14 October 2015 CPP Project 7282

Lend Lease Development Pty. Ltd.
30 The Bond
30 Hickson Road
Millers Point
NSW 2000

Attn: Mr. Warwick Bowyer

Subject: Wind Engineering – Lend Lease Circular Quay

Ref: (1) CPP report, Lend Lease Circular Quay, dated November 2013

Dear Mr. Bowyer,

Please find herein comments regarding the impact of changes to the tower and podium envelopes on the pedestrian level wind conditions at the Lend Lease Circular Quay development (LLCQ).

The Hassell drawings provided by Lend Lease, Figure 1 and 2, have been reviewed and assessed from an environmental wind perspective at ground level. Compared with the massing model used for the wind tunnel testing of LLCQ, Figure 3 and 4, the architectural form of the building has been developed, but the general massing of the building has remained similar. The maximum height of the tower has been increased by 48 m to rise 248 m above Underwood Street. The setback on Pitt Street remains and pedestrian level winds along Pitt Street are expected to remain within the Business walking category of the Lawson criterion.

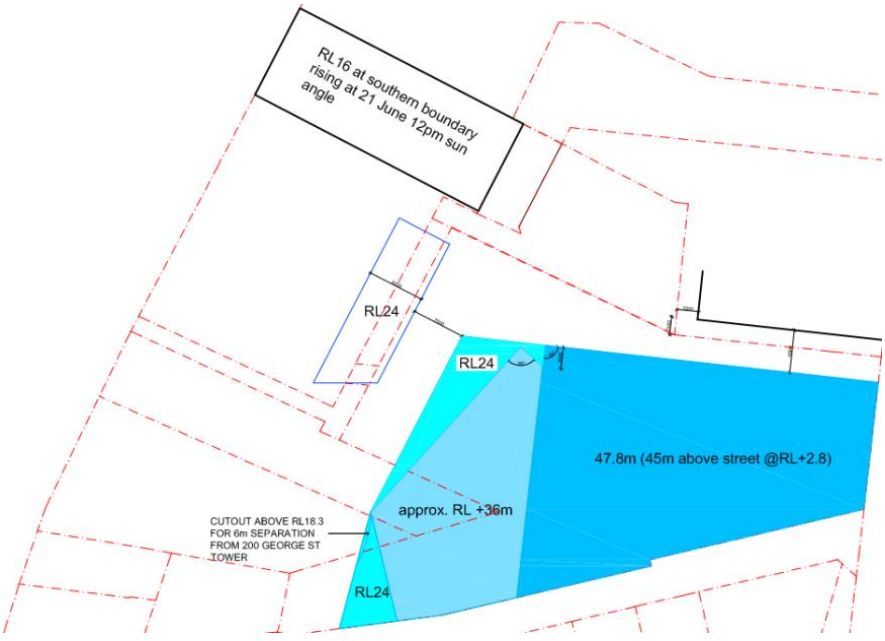


Figure 1: Elevation drawing of LLCQ podium (Hassell 005567-61A-P)

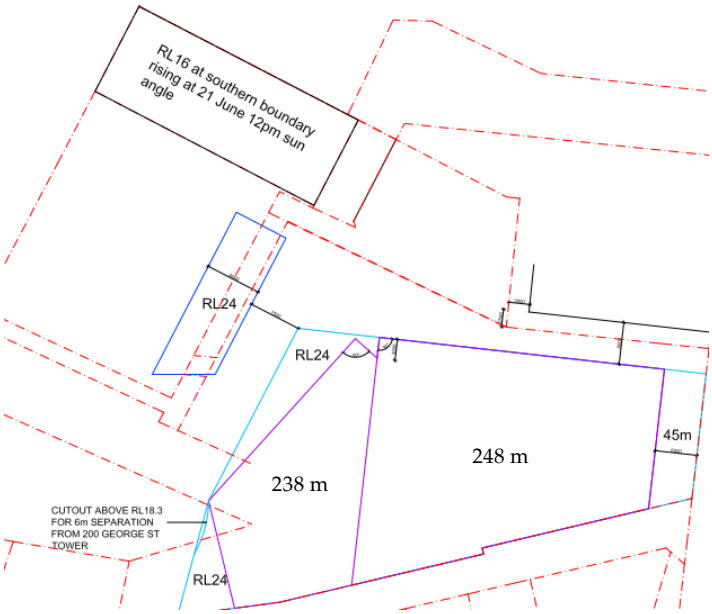


Figure 2: Elevation drawing of tower envelope refinements (Hassell 005567-61A-P)

The minimum distance to the 200 George Street development façade has been increased to 6 metres and the LLCQ façade in this area has been pulled back from the adjacent façade. This has been achieved by both moving the LLCQ façade eastwards and reducing the angle of the western corner. The podium geometry in this area is relatively unchanged, and conditions in the north-south laneway to the plaza are not expected to change significantly. The reduction in size of the structure on the west side of the plaza may improve conditions slightly in the north-south laneway to the detriment of conditions in the plaza.

Although the triangular overhang on the north-west corner of the podium has been removed (circled in Figure 3) and the plaza massing has been altered slightly, these modifications are not expected to significantly impact the wind amenity of both the east-west link and the plaza.

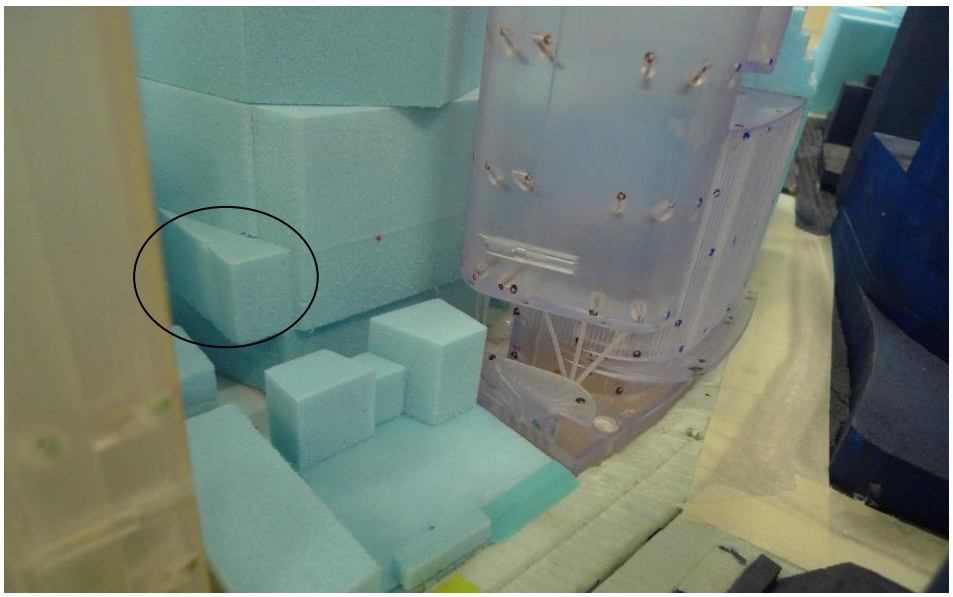


Figure 3: CPP Wind tunnel model of original LLCQ model, view from north-west

Figure 4: CPP Wind tunnel model of original LLCQ model, view from north-east

In summary, it is expected that the proposed changes to the LLCQ envelope will not significantly change the local wind conditions from those measured with the massing model during the November 2013 wind-tunnel testing. Conditions in the north-south laneway may improve slightly, and while conditions in the plaza may worsen slightly they are still expected to meet the "pedestrian standing" criteria as previously rated.

Additional updates to CPP report dated November 2013:

- Table 3, page 9: The Pitt Street and George Street properties are now owned by Lend Lease (Circular Quay) Pty. Ltd.
- Table 3, page 10: Jacksons on George is now owned by Lend Lease
- Table 3, page 10: Rugby Club is now owned by Wanda One Sydney Pty. Ltd.

I hope this is of assistance, please do not hesitate to contact me on 9551 2000 if you would like to discuss any aspect of this report.

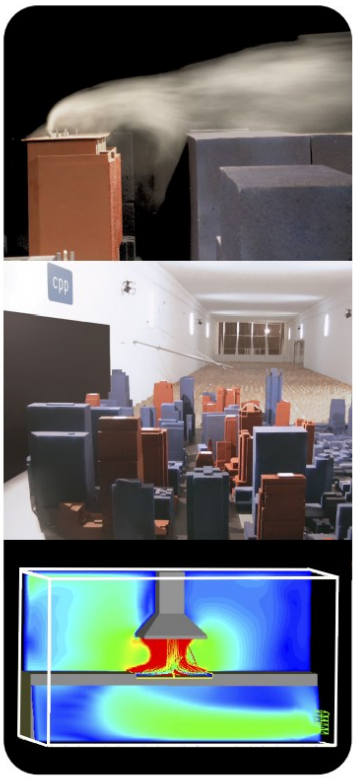
Yours sincerely,

Graeme Wood
Director
cc M.Glanville

CERMAK
PETERKA
PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

Final Report



Wind Tunnel Tests for:

LEND LEASE CIRCULAR QUAY

Sydney, Australia

Prepared for:

Lend Lease Development Pty. Ltd.

30 The Bond, 30 Hickson Road

Millers Point

NSW 2000

Prepared by:

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CPP Project 7282

18th November 2013

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EXECUTIVE SUMMARY

A wind tunnel study of the proposed Lend Lease Circular Quay (LLCQ) development at 174-182 George Street and 33-35 Pitt Street located in Sydney, was conducted to assess pedestrian wind comfort at ground level. A model of the project was fabricated to a 1:400 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 570 m radius were constructed and placed on the turntable.

CPP previously completed a Wind Opinion Assessment for 182 George Street and 33-35 Pitt Street Sydney, Australia ref No 7282 August 2013 and a copy of this previous opinion is found in Appendix 3. The findings of this wind tunnel study generally support the previous August 2013 opinion findings.

The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St Peters. Measurements of wind speeds likely to be experienced by pedestrians were made with a hot-film anemometer. Approach boundary layers representative of the environment surrounding the proposed development were established in the test section of the wind tunnel. The approach wind flow had appropriate turbulence characteristics corresponding to Terrain Category 3 as defined in Standards Australia (2011). The pedestrian wind environment was investigated at 22 locations for 16 wind directions each in accordance with Australasian Wind Engineering Society (2001). These points were tested in the proposed configuration and to determine the effect of mitigation measures where necessary. The measurements were combined with wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The street level wind environment has been found to be similar to typical wind conditions in the surrounding Sydney CBD area. Wind conditions in the plaza area to the west of the site were found to be relatively calm for an outdoor area in the Sydney CBD and would support the proposed land uses and general configurations contemplated under the proposal. All locations in the public domain were found to pass the distress criterion with the exception of locations along Pitt Street to the east of the site. From a pedestrian comfort perspective, windier conditions observed along Pitt Street are considered typical conditions for this area and are due in part to the existing surrounding building massing. Portions of the internal laneways were found to be suitable for window-shopping and café-style activities that would also support the proposed land uses and general configurations contemplated under the LLCQ proposal.

TABLE OF CONTENTS

LIST OF FIGURES (adjust for site area plan)

LIST OF TABLES

LIST OF SYMBOLS

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

1. INTRODUCTION

Pedestrian acceptability of footpaths, entrances, plazas, and terraces is often an important design parameter of interest to the statutory consent authority (in this case the City of Sydney), developers, building owners, and architects. Assessment of the acceptability of the pedestrian level wind environment is desirable during the project design phase so that modifications can be made, if necessary, to create wind conditions suitable for the intended use of the space.

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

Techniques have been developed which permit boundary layer wind tunnel modelling of buildings to determine wind velocities in pedestrian areas. The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St Peters. This report includes wind tunnel test procedures, test results, and a discussion of results. Table 1 summarises the model configurations, test methods, and data acquisition parameters used. All the data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2010).

Table 1: Configurations for data acquisition

Configuration A.1	
Geometry:	Proposed Lend Lease Circular Quay development with existing surrounding buildings and landscape (including approved 200 George Street under construction), as shown in Figure 5.
Pedestrian Velocities:	Pedestrian winds measured at 22 locations for 16 wind directions in 22.5° increments from 0° (north).
Configuration B.2	
Geometry:	Proposed Lend Lease Circular Quay development with surrounding buildings and landscape inclusive of proposed and approved developments, as shown in Figure 5
Pedestrian Velocities:	Pedestrian winds measured at 19 locations for 16 wind directions in 22.5° increments from 0° (north).
Configuration C.3	
Geometry:	As Configuration B with modifications to the plaza as shown in Figure 10.
Pedestrian Velocities:	Pedestrian winds measured at 8 locations for 16 wind directions in 22.5° increments from 0° (north).

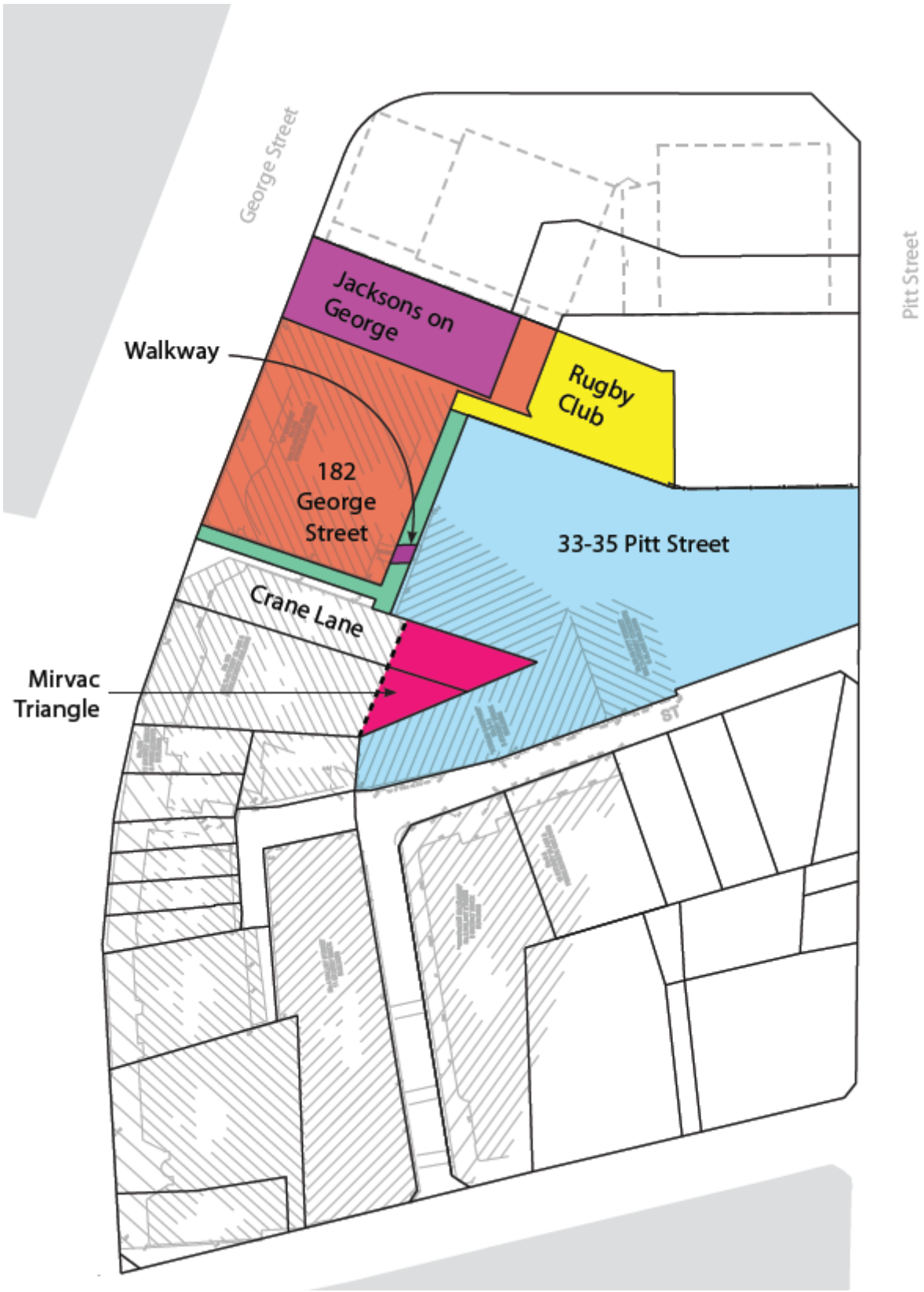

Figure 1: The LLCQ Site

1. THE WIND TUNNEL TEST

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

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 2. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by a vorticity generating fence and spires The spires, barrier, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in Figure 3 and are explained more fully in Section 3.1.1.

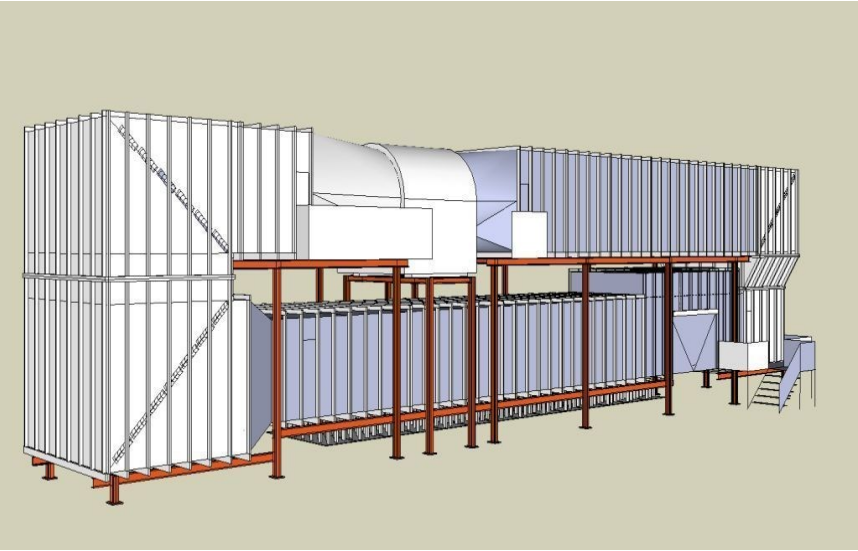

Figure 2: Schematic of the closed circuit wind tunnel

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

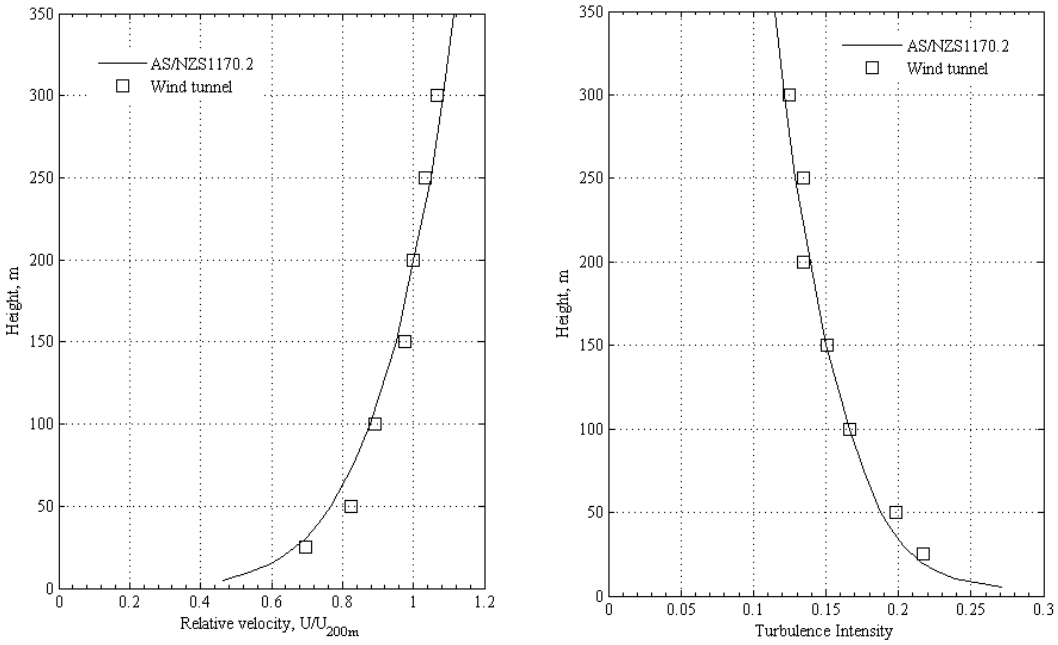

Figure 3: Mean velocity and turbulence profiles approaching the model, terrain category 3

Figure 4: Photograph of the Lend Lease Circular Quay model in the CPP wind tunnel – Configuration C

2. ENVIRONMENTAL WIND CRITERIA

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

Lawson's criteria have categories for discomfort, based on wind speeds exceeded five percent of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "business walking" to "pedestrian sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds[1]. In both cases, the wind speed used is the larger of a mean or gust equivalent-mean (GEM) wind speed. The GEM is defined as the peak gust wind speed divided by 1.85; this is intended to account for locations where the gustiness is the dominant characteristic of the wind. Assessment using the Lawson criteria provides a similar classification as using the once per annum gust, which was the basis of the City of Sydney (2011) DCP, however provides additional information regarding the serviceability wind climate. The current City of Sydney (2012) DCP specifies wind effects not to exceed 10 m/s, as the area is classified as an 'active frontage'. From discussions with Council this is a once per annum gust wind speed similar to the 2004 DCP, but is meant to be interpreted as a comfort level criterion to promote outdoor café style activities and is not a distress requirement.

Table 2: Summary of Lawson criteria

Comfort (maximum of mean or gust equivalent mean (GEM^{+}) wind speed exceeded 5% of the time)	
< 4 m/s	Pedestrian Sitting (considered to be of long duration)
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)
6 - 8 m/s	Pedestrian Walking
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)
> 10 m/s	Uncomfortable

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

Distress (maximum of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access area
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able bodied people would be expected; frail or cyclists would not be expected

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

3. DATA ACQUISITION AND RESULTS

3.1 Velocities

Velocity profile measurements were taken to verify that appropriate boundary layer flow approaching the site was established and to determine the likely pedestrian level wind climate around the test site. Pedestrian wind measurements and analysis are described in Section 3.1.2. All velocity measurements were made with hot-film anemometers, which were calibrated against a Pitot-static tube in the wind tunnel. The calibration data were described by a King's Law relationship (King, 1914)

3.1.1 Velocity Profiles

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in Figure 3. Turbulence intensities are related to the local mean wind speed. These profiles have the form as derived from Standards Australia (2011) and are appropriate for the approach conditions.

3.1.2 Pedestrian Winds

The proposed LLCQ development is situated centrally to the east of the block bounded by Alfred, Pitt, Dalley, and George Streets, Sydney, Figure 1. This block includes other developments listed below in Table 3. There are several existing through-site links that connect George, Underwood, and Pitt Streets, which are typically small laneways intended for vehicular access, cafés, and retail use. It is understood that the main entrance to the proposed commercial office tower development will be from the Public Plaza on George Street with a supporting Pitt Street entrance. Both building entries are proposed through revolving doors.

Table 3: Land to which the LLCQ Proposal Relates

Informal title	Address	Lot and DP	Ownership
The Pitt Street property	33-35 Pitt Street	Lot 7 DP 629694	Westpac Banking Corporation. LL has agreed to purchase in 2015.
The George Street Property	182 George Street	Lot 182 DP 606865	Westpac Banking Corporation. LL has agreed to purchase in 2015.

Jacksons on George	174-176A George Street	Lot 181 DP 606865	LL has exchanged contracts and will secure ownership in Oct 2013.
Mirvac Triangle	Part of 200 George Street development site	Lot 1 in DP 69466 and Lot 4 in DP 57434 The part of the above Lots to which the PP relates is referred to as Lot 2 in the draft plan of subdivision Nov 13, 2012 (Issue 7) contained in the executed VPA between the City of Sydney and Mirvac	Mirvac owns the land. Mirvac will transfer the new Lot 2 to the City of Sydney who will then transfer to LL in return for an equivalent area of completed public realm
Crane Lane including walkway (aerial bridge)	Crane Lane extending east from George St, then north to Rugby Place	Lot 1 and 2 in DP 880891. Lot 1 is in stratum above Lot 2.	City of Sydney
Rugby Club (Optional Site)	Rugby Place	Lot 180 DP 606866	The Rugby Club

The proposed commercial office tower has frontage of approximately 70 m on Underwood Street and 17 m on Pitt St, Figure 1. The proposed development consists of an essentially prismatic tower with flattened V-shape plan form rising approximately 200 m above Underwood Street level, and an open "Public Plaza" in the centre and to the west of the block. This Plaza will be created by the demolition of the St George Building at 182 George Street. The proposed tower has an articulated Underwood Street façade with minimal setback. There are podiums proposed on the east and west sides of the commercial office tower. This podium wraps around the northern side of the tower and is proposed to provide only a minor setback along the northern laneway to the Plaza from Pitt Street.

The proposed development is surrounded by many medium- to high-rise buildings, including the dominant Grosvenor Place, NAB House, Goldfields House, Gateway Plaza, SunCorp Tower, Four

Seasons Hotel, Shangri-La Hotel, Macquarie Bank, and Australia Square. There are two other approved developments on the same block. To the west is 200 George Street (DA 2012/893), currently under construction, which will be approximately 150 m tall. To the north of the site, a proposed tower to replace Goldfields House at One Alfred Street (DA 2010/2029) is expected to rise to 185 m with a smaller building to the north-east rising to 57 m. The effect of the One Alfred Street development is to increase the exposure of the current site to winds from the north-east. Another potential development is that of the Fairfax Site (D/2010/1533) to the immediate north of the site with a building rising to a maximum of 110 m above ground level. Topography surrounding the site is relatively flat in the north-south direction, but drops significantly down Essex Street from west to east, and there is an approximate drop of 4.5 m from George Street to Pitt Street.

Wind speed measurements were recorded at 22 locations to evaluate pedestrian comfort in and around the project site, Figure 5 and Figure 7. The points were tested for the configurations described in Table 1. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian comfort at the building corners where relatively severe conditions frequently are found, near building entrances, on adjacent pavements with heavy pedestrian traffic, and in open plaza areas. Three comparative pedestrian positions, located in a familiar or relatively undisturbed area near the project site, were tested for reference purposes, Figure 5.

The hot-film signal was sampled by for a period corresponding to one hour in prototype. All velocity data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the minimum size of a gust affecting a pedestrian and the gust duration on which the wind criteria are based. 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 $\frac{U_{pk}}{U_{ref}} = \frac{\overline{U} + 3U_{stdev}}{U_{ref}}$.

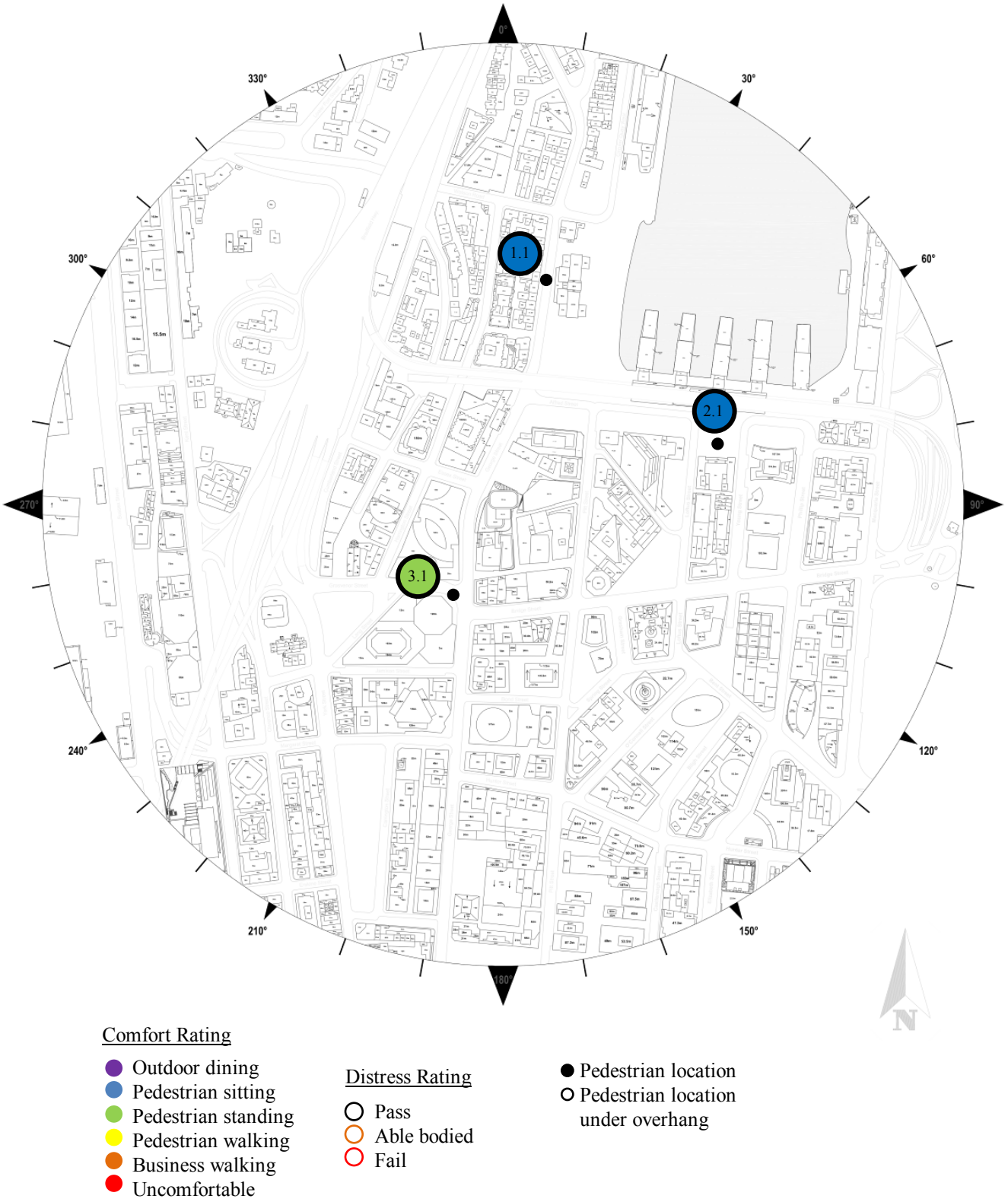

Figure 5: Site layout and remote pedestrian wind speed measurement locations with comfort/distress ratings, Configuration A

Figure 6: Site layout for Configuration B

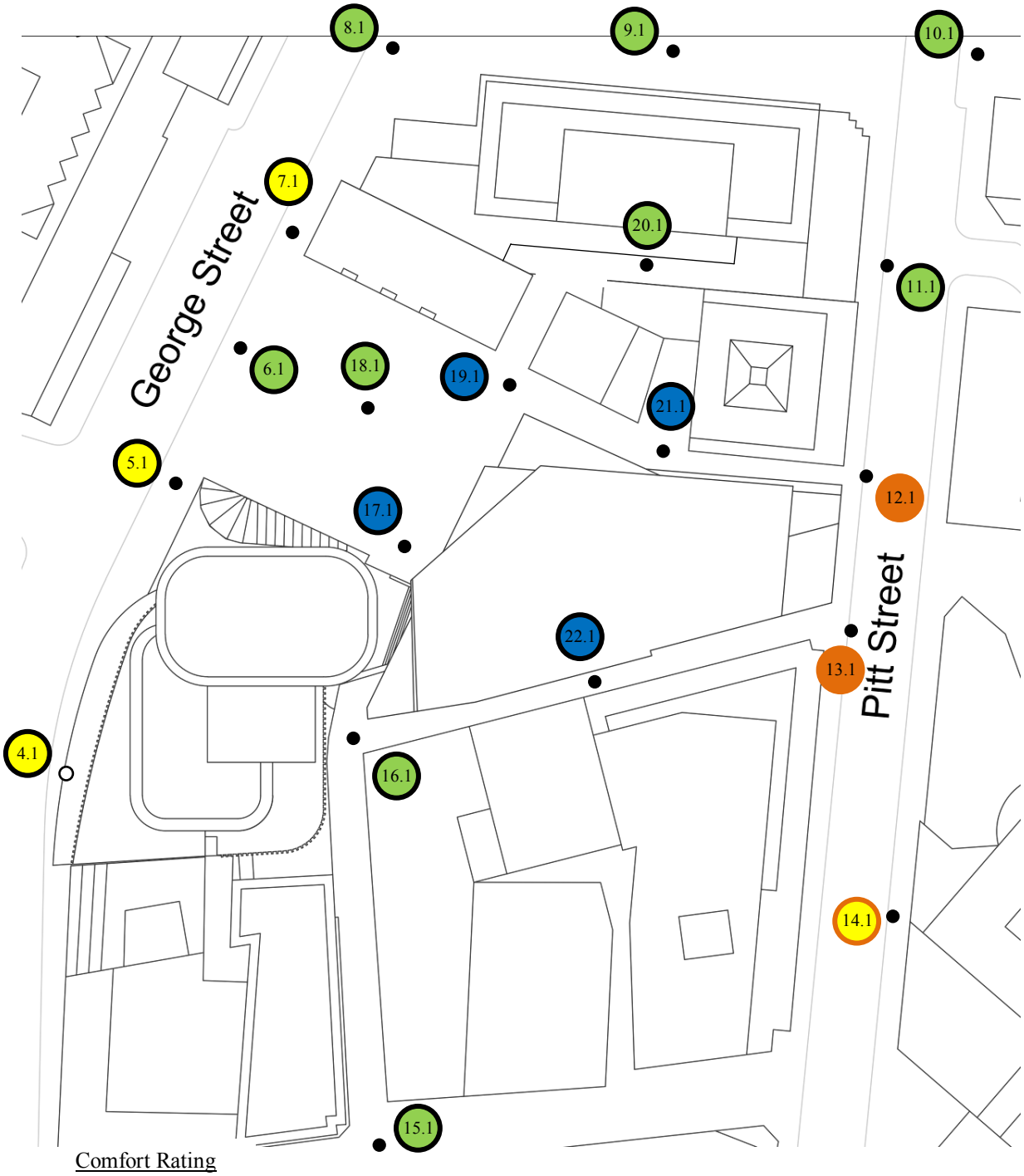

Figure 7: Pedestrian wind speed measurement locations with comfort/distress ratings – Config. A

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200 m are plotted in polar form in Appendix 2. The graphs show velocity magnitude and the approach wind direction for which that velocity was measured. The polar plots aid in visualisation of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust wind speed is of greater importance.

To enable a quantitative assessment of the wind environment, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1995 to 2012, Figure 8. From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 2; this gives additional information regarding directional sensitivity at each location.

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 8 to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 2. In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in Table 4 including qualitative descriptions of wind effects.

The tables in Appendix 2 also give the wind speed exceeded 5% and 0.022% for direct comparison with the Lawson criteria and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian comfort and safety with respect to the Lawson criteria is presented in Figure 5 and Figure 7 for each test location. Because some pedestrian wind measurement positions are purposely chosen at sites where large velocities of small spatial extent may exist, the general wind environment about the structure may be less severe than one might infer from an analysis only of Figure 5 and Figure 7. The implications of the results are discussed in Section 4.

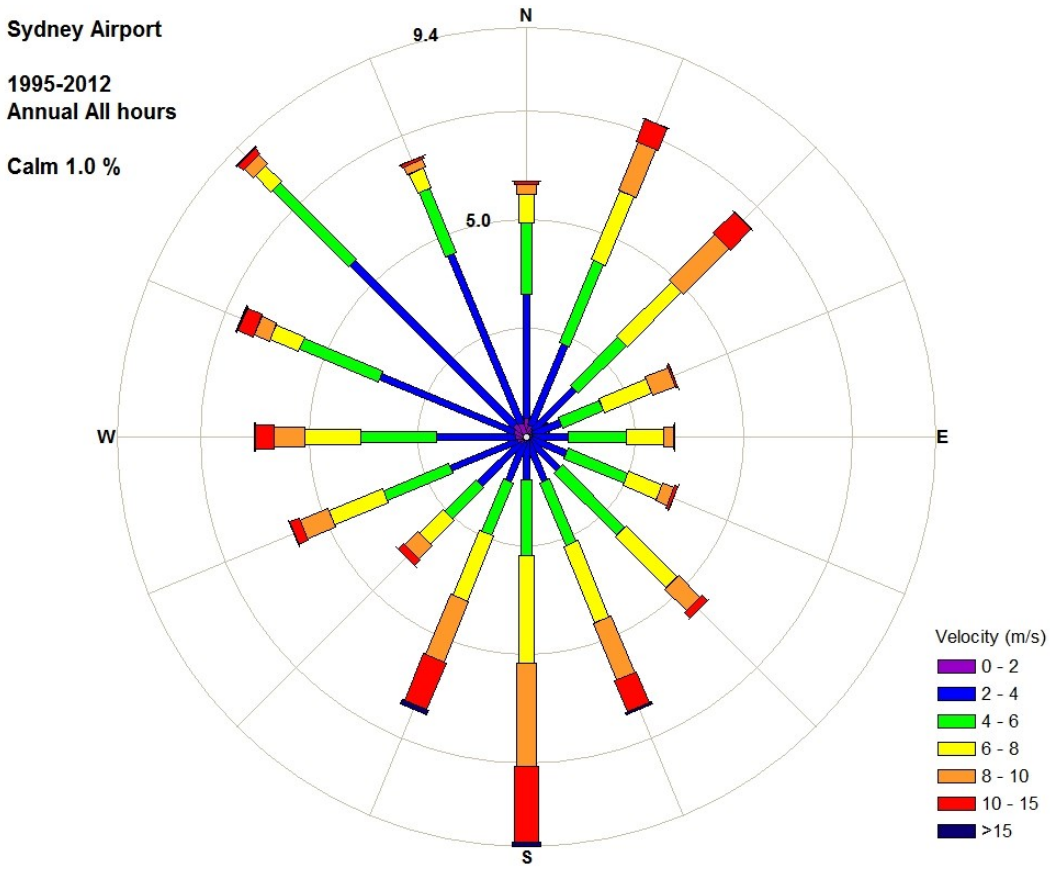

Figure 8: Wind rose of direction and speed for Sydney Airport

Table 4: Summary of wind effects on people, Penwarden (1973)

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

4. DISCUSSION

The wind climatology chart of Figure 8 indicates that the most frequent strong winds are from the south, and to a lesser extent, the west and north-east. The development is located in a section of the city with an irregular street pattern that is not aligned to the prevailing wind directions and is therefore beneficial in reducing the local wind speed. Individual locations around the development are more susceptible to winds from different directions, depending on the relative location of the point tested to the geometry of development. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the graphs in Appendix 2.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 5 to Figure 9, and Figure 11, which depict the locations selected for investigation of pedestrian wind comfort around the site along with the Lawson criteria rating for both comfort and distress in the various configurations. Note that testing was performed without planned trees, or other plantings to provide a worst case assessment; heavy streetscape planting typically reduces the wind speeds by less than 10%. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes the distress criterion. Mitigation measures are likely to be required for red locations, and may be necessary for other locations depending on the intended use of the space. Although conditions may be classified acceptable there may be certain wind directions that cause regular strong events, these can be determined by an inspection of the plots in Appendix 2.

4.1 Configuration A

It is evident from Figure 7 that the wind environment at the proposed LLCQ development in Configuration A is generally satisfactory for pedestrian sitting or standing and would support the proposed land uses and general configurations contemplated under the LLCQ proposal. The general wind amenity of the site and surrounds is similar to wind conditions remote from the site investigated at locations 1 to 3, which are suitable for pedestrian walking or sitting, Figure 5. These surrounding locations give a general indication of the surrounding wind climate and can be used for comparison with the wind environment in and around the development.

Locations 4.1 to 8.1 are positioned along George Street. Conditions in this area are primarily driven by the channelling of winds from the north-east and south along George Street. Locations 4.1 and 5.1 to the south of the development were both found to be suitable for pedestrian walking. Locations 6.1 and 7.1 are positioned at the George Street entrance to the proposed plaza and have a

similar wind environment, but Location 6.1 is rated as suitable for pedestrian standing, while location 7.1 is suitable for pedestrian walking. Location 8.1 is on the north-west corner of the city block, next to the existing Goldfields House building. Wind conditions here are calm for winds from the south quadrant and the bend in George Street diverts the channelled flow to the west side of the street, but windier during sea-breeze conditions where the wind blows over Circular Quay and accelerates into George Street. All locations pass the distress criterion.

Location 9.1 is located on Alfred Street directly in front of Goldfields House is classified as suitable for pedestrian standing. Winds from the north quadrant result in windier conditions due to the acceleration of downwash flow by the large front face of Goldfields House. Locations 4.1 to 9.1 all passed the distress criterion.

Locations 10.1 to 14.1 are located along Pitt Street in close vicinity to the proposed development. Wind conditions here are driven by the same flow mechanisms as George Street, where winds from the north-east and south are channelled down the corridor. Location 10.1 is on the corner of Pitt and Alfred Streets near the Ship Inn's outdoor tables. The wind amenity was rated as pedestrian standing, although the wind conditions here are suitable for outdoor sitting approximately 85% of the time. Location 11.1 is on the Pitt Street footpath adjacent to the south-eastern corner of Goldfields House, and is rated as suitable for pedestrian standing.

Windy conditions exist around the Fairfax site. Location 12.1 is positioned at the eastern exit of the through-site link on the south-east corner of this tower and is rated as suitable for able-bodied persons and business walking only from a distress and comfort perspective respectively. Winds from the north-east quadrant are channelled into Pitt Street by Goldfields House and the Gateway Plaza. Downwash from the Gateway Plaza combined with the the complex flow pattern between the tall buildings results in the flow impinging on Pitt Street between locations 12.1 and 13.1, before being channelled down the street. This location is expected to be suitable for pedestrian walking approximately 85% of the time. Location 13.1 is similar in wind amenity to location 12.1, with the added influence of downwash winds from the south façade of the tower discharging into Pitt Street then channelled between the developments on the opposite side of Pitt Street.

Location 14.1 is in front of the Harbour Marriot Hotel further south on Pitt Street. The flow here is predominantly in the north-south direction dictated by the Pitt Street corridor. The combination of Gateway Plaza and the Marriott on one side, with the proposed development and surrounding towers on the other side of Pitt Street creates channelled flow and leaves Location 14.1 suitable for pedestrian walking and able-bodied persons only from a comfort and distress perspective respectively. This rating

is dominated by north-easterly winds wrapping down and around Gateway Plaza before being channelled along Pitt Street.

Location 15.1 is positioned at the intersection of Daley Street and the north-south laneway to the plaza which runs past the 200 George Street development. This area is suitable for pedestrian standing, with windier conditions expected for winds from the north. Location 16.1 is at the corner of Underwood Street, opposite the 200 George Street development and is marginally suitable for pedestrian standing. The flow through this laneway is predominantly north-south with little to no easterly component. Further to the east on Underwood Street, location 22.1 is rated as suitable for pedestrian sitting, with conditions suitable for outdoor dining expected about 80 % of the time. The portion of Underwood Street that runs in the east-west direction would be the most suitable area in the precinct for outdoor dining activities. The 200 George Street development helps in this respect as it forms a blockage for winds from the east or west.

The proposed public space to the west of the LLCQ development is suitable for pedestrian standing in most areas, with some pockets rated as pedestrian sitting. Location 17.1 on the southern corner is suitable for pedestrian sitting, and would be appropriate for outdoor sitting activities approximately 95% of the time, once again supporting the proposed land uses and general configurations contemplated under the LLCQ proposal. The flow patterns in this area dictate that wind speed will increase south of location 17.1. It is slightly windier in the middle of the plaza, with location 18.1 rated as suitable for pedestrian standing, but suitable for sitting activities 90 % of the time. Location 19.1 is suitable for pedestrian sitting about 95% of the time and outdoor dining approximately 65 % of the time. The plaza benefits from shielding from the proposed building, Goldfields House, and 200 George Street combined with the kink in the north south pedestrian link helping to mitigate wind flow through the site.

4.2 Configuration B

This configuration includes the changes to the Goldfields House site, incorporating the 1 Alfred Street approved development as well as the Fairfax site. In general, the wind amenity in and around the site is similar to Configuration A, with some exceptions.

Along George Street at locations 4.2 and 5.2 and 7.2, the wind climate improves slightly with the reconfiguration of the block resulting in the comfort rating improving from pedestrian walking to standing. The improvement is primarily due to decreased susceptibility to winds from the north-east.

Location 10.2 on the north-east corner Pitt and Alfred Streets, the wind amenity deteriorate slightly, resulting in a rating of pedestrian walking. This is attributable to the increased massing caused by the

Fairfax development podium at 19 Pitt Street which channels more flow up Pitt Street. Further south, location 12.2 is still classified as suitable for able-bodied persons only from a distress perspective, but the comfort rating has improved from business walking to pedestrian walking. It is expected that the increased gap between the Fairfax building and the One Alfred development is allowing more north-east downwash from Gateway Plaza to escape south-west over the site, rather than down Pitt Street. This results in location 14.2 passing the safety criterion.

Location 15.2 and 16.2 both improve to a pedestrian sitting rating, due to decreased susceptibility to winds from the north-north-west caused by a complex interaction between the One Alfred and 200 George developments. The increased height of One Alfred over Goldfields House and its positioning further west alters the flow around 200 George, ultimately resulting in decreased wind speeds in the southern portion of the alleyway.

The wind conditions in the plaza are essentially unaffected by the changes to the north of the site, with the exception of location 19.2 where the wind amenity slightly deteriorates to pedestrian standing comfort rating, primarily due to the gap created through the One Alfred development, which is not attributable to the LLCQ proposal.

Location 20.2 is susceptible to downwash from the taller One Alfred tower and channelling between the towers. The comfort rating is changed to pedestrian walking, with high mean wind speeds expected for winds from the north-east. Once again, these impacts are not attributable to the LLCQ proposal.

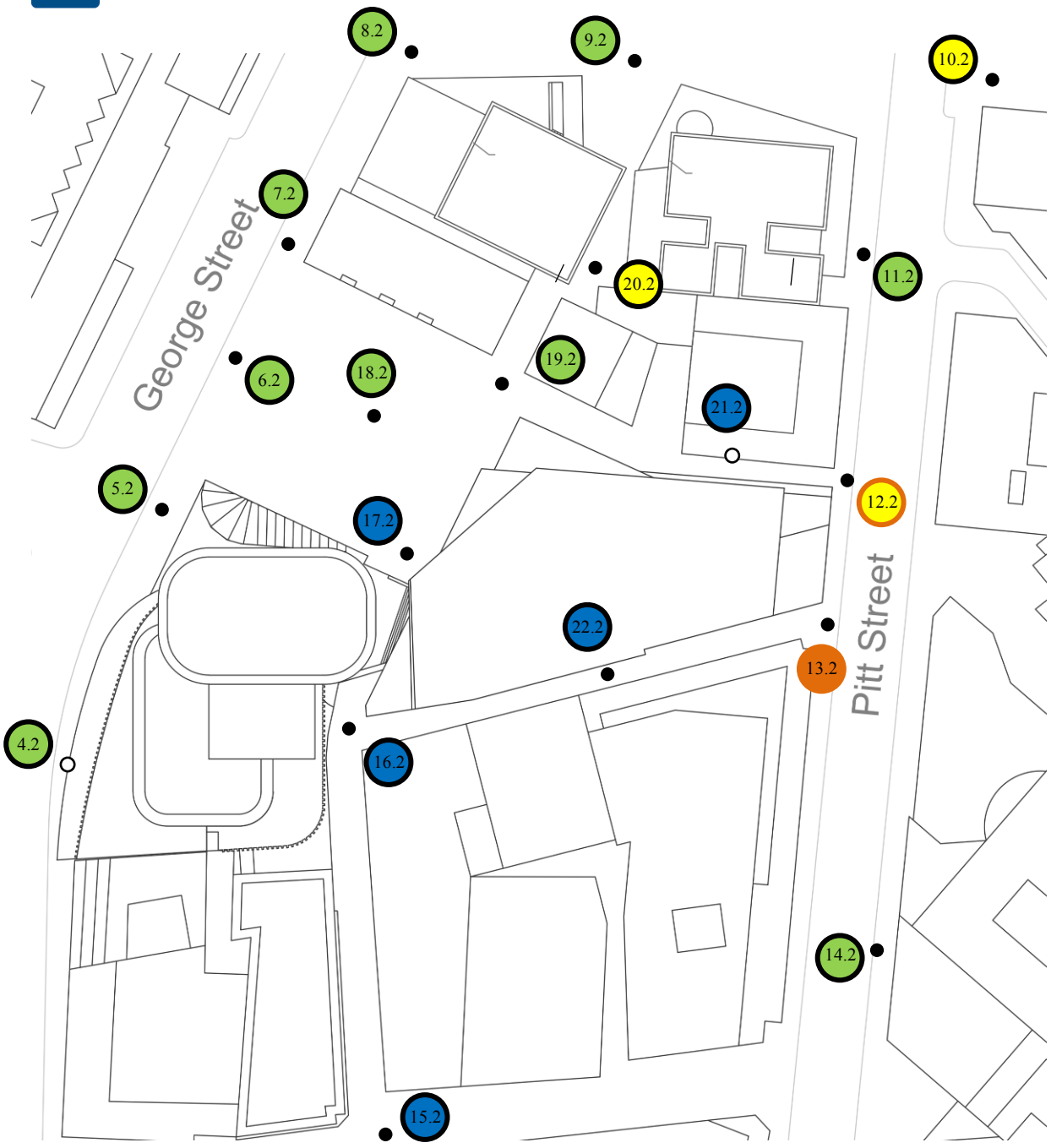

Figure 9: Pedestrian wind speed measurement locations with comfort/distress ratings – Config. B

4.3 Configuration C

Configuration C incorporates proposed design development amendments to the plaza with additional structures placed around its periphery. For the wind tunnel testing, only structures deemed as significant from an aerodynamic point of view were included in the model, as shown below in Figure 10.

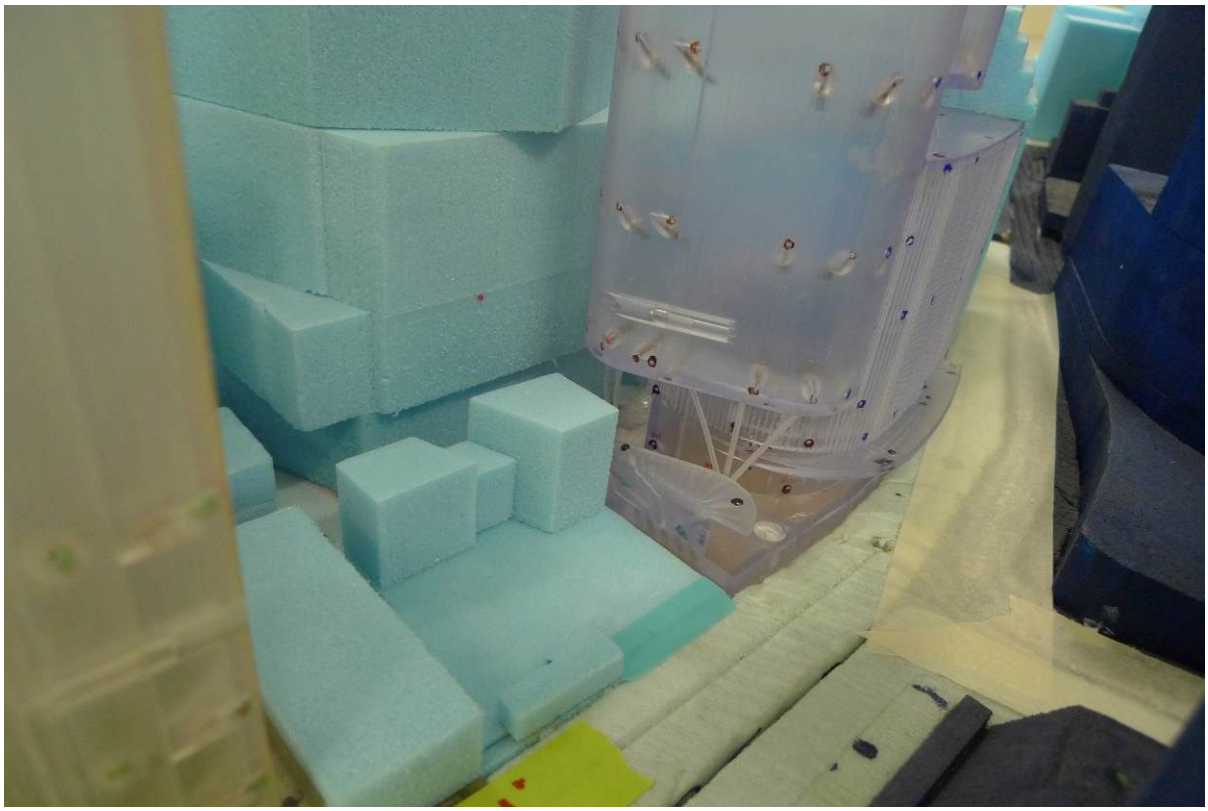

Figure 10: Changes to the plaza as tested (Configuration C)

Eight points around the plaza were tested in this configuration. Locations surrounding the plaza were unaffected by the changes.

The wind amenity at locations 17.3 and 19.3 on the south-east and north-east corner of the plaza respectively deteriorates slightly to pedestrian standing and walking respectively, due to the massing at the east of the plaza channelling more flow along the laneway to the north. As expected, the wind amenity at location 18.3 is improved to pedestrian sitting due to the shielding of the plaza against winds from the north-east and the channelled flow along the laneway. This location would be suitable for outdoor dining for approximately 80 % of the time in this configuration. The wind conditions along George Street were not affected by the minor changes to the plaza. Alternate plaza building configurations may achieve further simultaneous reductions along both the north-south laneway and the plaza, if required. In any case, the modelling results tend to support the proposed land uses and general configurations contemplated under the LLCQ proposal.

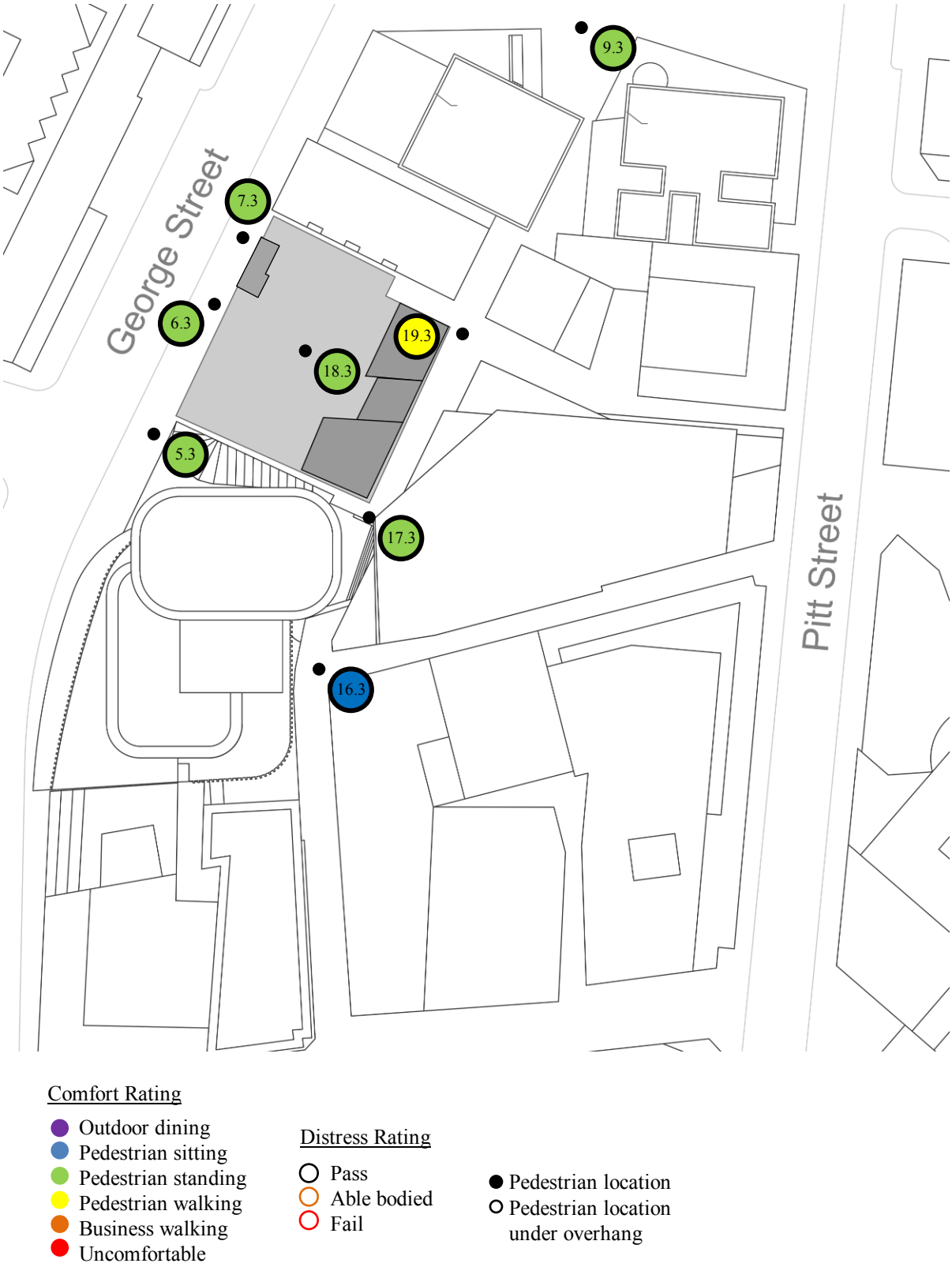

Figure 11: Pedestrian wind speed measurement locations with comfort/distress ratings – Config. C

5. CONCLUSIONS

A wind tunnel investigation of the pedestrian level wind environment around the proposed Lend Lease Circular Quay development at 174-182 George Street and 33-35 Pitt Street, Sydney, has been conducted. The street level wind environment has been found to be similar to typical street level wind conditions in the surrounding area. Wind conditions in the plaza area to the west of the site were found to be relatively calm for an outdoor area in the CBD thereby supporting the proposed public plaza land use and general configuration as contemplated under the LLCQ proposal. All locations in the public domain were found to pass the distress criterion with the exception of locations 13.1, 13.2, and 14.1, once again supporting the proposed land uses and general configurations contemplated under the LLCQ proposal. Windier conditions were observed along Pitt Street, but these conditions are considered typical of this location and due in large part to the surrounding massing. Portions of the internal laneways were found to be suitable for window-shopping and café-style activities thereby supporting the proposed laneway configuration for pedestrian access as contemplated under the LLCQ proposal.

6. REFERENCES

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Appendix 1: Additional Photographs of the Wind Tunnel Model

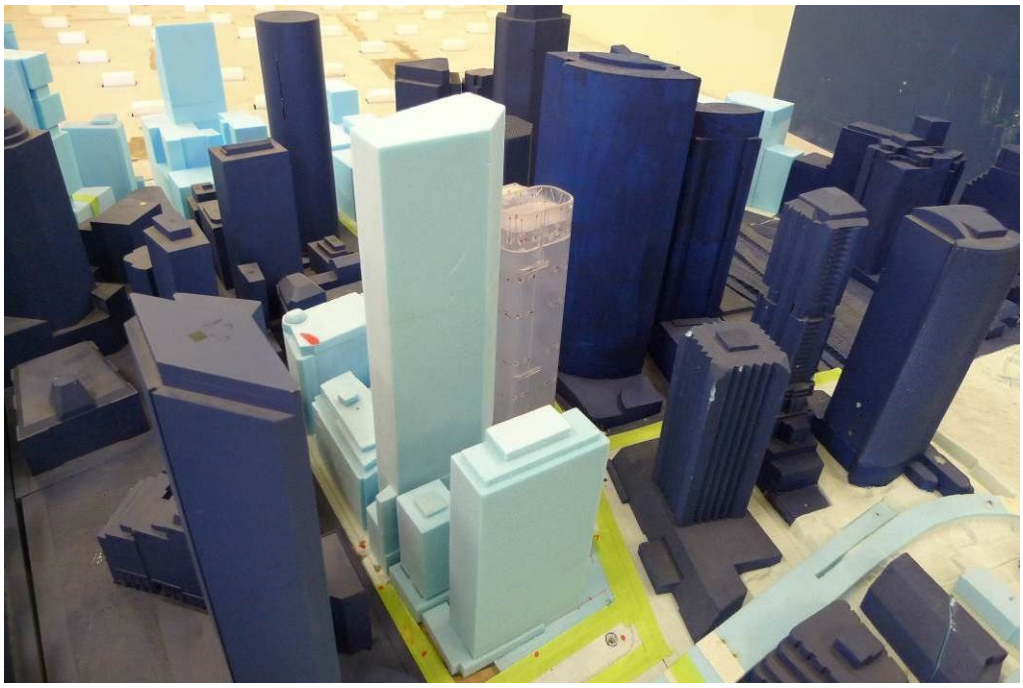


Figure 12: Configuration A – viewed from the north

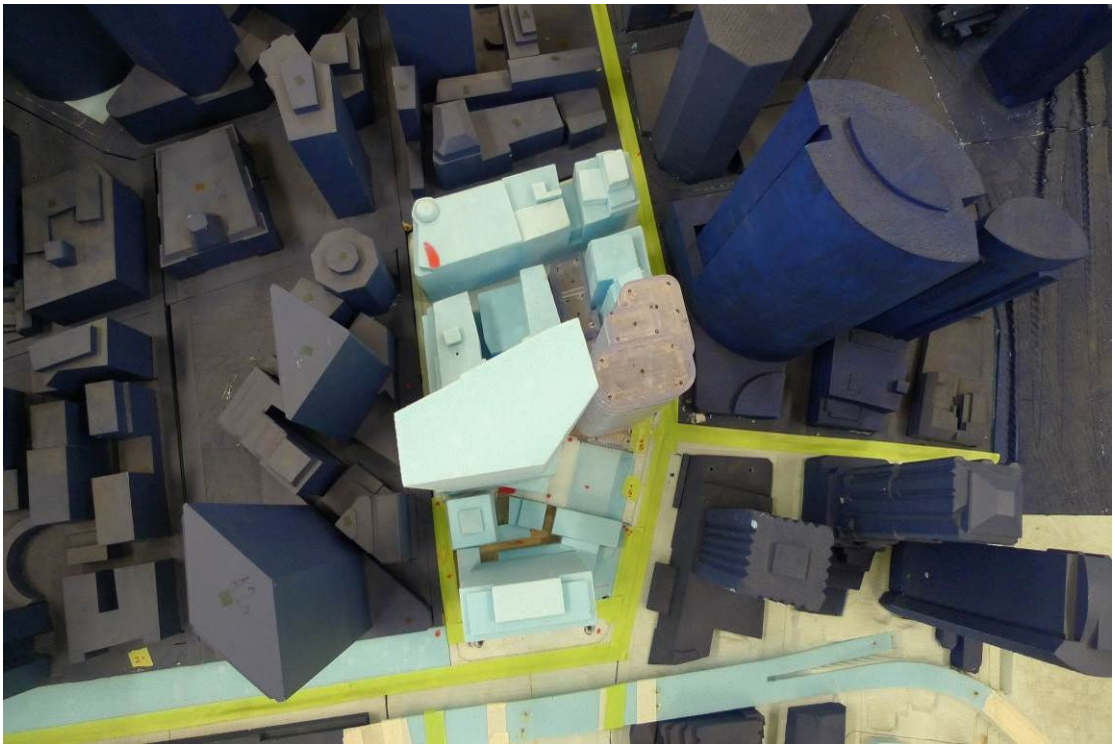


Figure 13: Configuration A viewed from above

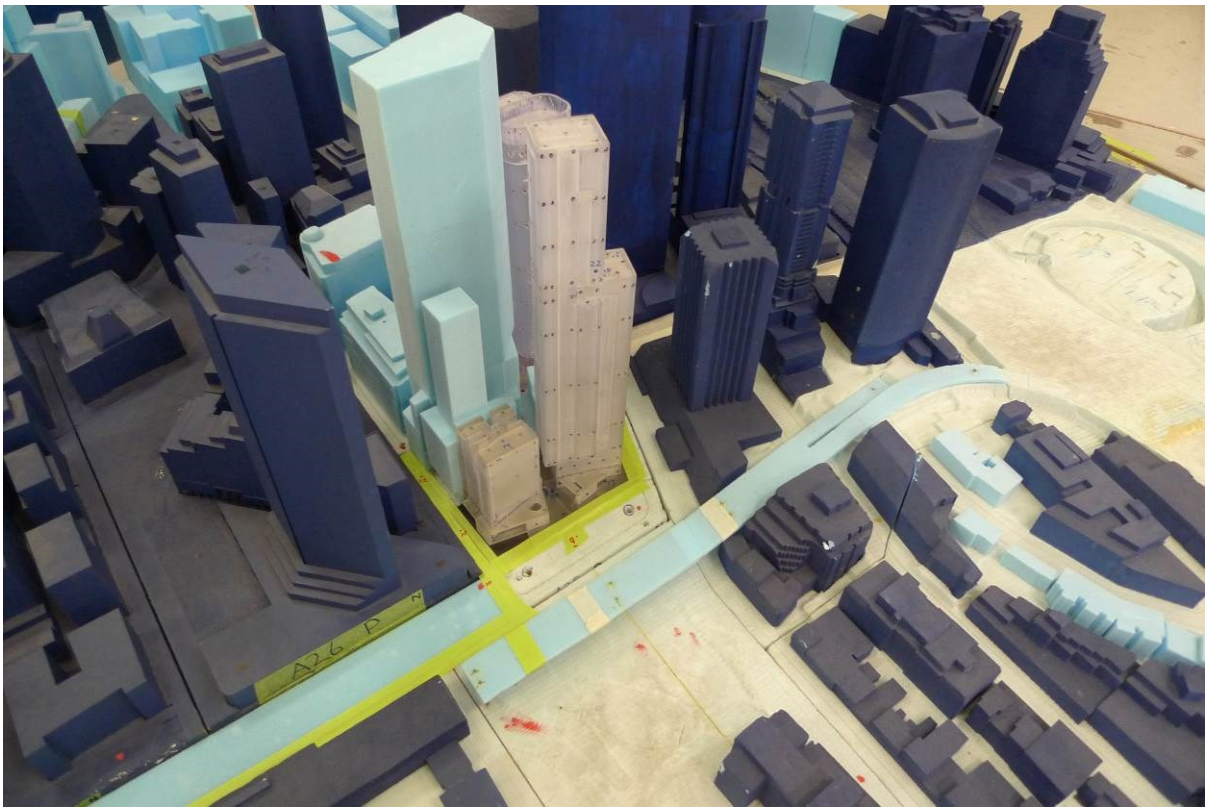


Figure 14: Configuration C – viewed from the north

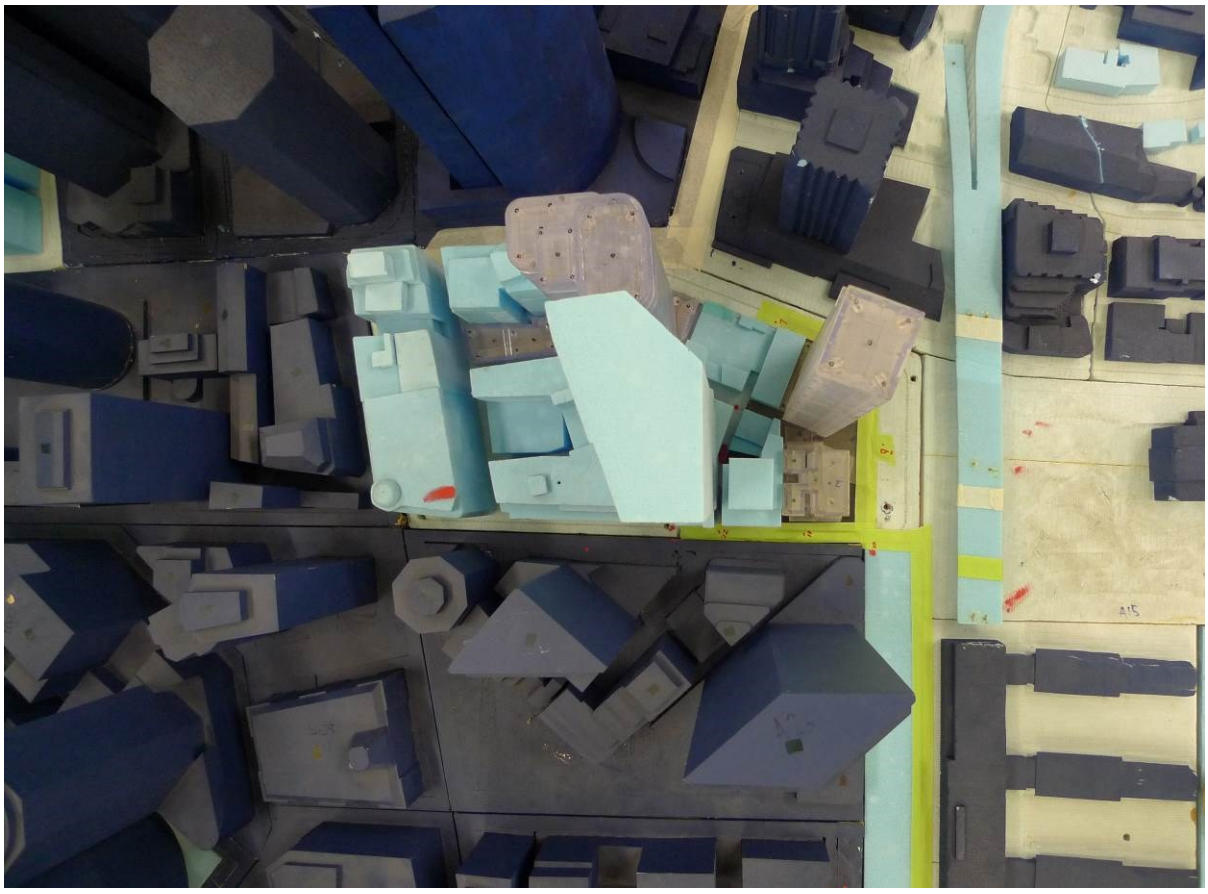
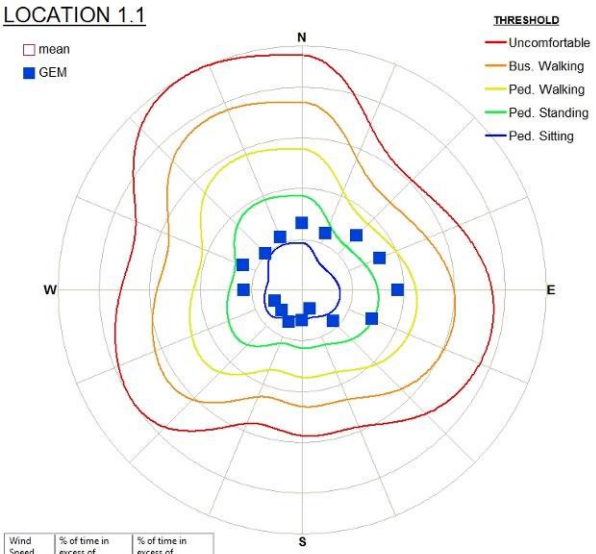


Figure 15: Configuration C – viewed from above

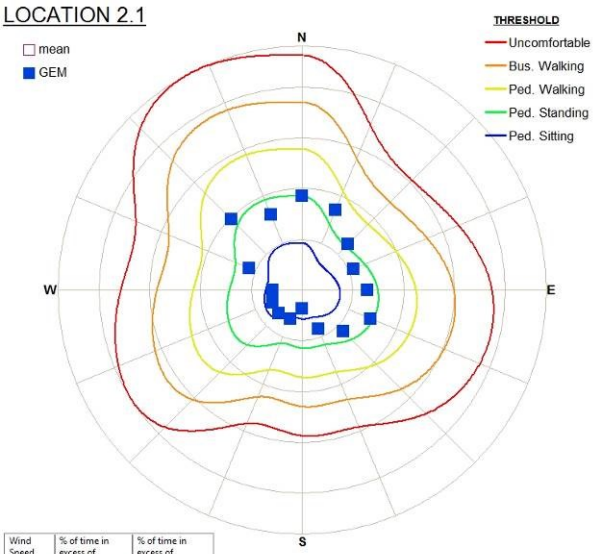
Appendix 2: Directional Wind Results

LOCATION 1.1



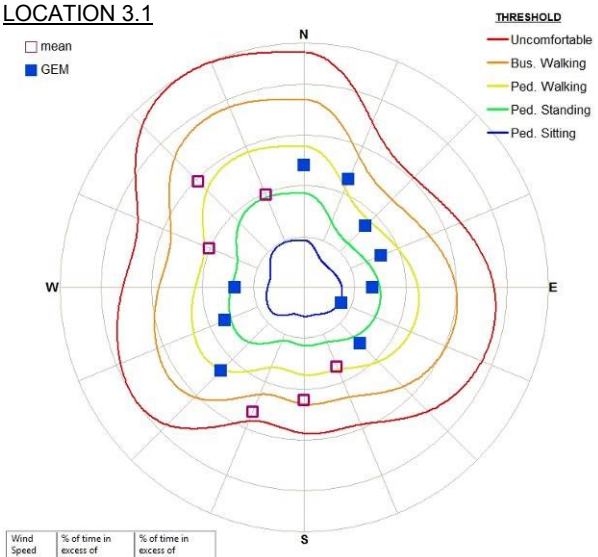
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	14.7	25.3
4.0	1.4	3.8
6.0	0.0	0.1
8.0	0.0	0.0
10.0	0.0	0.0
3.1	**5.0**	Ped Sitting
5.9	**0.022**	Pass
3.7	Ped Sitting	**5.0**
6.7	Pass	**0.022**

LOCATION 2.1



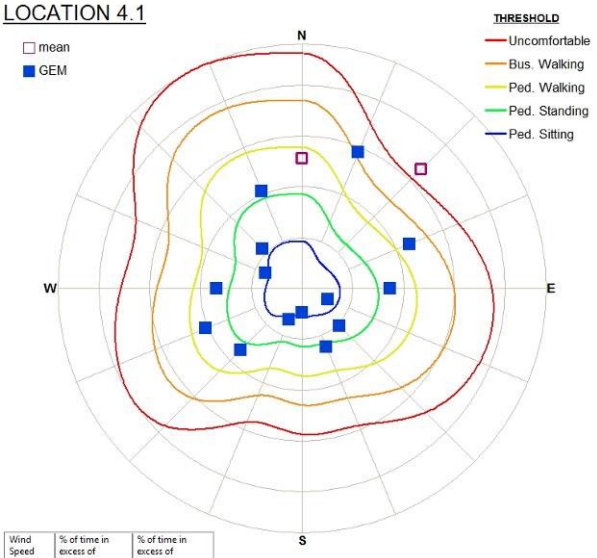
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	16.5	31.4
4.0	1.2	3.2
6.0	0.0	0.2
8.0	0.0	0.0
10.0	0.0	0.0
2.9	**5.0**	Ped Sitting
6.1	**0.022**	Pass
3.6	Ped Sitting	**5.0**
7.9	Pass	**0.022**

LOCATION 3.1



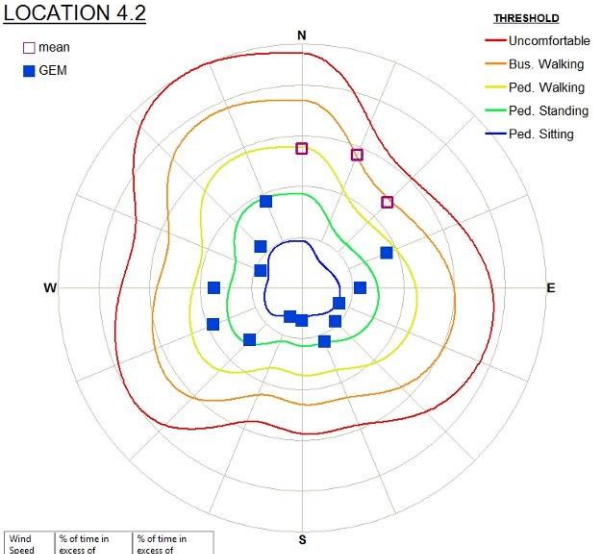
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	64.3	68.6
4.0	22.1	24.0
6.0	6.2	6.1
8.0	1.4	1.2
10.0	0.3	0.2
6.3	**5.0**	Ped Walking
13.7	**0.022**	Pass
6.2	Ped Walking	**5.0**
13.1	Pass	**0.022**

LOCATION 4.1



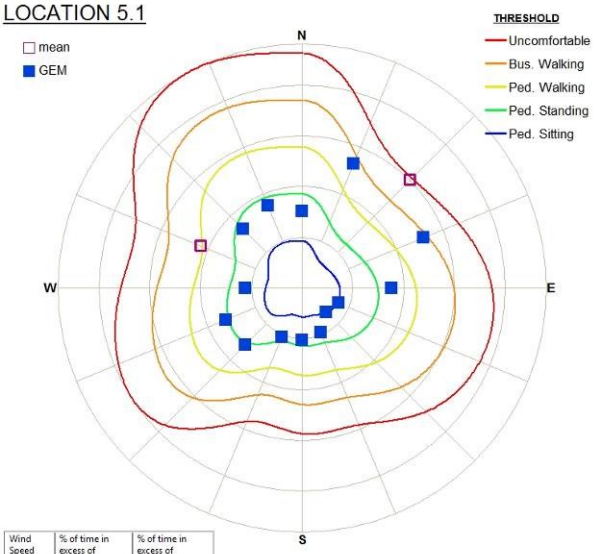
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	33.7	46.1
4.0	13.1	16.3
6.0	5.5	6.3
8.0	2.3	1.9
10.0	0.6	0.3
6.1	**5.0**	Ped Walking
13.7	**0.022**	Pass
6.4	Ped Walking	**5.0**
12.4	Pass	**0.022**

LOCATION 4.2



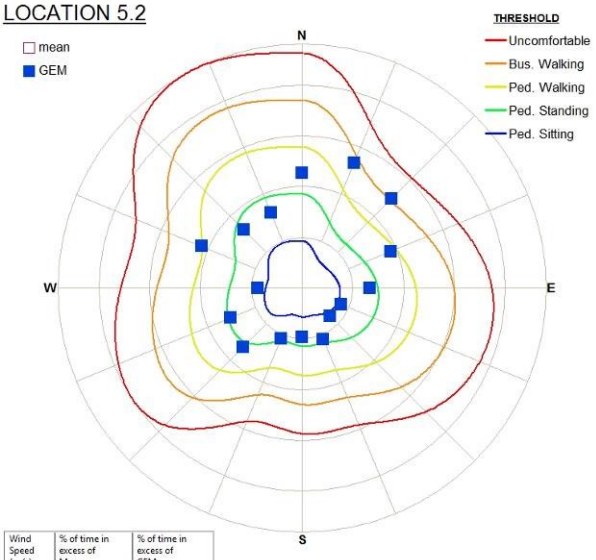
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	33.3	41.8
4.0	11.7	11.6
6.0	4.0	2.3
8.0	0.7	0.2
10.0	0.1	0.0
5.6	**5.0**	Ped Standing
10.5	**0.022**	Pass
5.1	Ped Standing	**5.0**
9.2	Pass	**0.022**

LOCATION 5.1



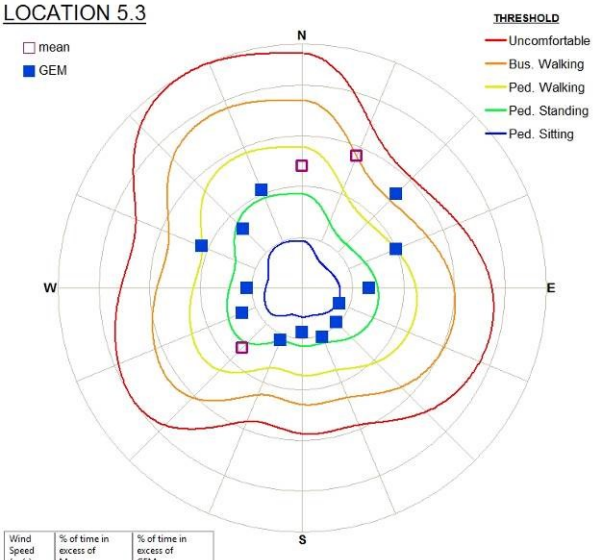
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	37.5	50.4
4.0	10.3	14.7
6.0	4.1	6.2
8.0	1.4	1.5
10.0	0.3	0.2
5.4	**5.0**	Ped Standing
12.5	**0.022**	Pass
6.3	Ped Walking	**5.0**
11.9	Pass	**0.022**

LOCATION 5.2



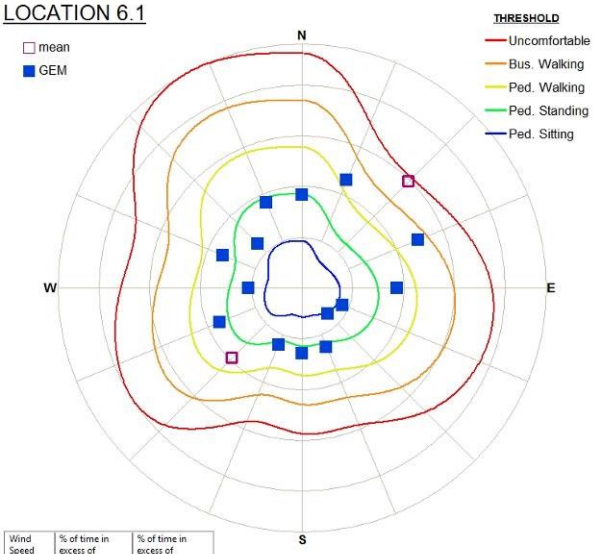
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	35.7	50.3
4.0	9.7	13.3
6.0	2.8	4.2
8.0	0.4	0.7
10.0	0.0	0.1
5.2	**5.0**	Ped Standing
9.7	**0.022**	Pass
5.7	Ped Standing	**5.0**
10.5	Pass	**0.022**

LOCATION 5.3



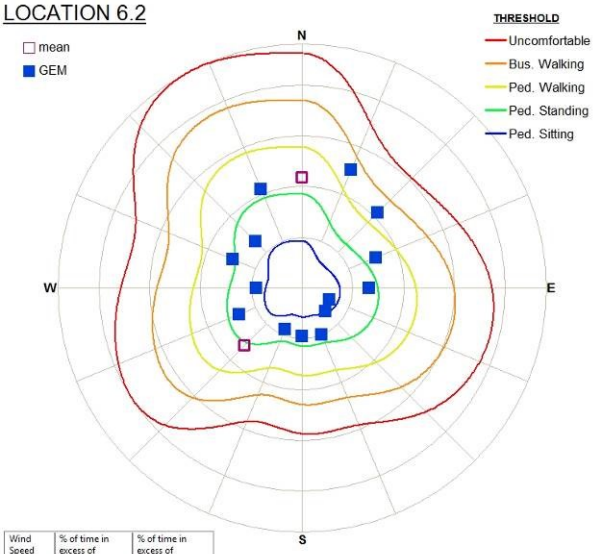
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	43.4	52.2
4.0	12.4	13.8
6.0	4.3	4.8
8.0	0.8	1.0
10.0	0.1	0.1
5.7	**5.0**	Ped Standing
10.6	**0.022**	Pass
5.9	Ped Standing	**5.0**
10.9	Pass	**0.022**

LOCATION 6.1



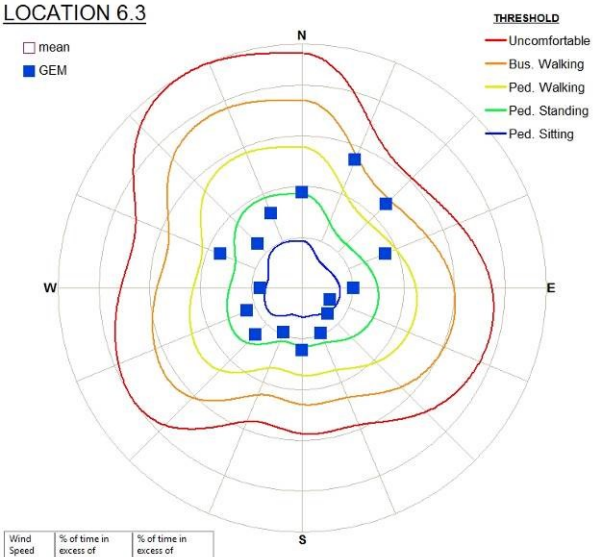
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	42.4	52.4
4.0	12.4	15.3
6.0	4.8	4.5
8.0	1.4	0.7
10.0	0.3	0.1
5.8	**5.0**	Ped Standing
12.3	**0.022**	Pass
5.8	Ped Standing	**5.0**
10.9	Pass	**0.022**

LOCATION 6.2



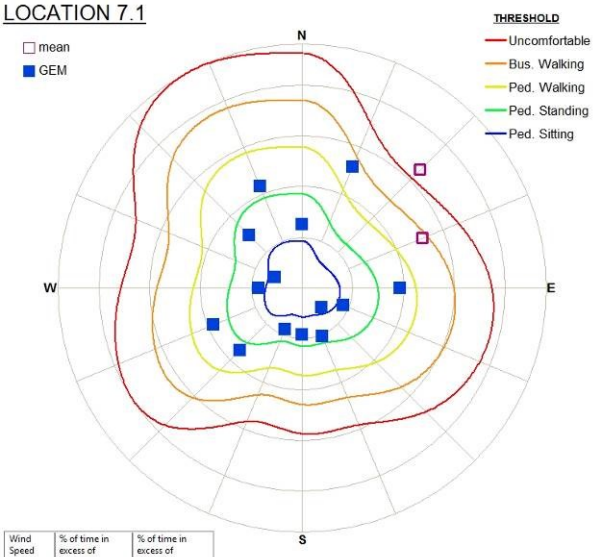
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	34.4	43.9
4.0	7.9	10.1
6.0	1.5	2.3
8.0	0.1	0.2
10.0	0.0	0.0
4.6	**5.0**	Ped Standing
9.1	**0.022**	Pass
5.0	Ped Standing	**5.0**
9.3	Pass	**0.022**

LOCATION 6.3



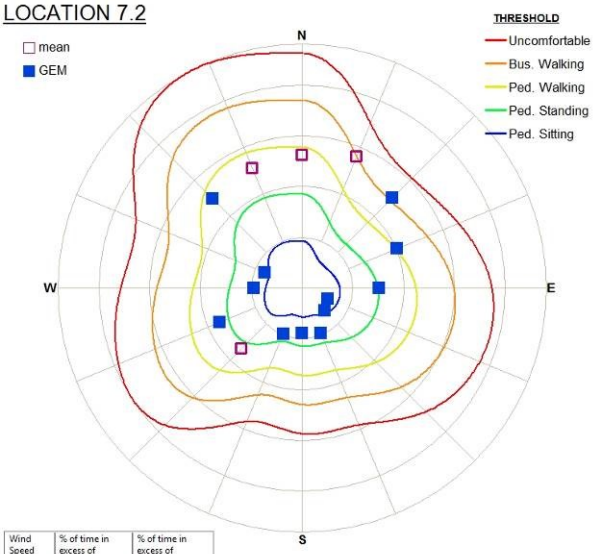
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	29.7	43.2
4.0	6.3	11.7
6.0	0.8	3.5
8.0	0.0	0.6
10.0	0.0	0.0
4.2	**5.0**	Ped Standing
8.0	**0.022**	Pass
5.4	Ped Standing	**5.0**
10.2	Pass	**0.022**

LOCATION 7.1



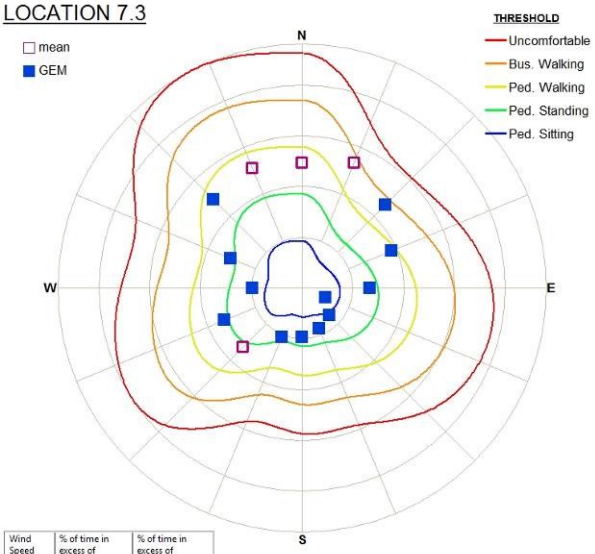
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	29.9	43.8
4.0	12.4	13.5
6.0	6.0	4.6
8.0	2.3	0.8
10.0	0.6	0.1
6.3	**5.0**	Ped Walking
13.6	**0.022**	Pass
5.8	Ped Standing	**5.0**
10.8	Pass	**0.022**

LOCATION 7.2



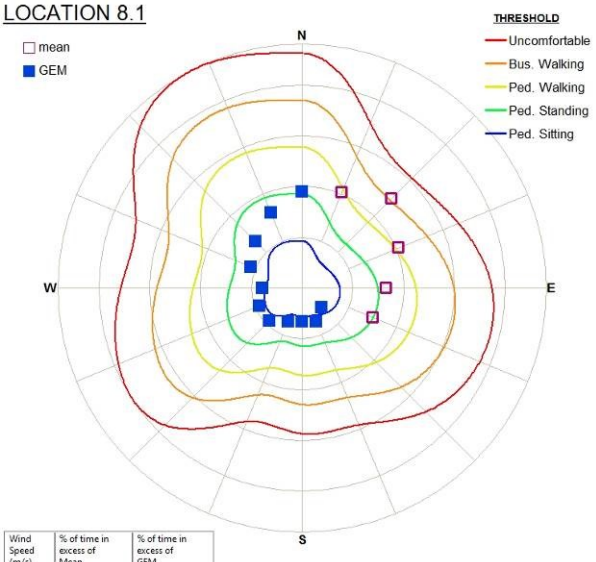
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	40.0	51.5
4.0	12.2	13.9
6.0	3.7	4.6
8.0	0.6	0.9
10.0	0.0	0.1
5.5	**5.0**	Ped Standing
10.4	**0.022**	Pass
5.8	Ped Standing	**5.0**
11.0	Pass	**0.022**

LOCATION 7.3



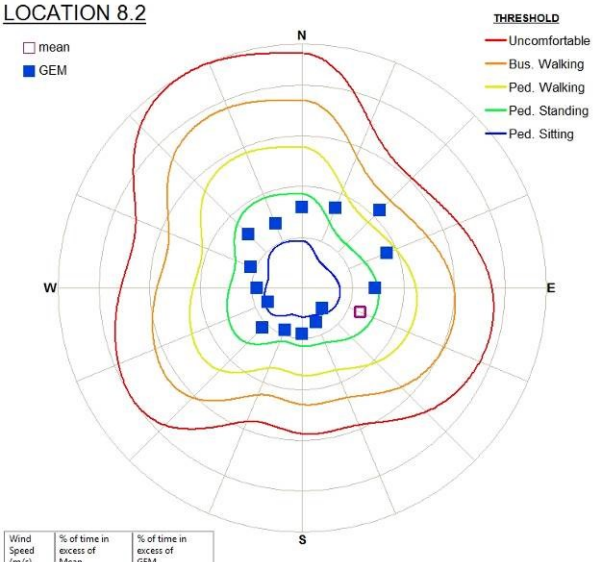
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	45.2	53.6
4.0	12.2	13.1
6.0	3.1	3.5
8.0	0.4	0.5
10.0	0.0	0.0
5.3	**5.0**	Ped Standing
10.1	**0.022**	Pass
5.5	Ped Standing	**5.0**
10.4	Pass	**0.022**

LOCATION 8.1



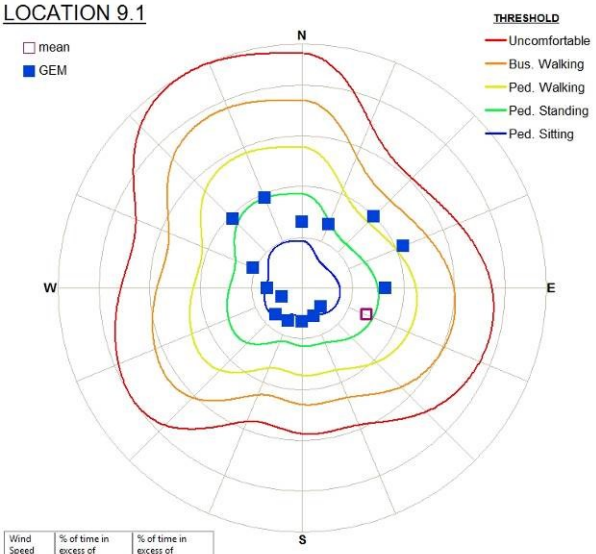
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	25.7	31.5
4.0	9.4	8.6
6.0	2.7	1.7
8.0	0.4	0.2
10.0	0.0	0.0
5.1	**5.0**	Ped Standing
10.3	**0.022**	Pass
4.7	Ped Standing	**5.0**
9.3	Pass	**0.022**

LOCATION 8.2



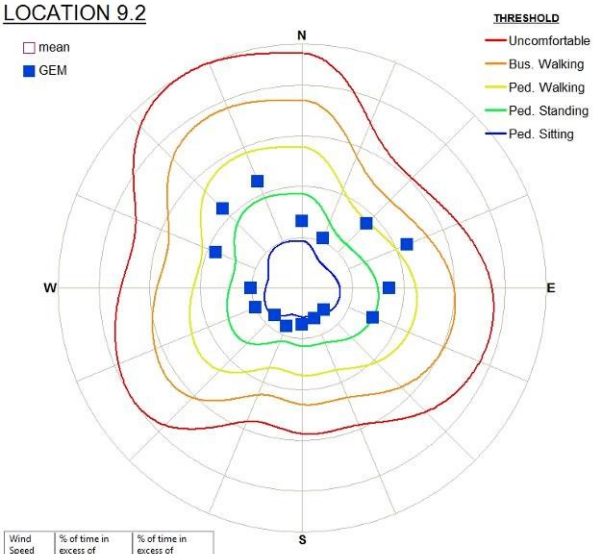
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	24.9	33.9
4.0	5.5	7.1
6.0	0.8	1.2
8.0	0.1	0.1
10.0	0.0	0.0
4.1	**5.0**	Ped Standing
8.4	**0.022**	Pass
4.4	Ped Standing	**5.0**
9.0	Pass	**0.022**

LOCATION 9.1



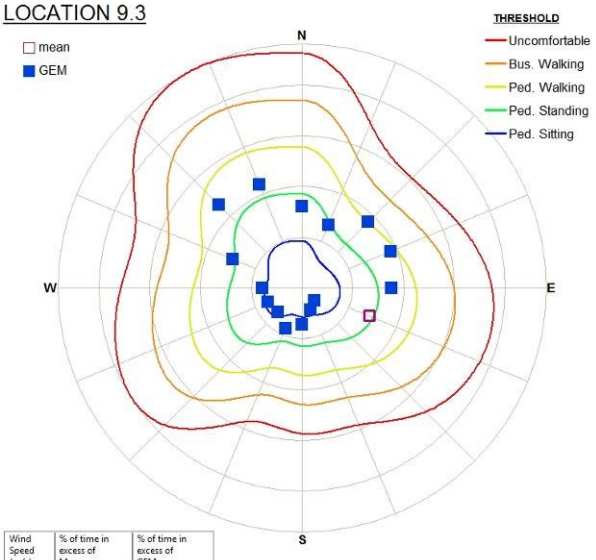
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	22.0	29.8
4.0	5.2	7.0
6.0	0.6	1.2
8.0	0.0	0.1
10.0	0.0	0.0
4.0	**5.0**	Ped Sitting
8.2	**0.022**	Pass
4.4	Ped Standing	**5.0**
8.7	Pass	**0.022**

LOCATION 9.2



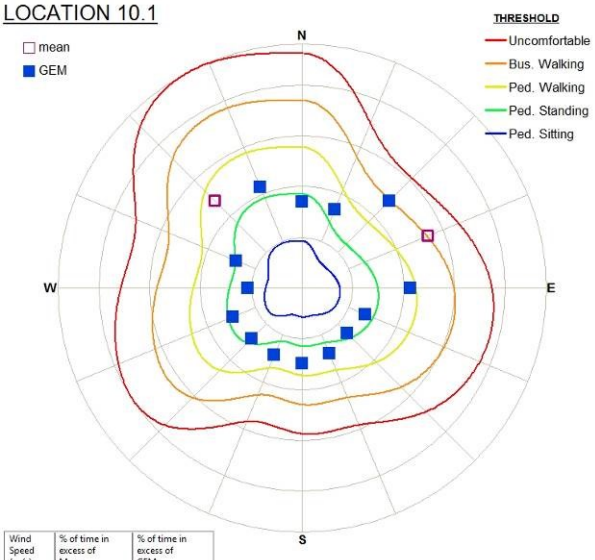
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	23.0	38.5
4.0	3.4	7.7
6.0	0.2	1.3
8.0	0.0	0.1
10.0	0.0	0.0
3.6	**5.0**	Ped Sitting
8.0	**0.022**	Pass
4.5	Ped Standing	**5.0**
9.2	Pass	**0.022**

LOCATION 9.3



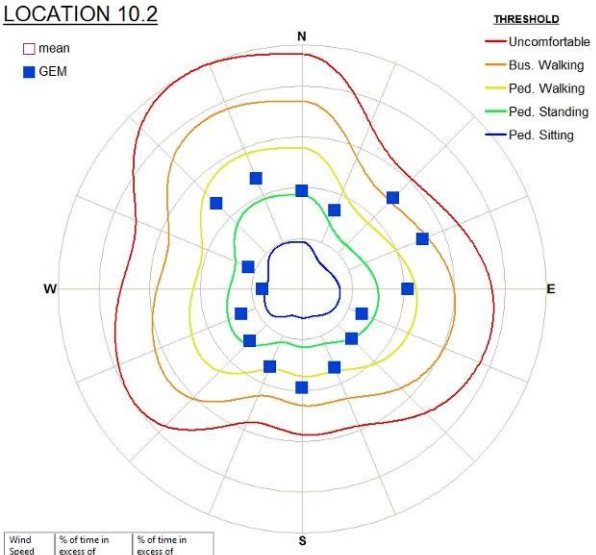
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.4	36.9
4.0	3.9	7.3
6.0	0.3	0.9
8.0	0.0	0.1
10.0	0.0	0.0
3.7	**5.0**	Ped Sitting
8.8	**0.022**	Pass
4.4	Ped Standing	**5.0**
9.3	Pass	**0.022**

LOCATION 10.1



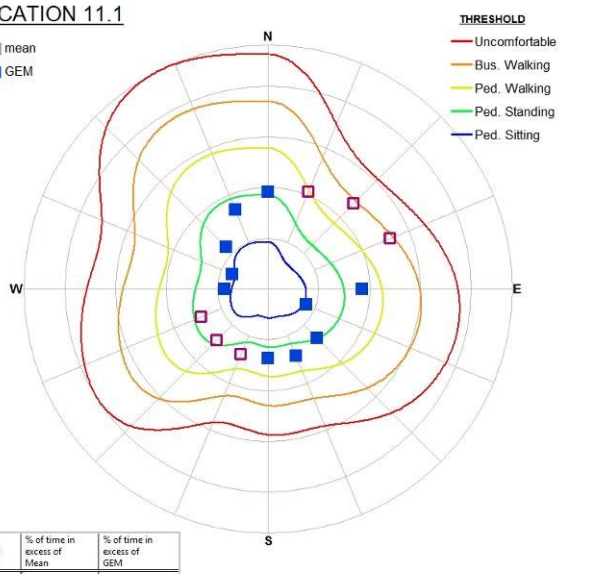
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	45.6	61.6
4.0	10.4	15.9
6.0	3.4	4.0
8.0	0.6	0.6
10.0	0.0	0.1
5.3	**5.0**	Ped Standing
10.5	**0.022**	Pass
5.6	Ped Standing	**5.0**
10.7	Pass	**0.022**

LOCATION 10.2



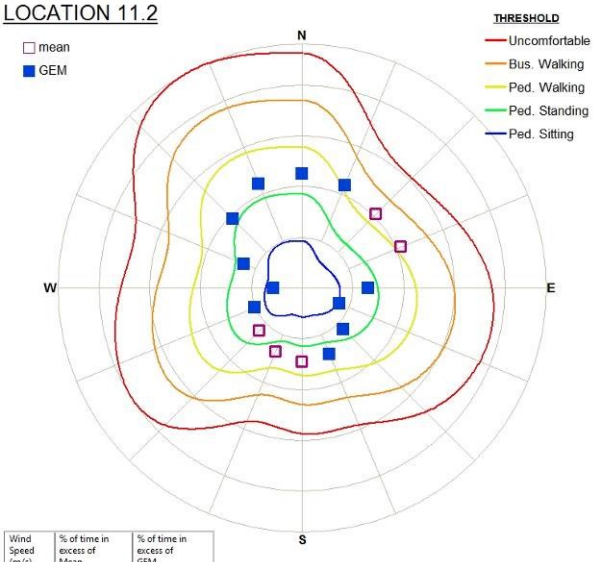
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	51.7	62.9
4.0	13.8	20.9
6.0	3.3	5.5
8.0	0.4	0.8
10.0	0.0	0.1
5.4	**5.0**	Ped Standing
10.3	**0.022**	Pass
6.1	Ped Walking	**5.0**
11.0	Pass	**0.022**

LOCATION 11.1



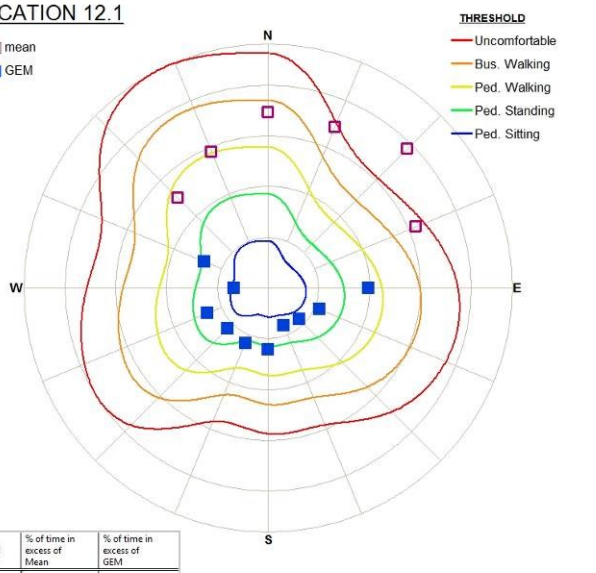
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	45.0	49.8
4.0	12.5	13.0
6.0	3.4	2.1
8.0	0.4	0.1
10.0	0.0	0.0
5.4	**5.0**	Ped Standing
10.1	**0.022**	Pass
5.1	Ped Standing	**5.0**
9.0	Pass	**0.022**

LOCATION 11.2



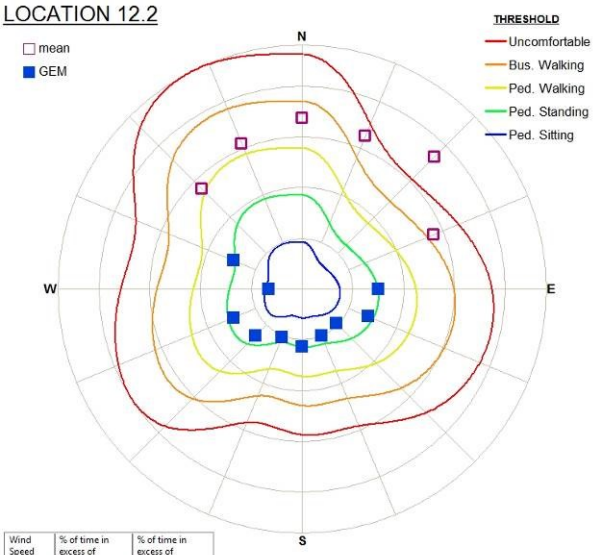
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	46.1	52.8
4.0	12.3	12.8
6.0	1.8	1.7
8.0	0.1	0.1
10.0	0.0	0.0
5.0	**5.0**	Ped Standing
8.8	**0.022**	Pass
5.0	Ped Standing	**5.0**
8.8	Pass	**0.022**

LOCATION 12.1



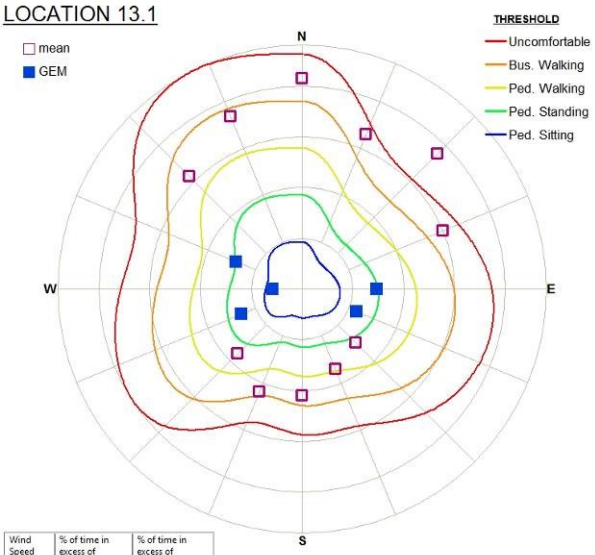
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	51.6	56.4
4.0	18.9	17.4
6.0	11.0	7.6
8.0	5.6	2.6
10.0	2.1	0.6
8.2	**5.0**	Bus Walking
16.1	**0.022**	Able Body
6.8	Ped Walking	**5.0**
13.6	Pass	**0.022**

LOCATION 12.2



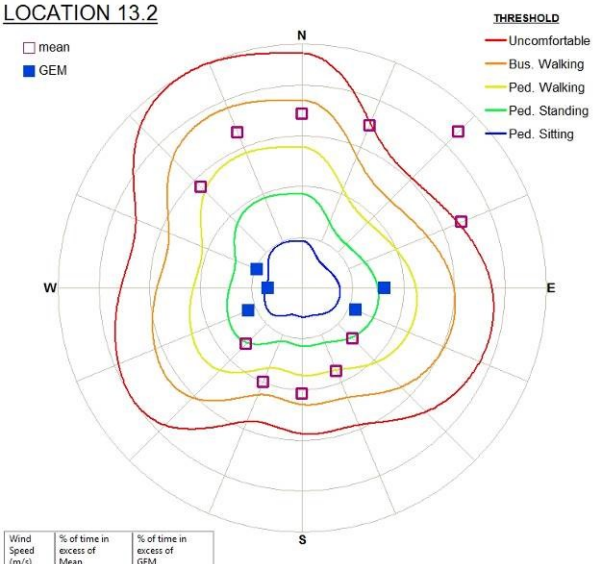
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	52.6	58.9
4.0	18.8	15.7
6.0	10.3	6.0
8.0	4.6	1.7
10.0	1.6	0.3
7.7	**5.0**	Ped Walking
15.3	**0.022**	Able Body
6.3	Ped Walking	**5.0**
12.5	Pass	**0.022**

LOCATION 13.1



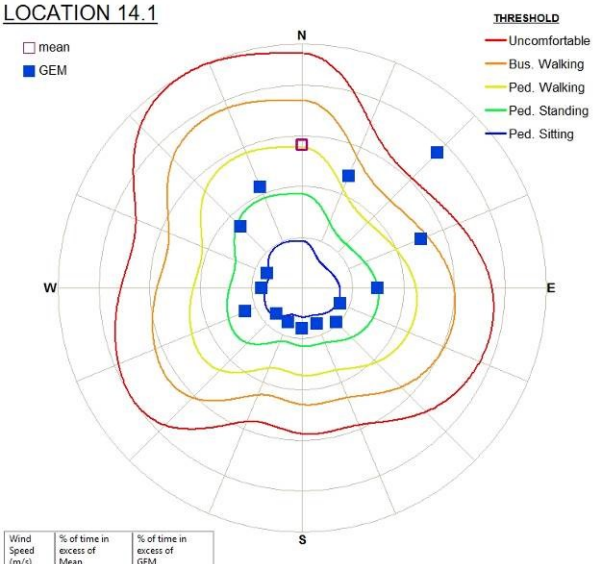
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	69.9	67.9
4.0	34.4	24.7
6.0	15.0	8.3
8.0	6.2	2.4
10.0	2.1	0.5
8.3	**5.0**	Bus Walking
15.8	**0.022**	Able Body
6.8	Ped Walking	**5.0**
13.2	Pass	**0.022**

LOCATION 13.2



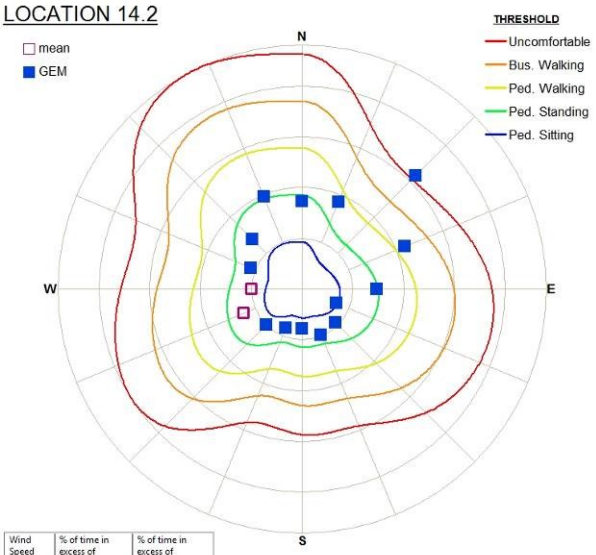
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	67.7	65.2
4.0	32.1	23.9
6.0	14.8	9.3
8.0	7.1	3.5
10.0	3.2	1.0
8.8	**5.0**	Bus Walking
18.1	**0.022**	Able Body
7.2	Ped Walking	**5.0**
14.4	Pass	**0.022**

LOCATION 14.1



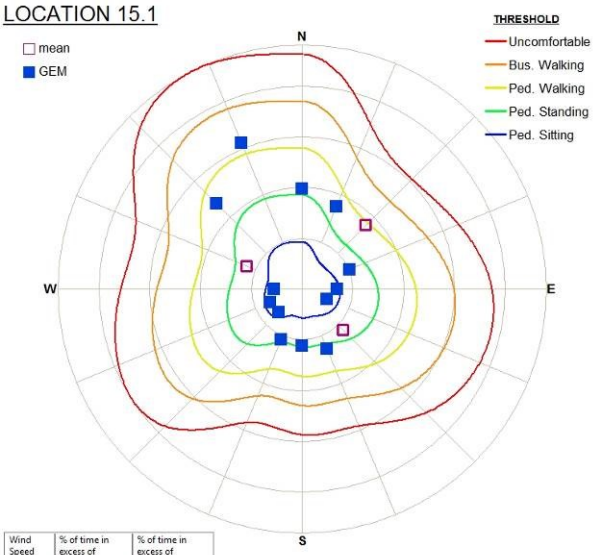
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	27.9	41.1
4.0	11.7	14.1
6.0	5.2	6.8
8.0	2.4	3.3
10.0	0.8	1.4
6.0	**5.0**	Ped Standing
14.2	**0.022**	Pass
6.7	Ped Walking	**5.0**
15.6	Able Body	**0.022**

LOCATION 14.2



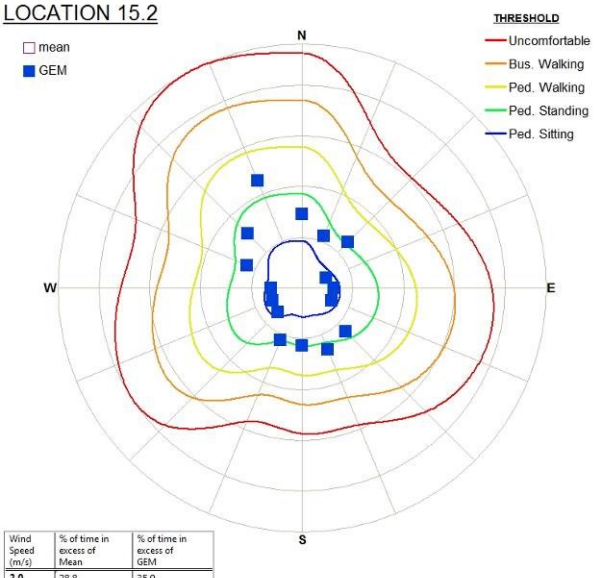
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	28.0	39.2
4.0	8.6	10.2
6.0	3.8	4.3
8.0	1.5	1.8
10.0	0.3	0.5
5.2	**5.0**	Ped Standing
12.6	**0.022**	Pass
5.5	Ped Standing	**5.0**
13.1	Pass	**0.022**

LOCATION 15.1



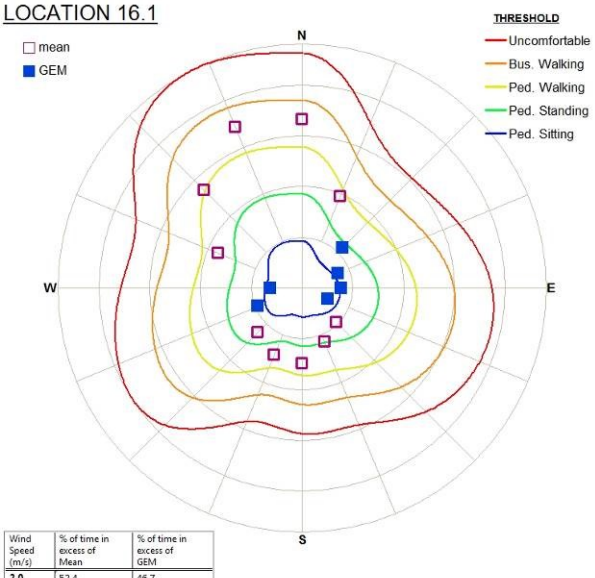
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	37.1	47.2
4.0	4.9	8.2
6.0	0.7	1.1
8.0	0.1	0.2
10.0	0.0	0.0
4.0	**5.0**	Ped Sitting
9.1	**0.022**	Pass
4.5	Ped Standing	**5.0**
10.8	Pass	**0.022**

LOCATION 15.2



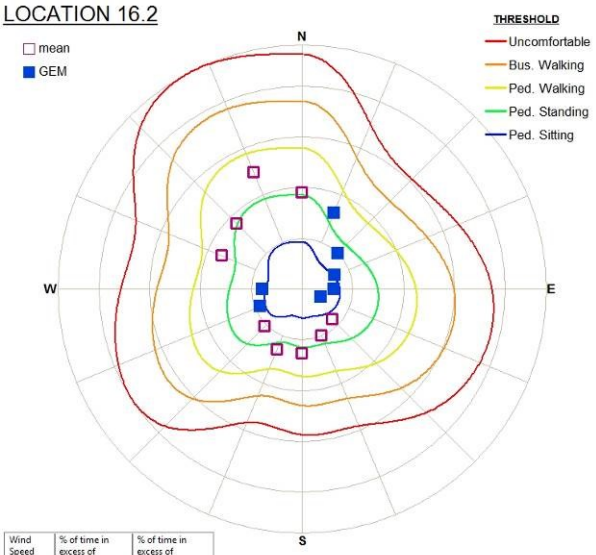
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	28.8	35.0
4.0	1.8	3.1
6.0	0.1	0.2
8.0	0.0	0.0
10.0	0.0	0.0
3.4	**5.0**	Ped Sitting
6.8	**0.022**	Pass
3.6	Ped Sitting	**5.0**
7.7	Pass	**0.022**

LOCATION 16.1



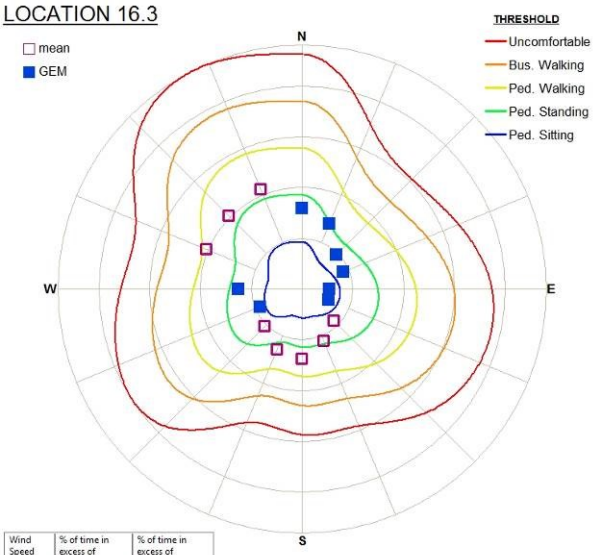
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	52.4	46.7
4.0	12.2	7.3
6.0	2.4	1.3
8.0	0.5	0.2
10.0	0.1	0.1
5.0	**5.0**	Ped Standing
12.1	**0.022**	Pass
4.4	Ped Standing	**5.0**
10.9	Pass	**0.022**

LOCATION 16.2



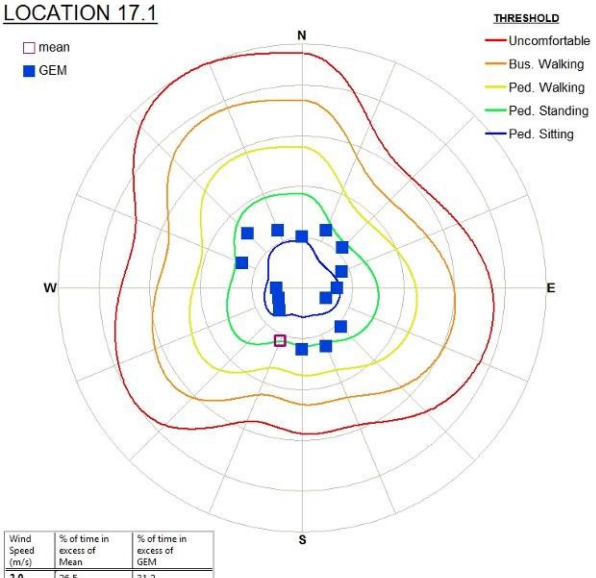
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	36.4	36.0
4.0	4.4	3.3
6.0	0.5	0.3
8.0	0.0	0.0
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
8.6	**0.022**	Pass
3.6	Ped Sitting	**5.0**
8.0	Pass	**0.022**

LOCATION 16.3



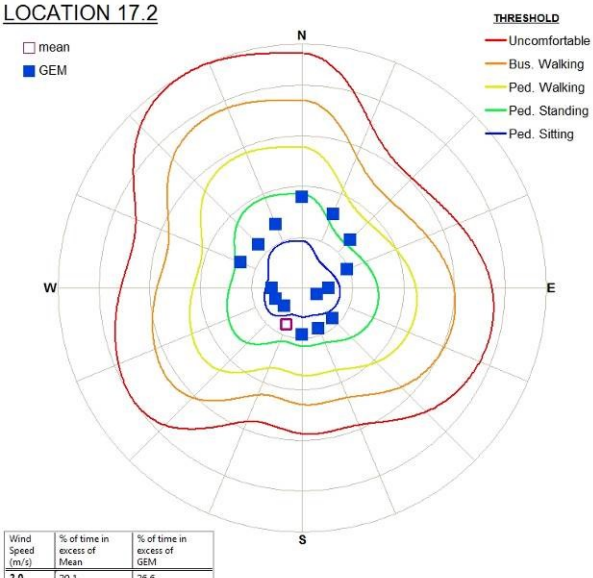
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	39.2	40.9
4.0	4.8	3.4
6.0	0.6	0.4
8.0	0.1	0.0
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
8.9	**0.022**	Pass
3.7	Ped Sitting	**5.0**
8.2	Pass	**0.022**

LOCATION 17.1



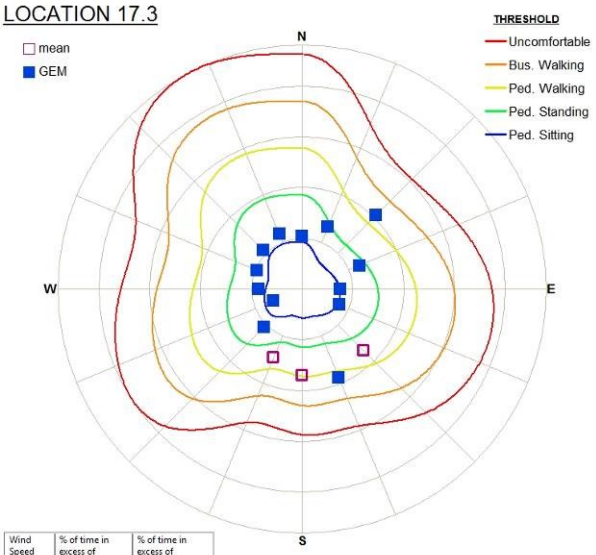
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.5	31.2
4.0	1.4	2.3
6.0	0.0	0.1
8.0	0.0	0.0
10.0	0.0	0.0
3.3	**5.0**	Ped Sitting
6.2	**0.022**	Pass
3.5	Ped Sitting	**5.0**
6.7	Pass	**0.022**

LOCATION 17.2



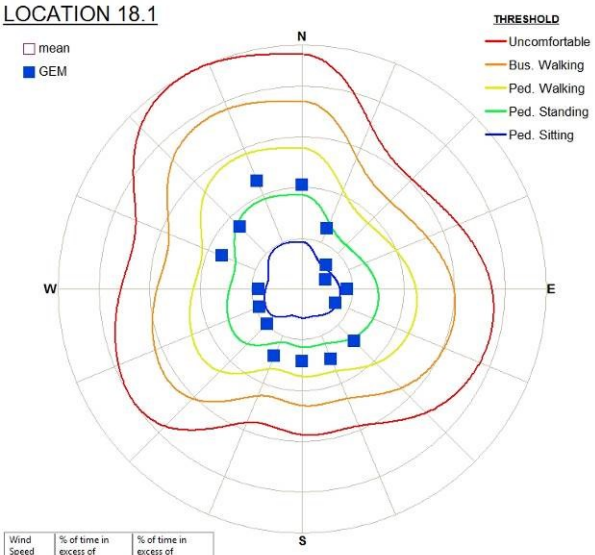
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	20.1	26.6
4.0	1.1	2.2
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
3.1	**5.0**	Ped Sitting
5.5	**0.022**	Pass
3.4	Ped Sitting	**5.0**
6.2	Pass	**0.022**

LOCATION 17.3



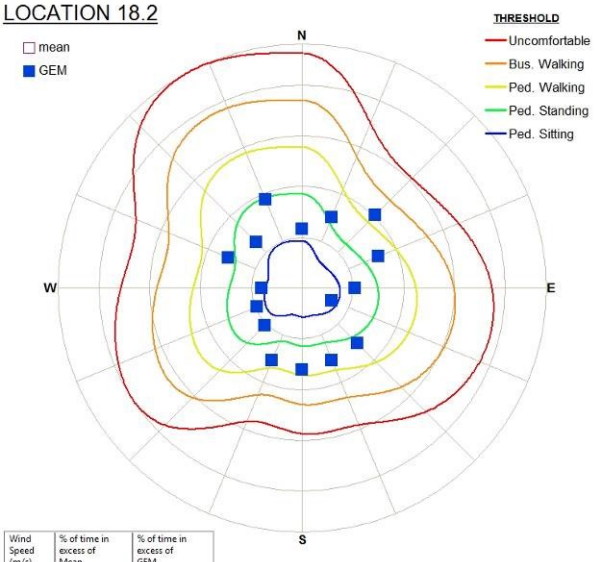
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	34.4	40.9
4.0	10.7	12.2
6.0	1.1	1.8
8.0	0.1	0.2
10.0	0.0	0.0
4.7	**5.0**	Ped Standing
8.8	**0.022**	Pass
5.0	Ped Standing	**5.0**
9.3	Pass	**0.022**

LOCATION 18.1



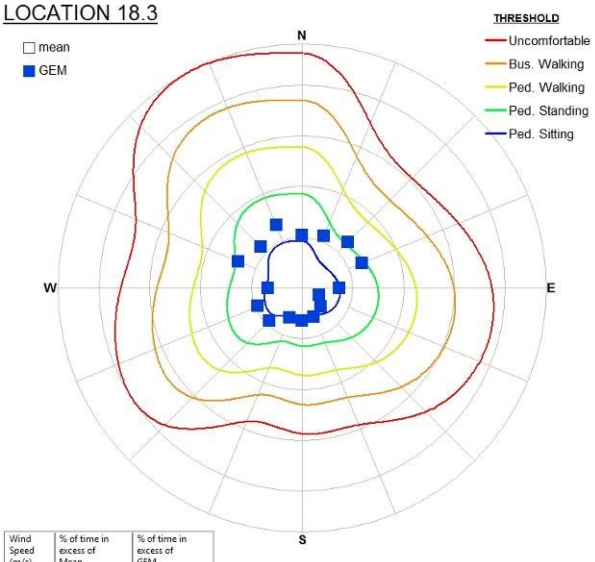
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	31.2	42.8
4.0	3.1	7.0
6.0	0.2	0.6
8.0	0.0	0.0
10.0	0.0	0.0
3.6	**5.0**	Ped Sitting
7.4	**0.022**	Pass
4.2	Ped Standing	**5.0**
8.3	Pass	**0.022**

LOCATION 18.2



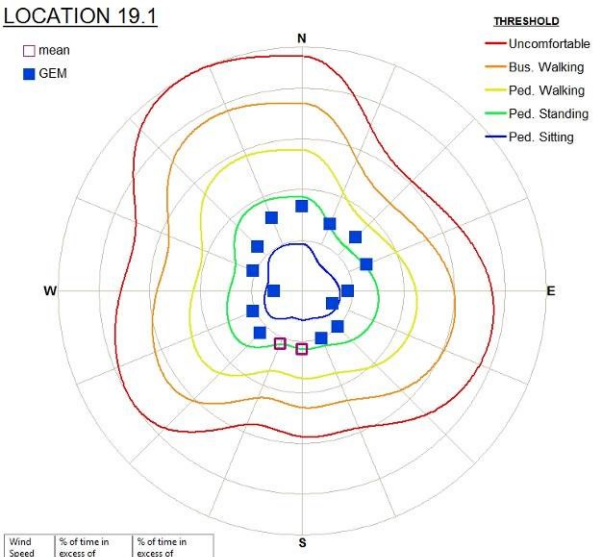
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	36.0	47.0
4.0	6.9	12.6
6.0	0.7	1.5
8.0	0.0	0.1
10.0	0.0	0.0
4.3	**5.0**	Ped Standing
8.0	**0.022**	Pass
4.9	Ped Standing	**5.0**
8.8	Pass	**0.022**

LOCATION 18.3



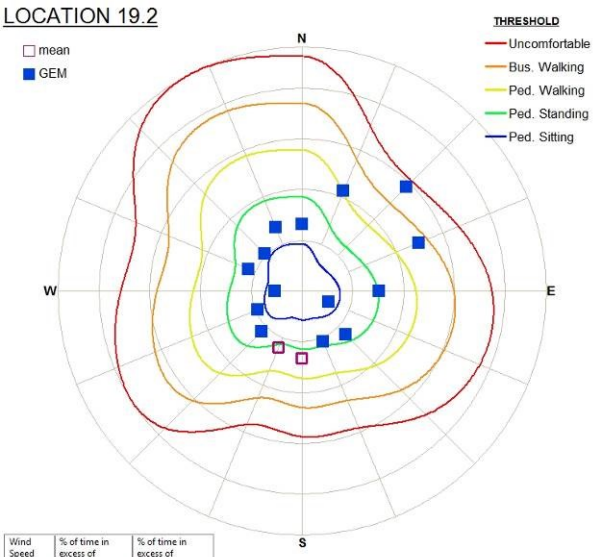
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	10.1	18.0
4.0	0.3	1.1
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
2.5	**5.0**	Ped Sitting
4.8	**0.022**	Pass
3.1	Ped Sitting	**5.0**
5.8	Pass	**0.022**

LOCATION 19.1



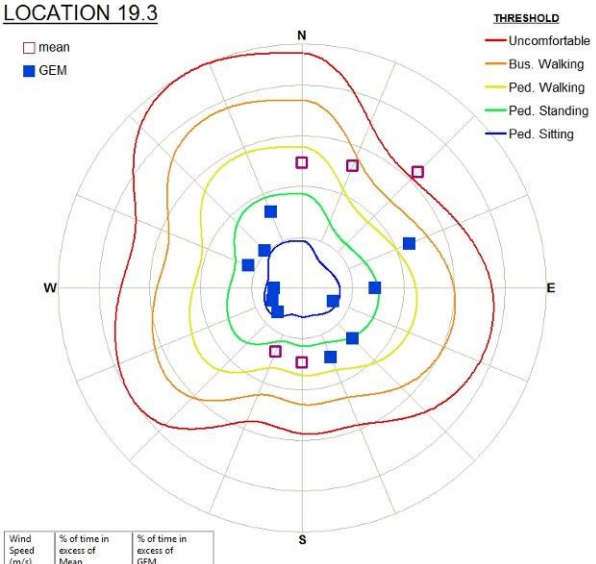
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	29.7	35.4
4.0	1.9	2.9
6.0	0.0	0.1
8.0	0.0	0.0
10.0	0.0	0.0
3.4	**5.0**	Ped Sitting
6.1	**0.022**	Pass
3.7	Ped Sitting	**5.0**
6.3	Pass	**0.022**

LOCATION 19.2



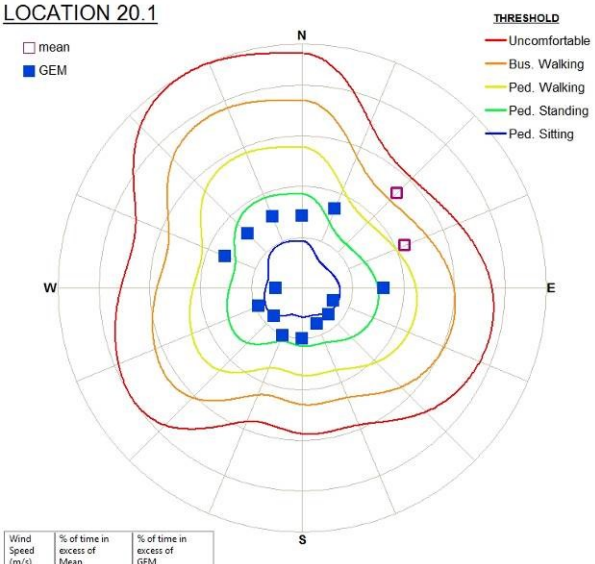
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	36.9	42.2
4.0	9.2	11.6
6.0	2.3	4.6
8.0	0.4	1.2
10.0	0.0	0.2
4.8	**5.0**	Ped Standing
10.2	**0.022**	Pass
5.7	Ped Standing	**5.0**
12.0	Pass	**0.022**

LOCATION 19.3



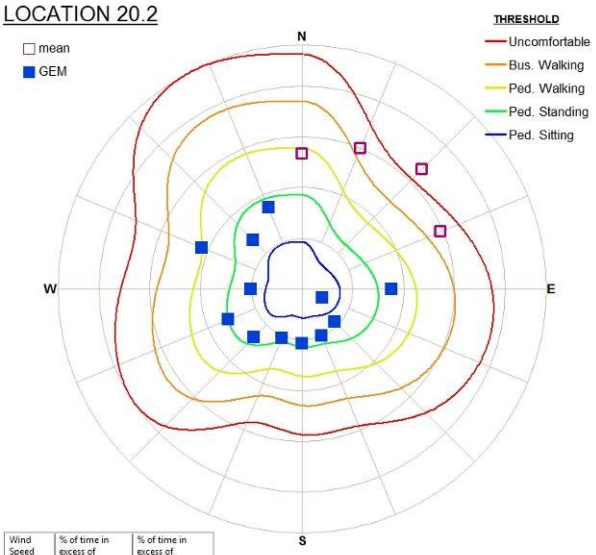
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	45.0	47.8
4.0	16.0	15.7
6.0	5.9	5.0
8.0	2.1	1.2
10.0	0.6	0.2
6.2	**5.0**	Ped Walking
13.4	**0.022**	Pass
5.9	Ped Standing	**5.0**
12.0	Pass	**0.022**

LOCATION 20.1



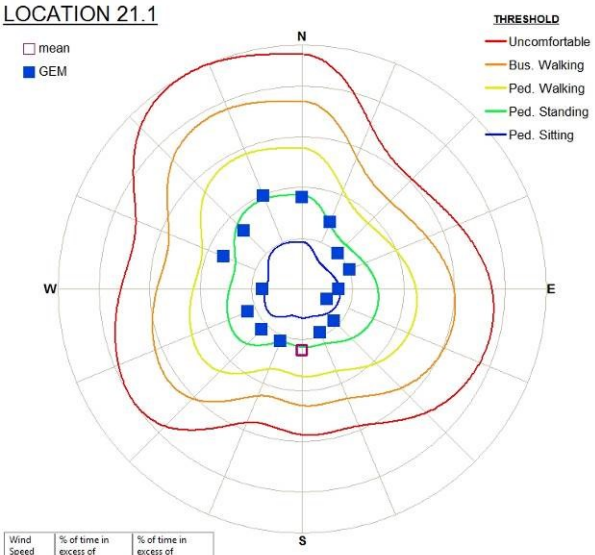
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.7	36.5
4.0	7.5	8.7
6.0	3.1	2.3
8.0	0.6	0.4
10.0	0.1	0.0
5.0	**5.0**	Ped Standing
11.0	**0.022**	Pass
4.8	Ped Standing	**5.0**
10.2	Pass	**0.022**

LOCATION 20.2



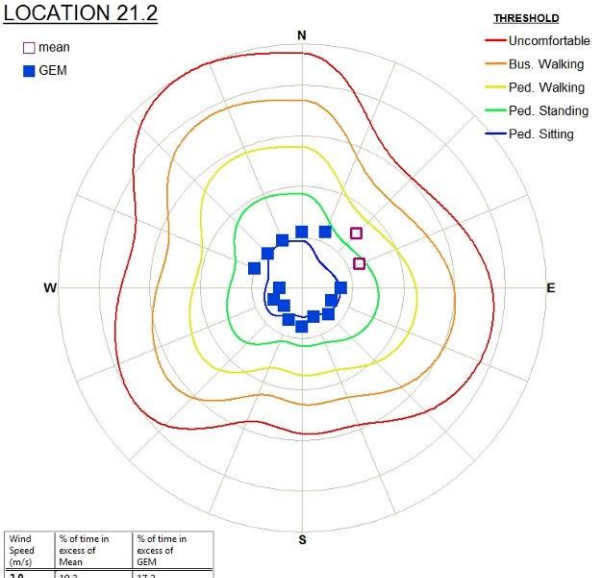
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	45.4	51.3
4.0	15.9	14.3
6.0	8.3	5.2
8.0	3.3	1.0
10.0	0.8	0.1
7.1	**5.0**	Ped Walking
13.8	**0.022**	Pass
6.0	Ped Standing	**5.0**
11.2	Pass	**0.022**

LOCATION 21.1



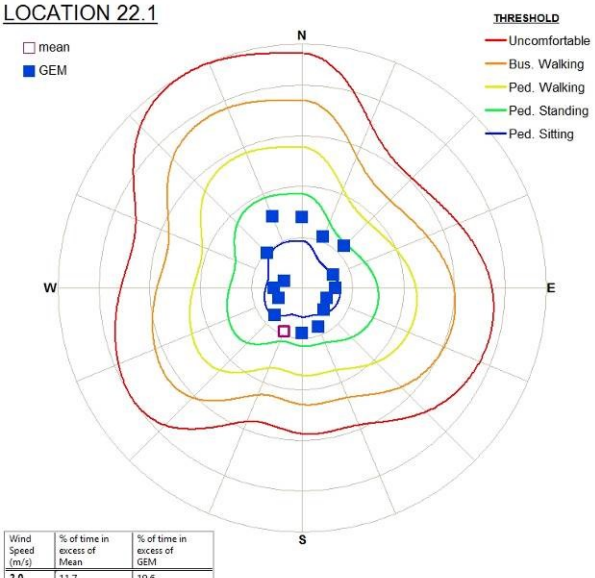
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	24.0	38.7
4.0	1.2	3.1
6.0	0.0	0.2
8.0	0.0	0.0
10.0	0.0	0.0
3.1	**5.0**	Ped Sitting
6.1	**0.022**	Pass
3.6	Ped Sitting	**5.0**
7.3	Pass	**0.022**

LOCATION 21.2



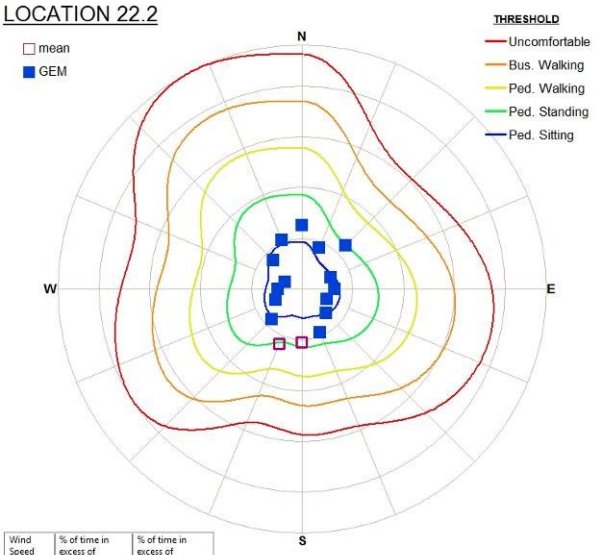
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	10.3	17.2
4.0	1.5	0.9
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
2.8	**5.0**	Ped Sitting
6.2	**0.022**	Pass
3.0	Ped Sitting	**5.0**
5.7	Pass	**0.022**

LOCATION 22.1



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	11.7	19.6
4.0	0.1	0.6
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
2.5	**5.0**	Ped Sitting
4.8	**0.022**	Pass
2.9	Ped Sitting	**5.0**
5.3	Pass	**0.022**

LOCATION 22.2



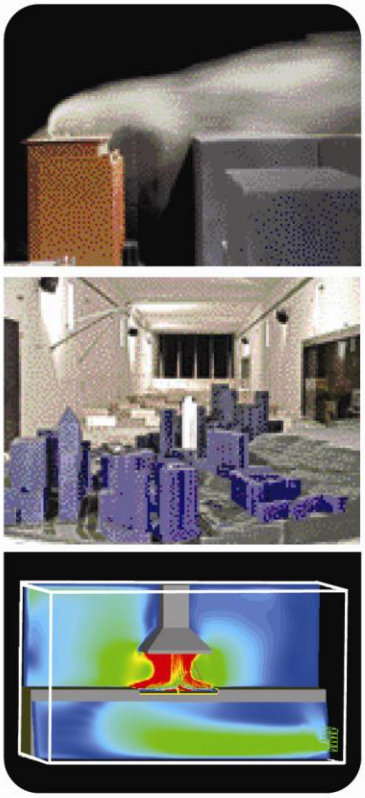
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	16.0	20.6
4.0	0.7	0.8
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
2.9	**5.0**	Ped Sitting
5.9	**0.022**	Pass
3.0	Ped Sitting	**5.0**
5.6	Pass	**0.022**

Appendix 3: Wind Opinion Assessment for 182 George Street and 33-35 Pitt Street Sydney, Australia. CPP Project Number 7282, August 2013.

CERMAK
PETERKA
PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

FINAL REPORT



Wind Assessment for:

182 GEORGE STREET AND 33-35 PITT STREET

Sydney, Australia

Prepared for:

Lend Lease Development Pty. Limited

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NSW 2000

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August 2013

CPP Project: 7282

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Introduction

Cermak Peterka Petersen Pty. Ltd. has been engaged by Lend Lease Development Pty. Limited to provide an opinion based assessment of the impact of the proposed development at 33-35 Pitt Street, Sydney, on the pedestrian level local wind environment in and around the proposed development.

The site is located on the northern side of Sydney CBD surrounded by similarly sized medium to high rise buildings, Figure 1.

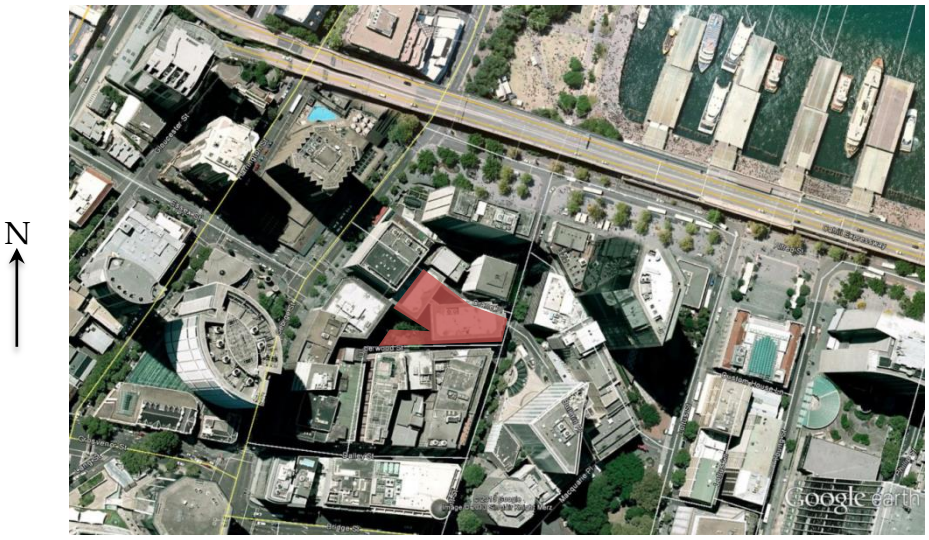

Figure 1 Location of the proposed development (Google, 2009)

Sydney Wind Climate

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 at Sydney Airport from 1995 to 2011 have been used in this analysis, Figure 2. It is noted from Figure 2 that strong prevailing winds are organised into three main groups which centre at about north-east, south, and west. This wind assessment is focused on these prevailing strong wind directions.

Summer winds occur mainly from the south quadrant and the north-east. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk.

Winter and early spring winds occur mainly from the south and west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year.

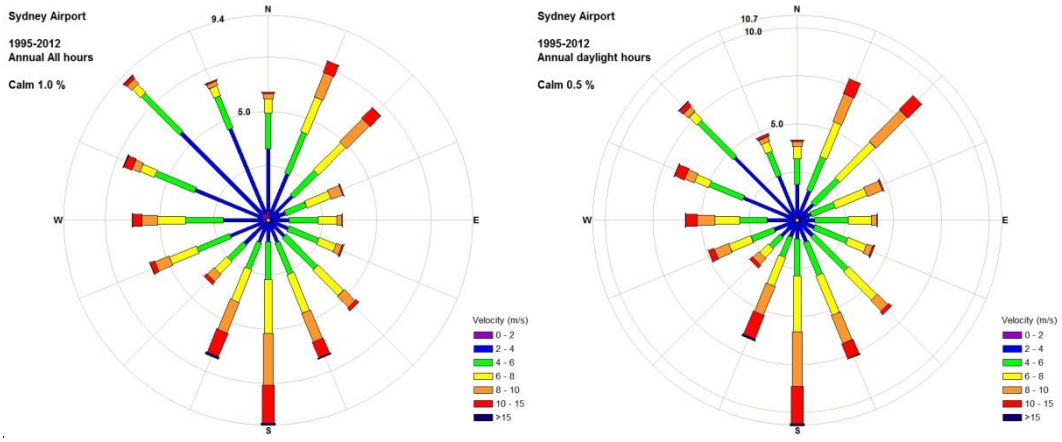

Figure 2: Wind rose of direction and speed for Sydney Airport: all hours (L), daylight hours (R)

Wind Flow Mechanisms

When the wind hits a large isolated building, the wind is accelerated down and around the windward corners, Figure 3; this flow mechanism is called downwash and causes the windiest conditions at ground level on the windward and sides of the building. In Figure 3 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 deeper the horizontal element generally 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.

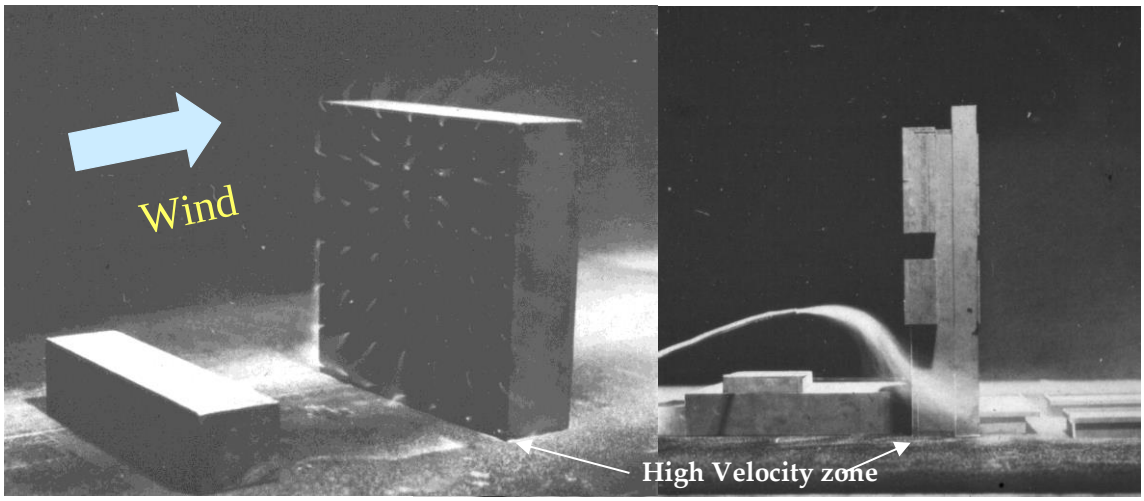

Figure 3: Flow visualisation around a tall building

Environmental Wind Speed Criteria

It is generally accepted that wind speed and the rate of change of wind velocity are the primary parameters that should be used in the assessment of how wind affects pedestrians. Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. Because pedestrians will tolerate higher wind speeds for a smaller period of time than for lower wind speeds, these criteria provide a means of evaluating the overall acceptability of a pedestrian location. A location can further be evaluated for its intended use, such as for an outdoor café or a footpath.

The current City of Sydney (2012) DCP specifies wind effects not to exceed 10 m/s, as the area around the site is classified as an 'active frontage'. From discussions with Council this is a once per annum gust wind speed similar to the City of Sydney 2004 DCP, but is meant to be interpreted as a comfort level criterion to promote outdoor café style activities and is not intended to be used as a distress requirement. The once per annum gust wind speed criterion used in the City of Sydney (2012) DCP is based on the work of Melbourne (1978), and the 10 m/s level is classified as generally acceptable for use as generally acceptable for pedestrian sitting. This criteria gives the once per annum wind speed, and uses this as an estimator of the general conditions at a site, which may be more relevant. To combat this limitation, as well as the once per annum maximum gust wind speed, this study is based upon the criteria of Lawson (1990), which are described in Table 1 for both pedestrian comfort and distress. The limiting criteria are defined for both a mean and gust equivalent mean (GEM) wind speed. The criteria based on the mean wind speeds define

when the steady component of the wind causes discomfort, whereas the GEM wind speeds define when the wind gusts cause discomfort.

Assessment using the Lawson criteria provides a similar classification as using the once per annum gust, which is the basis of the City of Sydney (2011) DCP, however also provides information regarding the serviceability wind climate.

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

The wind speed is either a mean wind speed or a gust equivalent mean (GEM) wind speed. The GEM wind speed is equal to the 3 s gust wind speed divided by 1.85.

Table 1: Pedestrian comfort criteria for various activities

Environmental Wind Assessment

The proposed development is situated centrally to the east of the block bounded by Alfred, Pitt, Dalley, and George Streets, Sydney, Figure 1 and Figure 4. There are several existing through-site links that connect George, Underwood, and Pitt Streets, which are typically small laneways intended for vehicular access, cafés, and retail use. It is understood that the main entrances to the proposed commercial office tower development will be from the Public Plaza and Pitt Street through revolving doors.

The proposed commercial office tower has frontage of approximately 70 m on Underwood Street and 17 m on Pitt St, Figure 4. The proposed development consists of an essentially prismatic tower with flattened V-shape plan form rising approximately 200 m above Underwood Street level, and an open “Public Plaza” in the centre and to the west of the block. This Plaza will be created by the demolition of the St George Building at 182 George Street, to the north of a current redevelopment of 200 George Street by Mirvac (DA 2012/893). The proposed tower has an articulated Underwood Street façade with minimal setback. There are podiums proposed on the east and west sides of the commercial office tower, which are to rise up to a maximum of approximately 45 m above the Underwood Street level. The eastern podium creates a maximum setback of up to 8 m along Pitt Street.

This podium wraps around the northern side of the tower and is proposed to provide only a minor setback along the northern laneway to the Plaza from Pitt Street.

The proposed development is surrounded by many medium- to high-rise buildings, including the dominant Grosvenor Place, NAB House, Goldfields House, Gateway Plaza, SunCorp Tower, Four Seasons Hotel, Shangri-La Hotel, Macquarie Bank, and Australia Square. There are two other approved developments on the same block. To the west is 200 George Street (DA 2012/893), currently under construction, which will be approximately 150 m tall. To the north of the site, a proposed tower to replace Goldfields House at One Alfred Street (DA 2010/2029) is expected to rise to 185 m with a smaller building to the north-east rising to 57 m. The effect of the One Alfred Street development is to increase the exposure of the current site to winds from the north-east. Another potential development is that of the Farifax Site (D/2010/1533) to the immediate north of the site with a building rising to a maximum of 110 m above ground level. Topography surrounding the site is relatively flat in the north-south direction, but drops significantly down Essex Street from west to east, and there is an approximate drop of 4.5 m from George Street to Pitt Street.

Winds in such a complex cityscape tend to be channelled along the streets with local effects being dictated by exposed large building and local topography. This is known to be true of this area of the city where winds from the west are brought to ground level in the form of downwash by the large buildings along and to the west of George Street with some protection from the slope down Essex Street and the high-rise buildings particularly Grosvenor Place and Gateway Plaza. In this redevelopment location at 182 George and 33-35 Pitt Street, winds from the west are generally shielded by upstream buildings and topography, and winds from the south are currently channelled along George Street and Pitt Street with reduced flow through the block due to the misaligned nature of the Laneway pattern resulting in a relatively benign wind environment in the laneways compared with other parts of the Sydney CBD. With the proposed commercial office tower being embedded in such complex flow and having a similar massing, albeit taller than the existing building in the immediate vicinity of the site, the local wind conditions around the site are expected to be generally similar to existing with the exception of certain locations under the action of winds from the north-east, which are discussed later in this report.

Existing wind conditions around the site are known to be windy, and would be expected to be classified for ‘pedestrian standing’ and pass the distress criterion. It is considered unlikely that the existing wind conditions would meet the City of Sydney DCP

requirements for the once per annum maximum gust to not exceed 10 m/s. The area would be useable for pedestrian sitting activities for at least 80% of the time.

From a wind engineering perspective, the main architectural differences between the proposed commercial office tower and existing buildings is the additional approximately120 m in height, the elongation of the building to the west, and the removal of 182 George Street. The potential Fairfax (D/2010/1533) building development (110 m) will have minimal impact on the local wind environment, which will be dictated by the larger neighbouring buildings.

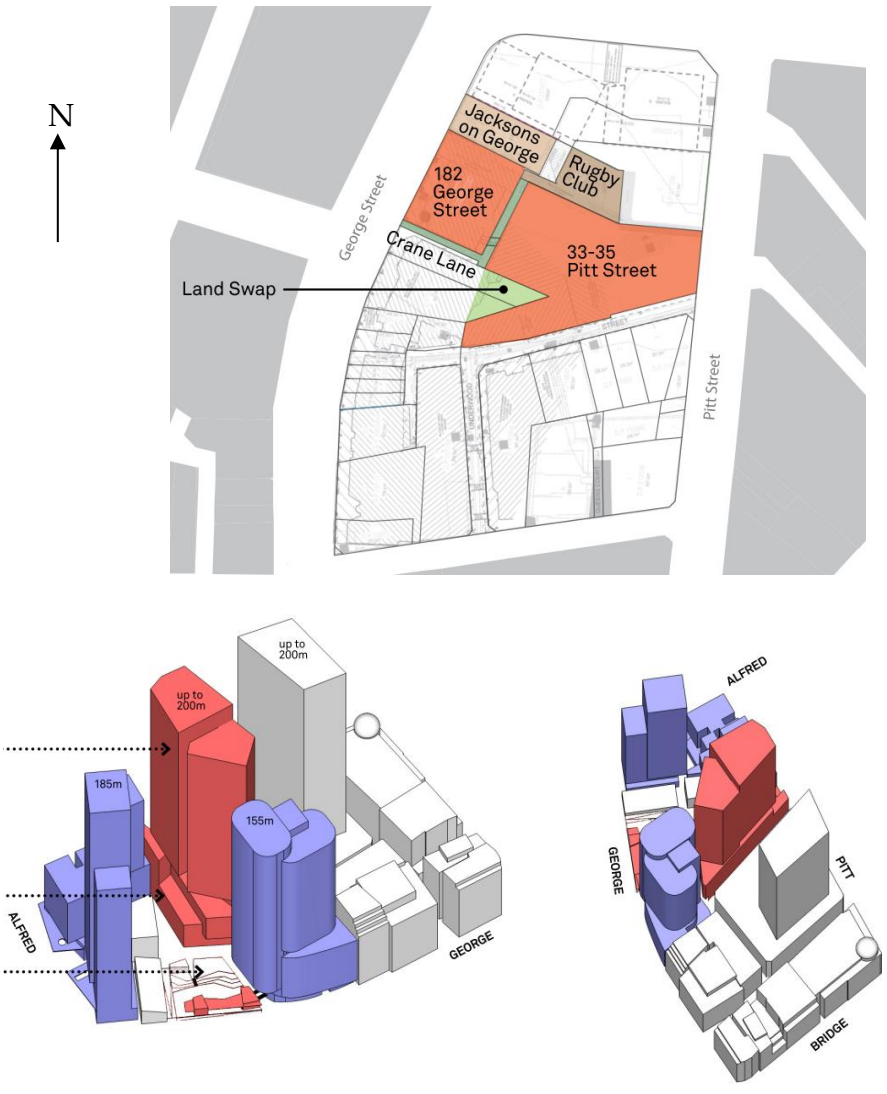

Figure 4: Site plan, north-west and south-west view of proposed development at 182 George and 33-35 Pitt Street

Winds from the north-east

The proposed site is located to the north of the city and is therefore exposed to winds from the north-east. In Sydney these winds occur on hot summer days and the hotter the weather the stronger the winds due to the pressure differential generated by the temperature gradient from land and sea. Because the winds are stronger on hotter days, they can bring welcome relief.

The general wind flow pattern in this area is governed by the larger buildings such as Gateway Plaza, Goldfields House, Four Seasons, Grosvenor Place, and Sydney Marriot. The tower is relatively well orientated to the other large buildings to reduce the effects of downwash for winds from the north-east. Compared with the existing Goldfields House, the proposed One Alfred Street development (DA 2010/2029) shifts the building massing to the west. This is expected to change the flow pattern exposing the proposed tower to increased wind speeds from Gateway Plaza. The combination of reduced shielding, downwash, and the downstream blockage of the cityscape is expected to produce relatively strong winds at ground level through the northern laneway into the Plaza, which is expected to be classified as acceptable for pedestrian walking, and would be suitable for outdoor sitting for about 80% of the time. Other areas in the Plaza will have improved wind conditions being suitable for pedestrian sitting and standing. With the Goldfields House remaining, it is expected that the wind conditions will be slightly improved with the north laneway and Plaza being expected to be classified as acceptable for pedestrian standing activities.

Winds from the south

Winds from the south are currently channelled along George and Pitt Streets. On reaching this section of the city the change in direction of George Street to the north of Grosvenor Tower and Essex Street tends to cause windier conditions on the west side of the street leaving the east side relatively calmer. With the removal of 182 George Street, there is an alternate clear path for the wind to discharge into George Street at ground level, which will increase the wind speed in this area compared with existing conditions. The impact of Goldfields House, or the approved One Alfred Street (DA 2010/2029) design on the local wind conditions at ground level around the proposed commercial office tower for winds from this direction are expected to be minimal. Evidently, if a continuous laneway is created from the Plaza to Alfred Street by the removal of Goldfields House and the inclusion of the One Alfred Street design, then the wind conditions along the laneway can

be expected to be significantly windier. It is expected that the laneway would be classified as suitable for pedestrian standing from the Lawson criterion, and would be suitable for sitting activities for approximately 80% of the time.

As discussed previously, in general, downwash is created by an exposed windward face of a building causing flow to descend the face of the building to ground level; especially when the building is taller than the upwind buildings. The increase in height of the proposed commercial office tower will expose a larger portion of the broad south face to winds from the south, which is expected to increase the amount of downwash. The orientation of the south façade is expected to direct more of the downwash flow along Pitt Street whereas the proximity to 200 George Street (DA 2012/893) is expected to generate channelled flow between the two towers. This channelled flow will discharge across the Plaza. Notwithstanding the above, due to the significant shielding generated by the massing of the city to the south, any increase in wind speed is expected to be minor and all areas are expected to be classified as at least acceptable for pedestrian walking and pass the distress criterion. As mentioned above, when integrated with the wind climate, the proposed Public Plaza area is expected to be useable for pedestrian sitting about 80% of the time, with larger zones of increased usage rates in more shielded areas of the Plaza.

Winds from the west

For winds from the west, the ground level is reasonably well protected by the topography to the west. The 200 George Street (DA 2012/893) development generates downwash, which was suppressed by the blockage to the east of the building. The removal of the St. George building at 182 George Street is expected to have a significant impact on the local wind environment at ground level by removing the blockage to the channelled flows down Essex Street, thereby increasing the wind speeds through this area. This effect will be reduced by the increased blockage caused by the proposed building and any increase in massing of the Fairfax building (D/2010/1533). The change in massing from Goldfields House to One Alfred Street is expected to have a minimal impact on the ground level wind environment as this site is more shielded by the tall buildings to the north of Essex Street.

The proposed commercial office tower is to a large part in the lee of 200 George Street (DA 2012/893) and is orientated in such a way as to minimise downwash from the upper section for winds from the west. The proposed commercial office tower is not expected to significantly impact on the local wind environment until the wind has a more northerly

component when there is potential for slightly windy conditions along the north laneway during strong north-westerly winds, due to the large surface area normal to the flow.

With the Plaza being raised to the George Street level, including some fragmented, suitably positioned low-rise buildings, or porous vertical screens, along the George Street frontage would be expected to slightly improve the wind amenity of the Plaza area for all wind directions. As mentioned above, when integrated with the wind climate, the proposed Public Plaza area is expected to be useable for pedestrian sitting about 80% of the time, with zones of increased usage rates in more shielded areas of the Plaza such as in the lee of the fragmented low-rise retail buildings would create calmer areas on the upwind and leeward faces of the structures and block the ground level flow across the Plaza to George Street.

Conclusions

Cermak Peterka Petersen Pty. Ltd. has provided an opinion based assessment of the impact on the local wind environment of the proposed development at 182 George Street and 33-35 Pitt Street, Sydney. Our summary assessment of the proposed redevelopment is as follows:

- Wind conditions at pedestrian level areas around the proposed development are expected to be similar to those currently experienced in this area of the city, except for some small areas for winds from certain directions as discussed above.
- All locations around the proposed commercial office tower are expected to at least meet the pedestrian walking criterion and pass the distress criterion, but like the majority of the city would not meet the 'active frontage' criterion in City of Sydney (2012). It is expected that the Plaza area would be acceptable for outdoor sitting in excess of 80% of the time, with larger zones of increased usage rates in more shielded areas of the Plaza.
- Opportunities are available to enhance the local wind conditions in the area surrounding the redevelopment of 182 George Street and 33-35 Pitt Street during the design development phase. Key aspects that can be addressed during detailed design include: the arrangement of the fragmented low rise retail buildings fronting George Street; the levels of the Public Plaza and laneway network with associated landscaping; the detailing of the commercial office tower podium; and the refinement of the commercial office tower geometry. These effects would be quantified via wind tunnel testing.

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