

The podium terrace areas on Levels 4 and 5, situated between Towers B and C at Locations 31 and 32, are prone to wind from the east and west channelling through the space between the buildings. Both of these locations are classified as suitable for Pedestrian Walking, with the windiest location meeting the wind speed associated with Pedestrian Sitting for approximately 70% of the time. The inclusion of vertical screening elements at both the Level 4 and 5 terrace areas, as well as an awning that wraps around the northern side of Tower B and the southern side of Tower C, at Level 5 should be considered, if conditions suitable for longer term stationary occupation are desired in these areas. Wind conditions at the north-eastern corner of Tower C are similar and rated Pedestrian Walking (Location 33). As mentioned previously, the undercut corner area experiences higher wind speeds as downwash accelerates through the undercut space. An awning around the northern side of Tower C will aid in reducing the impact of such flows and is recommended if milder wind conditions are desired.

Wind conditions in the northern and western regions of the podium terrace (Figure 7 and Figure 8 respectively) are rated Pedestrian Sitting or Pedestrian Walking (Locations 34-38). The strongest winds for these locations typically come from the south-west quadrant. Locations 34, 36 and 37 are rated Pedestrian Standing. Locations 35 and 38 are slightly calmer and rated Pedestrian Sitting.

In summary, the wind conditions at all areas on the podium terrace are acceptable for general pedestrian access/thoroughfare from a wind comfort perspective. Some areas, distanced from building corners or shielded by the tower structures, are calmer and suitable for medium-term stationary activities like standing or sitting. The residents' discretionary use of the podium space may render the need for further mitigation unnecessary. All locations satisfy the Lawson safety criterion.

BALCONIES

Wind conditions on a number of representative balconies and terraces are shown in Figure 9 to Figure 11. Wind conditions range from Outdoor Dining to Pedestrian Standing and all tested locations meet the safety standards defined by the Lawson criterion.

Balcony locations at the south-eastern and north-eastern corners of Tower B (Locations 39 and 42) and Tower C (Locations 41 and 43) are rated Pedestrian Sitting. Slightly stronger winds occur on balconies at the south-western corner of Tower B (Location 40) and the north-western corner of Tower C (Location 44), where a comfort rating of Pedestrian Standing was measured.

Balconies on the western side of Towers B and C (Locations 45 and 46) are suitable for Outdoor Dining with reference to the Lawson comfort criteria. The balconies as proposed are generally well designed and located from a wind perspective, representing relatively small volumes, and recessed within the floor plate.

Wind conditions on the tower balconies are suitable for medium to long-term stationary occupation. The windiest balcony location meets the wind speed associated with Pedestrian Sitting for 93% of the time and Outdoor Dining 75% of the time. Due to the discretionary use of balcony spaces by residence, further wind mitigation is likely unnecessary.

ROOF TERRACES

Wind conditions on the Tower roof terraces are shown in Figure 11 and are typically rated Pedestrian Sitting.

Location 49, on the roof terrace of Tower A, where the proposed rooftop bar is to be located, is rated Pedestrian Sitting. This location meets the wind speed associated with Outdoor Dining for 85% of the time. Similarly, Location 47, on the Tower C rooftop terrace is rated Pedestrian Sitting. Location 48, on the Tower B roof terrace is slightly windier and rated Pedestrian Standing.

The proposed roof terrace balustrades for each tower (approximately 2.1 m) reduces the exposed nature of the rooftops and created areas with reasonable wind comfort conditions.

All tested locations satisfy the Lawson safety criteria.

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 PA030557DA-PTW-AR-AA-M-A-1000.ifc received by CPP on 20 March 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.

5. Conclusion

CPP has conducted a wind tunnel study to quantify the pedestrian-level wind environment for the proposed Compass Centre Bankstown development. In general, most pedestrian-accessible areas around the site are assessed as suitable for Pedestrian Standing or Pedestrian Walking under the Lawson comfort criteria. These conditions are considered typical of those in the immediate surrounding areas and suitable for the intended use of public domain spaces. Milder wind conditions are available near the main entries to the building and in alcove areas. No significant adverse wind conditions as a result of the proposed development are foreseen, and all public domain areas satisfied the safety criterion. Conditions on the podium are similar and suitable for general pedestrian access/thoroughfare in all areas. Wind conditions on the tower balconies and roof terraces were shown to have milder conditions, suitable for discretionary use by occupants.

References

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

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

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).

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 modelled 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 modelled area are also modelled. The turbulence intensities are appropriate for the approach mean velocity profiles selected.

CPP SYDNEY WIND TUNNELS	
DIMENSIONS	
Test section length	21 m (69 ft)
Test section width	3 m (10 ft)
Ceiling height	2.4 m (8 ft)
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 (0 to 66 ft/s)
Boundary-layer thickness*	1.2 m (4 ft) (nominal)
Turbulence	About 2% at entrance to test section
Longitudinal pressure gradient	Zero by blockage tolerant roof

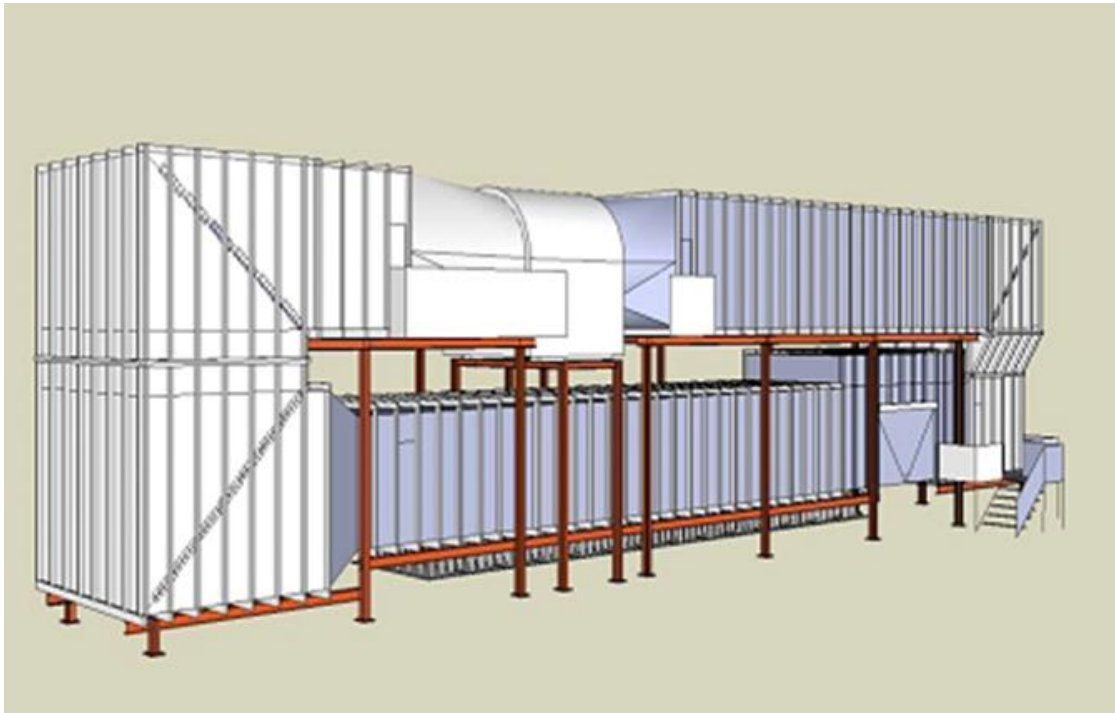
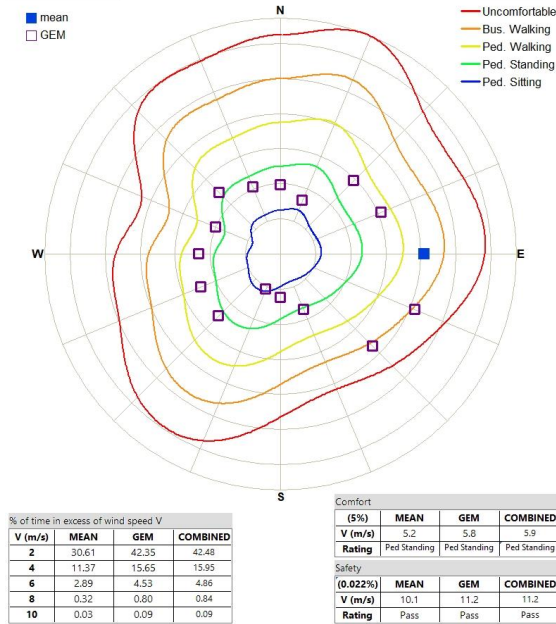


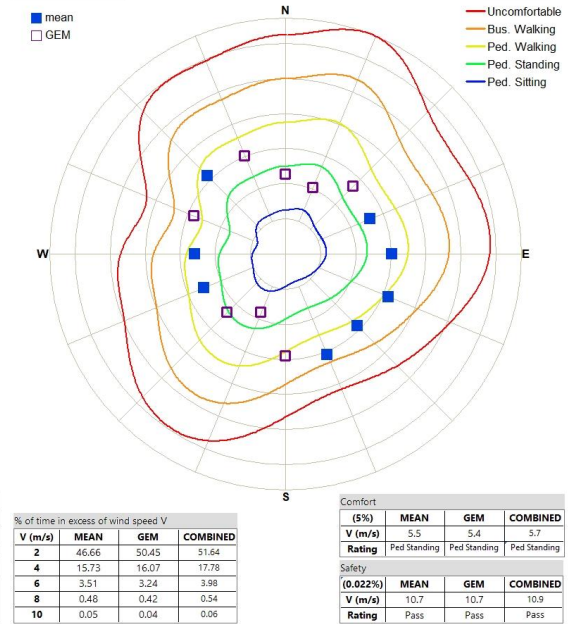
Figure A1: CPP Wind Tunnel - Sydney, Australia

Appendix B - Directional wind results

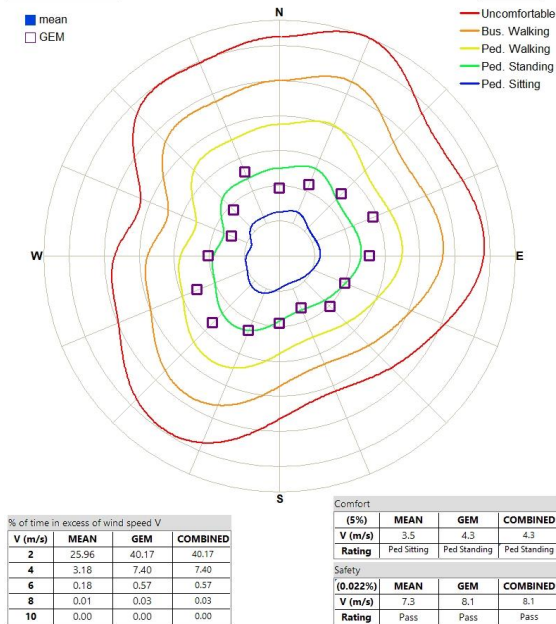
LOCATION 1



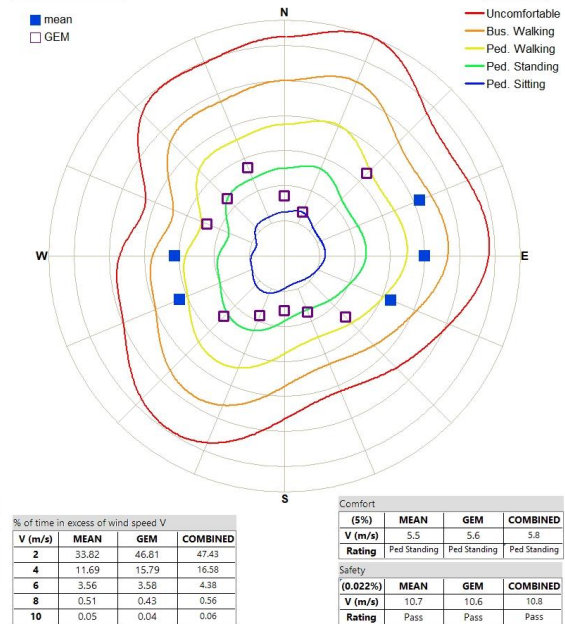
LOCATION 2



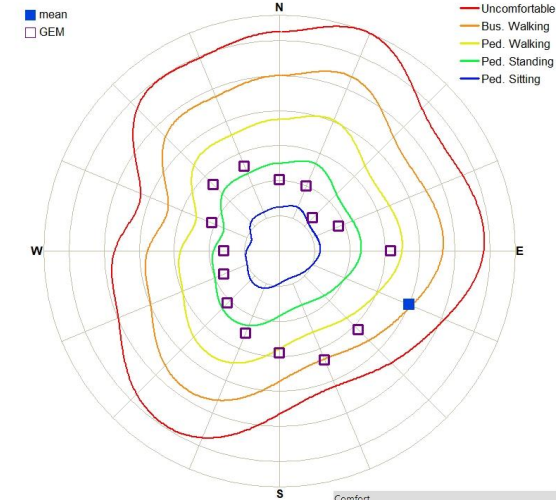
LOCATION 3



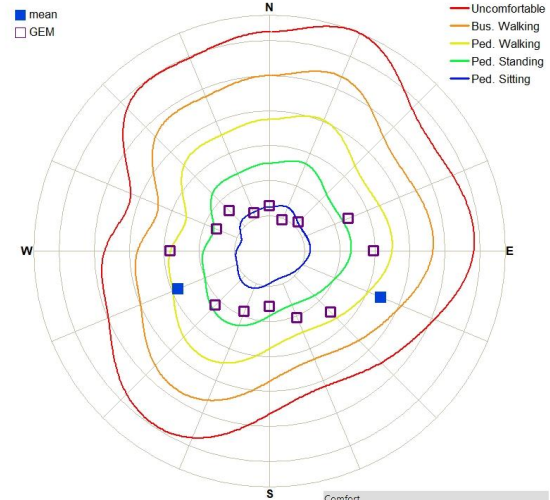
LOCATION 4



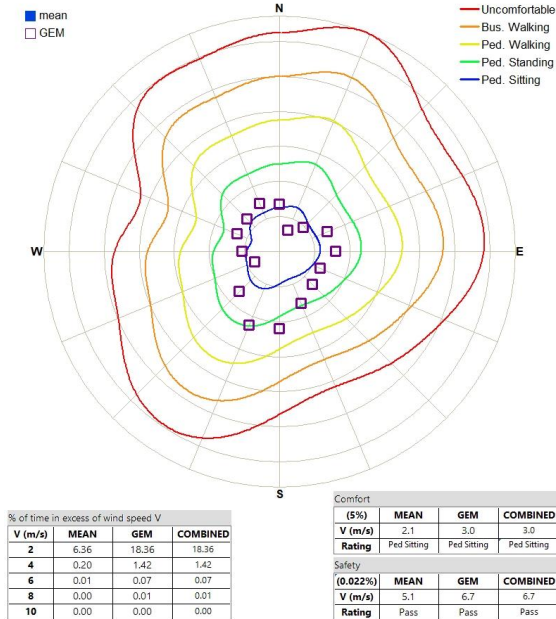
LOCATION 5



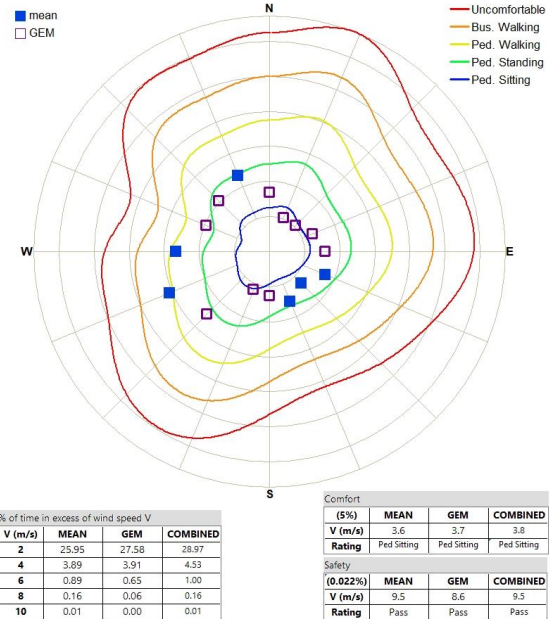
LOCATION 6



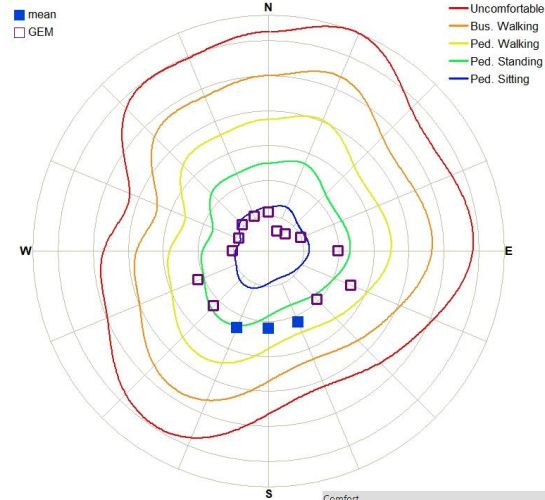
LOCATION 7



LOCATION 8



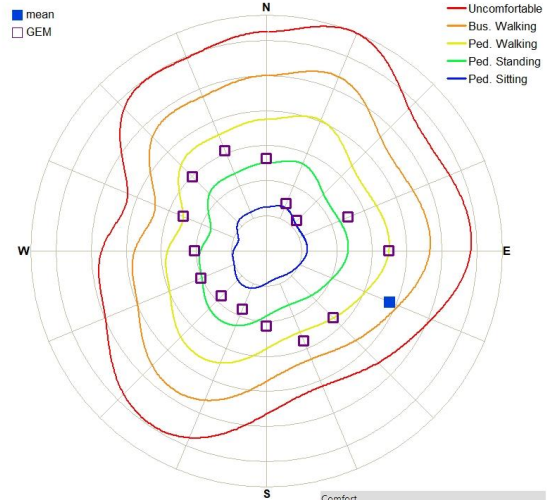
LOCATION 9



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	20.71	24.89	25.56
4	3.43	4.49	5.37
6	0.19	0.19	0.30
8	0.01	0.01	0.02
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	3.9	4.0
Rating	Ped Sitting	Ped Sitting	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.4	7.3	7.7
Rating	Pass	Pass	Pass

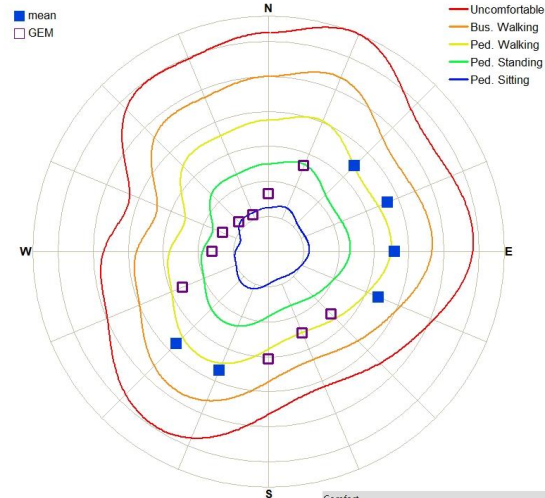
LOCATION 10



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	32.20	44.81	44.96
4	9.12	14.39	14.80
6	1.79	2.77	3.32
8	0.20	0.27	0.38
10	0.01	0.02	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.4	5.5
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.6	10.0	10.3
Rating	Pass	Pass	Pass

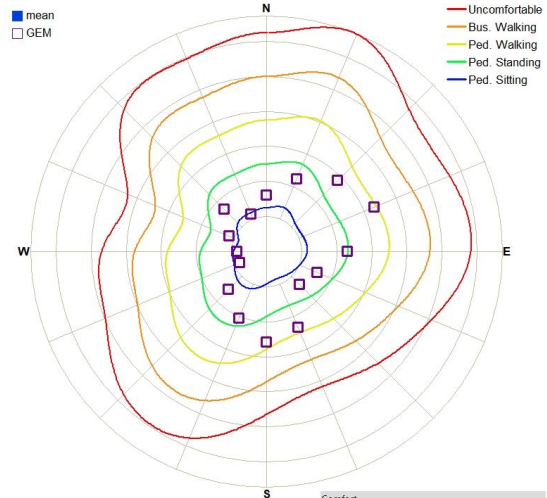
LOCATION 11



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	37.67	42.86	44.79
4	13.51	15.28	18.32
6	2.88	2.40	3.86
8	0.33	0.22	0.42
10	0.04	0.02	0.05

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.4	5.3	5.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	10.0	10.8
Rating	Pass	Pass	Pass

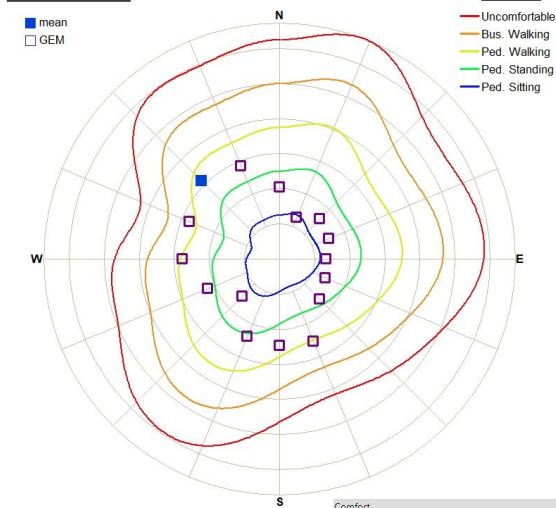
LOCATION 12



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	15.72	28.42	28.42
4	2.81	6.75	6.75
6	0.09	0.68	0.68
8	0.00	0.03	0.03
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.4	4.3	4.3
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.7	8.1	8.1
Rating	Pass	Pass	Pass

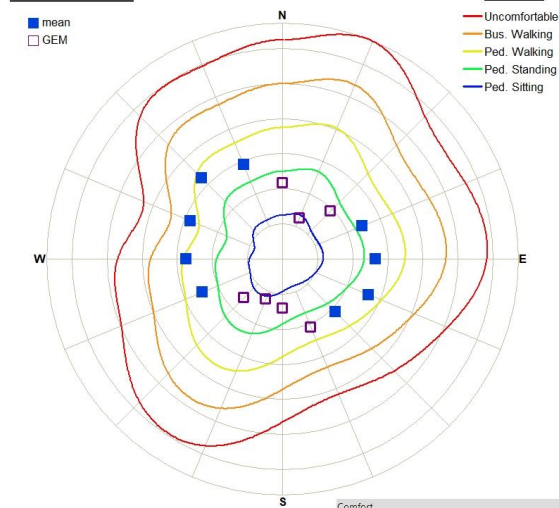
LOCATION 13



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	26.02	37.77	38.06
4	5.42	8.31	8.43
6	0.82	1.78	1.85
8	0.12	0.29	0.32
10	0.02	0.03	0.04

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	4.7	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	10.2	10.4
Rating	Pass	Pass	Pass

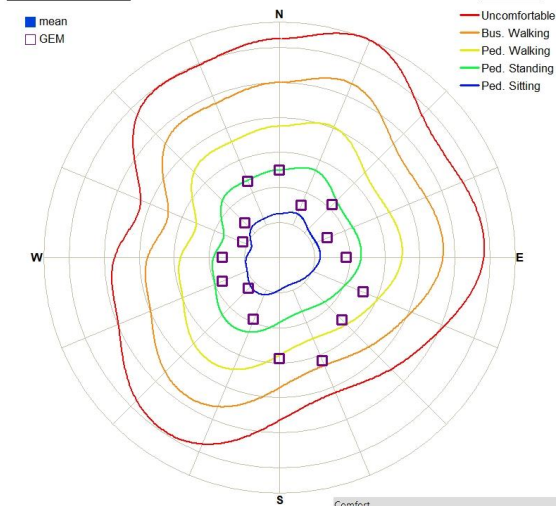
LOCATION 14



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.34	38.31	43.01
4	9.46	6.52	9.99
6	1.56	0.75	1.60
8	0.32	0.06	0.33
10	0.04	0.00	0.04

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	4.2	4.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.6	8.7	10.6
Rating	Pass	Pass	Pass

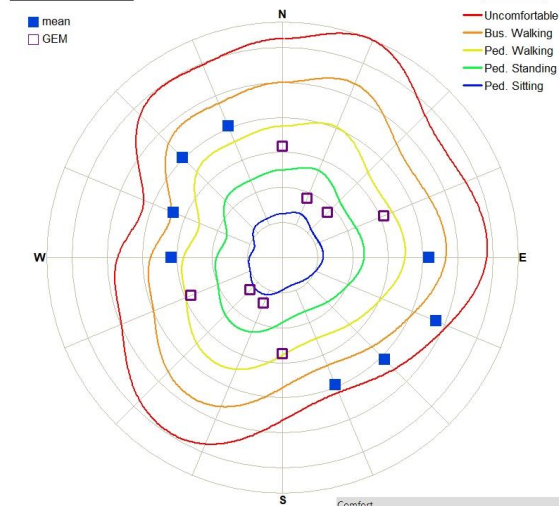
LOCATION 15



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	21.13	34.66	34.66
4	6.14	9.20	9.20
6	1.39	2.00	2.00
8	0.19	0.26	0.26
10	0.02	0.03	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.8	10.2	10.2
Rating	Pass	Pass	Pass

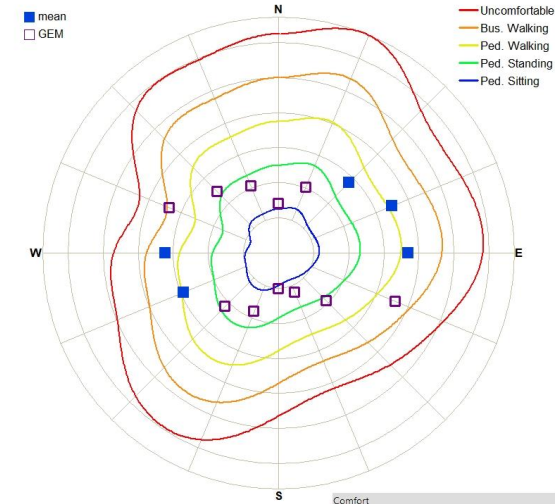
LOCATION 16



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	47.95	51.38	52.91
4	22.89	22.25	25.42
6	10.55	7.74	11.15
8	3.56	1.56	3.61
10	0.73	0.20	0.74

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.4	6.5	7.4
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.9	12.1	13.9
Rating	Pass	Pass	Pass

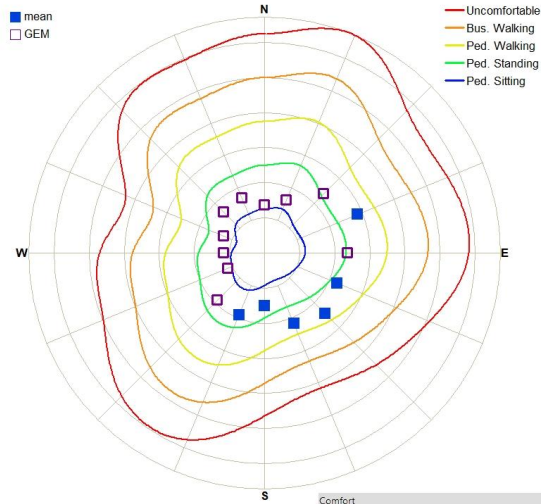
LOCATION 17



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	31.85	42.15	43.23
4	10.15	12.43	14.03
6	2.42	2.93	3.73
8	0.43	0.63	0.76
10	0.06	0.11	0.14

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.3	5.6
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	11.5	11.8
Rating	Pass	Pass	Pass

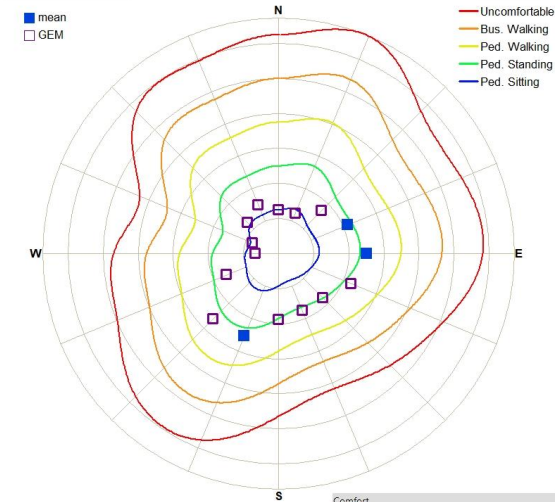
LOCATION 18



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	26.85	30.05	31.20
4	5.66	4.39	6.32
6	0.31	0.09	0.32
8	0.01	0.00	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	3.9	4.2
Rating	Ped Standing	Ped Sitting	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.5	6.7	7.5
Rating	Pass	Pass	Pass

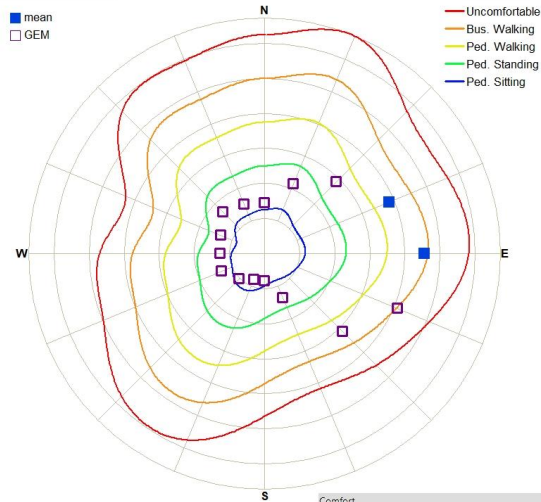
LOCATION 19



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.80	27.34	28.08
4	2.76	2.90	3.43
6	0.14	0.15	0.18
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	3.6	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.2	7.3	7.4
Rating	Pass	Pass	Pass

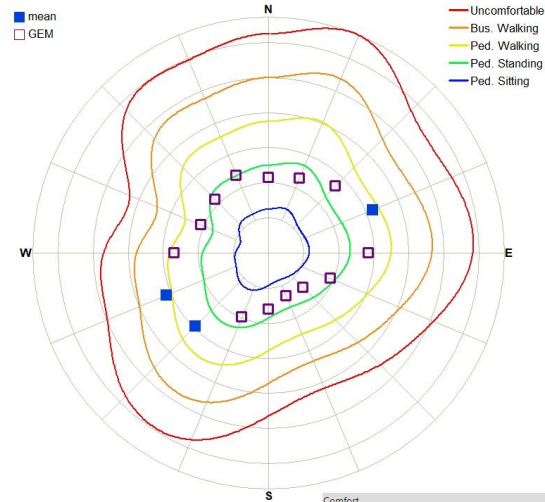
LOCATION 20



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	20.74	29.54	29.67
4	7.81	12.13	12.55
6	2.06	3.79	4.44
8	0.24	0.48	0.63
10	0.01	0.04	0.05

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.6	5.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.4	10.4	10.7
Rating	Pass	Pass	Pass

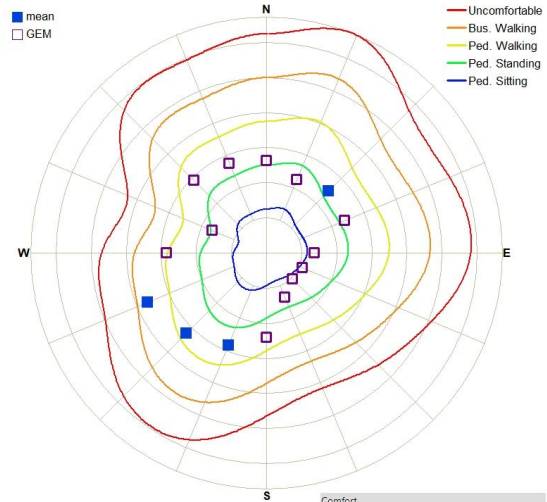
LOCATION 21



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	26.04	41.38	41.81
4	5.90	8.62	9.14
6	1.06	1.31	1.50
8	0.13	0.18	0.20
10	0.01	0.01	0.02

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	4.6	4.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.5	9.6	9.8
Rating	Pass	Pass	Pass

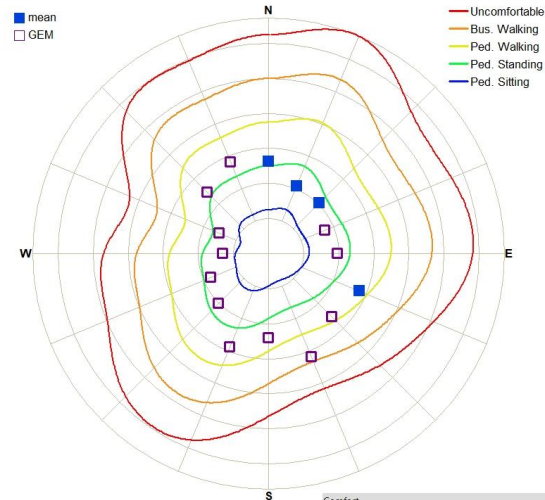
LOCATION 22



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	30.12	39.52	40.61
4	6.80	8.65	9.56
6	1.62	1.94	2.24
8	0.35	0.36	0.51
10	0.07	0.04	0.08

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.3	4.6	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.0	10.5	11.1
Rating	Pass	Pass	Pass

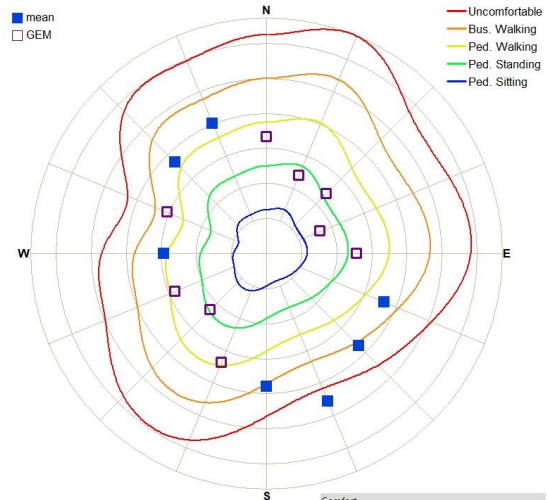
LOCATION 23



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	33.03	41.11	41.49
4	8.60	10.33	10.72
6	1.62	2.08	2.16
8	0.19	0.27	0.27
10	0.02	0.03	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.6	4.8	4.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	10.2	10.2
Rating	Pass	Pass	Pass

LOCATION 24

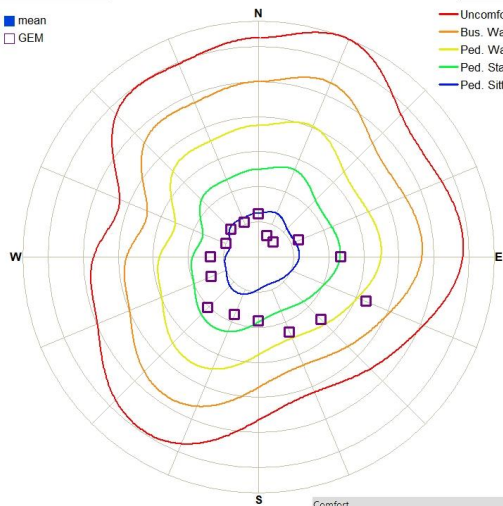


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	50.32	55.24	56.18
4	21.65	21.06	23.21
6	9.48	7.31	9.72
8	3.21	1.91	3.34
10	0.85	0.33	0.87

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.1	6.6	7.2
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	14.5	13.0	14.5
Rating	Pass	Pass	Pass

LOCATION 25

■ mean
□ GEM

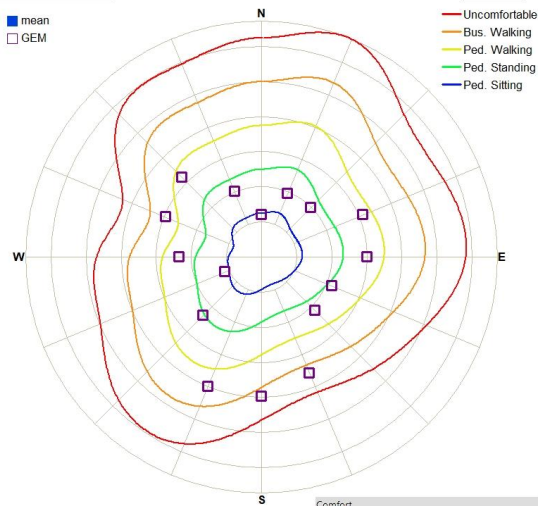


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	17.74	25.69	25.69
4	4.90	7.08	7.08
6	0.51	0.89	0.89
8	0.02	0.05	0.05
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.0	8.5	8.5
Rating	Pass	Pass	Pass

LOCATION 26

■ mean
□ GEM

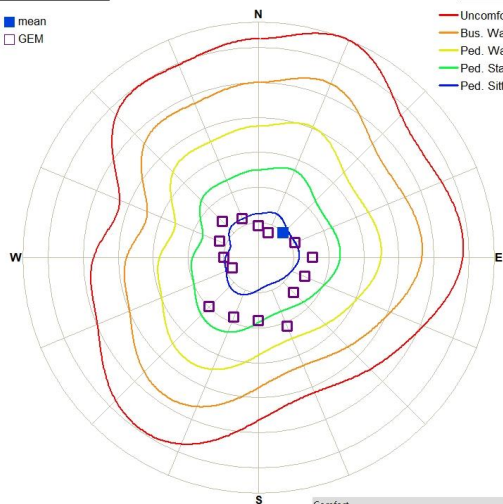


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	30.01	45.64	45.64
4	8.05	15.56	15.56
6	2.00	5.09	5.09
8	0.27	1.39	1.39
10	0.03	0.24	0.24

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.9	5.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.2	12.7	12.7
Rating	Pass	Pass	Pass

LOCATION 27

■ mean
□ GEM

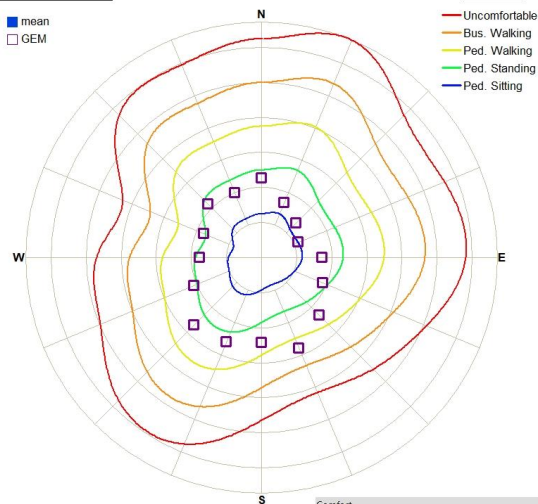


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	12.23	17.96	18.00
4	0.67	1.96	1.96
6	0.01	0.09	0.09
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.7	6.8	6.8
Rating	Pass	Pass	Pass

LOCATION 28

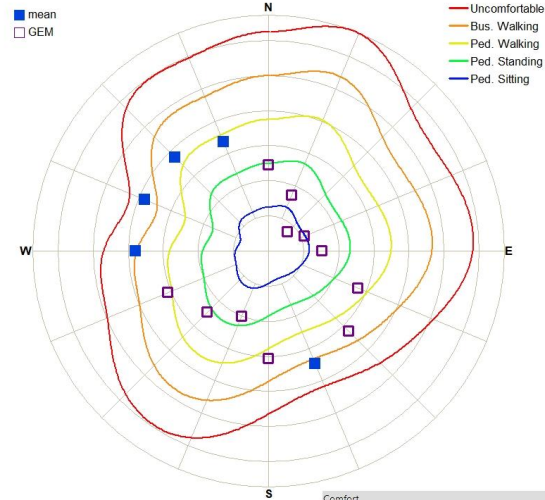
■ mean
□ GEM



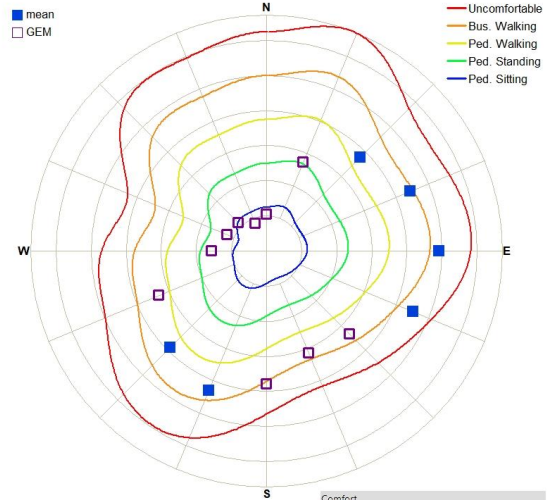
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	18.64	35.13	35.13
4	1.52	8.12	8.12
6	0.04	1.18	1.18
8	0.00	0.09	0.09
10	0.00	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	4.5	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.3	9.1	9.1
Rating	Pass	Pass	Pass

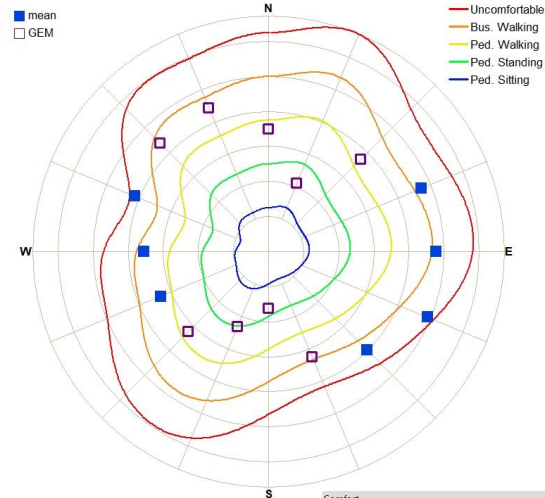
LOCATION 29



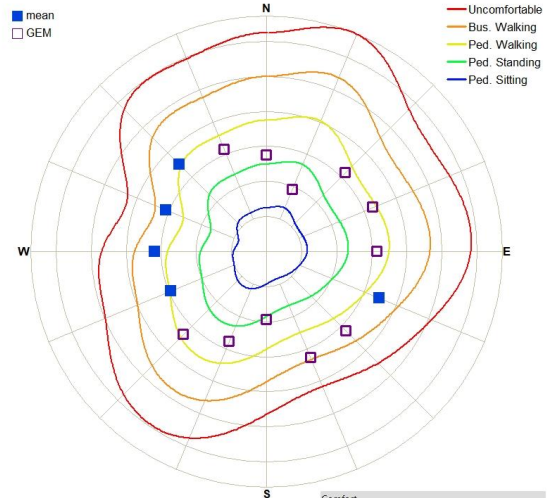
LOCATION 30



LOCATION 31

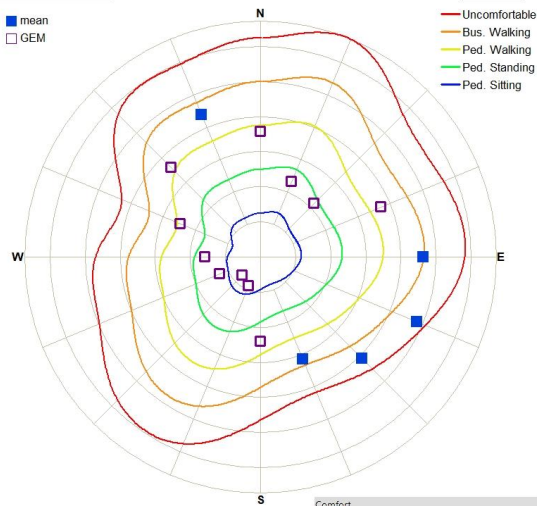


LOCATION 32



LOCATION 33

■ mean
□ GEM

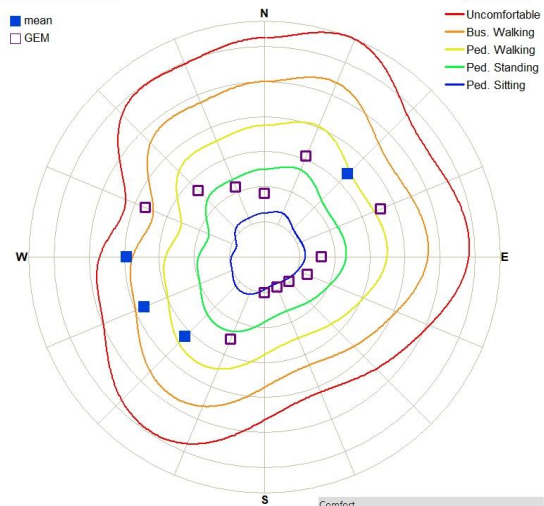


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.92	45.70	46.72
4	20.25	19.18	22.44
6	8.72	5.60	9.49
8	2.52	0.86	2.61
10	0.46	0.13	0.47

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.9	6.1	7.0
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.1	11.8	13.1
Rating	Pass	Pass	Pass

LOCATION 34

■ mean
□ GEM

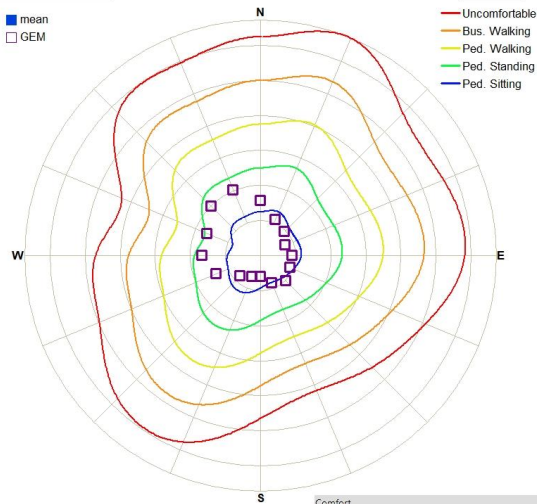


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.98	38.65	40.27
4	9.51	11.30	12.87
6	3.30	3.49	4.24
8	1.13	0.94	1.38
10	0.32	0.25	0.40

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.3	5.6
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.1	12.6	13.5
Rating	Pass	Pass	Pass

LOCATION 35

■ mean
□ GEM

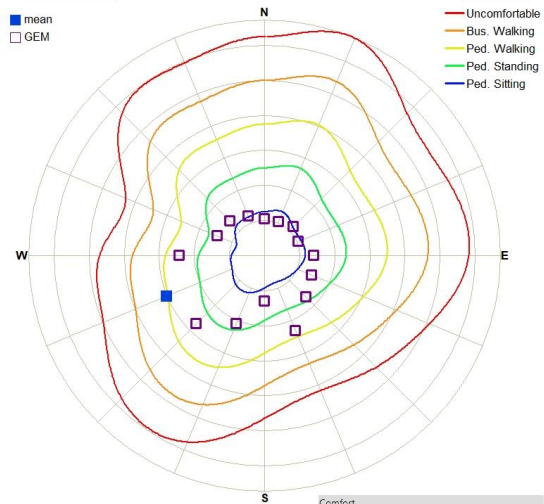


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	3.73	9.55	9.35
4	0.11	0.97	0.97
6	0.00	0.05	0.05
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	1.8	2.5	2.5
Rating	Outdoor Dining	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.8	6.4	6.4
Rating	Pass	Pass	Pass

LOCATION 36

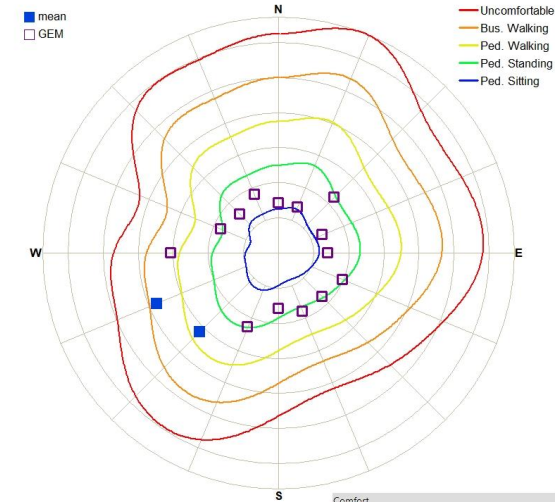
■ mean
□ GEM



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	13.72	26.11	26.47
4	2.57	5.21	5.44
6	0.59	0.85	0.99
8	0.08	0.08	0.11
10	0.01	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	4.0	4.1
Rating	Ped Sitting	Ped Sitting	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	8.9	9.2
Rating	Pass	Pass	Pass

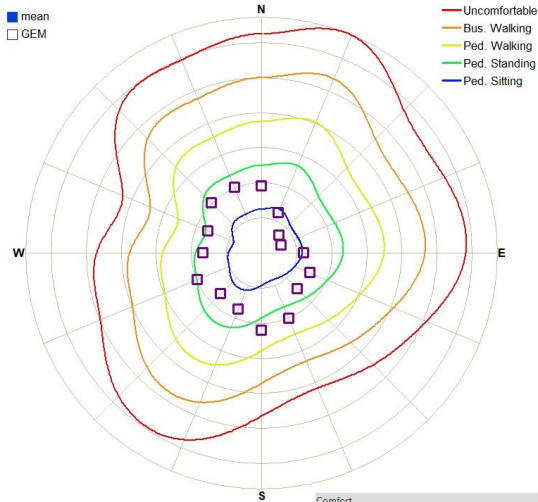
LOCATION 37



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	23.96	34.50	35.26
4	4.75	6.40	7.12
6	1.55	1.49	1.87
8	0.44	0.30	0.53
10	0.08	0.04	0.10

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.2	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.2	10.3	11.4
Rating	Pass	Pass	Pass

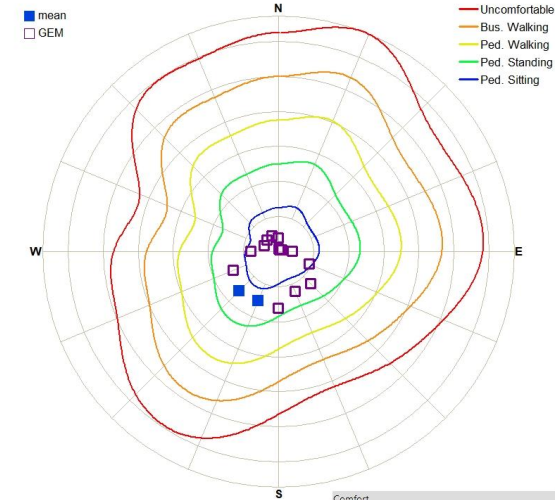
LOCATION 38



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	17.82	24.36	24.36
4	1.52	3.42	3.42
6	0.04	0.16	0.16
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	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)	6.3	7.2	7.2
Rating	Pass	Pass	Pass

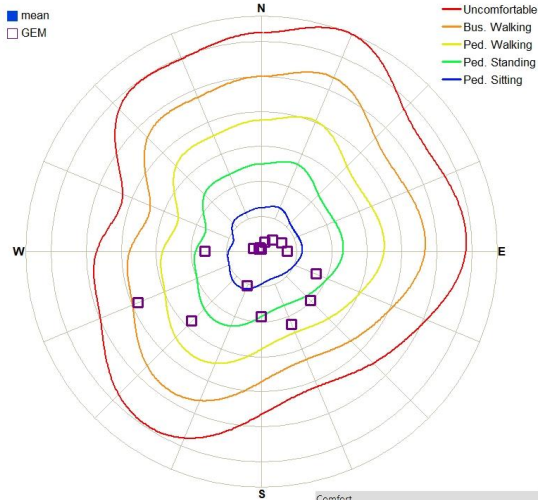
LOCATION 39



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	4.86	8.78	9.28
4	0.14	0.19	0.23
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)	2.0	2.4	2.5
Rating	Outdoor Dining	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.7	4.9	5.0
Rating	Pass	Pass	Pass

LOCATION 40

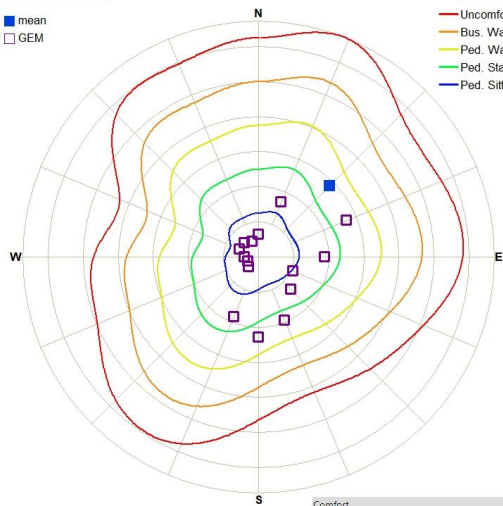


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	16.78	23.24	23.24
4	3.35	5.97	5.97
6	0.46	1.29	1.29
8	0.05	0.38	0.38
10	0.00	0.08	0.08

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	11.3	11.3
Rating	Pass	Pass	Pass

LOCATION 41

■ mean
□ GEM

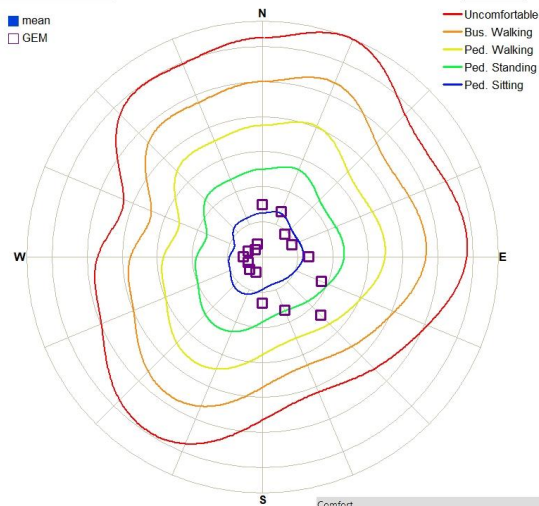


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	12.12	19.59	19.61
4	1.92	3.84	3.85
6	0.06	0.17	0.17
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	3.7	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.4	7.2	7.2
Rating	Pass	Pass	Pass

LOCATION 42

■ mean
□ GEM

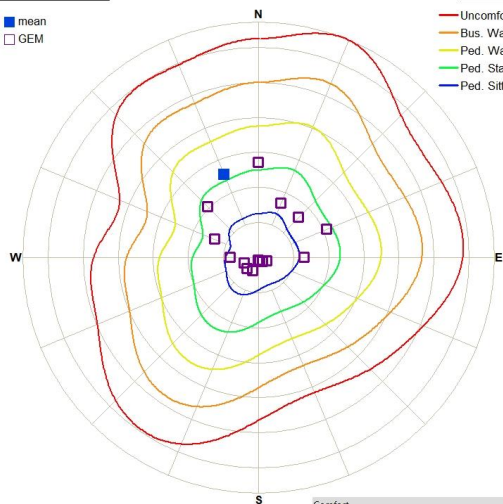


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	9.64	13.32	13.32
4	0.73	1.94	1.94
6	0.01	0.09	0.09
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.7	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.8	6.8	6.8
Rating	Pass	Pass	Pass

LOCATION 43

■ mean
□ GEM

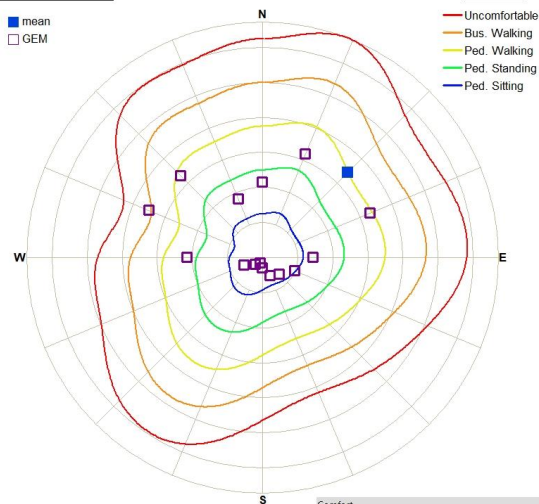


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	10.43	13.30	13.46
4	0.96	1.32	1.38
6	0.09	0.13	0.14
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.9	7.1	7.2
Rating	Pass	Pass	Pass

LOCATION 44

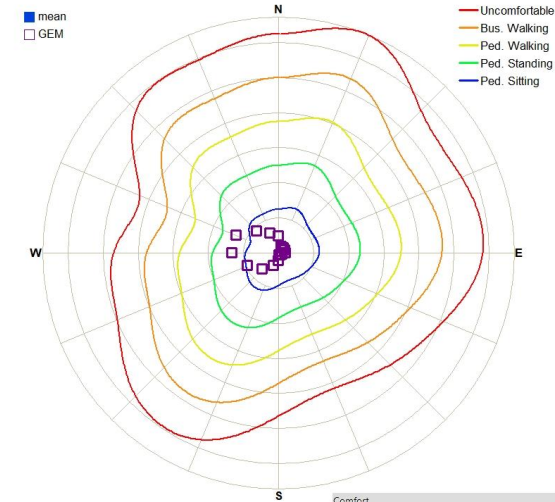
■ mean
□ GEM



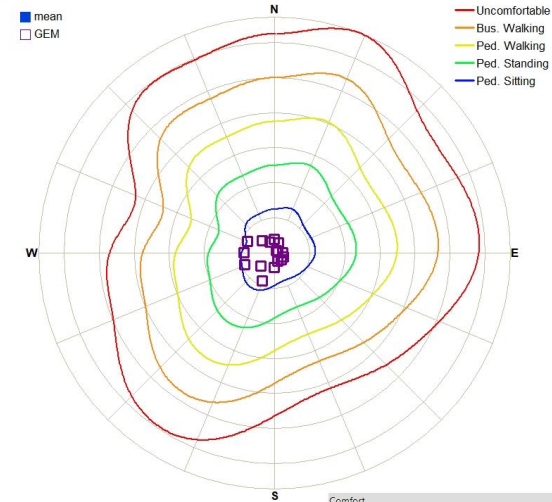
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	19.20	24.40	24.67
4	5.13	7.03	7.36
6	1.22	1.71	1.87
8	0.33	0.55	0.56
10	0.05	0.14	0.14

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	4.5	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	11.9	11.9
Rating	Pass	Pass	Pass

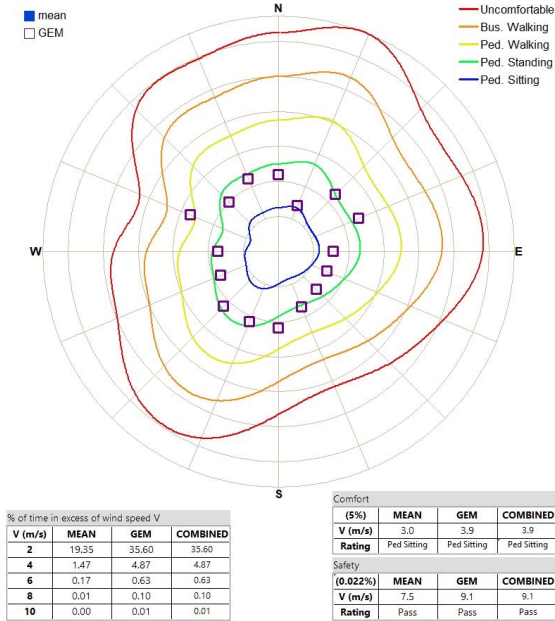
LOCATION 45



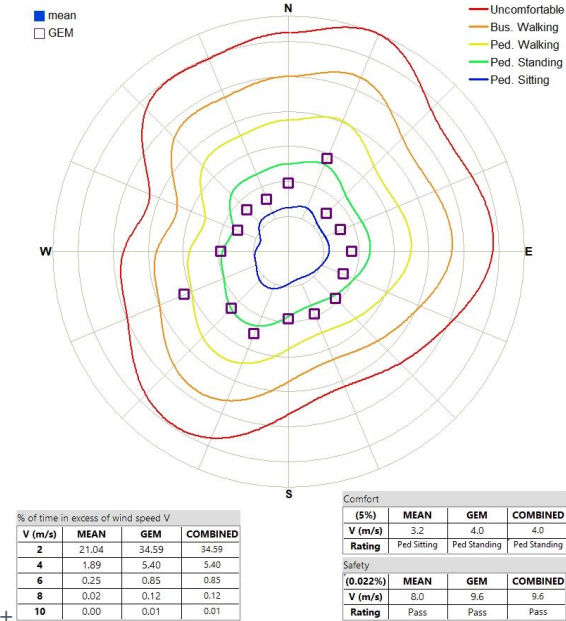
LOCATION 46



LOCATION 47



LOCATION 48



LOCATION 49

