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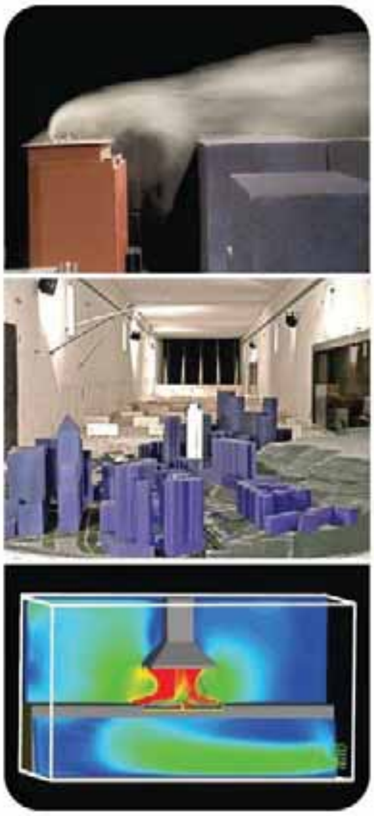
Final Report



Wind Tunnel Tests for:

# EMBASSY TOWER

Marshall Avenue, St. Leonards,
Australia

CPP Project 8702

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# EXECUTIVE SUMMARY

Detailed wind tunnel studies were conducted to assess pedestrian wind comfort in and around the proposed mixed used Embassy Tower development in Marshall Avenue, St. Leonards. Wind-tunnel tests were conducted at locations in and around the development site. In addition, four comparative locations were investigated in the existing configuration without the proposed development. Testing was carried out with existing vegetation along the surrounding streets. The testing focused on point locations near the main tower at ground level, as well as selected balcony locations on each of the building façades.

A model of the project was fabricated to a 1:300 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 430 m radius were constructed and placed on the turntable. The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. 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).

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 34 locations for 16 wind directions each. 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.

One location to the north-east of the site was the object of further investigations as it initially marginally exceeded both the comfort and distress criteria. A short line of trees along Marshall Lane was found to provide sufficient mitigation for this location to pass the Lawson distress and comfort criterion.

Overall, for the intended use of the surrounding space, the project will result in an acceptable wind environment.

## DOCUMENT VERIFICATION

| Date | Revision | Prepared by | Checked by | Approved by |
|---|---|---|---|---|
| 19/11/15 | Initial release | PG | GSW | GSW |
| 20/11/15 | Minor amendments | GSW | GSW | GSW |
| 24/11/15 | Minor amendments | GSW | GSW | GSW |
| 26/11/15 | Minor amendments | GSW | GSW | GSW |

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| | |
|---|---|
| $D$ | Characteristic dimension (building height, width, etc.), m |
| $n$ | Mean velocity profile power law exponent |
| $T_u$ | Turbulence intensity, $U_{rms}/U$ |
| $U$ | Local mean velocity, m/s |
| $U_{ref}$ | Reference velocity at reference height $z_{ref}$, m/s |
| $U_{pk}$ | Peak wind speed in pedestrian studies, m/s |
| $U_{rms}$ | Root-mean-square of fluctuating velocity, m/s |
| $z$ | Height above surface, m |
| $\nu$ | Kinematic viscosity of approach flow, $m^2/s$ |
| $\sigma(\ )$ | Standard deviation of $(\ ),=(\ )'_{rms}$ |
| $\rho$ | Density of approach flow, $kg/m^3$ |
| $(\ )_{max}$ | Maximum value during data record |
| $(\ )_{min}$ | Minimum value during data record |
| $(\ )_{mean}$ | Mean value during data record |
| $(\ )_{rms}$ | Root mean square about the mean |

# 1. INTRODUCTION

Pedestrian acceptability of footpaths, entrances, plazas, and terraces is often an important design parameter of interest to the building owner and architect. Assessment of the acceptability of the pedestrian level wind environment is desirable and more appropriate 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.

Techniques have been developed that permit boundary layer wind tunnel modelling of buildings to determine wind velocities in pedestrian areas. This report includes wind tunnel test procedures, test results, and a discussion of test results obtained. Table 1 summarises the model configurations, test methods, and data acquisition parameters used. All data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2006). 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.

Table 1: Configurations for data acquisition

| | |
|---|---|
| *General Information* | |
| Model length scale | 1:300 |
| Surrounding model radius (full-scale) | 430 m |
| Reference height (full-scale) | 200 m above ground level |
| Approach Terrain Category | Terrain Category 3 |
| *Study Information* | |
| Number of additional test locations | 34 |
| Wind directions | 16 wind directions in 22.5° increments from 0° (north) |
| *Geometric Configuration(s)* | |
| Configuration A | Existing surrounds with proposed Embassy Tower development, proposed plaza extension over the railway line and vegetation included |
| Configuration B | Existing surrounds without the proposed Embassy Tower development. Foot print area of the site modelled as shown on Google Earth (8/10/15). Vegetation included. |

## 2. THE WIND TUNNEL TEST

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

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 1. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by a vorticity generating fence and spires The spires, barrier, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in Figure 2 and are explained more fully in Section 4.1.1.

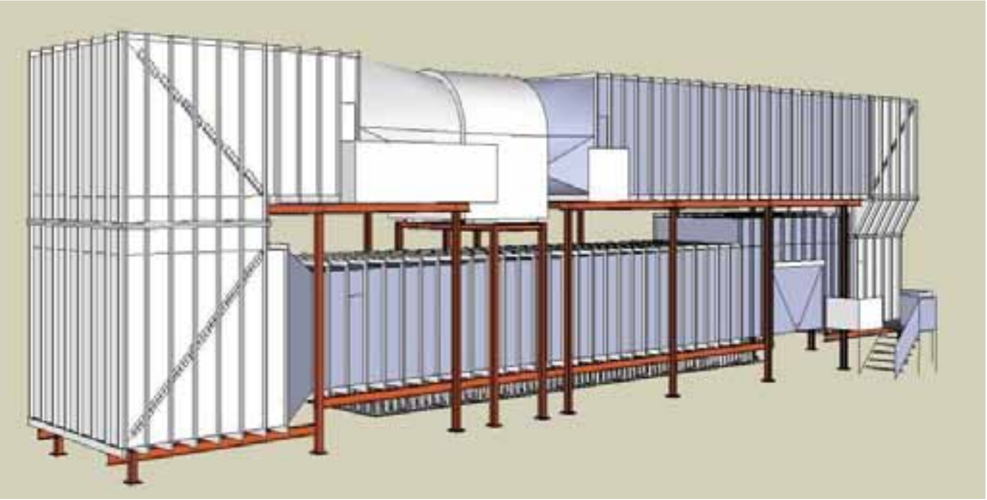


Figure 1: Schematic of the closed circuit wind tunnel

A model of the proposed development and surrounds to a radius of 430 m was constructed at a scale of 1:300, Figure 3. The model scale 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 wind speeds from any approach wind direction. Additional photos of the testing are presented in Appendix 1.

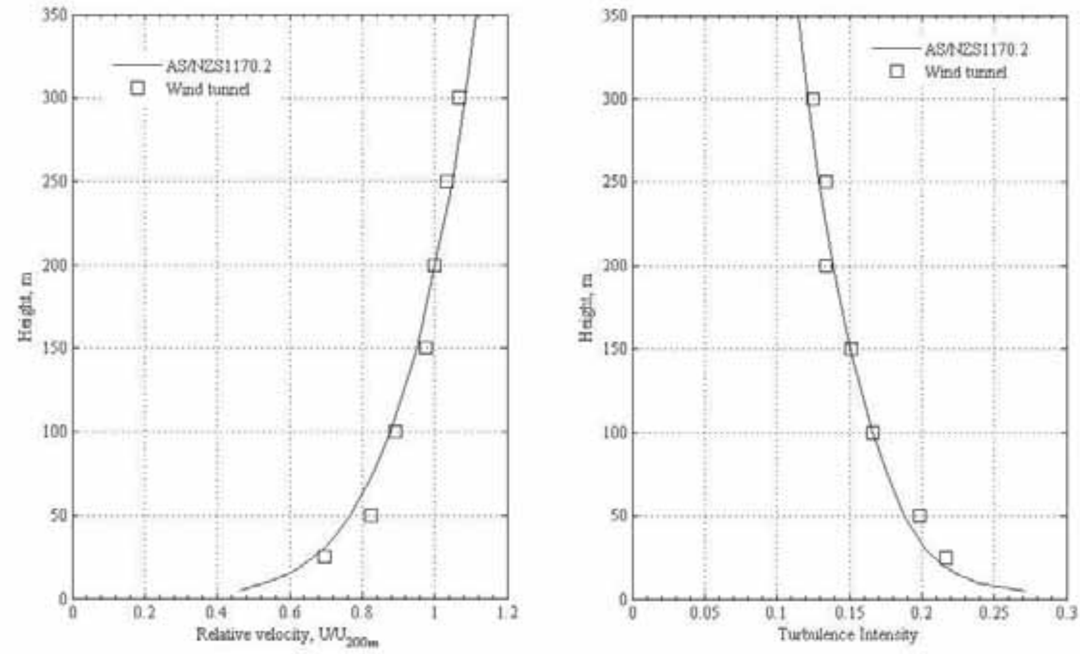
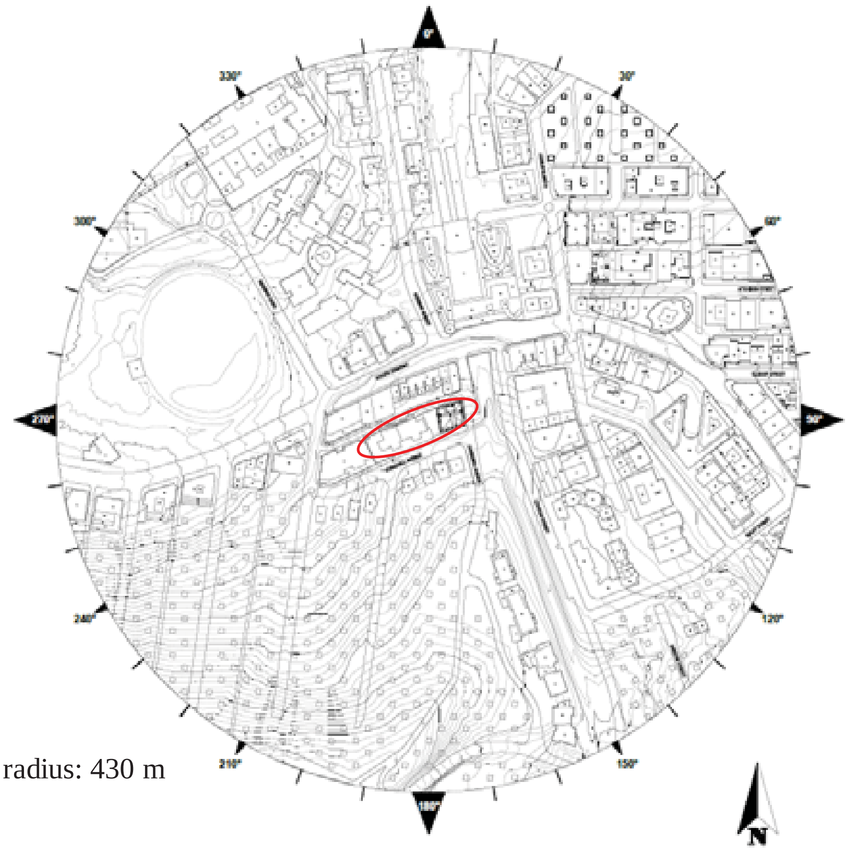



Figure 2: Mean velocity and turbulence profiles approaching the model




Turntable radius: 430 m

Figure 3: General turntable layout for Embassy Tower development


Figure 4: Photograph of the model from the south east

## 3. ENVIRONMENTAL WIND CRITERIA

The current Lane Cove DCP (2011) specifies wind effects not to exceed 13 m/s along major streets, and 16 m/s in all other streets. It is not clear in the document, either the duration of the gust or the frequency of the wind event. These criteria are similar to the City of Sydney (2012) DCP. There are few street locations in the Sydney region that would meet either of these wind speed levels without some level of shielding to improve the wind conditions. From discussions with City of Sydney Council this is a nominal once per annum gust wind speed, similar to the wind criteria specified in City of Sydney (2011) DCP. The wind speed levels are meant to be interpreted as a comfort level criterion to promote outdoor café style activities and are not intended to be used as a distress requirement. This is assumed to be similar to the Lane Cove DCP.

The once per annum gust wind speed criterion is based on the work of Melbourne (1978), and the 16 m/s level is classified as acceptable for pedestrian walking along a main accessway, and 13 m/s level is classified as generally acceptable for use for pedestrian standing. This criterion gives the nominal once per annum (actually about 0.1% of the time) gust 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), as described below. Assessment using the Lawson criteria provides a similar comfort classification as using Melbourne (1978) which is considered to be the basis of the Lane Cove DCP; however, it provides significantly more information regarding the serviceability wind climate.

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

Lawson's criteria have categories for discomfort, based on wind speeds exceeded five percent of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "Business walking" to "Pedestrian sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds[1]. In both cases, the wind speed used the

[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

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.

Table 2: Summary of Lawson criteria

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

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

water, blowing dust or particulates, and other variables in addition to the wind speed.

# 4. DATA ACQUISITION AND RESULTS

## 4.1 Velocities

Velocity profile measurements were taken to verify that appropriate boundary layer flow approaching the site was established and to determine the likely pedestrian level wind climate around the test site. Pedestrian wind measurements and analysis are described in Section 4.1.2. All wind speed measurements were made with hot-film anemometers, which were calibrated against a Pitot-static tube in the wind tunnel. The calibration data were described by a King's Law relationship (King, 1914)

### *4.1.1 Velocity Profiles*

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in Figure 2. Turbulence intensities are related to the local mean wind speed. These profiles have the form as derived from Standards Australia (2011) and are appropriate for the approach conditions.

### *4.1.2 Pedestrian Winds*

Wind speed measurements were recorded at 34 locations to evaluate pedestrian comfort in and around the project site, the results are presented in Figure 6 to Figure 9. Wind speed measurements were made at the model scale equivalent of 1.5 to 2.1 m above the ground surface for 16 wind directions at 22.5° intervals. Locations were chosen in conjunction with the design team to investigate areas of concern.

The hot-film signal was sampled for a period corresponding to one hour in prototype. All wind speed data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the size of a gust affecting a pedestrian and used as the basis for the assessment criterion. 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:

$$\frac{U_{pk}}{U_{ref}} = \frac{U + 3 \cdot U_{rms}}{U_{ref}}$$

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200 m are plotted in polar form in Appendix 2. The graphs show velocity magnitude and the approach wind direction for which that velocity was measured. The polar plots aid in visualisation of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust 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 2013, Figure 5. From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 2; this gives additional information regarding directional sensitivity at each location.

The Lawson criteria consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 5 to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 2. In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in Table 3 including qualitative descriptions of wind effects.

The tables in Appendix 2 also give the wind speed exceeded 5% and 0.022% for direct comparison with the Lawson comfort and distress criteria and the associated Lawson ratings for both mean, GEM, and combined wind speeds. Colour coded summary assessments of pedestrian comfort and safety with respect to the Lawson criteria are presented in Figure 6 to Figure 9 for each test location for both configurations. Because some pedestrian wind measurement positions are 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 of these summary findings. The implications of the results are discussed in Section 5.

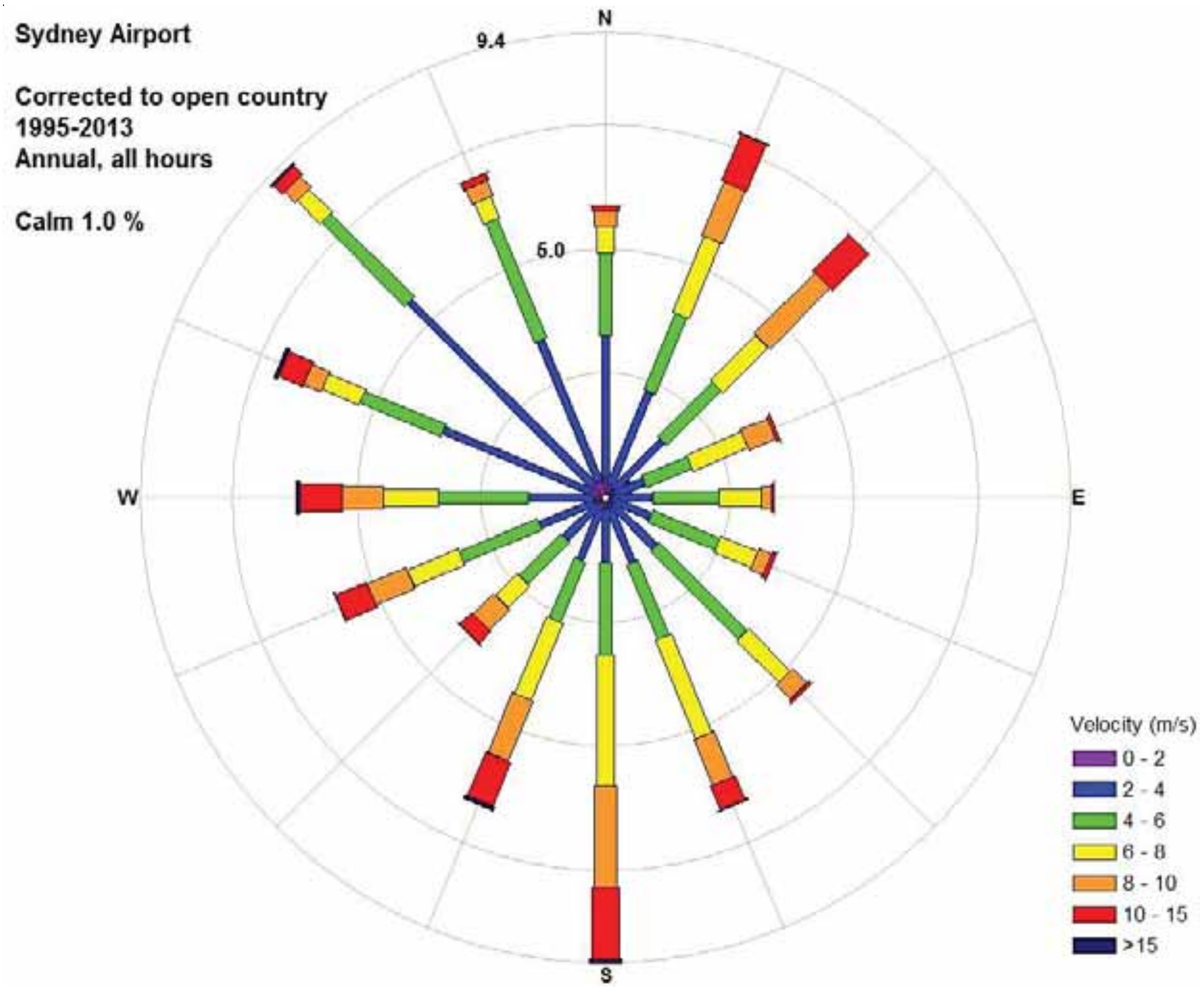



Figure 5: Wind rose of direction and speed for Sydney Airport

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

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

## 5. DISCUSSION

The wind climatology chart of Figure 5 indicates that the most frequent strong winds are from the south, and to a lesser extent, the west and north-east. The locations tested around the development site are susceptible to winds from different directions, depending on the relative location of the point tested to the geometry of development. However, in general terms the winds from the north-east, south, and west quadrants had the most pronounced effect on the site as higher level winds were brought to street level as downwash, and channelled between the surrounding building. 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 6 to Figure 9, 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. It should be noted that the comfort criteria are based on 95% of the time that the mean wind speed is below specific wind speed levels. 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 any orange and 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. In all the testing, existing vegetation along Marshall Avenue and Canberra Avenue was included.

Results on Figure 6 indicate that the wind conditions at Locations 1 to 3, and 7 remote from the site are classified as suitable for pedestrian walking. The influence of Embassy Tower would not be expected to significantly influence the wind conditions at these remote locations. Location 4 is located in the proposed plaza area above the rail corridor. The space was left open as there was no information regarding landscaping or other public structures in the plaza. These would be developed by Council during the design of the space. It is evident from the results in Figure 6 for Location 4 that this area is exposed to relatively strong wind conditions, and if this intended use of this area is for stationary activities then local amelioration would be required. It is expected that wind amelioration devices would form a key component of the design of the plaza. Locations 1 to 7 all passed the Lawson distress criterion. Figure 6 confirms that St. Leonards is a relatively windy area, primarily due to the local topography relative to the prevailing wind directions.


Figure 6 Pedestrian wind conditions surrounding the site (Configuration A)

Results presented in Figure 7 depict the pedestrian wind conditions at the ground plane around the proposed development. Locations 9 to 19 circling the low rise component of the development were all classified as pedestrian sitting or standing, and all passed the distress criterion. Locations 9, 12, 17, and 18 represent the proposed main entrances to the development. Wind conditions at Locations 8, and 18 to 22, to the east and north of the tower are exposed to the prevailing wind directions and were windier than around the low-rise being generally classified as suitable for pedestrian walking similar to other sections of St. Leonards. Wind conditions at Location 21 to the north-east of the site marginally exceeded both the pedestrian walking and safety criterion. The extent of this high-wind area is expected to be relatively short and is caused by winds from the south and west being channelled along Canberra Avenue and Marshall Lane respectively. A mitigation measure has been developed in order to reduce the severity of the wind condition at this location, which is discussed later in this report.

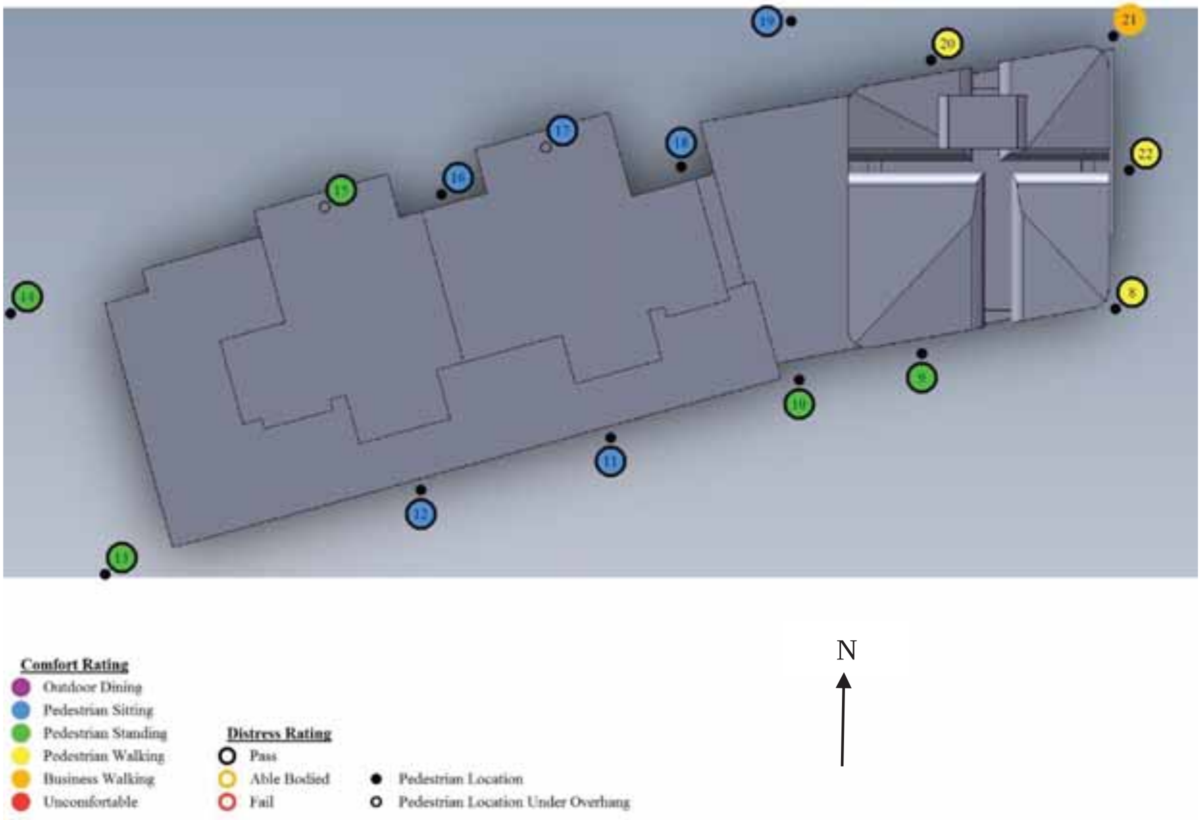



Figure 7 Pedestrian wind condition around the site at the ground plane (Configuration A)

Location 23 to 25 represent the wind conditions on the podium level, Figure 8. Wind conditions at Location 23 on the centre of the main podium was classified as uncomfortable and suitable for able bodied person only, yet would still meet the wind speed associated with the outdoor sitting criterion for about 60% of the time. This location was highly affected by prevailing winds from the south. This location highlights the primary purpose of a podium in redirecting downwash away from pedestrians at ground level. The podium roof area is private space and will be used by residents when environmental conditions suit personal requirements. The wind flow across the podium roof will be a combination of horizontal and vertical flow and it is considered that there would be no single solution to improve the wind conditions across the entire podium roof. Local wind conditions would be improved with the inclusion of horizontal or vertical elements to create calm areas, such as an awning extending from the west face of the tower with a solid or porous wall along the southern edge of the awning to protect from downwash and channelled flow. Additional local shielded areas could be developed across the podium roof space to provide calm areas around provided common facilities for residents. It is expected that with appropriate design against downwash and channelled wind flow, these local amelioration measures would significantly increase the amount of time these protected areas would be useable by residents from 60 to over 80%. Further development of these measures would be developed during detailed design. More information regarding directional sensitivity for each location can be extracted by reviewing the polar plots in Appendix 2. Wind conditions at Locations 24 and 25 on the podium of the low-rise building improved significantly and would be useable more often without mitigation measures.

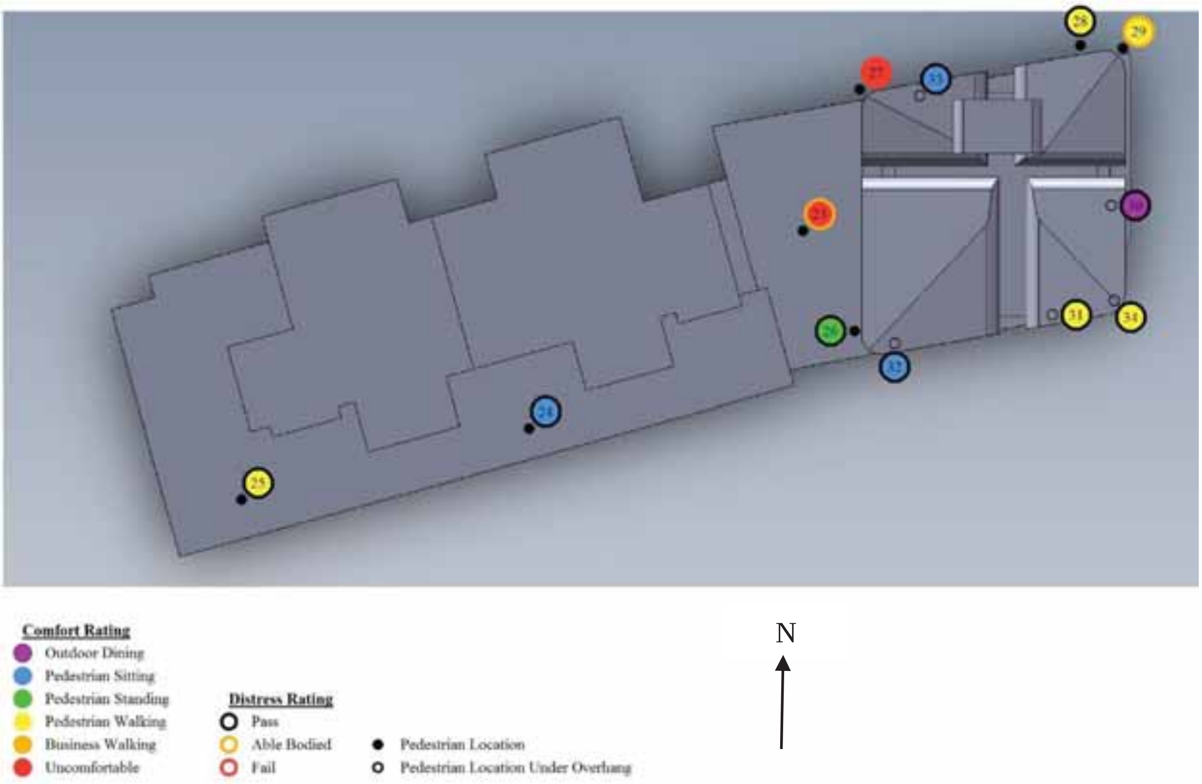



Figure 8 Pedestrian wind condition at podium and balconies level (configuration A)

Wind conditions at Location 26, on the Level 4 balcony to the south-west corner of the tower, are classified as suitable for pedestrian standing from a comfort perspective. This area would be suitable for the wind speed associated with the upper bound of pedestrian sitting, 4 m/s, for 80% of the time. This is considered a wind speed level where the balcony would be used.

Location 27 to 29 represent the wind condition near corner balcony locations on Level 12 of the main tower. The wind conditions on these balconies are very windy, failing the distress criterion and could pose a safety risk to residents. The twice per annum **mean** wind speed is expected to reach 21 m/s at Location 27, and 16 m/s at Location 29 and would be potentially useable for 50% to 60% of the time. It would be recommended to partially or fully enclose these corner balconies, or to delete them entirely. The wind conditions measured on these balconies would be expected to be representative of similar balconies on higher levels at the same location around the perimeter of the tower.

Locations 30 to 33 are located on inset balconies on Level 21 of the main tower. All balcony location on level 21 passed the distress criterion and their comfort rating ranged from outdoor dining for location 30 to pedestrian walking for location 31 being potentially useable for over 80% of the time. Similarly, the wind conditions on these inset balconies would be representative of similar balconies on other mid-levels of the tower at the same location on the perimeter of the tower.

Wind conditions at Location 34, on the south-east penthouse, Figure 8, were classified as pedestrian walking and passed the distress criterion. The corner of the terrace meets the wind speed associated with the upper bound of the pedestrian sitting classification for about 75% of the time. Calmer conditions would be experienced further from the corner and being a corner terrace there is an option for residents to use different portions of the terrace, which will have significantly different wind conditions depending on the incident wind direction.

Four comparative locations were chosen to investigate the existing wind conditions around the site, and are appended with the number "1" to symbolise the existing configuration (Configuration B, Table 1). In Configuration B, wind conditions were found to be suitable for standing activities at most, and all passing the distress criterion. Wind conditions at Locations 12 and 19 are similar in both configurations, whereas Locations 4 and 8 to the east of the site are windier with the proposed development.


Figure 9 Pedestrian wind conditions without the test building as shown on Google Earth (2015, Configuration B)

Location 21 was initially tested without any mitigation measures in place. With the slight exceedance of the comfort and distress criteria (15.4 m/s compared with the criterion level of 15 m/s) on the north-east corner of the site, mitigation was undertaken to ameliorate the wind conditions. Two 3 m wide awning configurations were tested wrapping half and the full length of the north and east tower façades. Neither awning configuration sufficiently ameliorated the distress wind conditions. After further investigations with flow visualisation, the mechanism causing the severity of the wind conditions at this location is primarily due to a strong horizontal component of the flow for winds from the west. These winds are channelled between the proposed and neighbouring building to the north accentuated by the open nature of the terrain to the west and the development being located to the south-west of St. Leonards CBD. For a horizontal flow mechanism, vertical obstructions are required to ameliorate the flow. Additional testing was conducted to illustrate the benefit of a vertical porous element using a relatively short row of trees along Marshall Lane. Figure 10 shows the tree layout employed by CPP in order to mitigate the wind conditions at Location 21. After mitigation, Location 21 (named 21.2 for clarity) was classified as pedestrian walking and passed the distress rating; the measurements showed a change in peak annual mean/GEM wind speed from 15.4 to 12.8 m/s, compared with the criterion acceptance level of 15 m/s. It is evident that the trees offer a significant benefit to the wind environment and number of trees could be reduced. The trees used are an example of a potential solution and if used should be evergreen, and if reduced in number should maintain at least three trees close to the north-east corner. Further advice can be provided to develop a solution suitable to Council and the design team.

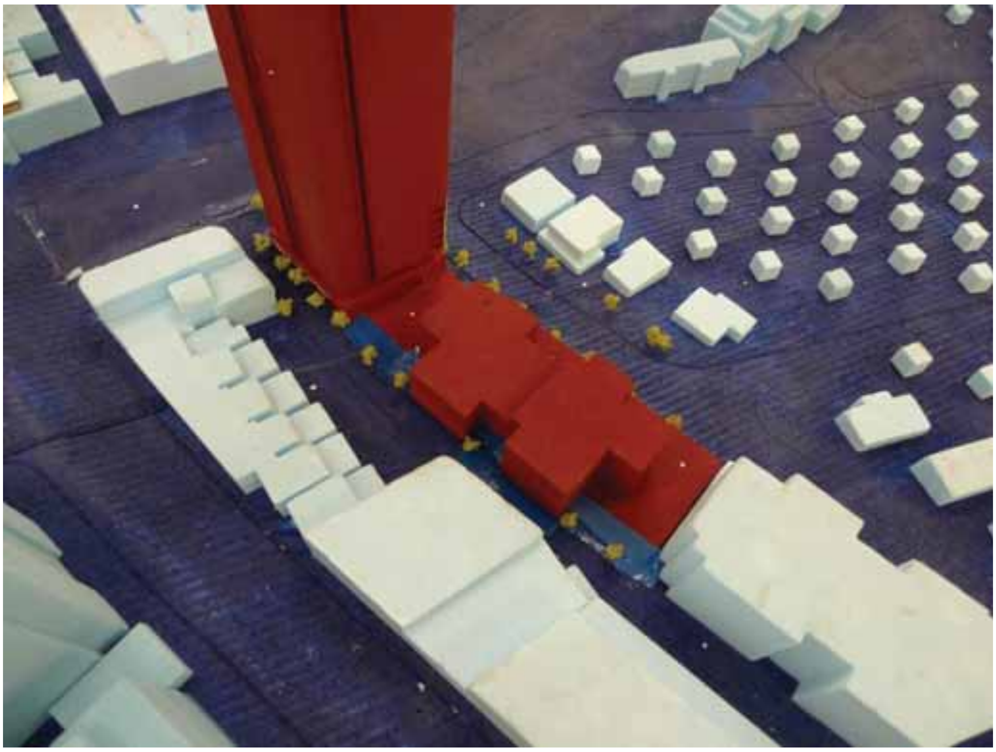


Figure 10 Mitigation measure tested by CPP (location 21)

## 6. CONCLUSIONS

A wind tunnel study at ground plane of the public domain around the proposed Embassy Tower development was conducted to assess pedestrian wind comfort. Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 34 locations for 16 wind directions each. Tests were conducted in two configurations in order to discern the impact of the proposed building on the wind conditions along nearby streets, the main podium, and private balconies.

The test locations were taken in appropriate locations to study the intended use of the space including pedestrian access ways. The measurements were combined with wind climate statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The proposed Embassy Tower development is expected to have an impact on the local wind amenity particularly along Canberra Avenue and Marshall Lane. In general, the impact of the entire development is expected to produce windier conditions than existing, but will be similar to wind conditions in other areas of St. Leonards. Mitigation in the form of porous vertical barriers, such as trees along Marshall Lane has been shown to improve wind conditions in the public space to an acceptable level.

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**Appendix 1: Additional Photographs of the CPP Wind Tunnel Model**

Figure 11: Existing site viewed from above (configuration B)

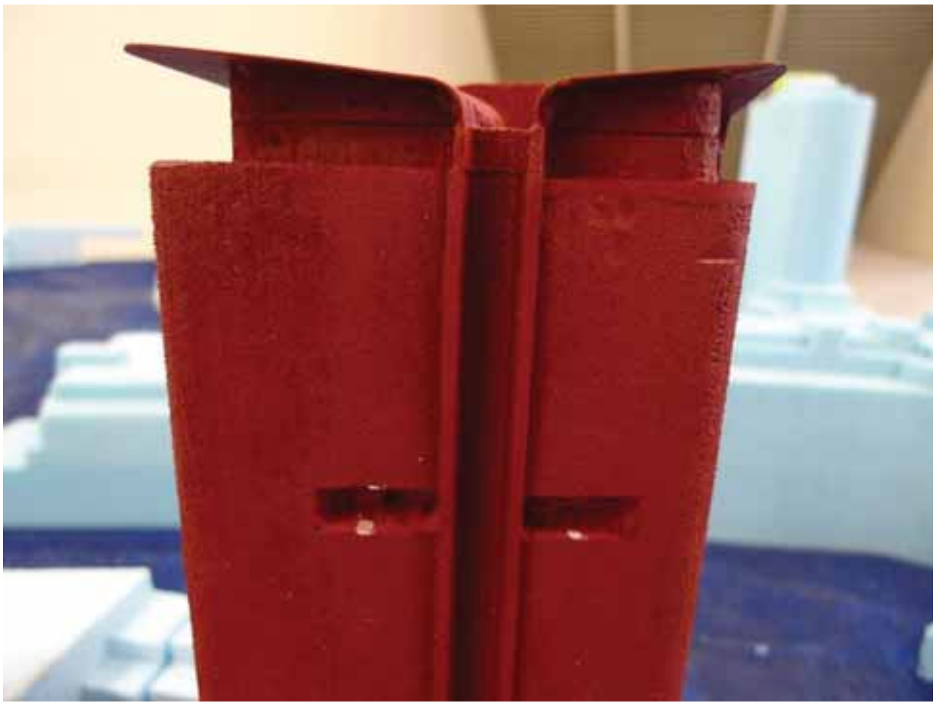
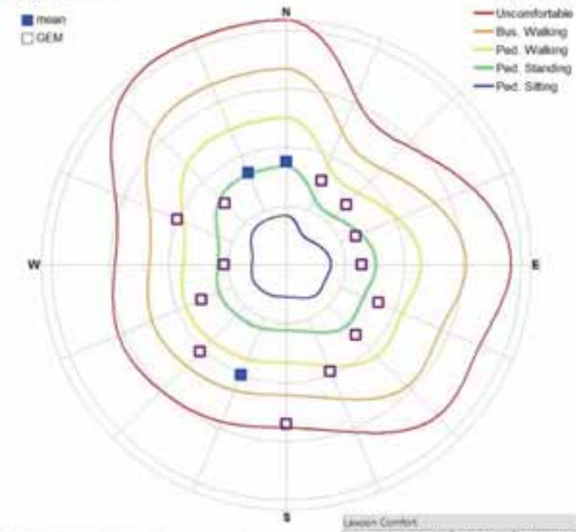


Figure 12 Balcony modelled on South façade, level 21

## Appendix 2: Directional Wind Results

### Configuration A

#### LOCATION 1

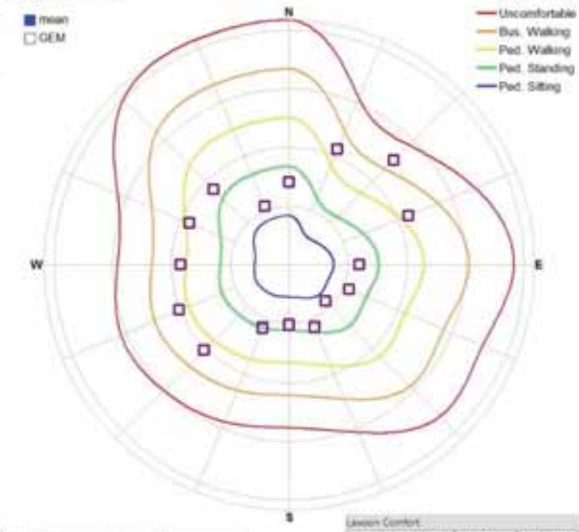



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 56.45 | 62.54 | 63.28 |
| 4 | 18.89 | 21.94 | 22.15 |
| 6 | 5.77 | 6.61 | 6.67 |
| 8 | 1.54 | 1.86 | 1.87 |
| 10 | 0.32 | 0.42 | 0.42 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.2 | 6.4 | 6.4 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 13.1 | 13.5 | 13.5 |
| Rating | Pass | Pass | Pass |

#### LOCATION 2

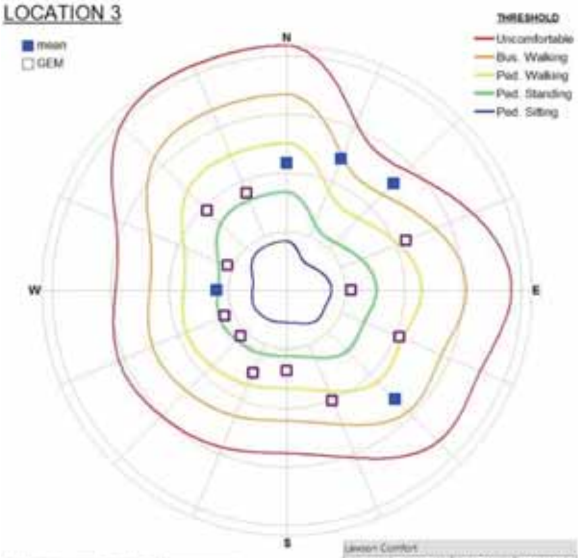



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 37.16 | 55.24 | 55.24 |
| 4 | 10.15 | 17.58 | 17.88 |
| 6 | 2.81 | 5.94 | 5.94 |
| 8 | 0.49 | 1.08 | 1.08 |
| 10 | 0.04 | 0.11 | 0.11 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.1 | 6.2 | 6.2 |
| Rating | Ped Standing | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 10.4 | 11.2 | 11.2 |
| Rating | Pass | Pass | Pass |

#### LOCATION 3




| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 58.94 | 63.41 | 64.05 |
| 4 | 20.35 | 22.94 | 23.53 |
| 6 | 5.87 | 6.43 | 6.83 |
| 8 | 1.30 | 1.25 | 1.40 |
| 10 | 0.14 | 0.14 | 0.15 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.2 | 6.3 | 6.4 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 11.3 | 11.3 | 11.4 |
| Rating | Pass | Pass | Pass |

#### LOCATION 4


| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 56.91 | 69.82 | 69.81 |
| 4 | 22.73 | 29.70 | 30.28 |
| 6 | 7.36 | 11.02 | 11.30 |
| 8 | 1.67 | 3.39 | 3.44 |
| 10 | 0.26 | 0.88 | 0.88 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.5 | 7.3 | 7.3 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 12.7 | 14.7 | 14.7 |
| Rating | Pass | Pass | Pass |

## LOCATION 5


| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 47.20 | 60.15 | 60.49 |
| 4 | 5.48 | 15.15 | 15.60 |
| 6 | 1.30 | 2.39 | 2.70 |
| 8 | 0.43 | 0.37 | 0.48 |
| 10 | 0.08 | 0.07 | 0.08 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.7 | 5.2 | 5.3 |
| Rating | Ped Standing | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 11.1 | 11.0 | 11.2 |
| Rating | Pass | Pass | Pass |

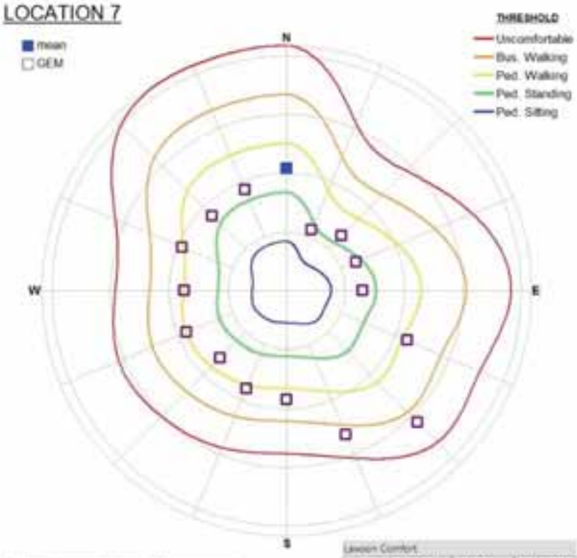
## LOCATION 6


| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 16.45 | 37.64 | 37.64 |
| 4 | 1.11 | 6.08 | 6.08 |
| 6 | 0.01 | 0.49 | 0.49 |
| 8 | 0.00 | 0.01 | 0.01 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 2.9 | 4.2 | 4.2 |
| Rating | Ped Sitting | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.7 | 7.6 | 7.6 |
| Rating | Pass | Pass | Pass |

## LOCATION 7

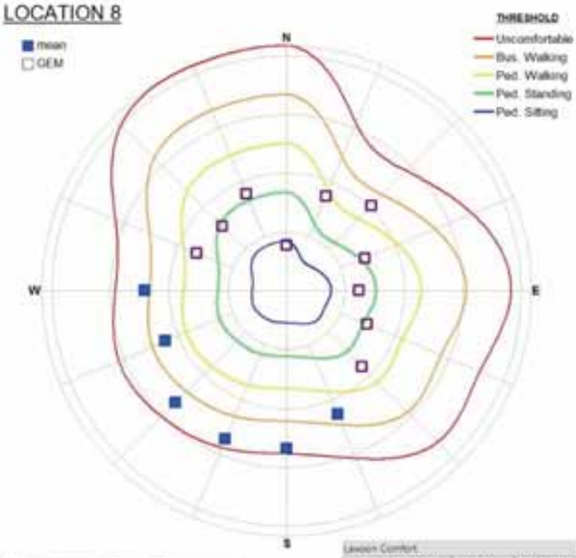



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 57.58 | 67.30 | 67.44 |
| 4 | 17.43 | 25.24 | 25.29 |
| 6 | 3.39 | 6.46 | 6.47 |
| 8 | 0.50 | 1.30 | 1.30 |
| 10 | 0.05 | 0.20 | 0.20 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.5 | 6.3 | 6.3 |
| Rating | Ped Standing | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 10.8 | 12.4 | 12.4 |
| Rating | Pass | Pass | Pass |

## LOCATION 8

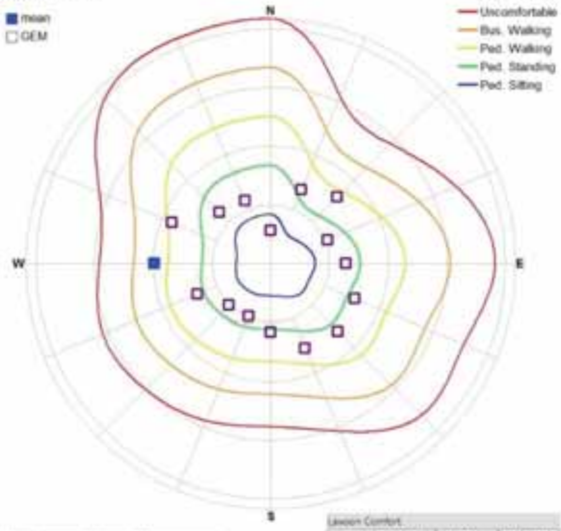



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 59.01 | 66.01 | 67.83 |
| 4 | 28.63 | 27.79 | 31.83 |
| 6 | 11.89 | 7.50 | 12.55 |
| 8 | 3.43 | 1.28 | 3.47 |
| 10 | 0.80 | 0.17 | 0.81 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 7.4 | 6.5 | 7.4 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 14.2 | 11.7 | 14.2 |
| Rating | Pass | Pass | Pass |

## LOCATION 9

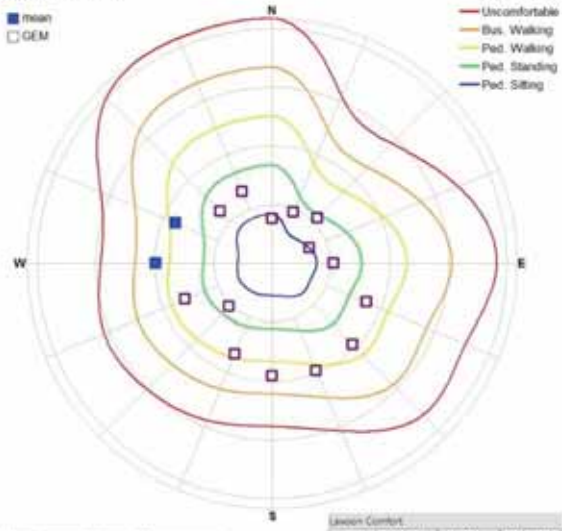



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 17.59 | 49.94 | 50.21 |
| 4 | 5.12 | 10.02 | 10.12 |
| 6 | 0.87 | 1.20 | 1.36 |
| 8 | 0.12 | 0.14 | 0.18 |
| 10 | 0.01 | 0.01 | 0.01 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.2 | 4.6 | 4.8 |
| Rating | Ped Sitting | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.4 | 5.3 | 5.5 |
| Rating | Pass | Pass | Pass |

## LOCATION 10

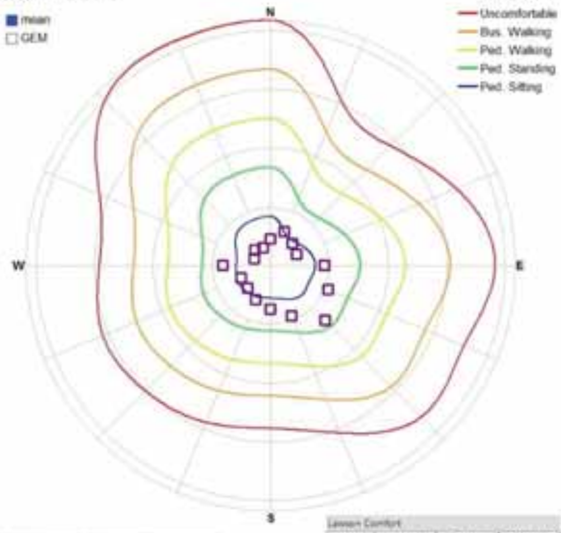



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 40.79 | 50.21 | 51.38 |
| 4 | 11.51 | 14.78 | 16.07 |
| 6 | 1.90 | 2.45 | 2.88 |
| 8 | 0.22 | 0.22 | 0.35 |
| 10 | 0.01 | 0.02 | 0.03 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.9 | 5.2 | 5.4 |
| Rating | Ped Standing | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 9.8 | 9.8 | 10.1 |
| Rating | Pass | Pass | Pass |

## LOCATION 11

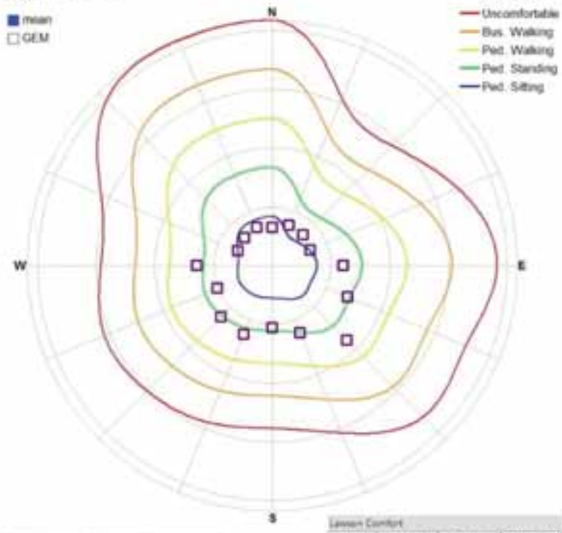



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 1.41 | 12.16 | 12.16 |
| 4 | 0.00 | 0.18 | 0.18 |
| 6 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 1.5 | 2.5 | 2.5 |
| Rating | Outdoor Dining | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.3 | 4.9 | 4.9 |
| Rating | Pass | Pass | Pass |

## LOCATION 12

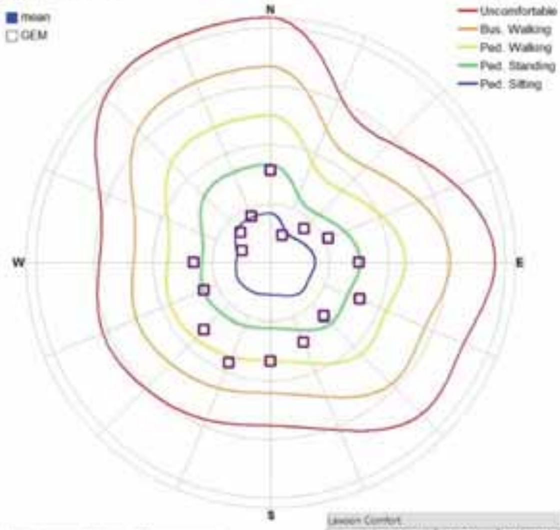



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 11.28 | 33.40 | 33.60 |
| 4 | 0.15 | 3.15 | 3.33 |
| 6 | 0.00 | 0.12 | 0.12 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 2.4 | 3.6 | 3.6 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.8 | 7.0 | 7.0 |
| Rating | Pass | Pass | Pass |

## LOCATION 13

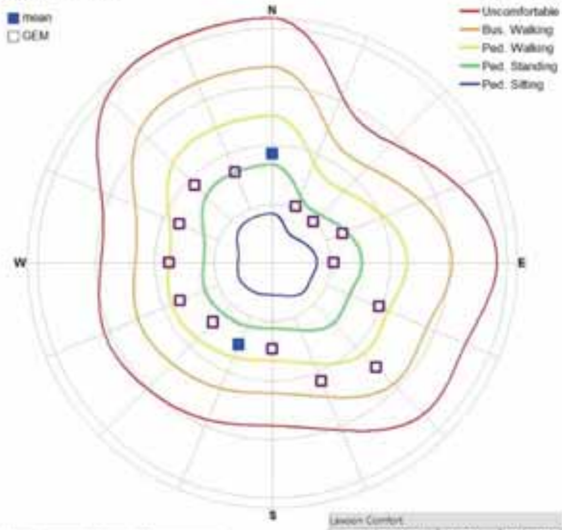



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 22.57 | 42.48 | 42.48 |
| 4 | 1.51 | 9.24 | 9.24 |
| 6 | 0.05 | 1.17 | 1.17 |
| 8 | 0.00 | 0.10 | 0.10 |
| 10 | 0.00 | 0.01 | 0.01 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.2 | 4.6 | 4.6 |
| Rating | Ped Sitting | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.4 | 9.1 | 9.1 |
| Rating | Pass | Pass | Pass |

## LOCATION 14

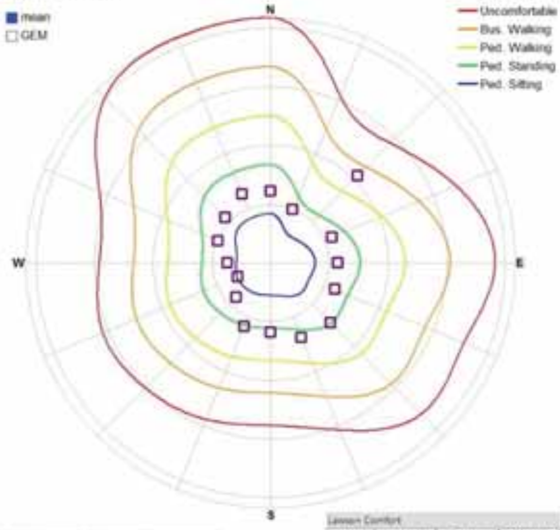



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 48.67 | 60.57 | 60.68 |
| 4 | 10.14 | 16.30 | 16.36 |
| 6 | 1.16 | 2.79 | 2.80 |
| 8 | 0.09 | 0.33 | 0.33 |
| 10 | 0.01 | 0.04 | 0.04 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.7 | 5.4 | 5.4 |
| Rating | Ped Standing | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.5 | 10.3 | 10.3 |
| Rating | Pass | Pass | Pass |

## LOCATION 15

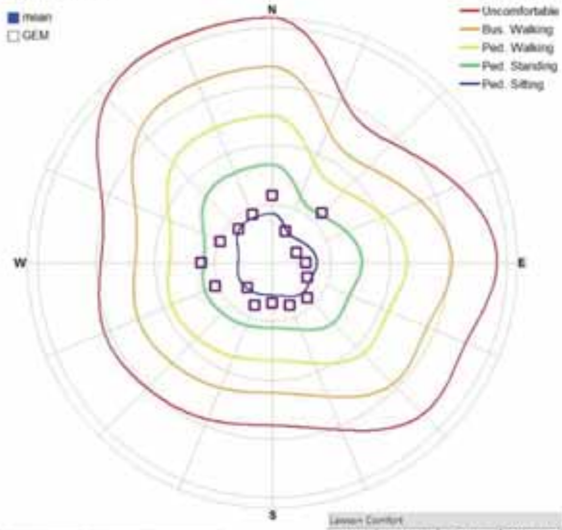



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 25.14 | 39.23 | 39.23 |
| 4 | 3.74 | 6.17 | 6.17 |
| 6 | 0.50 | 1.41 | 1.41 |
| 8 | 0.01 | 0.14 | 0.14 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.6 | 4.2 | 4.2 |
| Rating | Ped Sitting | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 7.8 | 9.1 | 9.1 |
| Rating | Pass | Pass | Pass |

## LOCATION 16

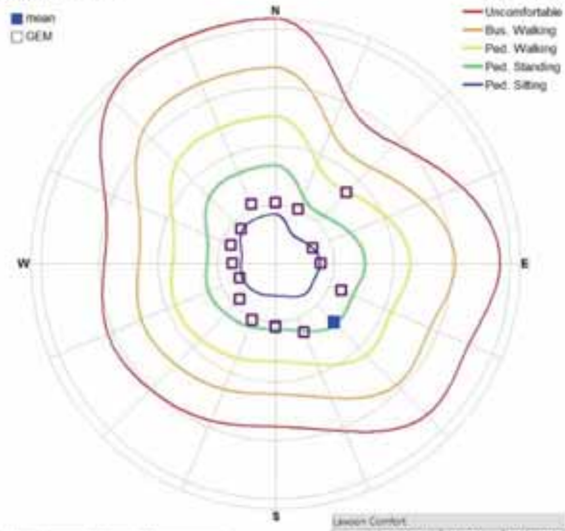



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 4.97 | 18.28 | 18.28 |
| 4 | 0.01 | 1.07 | 1.07 |
| 6 | 0.00 | 0.01 | 0.01 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 2.0 | 3.0 | 3.0 |
| Rating | Outdoor Dining | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.9 | 5.8 | 5.8 |
| Rating | Pass | Pass | Pass |

## LOCATION 17

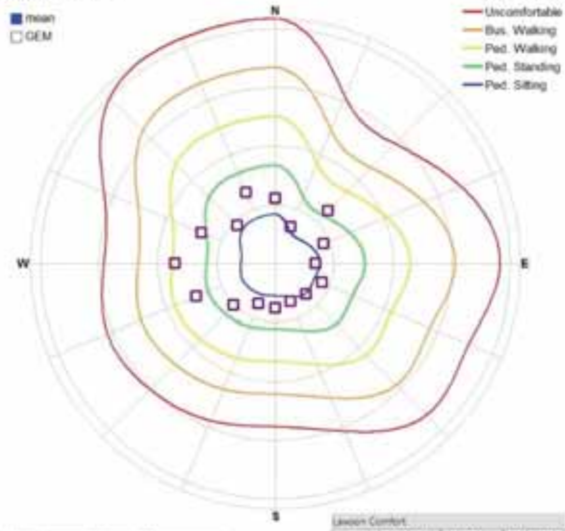



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 20.17 | 32.55 | 32.82 |
| 4 | 1.31 | 4.03 | 4.14 |
| 6 | 0.02 | 0.34 | 0.34 |
| 8 | 0.00 | 0.01 | 0.01 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.2 | 3.7 | 3.7 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.9 | 7.4 | 7.4 |
| Rating | Pass | Pass | Pass |

## LOCATION 18

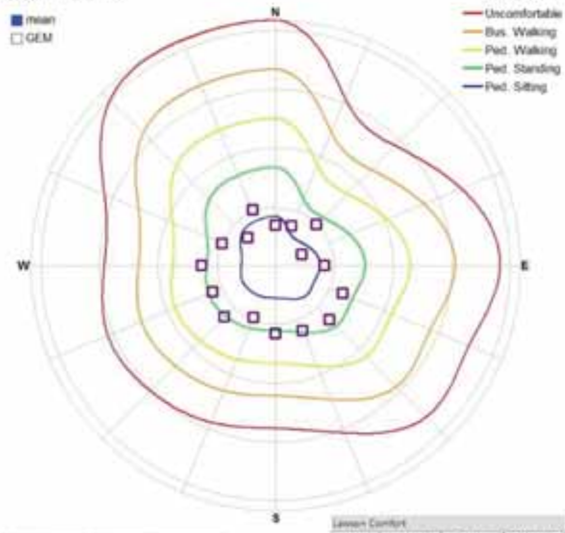



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 14.20 | 26.64 | 26.64 |
| 4 | 1.43 | 3.78 | 3.78 |
| 6 | 0.07 | 0.39 | 0.39 |
| 8 | 0.00 | 0.03 | 0.03 |
| 10 | 0.00 | 0.00 | 0.00 |

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

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.7 | 8.2 | 8.2 |
| Rating | Pass | Pass | Pass |

## LOCATION 19

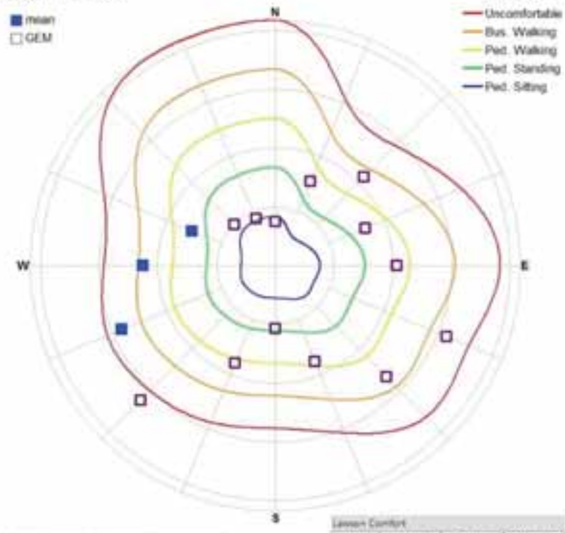



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 21.96 | 32.84 | 32.84 |
| 4 | 0.87 | 2.24 | 2.24 |
| 6 | 0.01 | 0.06 | 0.06 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.0 | 3.5 | 3.5 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.7 | 6.4 | 6.4 |
| Rating | Pass | Pass | Pass |

## LOCATION 20

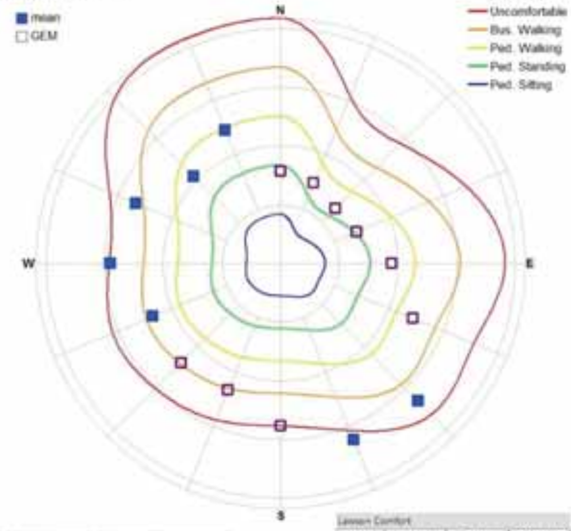



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 51.68 | 60.48 | 61.05 |
| 4 | 19.10 | 26.22 | 27.38 |
| 6 | 6.85 | 7.80 | 8.87 |
| 8 | 1.70 | 1.90 | 2.48 |
| 10 | 0.33 | 0.47 | 0.61 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.4 | 6.6 | 6.8 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 13.4 | 14.5 | 14.7 |
| Rating | Pass | Pass | Pass |

## LOCATION 21




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 73.56 | 73.95 | 77.41 |
| 4 | 33.68 | 34.72 | 38.08 |
| 6 | 15.53 | 13.59 | 17.29 |
| 8 | 5.52 | 4.07 | 6.07 |
| 10 | 1.58 | 0.94 | 1.71 |

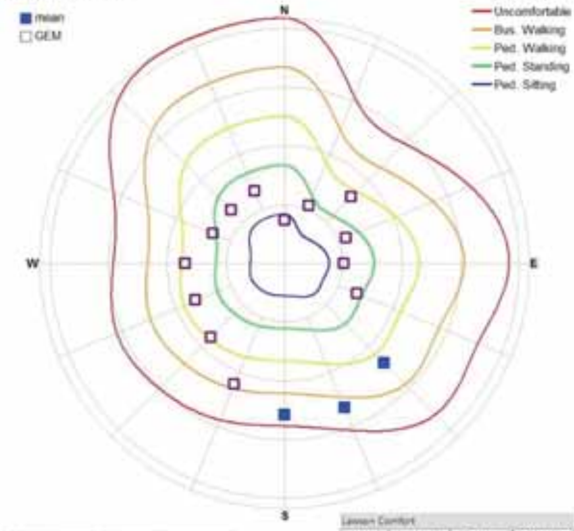
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 8.1 | 7.6 | 8.2 |
| Rating | Bus Walking | Ped Walking | Bus Walking |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 15.3 | 14.2 | 15.4 |
| Rating | Able Body | Pass | Able Body |

## LOCATION 22




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 43.33 | 56.43 | 58.86 |
| 4 | 18.50 | 24.02 | 24.82 |
| 6 | 6.60 | 7.20 | 8.24 |
| 8 | 1.81 | 1.88 | 2.33 |
| 10 | 0.38 | 0.30 | 0.43 |

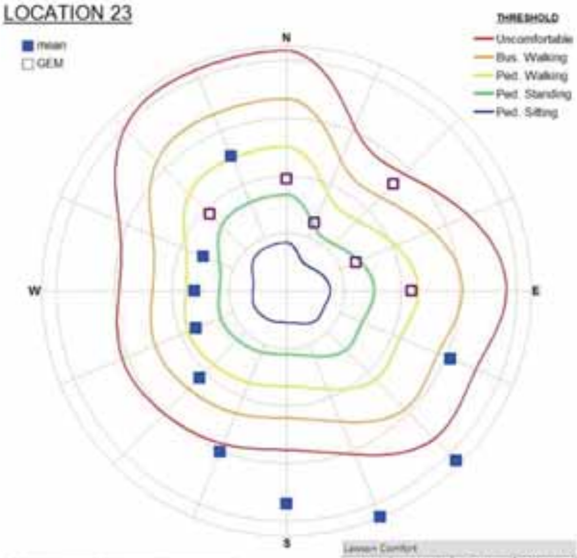
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 6.4 | 6.5 | 6.7 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 13.1 | 12.7 | 13.2 |
| Rating | Pass | Pass | Pass |

## LOCATION 23




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 66.62 | 72.65 | 74.35 |
| 4 | 37.60 | 36.86 | 40.23 |
| 6 | 22.97 | 18.15 | 23.42 |
| 8 | 11.80 | 6.56 | 12.34 |
| 10 | 5.16 | 1.85 | 5.28 |

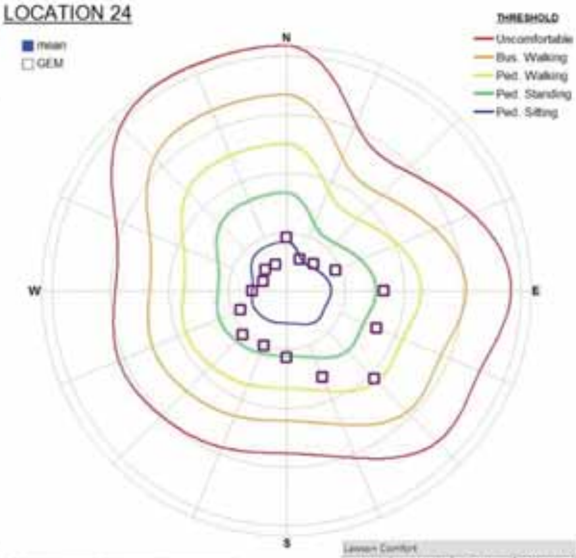
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 10.0 | 8.4 | 10.0 |
| Rating | Bus Walking | Bus Walking | Uncomfortable |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 19.8 | 15.8 | 19.8 |
| Rating | Able Body | Able Body | Able Body |

## LOCATION 24




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 14.08 | 30.71 | 30.71 |
| 4 | 0.67 | 4.51 | 4.51 |
| 6 | 0.02 | 0.39 | 0.39 |
| 8 | 0.00 | 0.02 | 0.02 |
| 10 | 0.00 | 0.00 | 0.00 |

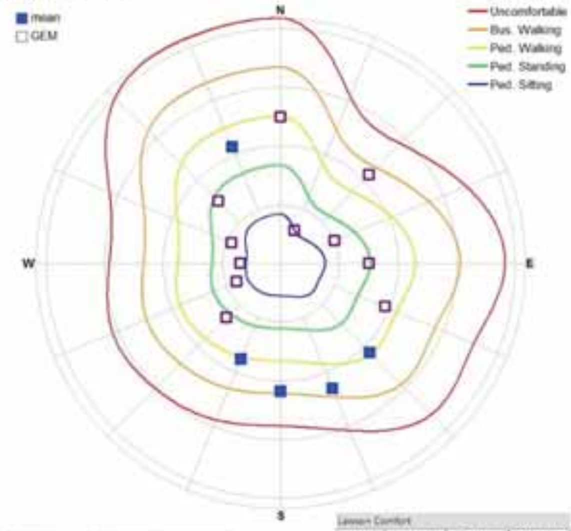
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 2.7 | 3.5 | 3.8 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 5.5 | 7.5 | 7.8 |
| Rating | Pass | Pass | Pass |

## LOCATION 25




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 45.40 | 54.16 | 54.66 |
| 4 | 18.55 | 20.04 | 21.23 |
| 6 | 4.28 | 4.95 | 5.87 |
| 8 | 0.71 | 0.62 | 0.91 |
| 10 | 0.08 | 0.05 | 0.09 |

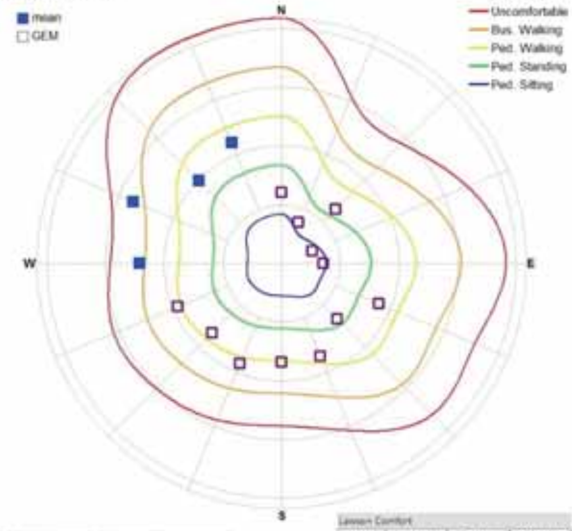
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 5.8 | 5.9 | 6.1 |
| Rating | Ped Standing | Ped Standing | Ped Walking |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 11.2 | 10.6 | 11.2 |
| Rating | Pass | Pass | Pass |

## LOCATION 26




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 48.95 | 59.03 | 60.44 |
| 4 | 13.28 | 18.23 | 18.37 |
| 6 | 3.27 | 3.80 | 4.35 |
| 8 | 1.01 | 0.72 | 1.12 |
| 10 | 0.30 | 0.12 | 0.31 |

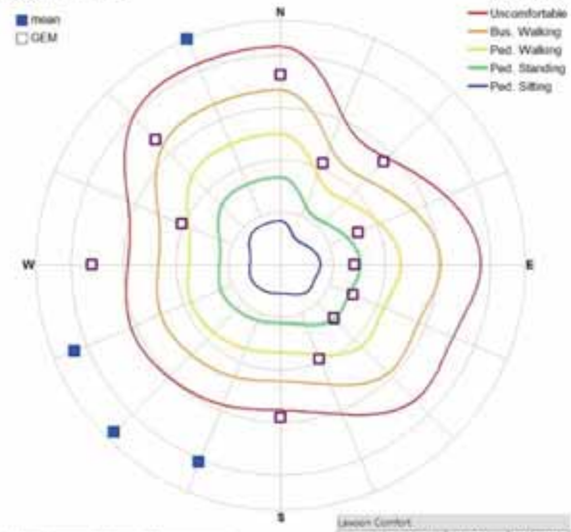
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 5.4 | 5.6 | 5.8 |
| Rating | Ped Standing | Ped Standing | Ped Standing |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 13.1 | 11.5 | 13.1 |
| Rating | Pass | Pass | Pass |

## LOCATION 27




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 73.62 | 85.60 | 85.62 |
| 4 | 38.70 | 48.44 | 50.08 |
| 6 | 21.50 | 24.86 | 27.66 |
| 8 | 11.03 | 12.11 | 14.47 |
| 10 | 5.83 | 4.74 | 7.00 |

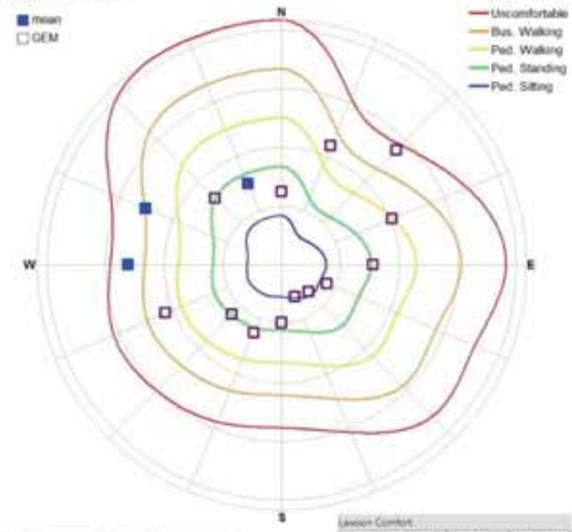
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 10.1 | 9.8 | 10.7 |
| Rating | Uncomfortable | Bus Walking | Uncomfortable |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 21.6 | 19.0 | 21.7 |
| Rating | Fail | Able Body | Fail |

## LOCATION 28




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 40.92 | 52.04 | 52.84 |
| 4 | 13.18 | 18.81 | 18.88 |
| 6 | 5.56 | 7.16 | 7.77 |
| 8 | 1.72 | 2.13 | 2.48 |
| 10 | 0.39 | 0.41 | 0.56 |

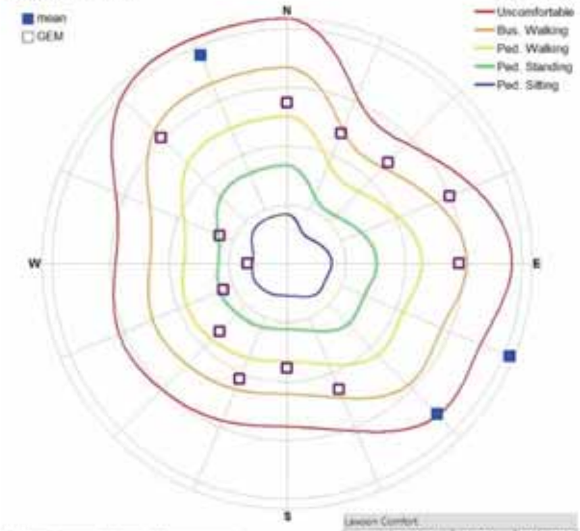
Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 6.1 | 6.7 | 6.8 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 12.7 | 12.4 | 13.0 |
| Rating | Pass | Pass | Pass |

## LOCATION 29

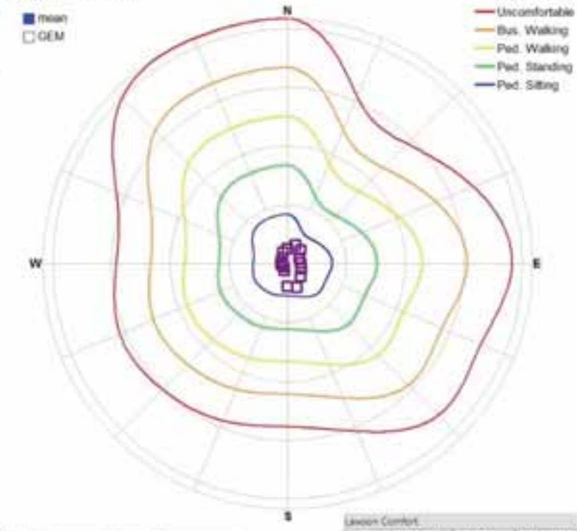



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 65.12 | 75.80 | 78.11 |
| 4 | 29.19 | 40.19 | 41.40 |
| 6 | 10.45 | 15.66 | 16.61 |
| 8 | 3.21 | 4.27 | 4.88 |
| 10 | 1.05 | 0.95 | 1.28 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 7.2 | 7.7 | 7.9 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 16.0 | 15.2 | 16.2 |
| Rating | Able Body | Able Body | Able Body |

## LOCATION 30

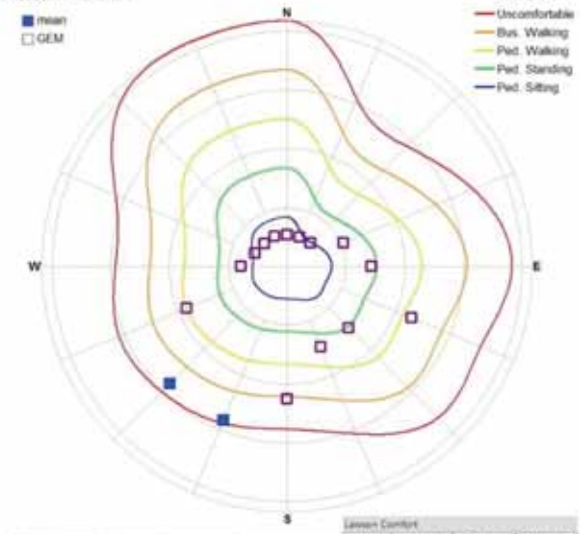



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 0.01 | 0.04 | 0.04 |
| 4 | 0.00 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 0.8 | 1.1 | 1.1 |
| Rating | Outdoor Dining | Outdoor Dining | Outdoor Dining |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 1.9 | 2.1 | 2.1 |
| Rating | Pass | Pass | Pass |

## LOCATION 31

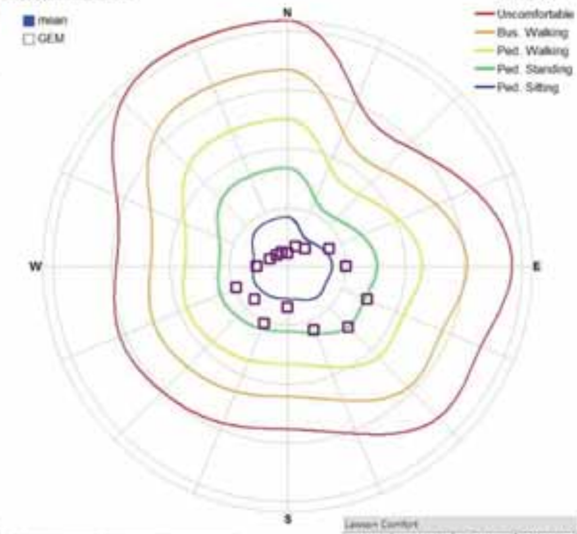



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 31.84 | 40.43 | 40.69 |
| 4 | 14.77 | 17.04 | 17.87 |
| 6 | 6.28 | 5.92 | 6.82 |
| 8 | 1.93 | 1.45 | 2.01 |
| 10 | 0.49 | 0.26 | 0.30 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 6.4 | 6.2 | 6.5 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 13.9 | 12.7 | 13.8 |
| Rating | Pass | Pass | Pass |

## LOCATION 32

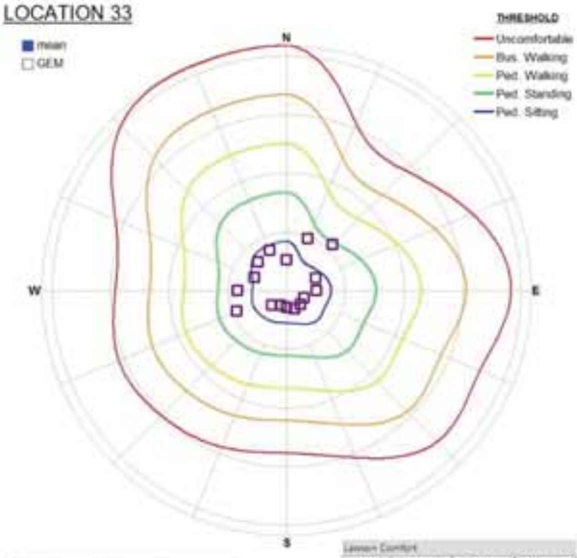



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 11.12 | 19.48 | 19.46 |
| 4 | 0.48 | 1.00 | 1.00 |
| 6 | 0.01 | 0.01 | 0.01 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 2.5 | 3.0 | 3.0 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.8 | 5.5 | 5.8 |
| Rating | Pass | Pass | Pass |

## LOCATION 33




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 5.58 | 10.55 | 10.55 |
| 4 | 0.03 | 0.32 | 0.32 |
| 6 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 2.1 | 2.6 | 2.6 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 4.1 | 4.9 | 4.9 |
| Rating | Pass | Pass | Pass |

## LOCATION 34


% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 45.79 | 55.50 | 55.50 |
| 4 | 18.87 | 26.10 | 26.10 |
| 6 | 6.87 | 11.19 | 11.19 |
| 8 | 2.08 | 3.43 | 3.43 |
| 10 | 0.45 | 0.75 | 0.75 |

Lawson Comfort

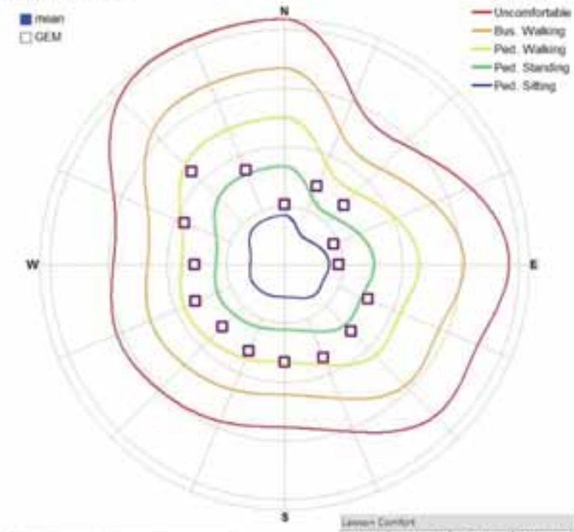
| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 6.5 | 7.1 | 7.1 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 12.9 | 13.7 | 13.7 |
| Rating | Pass | Pass | Pass |

## Configuration B

### LOCATION 4.1

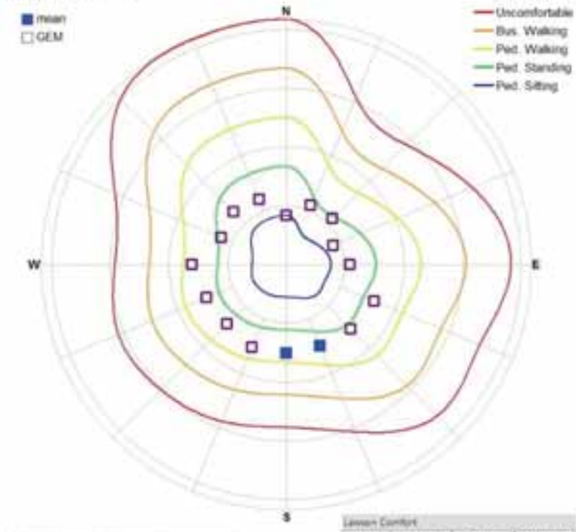



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 43.83 | 60.61 | 60.61 |
| 4 | 6.94 | 15.40 | 15.40 |
| 6 | 0.50 | 1.99 | 1.99 |
| 8 | 0.03 | 0.23 | 0.23 |
| 10 | 0.00 | 0.03 | 0.03 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.2 | 5.1 | 5.1 |
| Rating | Ped Standing | Ped Standing | Ped Standing |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 8.2 | 10.2 | 10.2 |
| Rating | Pass | Pass | Pass |

### LOCATION 8.1

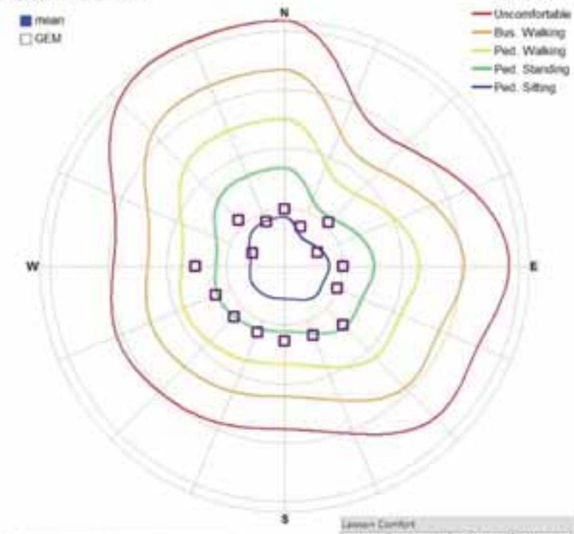



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 35.57 | 48.34 | 48.49 |
| 4 | 6.35 | 8.53 | 8.84 |
| 6 | 0.47 | 0.67 | 0.75 |
| 8 | 0.02 | 0.03 | 0.03 |
| 10 | 0.00 | 0.00 | 0.00 |

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

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

### LOCATION 12.1

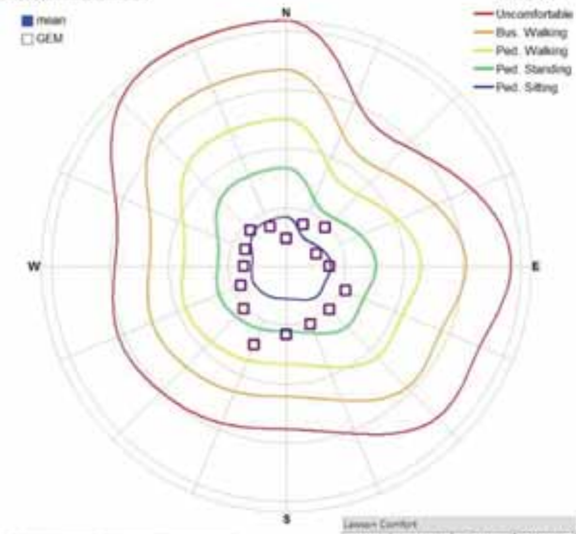



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 21.44 | 36.58 | 36.58 |
| 4 | 1.13 | 4.06 | 4.06 |
| 6 | 0.02 | 0.23 | 0.23 |
| 8 | 0.00 | 0.01 | 0.01 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 3.1 | 3.8 | 3.8 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 5.9 | 7.4 | 7.4 |
| Rating | Pass | Pass | Pass |

### LOCATION 19.1

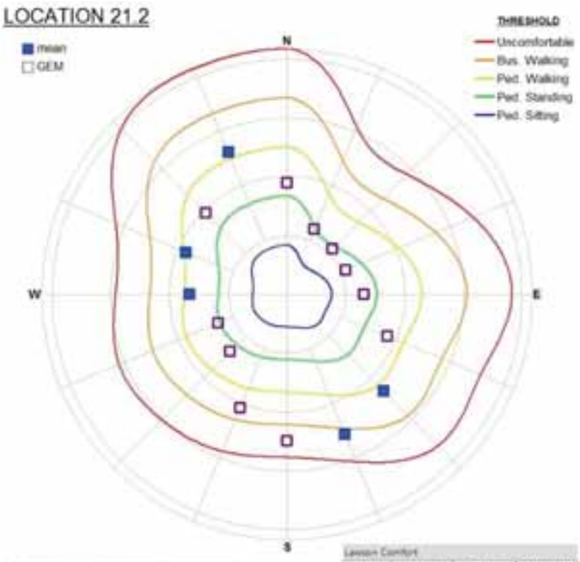



| % of time in excess of wind speed V | | | |
|---|---|---|---|
| V (m/s) | MEAN | GEM | COMBINED |
| 2 | 7.08 | 26.86 | 26.86 |
| 4 | 0.05 | 2.02 | 2.02 |
| 6 | 0.00 | 0.10 | 0.10 |
| 8 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 |

| Lawson Comfort | | | |
|---|---|---|---|
| (5%) | MEAN | GEM | COMBINED |
| V (m/s) | 2.1 | 3.5 | 3.5 |
| Rating | Ped Sitting | Ped Sitting | Ped Sitting |

| Lawson Safety | | | |
|---|---|---|---|
| (0.022%) | MEAN | GEM | COMBINED |
| V (m/s) | 4.3 | 6.9 | 6.9 |
| Rating | Pass | Pass | Pass |

**Mitigation for location 21 (renamed 21.2)**




% of time in excess of wind speed V

| V (m/s) | MEAN | GEM | COMBINED |
|---|---|---|---|
| 2 | 58.47 | 64.99 | 66.45 |
| 4 | 20.45 | 21.72 | 23.81 |
| 6 | 6.36 | 6.62 | 7.77 |
| 8 | 1.42 | 1.51 | 1.84 |
| 10 | 0.23 | 0.25 | 0.33 |

Lawson Comfort

| (5%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 6.3 | 6.3 | 6.6 |
| Rating | Ped Walking | Ped Walking | Ped Walking |

Lawson Safety

| (0.022%) | MEAN | GEM | COMBINED |
|---|---|---|---|
| V (m/s) | 12.3 | 12.6 | 12.8 |
| Rating | Pass | Pass | Pass |