

**ENVIRONMENTAL WIND SPEED MEASUREMENTS ON A WIND
TUNNEL MODEL OF THE GLEN SHOPPING CENTRE
REDEVELOPMENT,
GLEN WAVERLEY**

**By
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SUMMARY

Wind tunnel tests have been conducted on a 1/400 scale model of The Glen Shopping Centre Redevelopment to provide data on the environmental wind conditions in the surrounding street scapes and the new Square area at the southwest corner of the site. The model of the shopping centre, within surrounding buildings, was tested in a simulated upstream boundary layer of the natural wind. The wind conditions measured have been related to the free stream mean wind speed at a reference height of 300m and compared with criteria developed for the Melbourne region as a function of wind direction.

For the Basic Configuration the wind conditions at many locations achieved the criterion for walking comfort for all wind directions. However, there were several locations, particularly near ground level corners below the apartment buildings, where the wind conditions were above the criterion for walking comfort for ranges of wind directions. Wind mitigation strategies have been developed to improve the wind conditions at these locations to be either on or within the criterion for walking comfort for all wind directions.

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OF THE GLEN SHOPPING CENTRE REDEVELOPMENT,
GLEN WAVERLEY**

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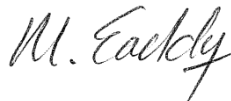
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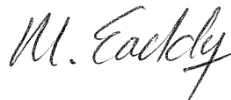
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1. INTRODUCTION

The Glen Shopping Centre is located in the suburb of Glen Waverley and it has been proposed to redevelop the existing shopping centre to the south towards O'Sullivan Road. The redevelopment includes retail tenancies, an outdoor plaza on the corner of O'Sullivan Road and Snedden Drive, and three residential apartment towers. The three residential apartment towers are as follows:

Tower A – On the corner of Springvale and O'Sullivan Roads

Tower B – Between Towers A and C running parallel to Tower C

Tower C – Sneddon Drive

There is an apartment building proposed for the south side of O'Sullivan Road and at this stage only the envelope is known. The wind tunnel model has considered this building in the study and data has been collected without this building for nearby locations.

A wind tunnel model study was commissioned by Time & Place on behalf of Golden Age to undertake measurements of environmental wind conditions around the proposed development and, if necessary, develop wind amelioration features.

These tests were carried out in the MEL Consultants 400kW Boundary Layer Wind Tunnel during August 2017.

2. ENVIRONMENTAL WIND CRITERIA

The advancement of wind tunnel testing techniques, using large boundary layer flows to simulate the natural wind, has facilitated the prediction of wind speeds likely to be induced around a development. To assess whether the predicted wind conditions are likely to be acceptable or not, some form of criteria are required. A discussion of criteria for environmental wind conditions has been made in a paper by Melbourne, Reference 1. This paper notes that it is the forces caused by the peak gust wind speeds and associated gradients which people feel most and criteria have been stated in terms of gust wind speeds. The probabilistic inference of these criteria in relation to hourly mean wind speeds and frequency of occurrence is discussed. The basic criteria can be summarised as follows:

In main public access-ways wind conditions are considered

- (a) unacceptable if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5° wind direction sector exceeds 23ms⁻¹ (the gust wind speed at which people begin to get blown over);
- (b) generally acceptable for walking in waterfront locations if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5° wind direction sector does not exceed 20 ms⁻¹ (which results in 75% of the wind pressure of a 23 ms⁻¹ gust).
- (c) generally acceptable for walking in urban and suburban areas if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5° wind direction sector does not exceed 16 ms⁻¹ (which results in half the wind pressure of a 23 ms⁻¹ gust).

For more recreational activities wind conditions are considered

- (d) generally acceptable for stationary short exposure activities (window shopping, standing or sitting in plazas) if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5° wind direction sector does not exceed 13 ms⁻¹;
- (e) generally acceptable for stationary, long exposure activities (outdoor restaurants, theatres) if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5° wind direction sector does not exceed 10 ms⁻¹.

The probability of exceedence of 0.1% relates approximately to the annual maximum mean wind speed occurrence for each wind direction sector. These criteria can be developed in terms of hourly mean wind speed versus frequency of occurrence as shown in References 1 and 2.

For the purpose of comparison, or integrating with local wind data, it is necessary to be able to relate the local velocity measurement to a reference velocity well clear of the influence of buildings. Because the wind force is related to wind velocity squared, it is often more convenient to express criteria in terms of velocity ratio squared, or velocity pressure ratio as this becomes. To this end, two velocity pressure ratios referenced to conditions at 300m height in suburban terrain [terrain category 3] (as a convenient reference) are defined as,

$$\text{mean velocity pressure ratio} \quad \left| \frac{\bar{V}_{\text{local}}}{\bar{V}_{300\text{m}}} \right|^2$$

and

$$\text{peak velocity pressure ratio} \quad \left| \frac{\hat{V}_{\text{local}}}{\bar{V}_{300\text{m}}} \right|^2$$

where the peak velocity is the 3-second mean maximum gust wind speed in full scale conditions.

For wind conditions in Melbourne these criteria can be expressed in terms of velocity pressure ratios, calculated from hourly mean wind speed data as per the methodology given in Reference 1. Corrections have been made where long distance approach terrain is different to Terrain Category 3.

The criteria in terms of peak velocity pressure ratios are illustrated in Figure 1 and appear in subsequent figures to enable immediate assessment of the wind conditions as measured on the model.

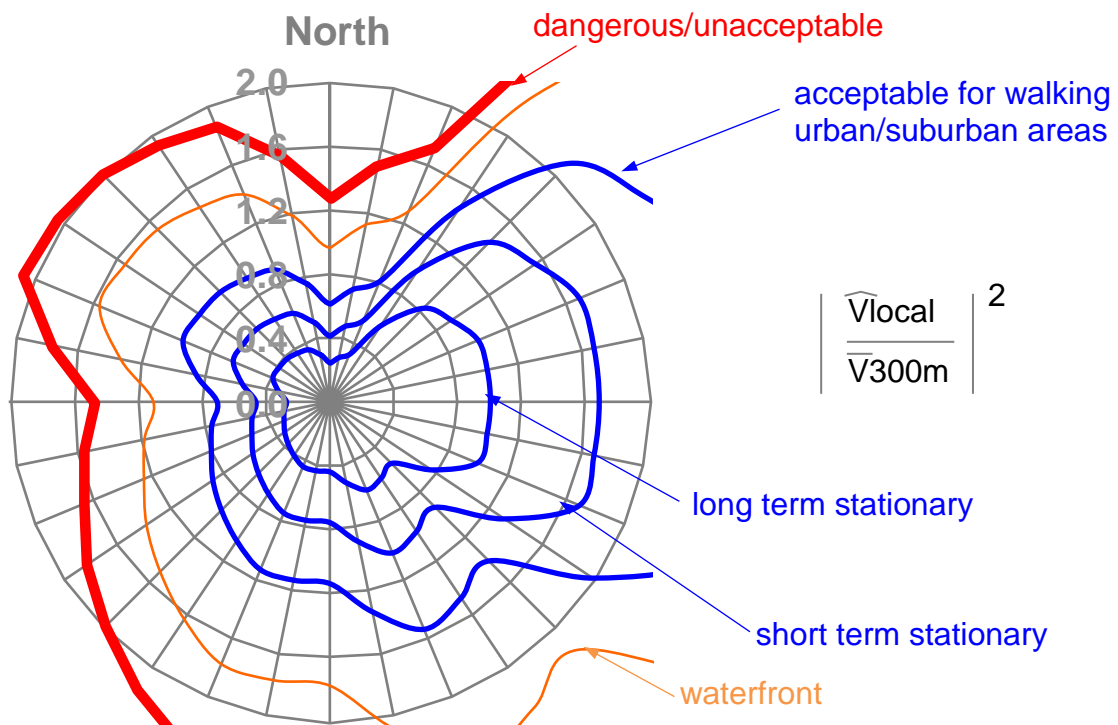


Figure 1 - Environmental wind criteria for the Melbourne Region expressed in terms of peak velocity pressure ratios

The velocity pressure ratio values considered as unacceptable in Figure 1 are equivalent to conditions which have existed in some areas in Australian capital cities where people have been blown over by the wind. The velocity pressure ratios considered as acceptable for walking in urban and suburban areas are equivalent to conditions existing at corners in these areas before high rise development commenced.

The velocity pressure ratios considered as acceptable for walking near waterfronts are typical of waterfront wind conditions in southern Australia.

3. MODEL AND EXPERIMENTAL TECHNIQUES

A 1/400 scale model of The Glen Shopping Centre was constructed from drawings by Rothe Lowman received 2 August, 2017. The wind tunnel model included the topography of the surrounding area as there are land elevation changes to the east and west of the site.

The 1/400 scale model of The Glen Shopping Centre and surrounding buildings were tested in a model of the natural wind generated by flow over roughness elements augmented by vorticity generators at the entrance of the wind tunnel working section. The basic natural wind model was for flow over suburban terrain roughness, which had a mean velocity power law profile with an exponent of 0.2, i.e. $\bar{V}_z = f(z)^{0.2}$ and a turbulence intensity at a scaled height of 100m of $\sigma_v/\bar{V} = 0.17$, as shown in Figure 2. Photographs of the model Buildings are shown in Figures 3 and 4.

The techniques used to investigate the environmental wind conditions and the method of determining the local criteria are given in detail in Reference 2. In these tests measurements in the development areas are inside separated regions and peak velocity squared ratios were required to make conclusions about likely wind conditions. In summary, measurements were made of the peak gust wind velocity with a hot wire anemometer at various stations and expressed as a squared ratio with the mean wind velocity at a scaled reference height of 300m. This gives the peak velocity squared ratio

$$\left(\hat{V}_{\text{local}}/\bar{V}_{300\text{m}}\right)^2$$

as defined in Section 2. This peak velocity squared ratio can then be compared with the velocity squared ratio criteria for Melbourne given in Figure 1.

Measurements were made at various locations in and around the development, for different wind directions at 22.5° intervals. Turbulent gusty wind flows, caused by separated flows, were generally observed with a combination of low and high mean wind speeds. To quantify this, peak gust wind speeds were measured, using the hot wire anemometer, and related to the environmental wind criteria via the calculated peak velocity squared ratios. The results of these measurements are presented on polar diagrams

against a background plot of the various criteria for each Test Location. The Test Locations are shown in Figures 5a and 5b for Ground, and Level 1 and Podium Level, respectively.

4. DISCUSSION OF RESULTS

The Basic Configuration was defined according to drawings supplied by Rothe Lowman received 2 August, 2017. The following Sections detail the results for the various areas tested.

The Basic Configuration was studied and where wind conditions were found to be above the criteria for the intended activation, then wind mitigation strategies were developed. The following strategies were developed:

- Trees along O'Sullivan Street (both sides)
- Trees along Sneddon Drive
- Canopy along the O'Sullivan Road
- Canopy over designated barbeque areas on Podium Level

These strategies are detailed in Figures 6.

4.1 Summary of discussion (Figures 7a and 7b)

The findings of this study of the pedestrian level wind conditions in the surrounding streetscapes have been summarised using a colour code system in Figures 7a and 7b for the Basic Configuration at Ground and Level 1 respectively. Figures 7c and 7d summarised the wind conditions for the Basic with Mitigation Strategies Configuration for Ground and Level 1, respectively. The summaries are the highest wind condition at each Test Location for all wind directions (i.e. $0^{\circ} \rightarrow 360^{\circ}$). Different colours have been used to represent the highest wind criteria achieved at each Test Location. Where the wind conditions at a Test Location were distributed across several criteria, the criteria colours have been graduated.

4.2 Springvale Road (Figure 8)

The wind conditions for the Basic Configuration along Springvale Road away from the corner of Springvale and O'Sullivan Roads (Test Locations 1, 2, and 3) have been shown to be either on or within the criterion for walking comfort for all wind directions. The wind conditions at the corner (Test Location 4) have been shown to exceed the criterion for

walking comfort for the south-westerly wind directions. The flow visualisation indicated that the increased wind conditions were caused by the wind flow deflected off the south face of the Tower A. The addition of the canopy and street trees along O'Sullivan Road have been shown to be mitigate the wind conditions to be within the criterion for walking comfort for all wind directions.

4.3 O'Sullivan Road (Figures 9 and 10)

The wind conditions for the Basic Configuration on the north side footpath of O'Sullivan Road (Test Locations 7, and 25) have been shown to be achieve the criterion for walking comfort for all wind directions. The wind conditions for the Basic Configuration outside the ground level entrance to the Tower A (Test Location 6) have been shown to be or within the criterion for walking comfort and achieve the short term stationary criterion for most wind directions. The wind conditions for the Basic Configuration increase as the corner of O'Sullivan and Springvale Roads is approached (Test Location 5) and have been shown to be above the criterion for walking comfort for the south-westerly wind directions, and either on or within the criterion for the remaining wind directions. Again, the addition of a canopy and street trees has been shown to improve wind conditions to be within the criterion for walking comfort at Test Location 5.

The wind conditions along the south side of O'Sullivan Road (Test Locations 22 and 23) have been shown to exceed the walking comfort criterion for the south and west wind directions, respectively, and within for the remaining wind directions. It has been shown that the wind conditions could be mitigated by street trees along the south side of O'Sullivan Road. The wind conditions for the Basic Configuration at the corner of Springvale and O'Sullivan Roads (Test Location 24) have been shown to be just above the criterion for walking comfort for the southwest wind directions and within the criterion for the remaining wind directions. Again, the addition of the street trees along O'Sullivan Road has been shown to mitigate the wind conditions at the corner to be within the criterion for walking comfort.

4.4 Public Square (Figures 11 to 13)

The wind conditions for the Basic Configuration in the Square (Test Locations 9, 10, 11, 12, 13, 14, 15, 16, and 17) have been shown to be either on or within the criterion for walking comfort for all wind directions. The drawings indicated that locations within the Square would be used for outdoor seated retail activities and other stationary activities and wind mitigation strategies (e.g. screens, canopies, etc.) would need to be developed once the activation areas are known.

4.5 Sneddon Drive (Figure 14)

The wind conditions for the Basic Configuration along Sneddon Drive, away from the south corner of the Tower C (Test Locations 20 and 21) have been shown to be within the criterion for walking comfort for all wind directions. The wind conditions increased at the corner (Test Location 19) to be above the criterion for walking comfort for the west wind directions, and within the criterion for the remaining wind directions. It has been shown that the addition of street trees along Sneddon Drive improved the wind conditions at Test Location 19 to be within the criterion for walking comfort for all wind directions.

The wind conditions for the Basic Configuration on the Sneddon Drive west of the Public Square (Test Locations 18) have been shown to be either on or within the criterion for walking comfort for all wind directions.

4.6 Level 1 and Podium Level (Figures 15 to 18)

The wind conditions for the Basic Configuration in the Level 1 walkway (Test Locations B1 to B4) have been shown to be within the criterion for stationary activities for all wind directions.

The wind conditions for the Basic Configuration east Recreation area (Test Location P1) have been shown to achieve the criterion for walking comfort for all wind directions with most wind directions meeting stationary conditions.

In the Recreation area to the west of P1 (Test Location P2) wind conditions were shown to meet the walking comfort criterion for all wind directions for the Basic Configuration except for the north wind direction.

In the gathering zone to the north of the gap between Towers A and B (Test Locations P3a and P3b) for the Basic Configuration, westerly winds have been shown to accelerate through the gap and produce wind conditions that significantly exceed the criterion for walking comfort, approaching dangerous/unacceptable levels for winds from the west wind direction. Winds from the remaining wind directions, except for the north wind direction for Test Location P3a, were shown to be within the walking comfort criterion. The high wind conditions from west winds through the gap would be expected to affect most, if not all, of the gathering area, and it would be expected that local screening and/or trees in this area would only provide improvement of the wind conditions for parts of the gathering area.

The wind conditions to the east of the gathering zone (Test Location 3) for the Basic Configuration have been shown to be within the walking comfort criterion, indicating that this location is outside the area affected by the accelerated flow through the gap between Towers A and B.

Wind conditions to the east of Tower B (Test Location P4) wind conditions were shown to be either on or within the criterion for walking comfort for all wind directions for the Basic Configuration.

At the northeast corner of Tower B (Test Location P5) wind conditions for the Basic Configuration were shown to meet the walking comfort criterion for all wind directions with the exception of the north wind direction, which was shown to just exceed the walking comfort criterion.

In the Recreation area to the north of the Podium Level (Test Location P7) wind conditions for the Basic Configuration were shown to meet the walking comfort criterion for all wind directions except the north wind direction, which was affected by the flow separating off the north-east corner of Tower C, resulting in wind conditions that significantly exceeded the walking comfort criterion.

In the seated area to the north of the gap between Towers B and C (Test Location P6), wind conditions for the Basic Configuration have been shown to meet the criterion for walking comfort for all wind directions. At the shelter to the east of Test Location P6 (Test Location P6a) the wind conditions for the Basic Configuration were shown to exceed the walking comfort criterion for the west wind direction, with all remaining wind directions meeting the walking comfort criterion. It was shown that with a canopy over this shelter area the wind conditions for all wind directions achieve the walking comfort criterion and that with a canopy and 3 sides sealed the wind conditions at Test Location P6a meet the criterion for long term stationary activities.

4.7 Town Planning Drawings

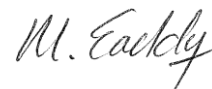
The design of the Glen Redevelopment has undergone minor changes that are detailed in the town planning drawings dated 27th September, 2017. The changes do not significantly alter the built form/massing of the development and would not have any impact on the ground level pedestrian wind conditions. Therefore, the data presented in this report would be valid for the town planning drawings, dated 27th September, 2017.

5. CONCLUSIONS

Wind tunnel tests have been conducted on a 1/400 scale model of The Glen Shopping Centre Redevelopment to provide data on the environmental wind conditions in the surrounding street scapes and the new Square area at the southwest corner of the site. The model of the shopping centre, within surrounding buildings, was tested in a simulated upstream boundary layer of the natural wind. The wind conditions measured have been related to the free stream mean wind speed at a reference height of 300m and compared with criteria developed for the Melbourne region as a function of wind direction.

For the Basic Configuration the wind conditions at many locations achieved the criterion for walking comfort for all wind directions. However, there were several locations, particularly near ground level corners below the apartment buildings, where the wind conditions were above the criterion for walking comfort for ranges of wind directions. Wind mitigation strategies have been developed to improve the wind conditions at these locations to be either on or within the criterion for walking comfort for all wind directions in the surrounding streetscapes.

The wind conditions have been measured on the Level 1 terraces and Podium Level to inform the design team and assist with the design of these spaces.



M. Eaddy



September 2017

REFERENCES

1. W. H. Melbourne, Criteria for environmental wind conditions, Journal of Industrial Aerodynamics, Volume 3, 1978, pp. 241-249
2. W. H. Melbourne, Wind environment studies in Australia, Journal of Industrial Aerodynamics, Volume 3, 1978, pp. 201-214

FIGURES

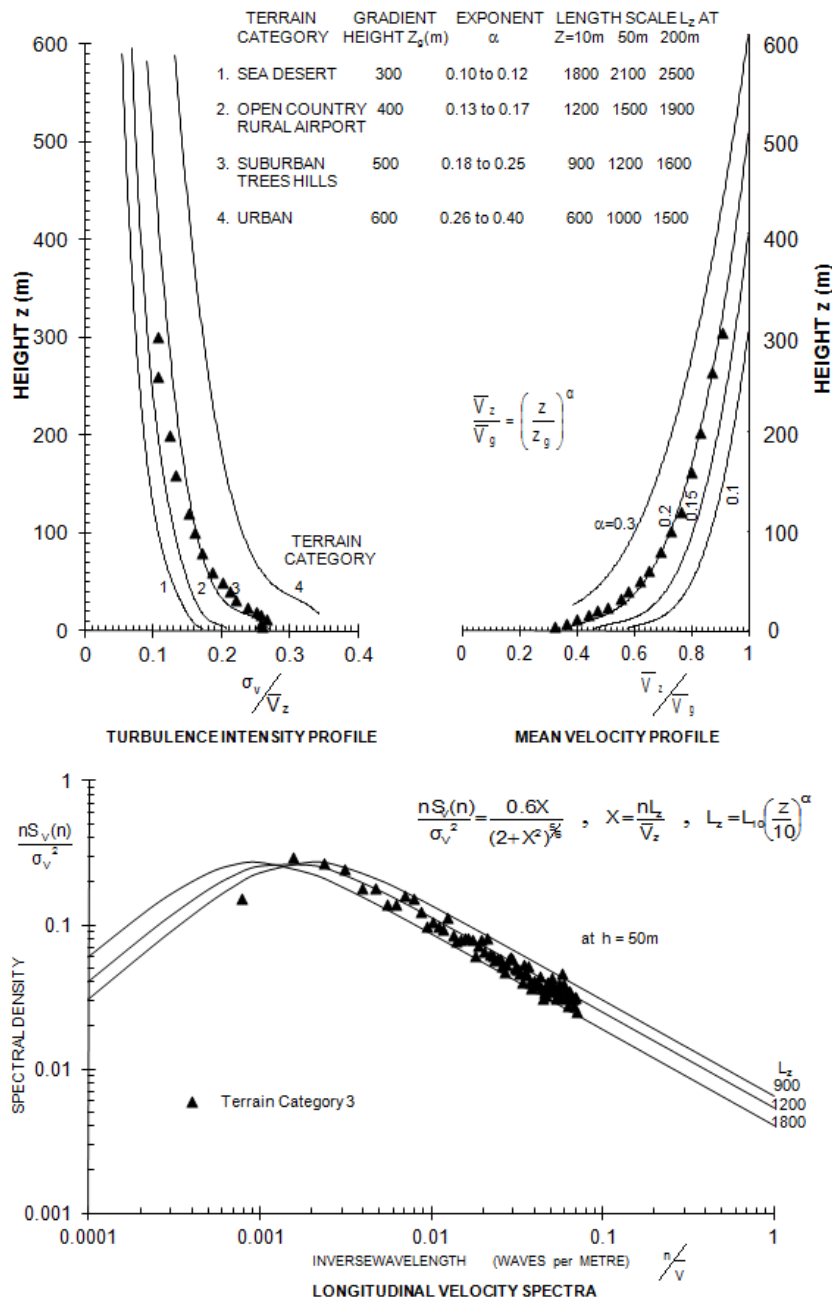


Figure 2 – 1/400 scale Terrain Category 3 boundary layer turbulence intensity and mean velocity profiles and spectra in the MEL Consultants Boundary Layer Wind Tunnel 4m x 2m working section, scaled to full scale dimensions

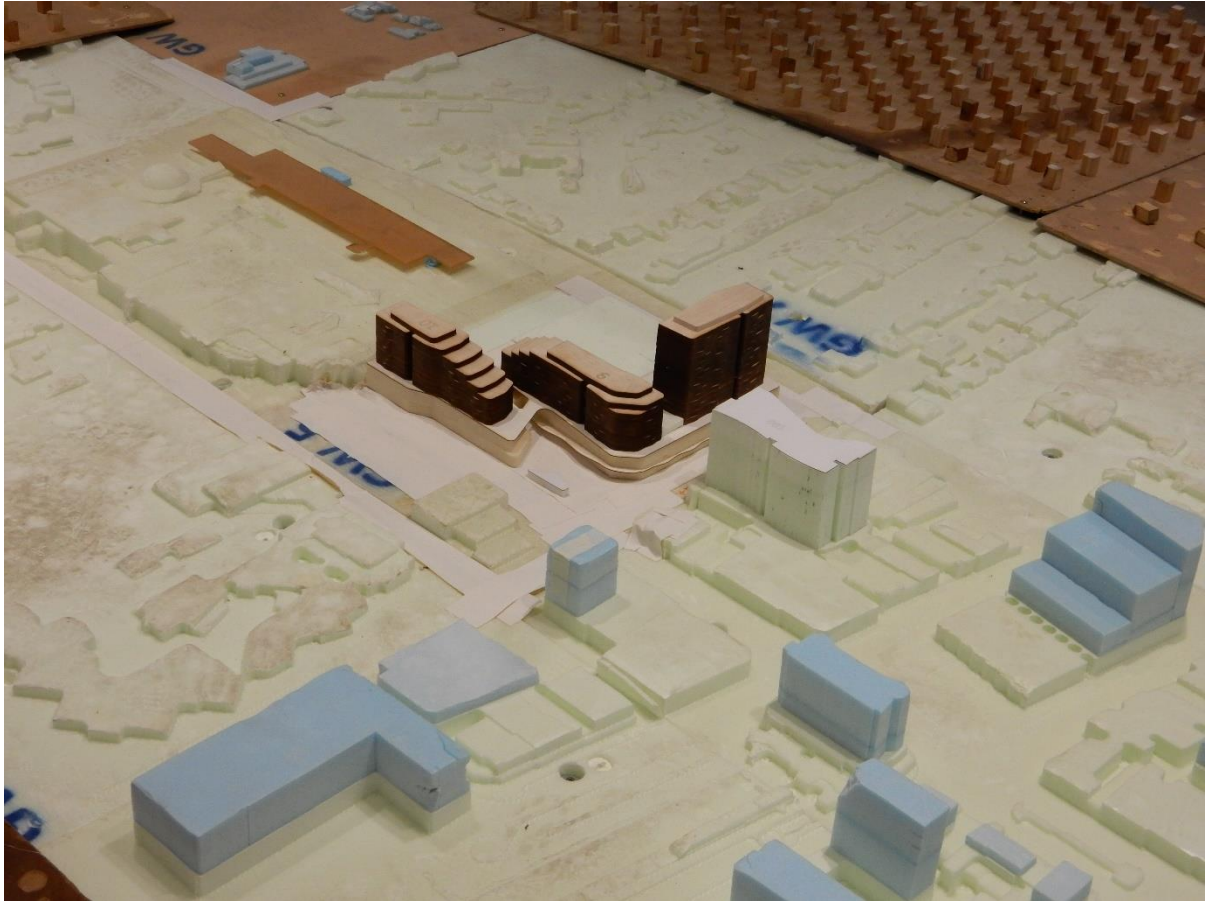


Figure 3 – 1/400 scale model of The Glen Shopping Centre Redevelopment viewed from the southwest direction.



Figure 4 – 1/400 scale model of The Glen Shopping Centre Redevelopment viewed from the southeast direction.

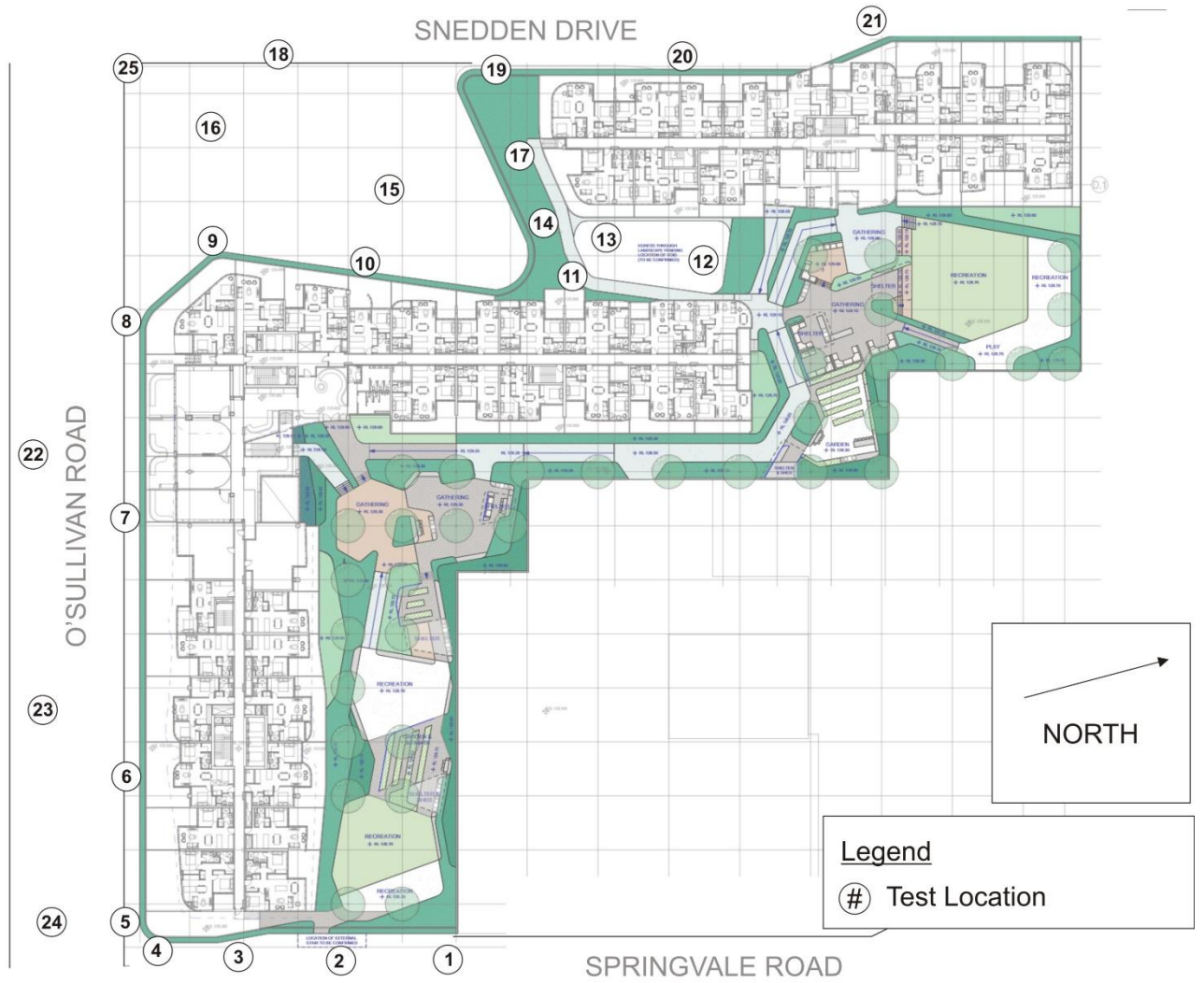


Figure 5a – Ground Level Test Locations for the proposed The Glen Shopping Centre Redevelopment

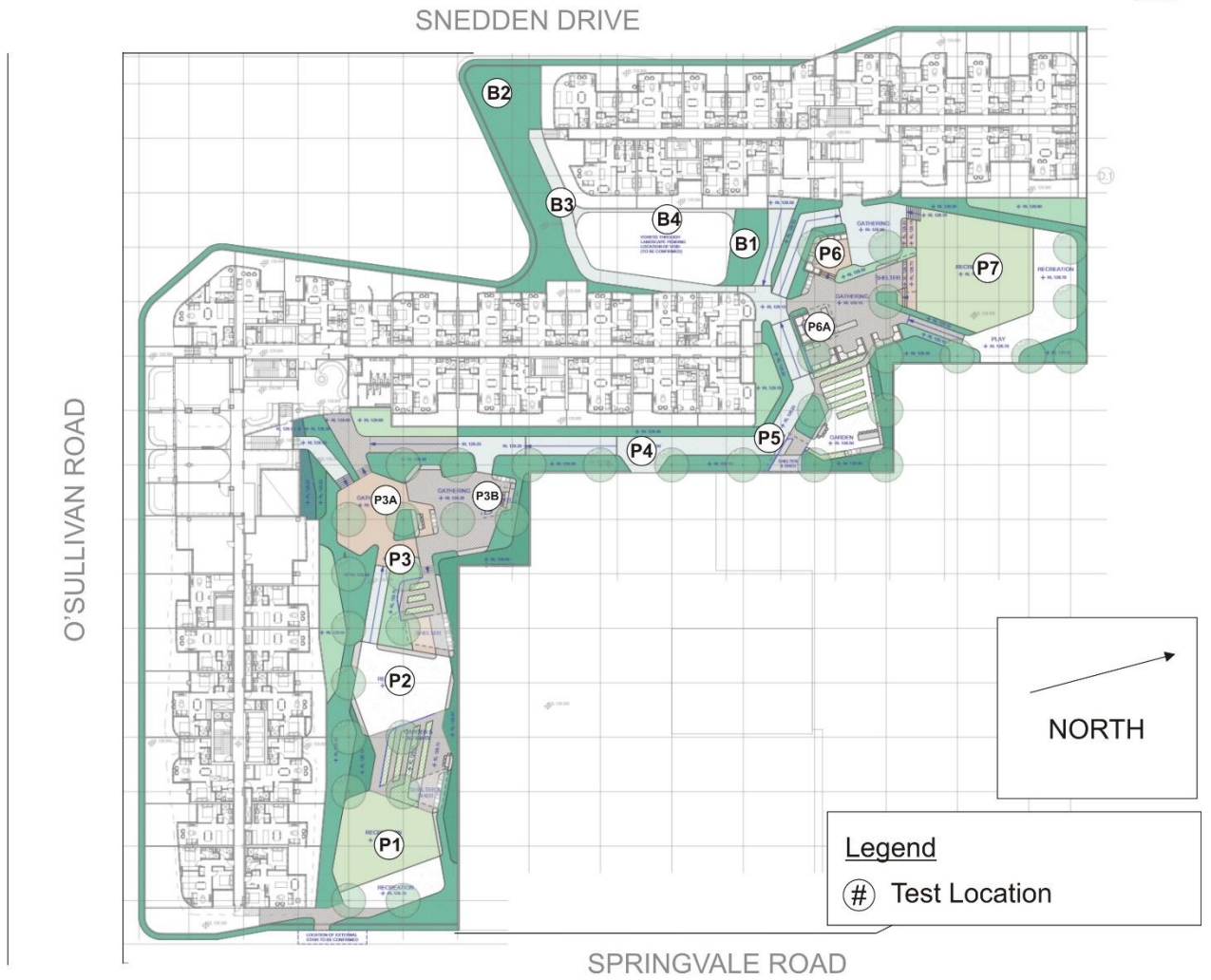


Figure 5b – Level 1 and Podium Level Test Locations for the proposed The Glen Shopping Centre Redevelopment

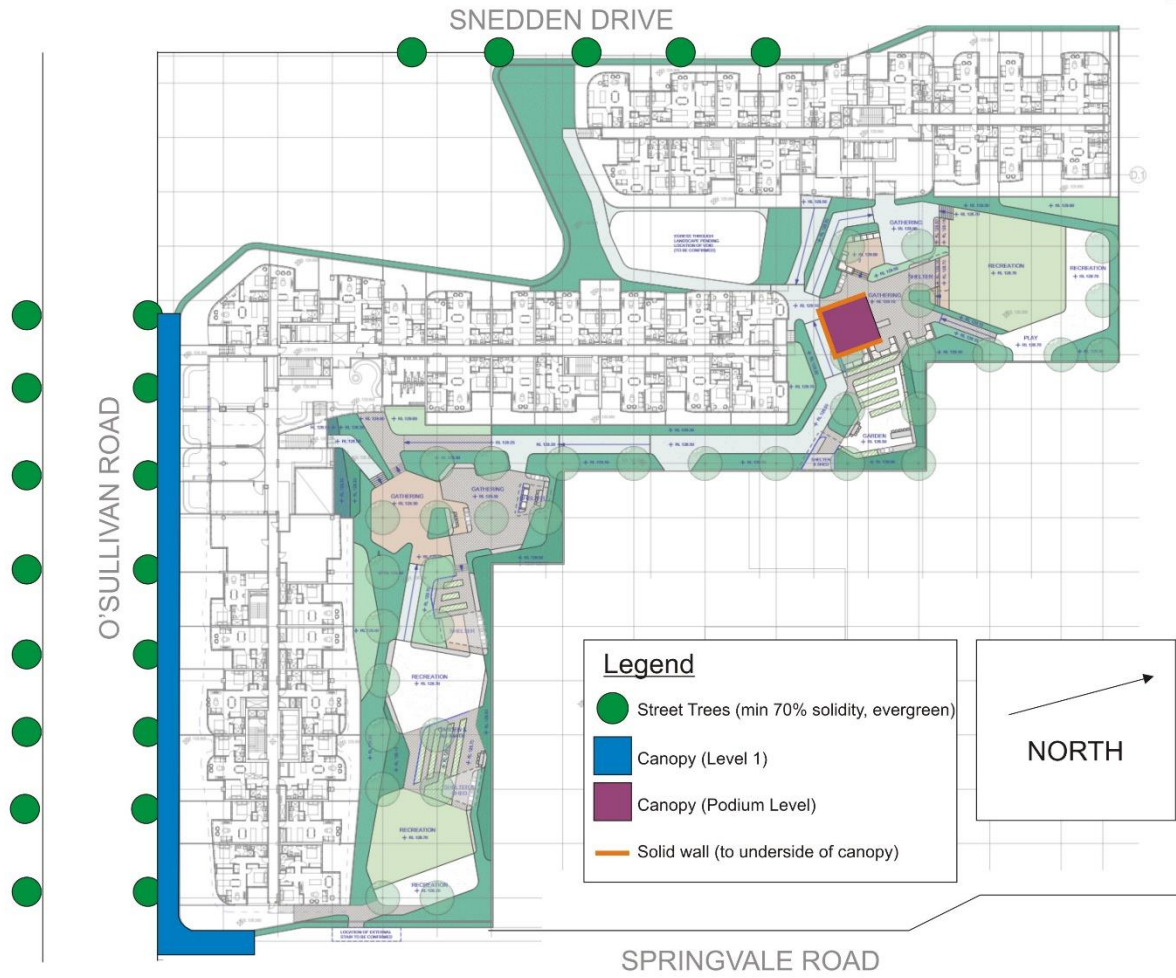


Figure 6 –Wind Mitigation Strategies at Ground Level and Podium Level

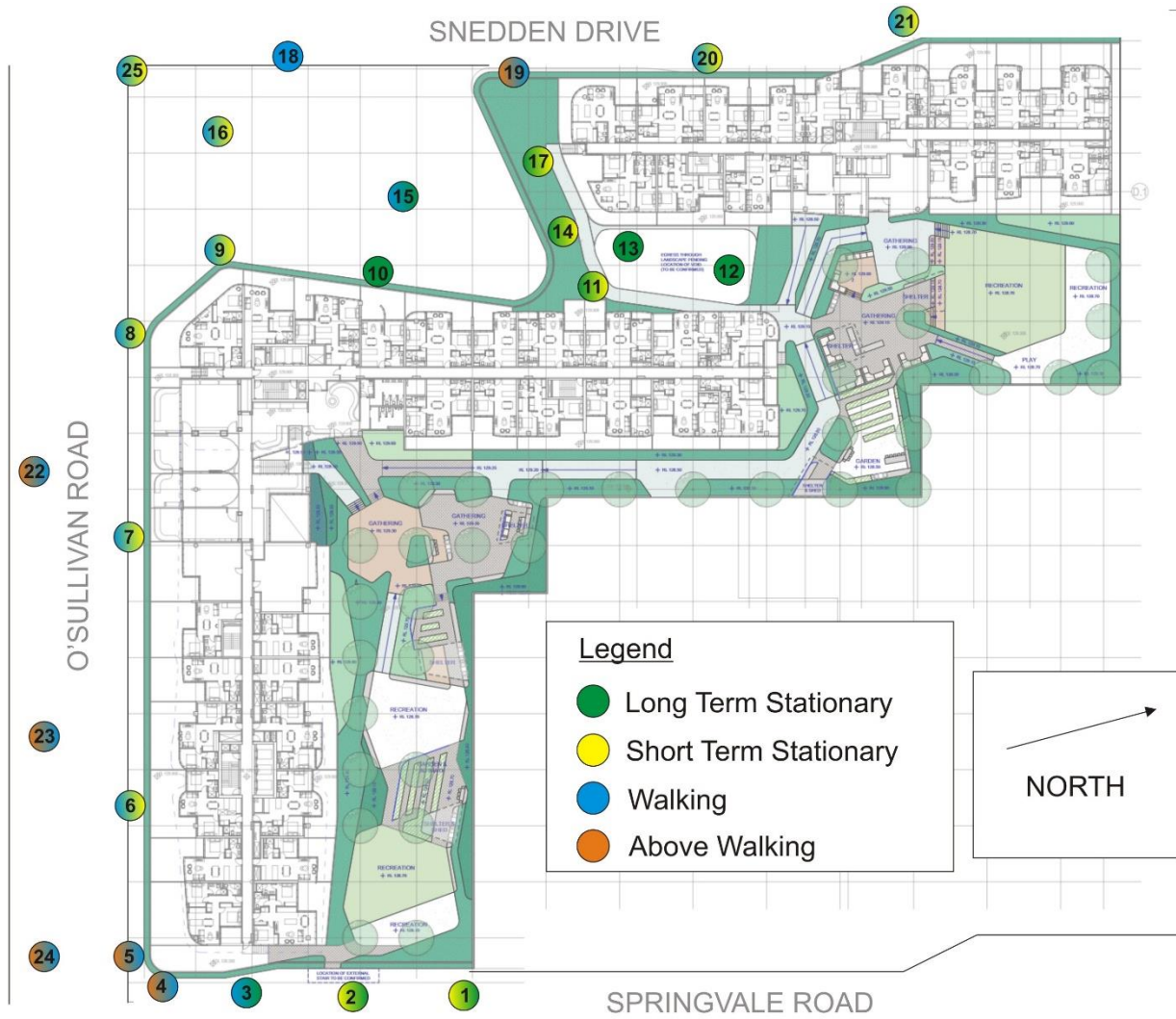


Figure 7a – Summary of Wind Conditions on Ground Level for the Basic Configuration

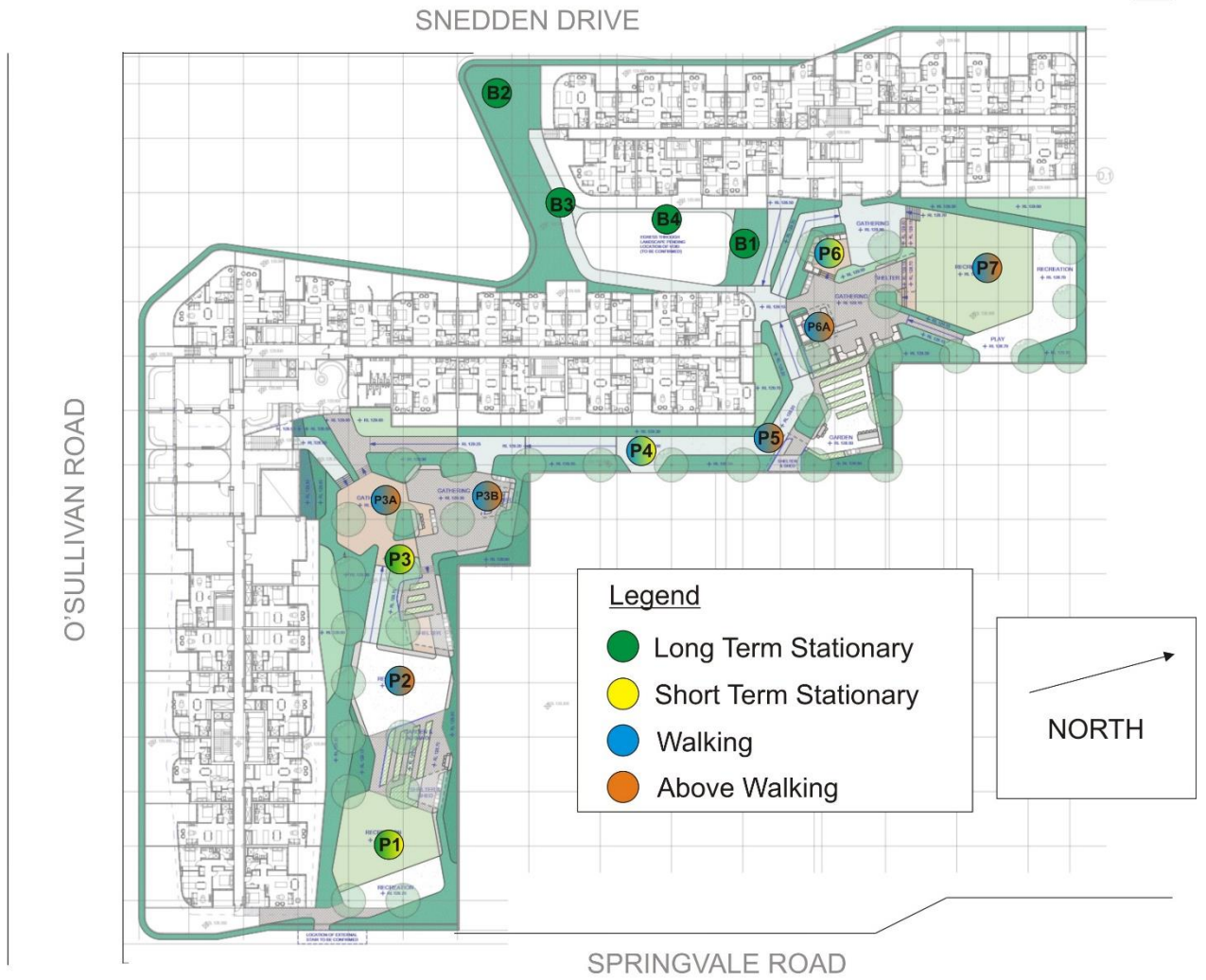


Figure 7b – Summary of Wind Conditions on Level 1 and Podium Level for the Basic Configuration

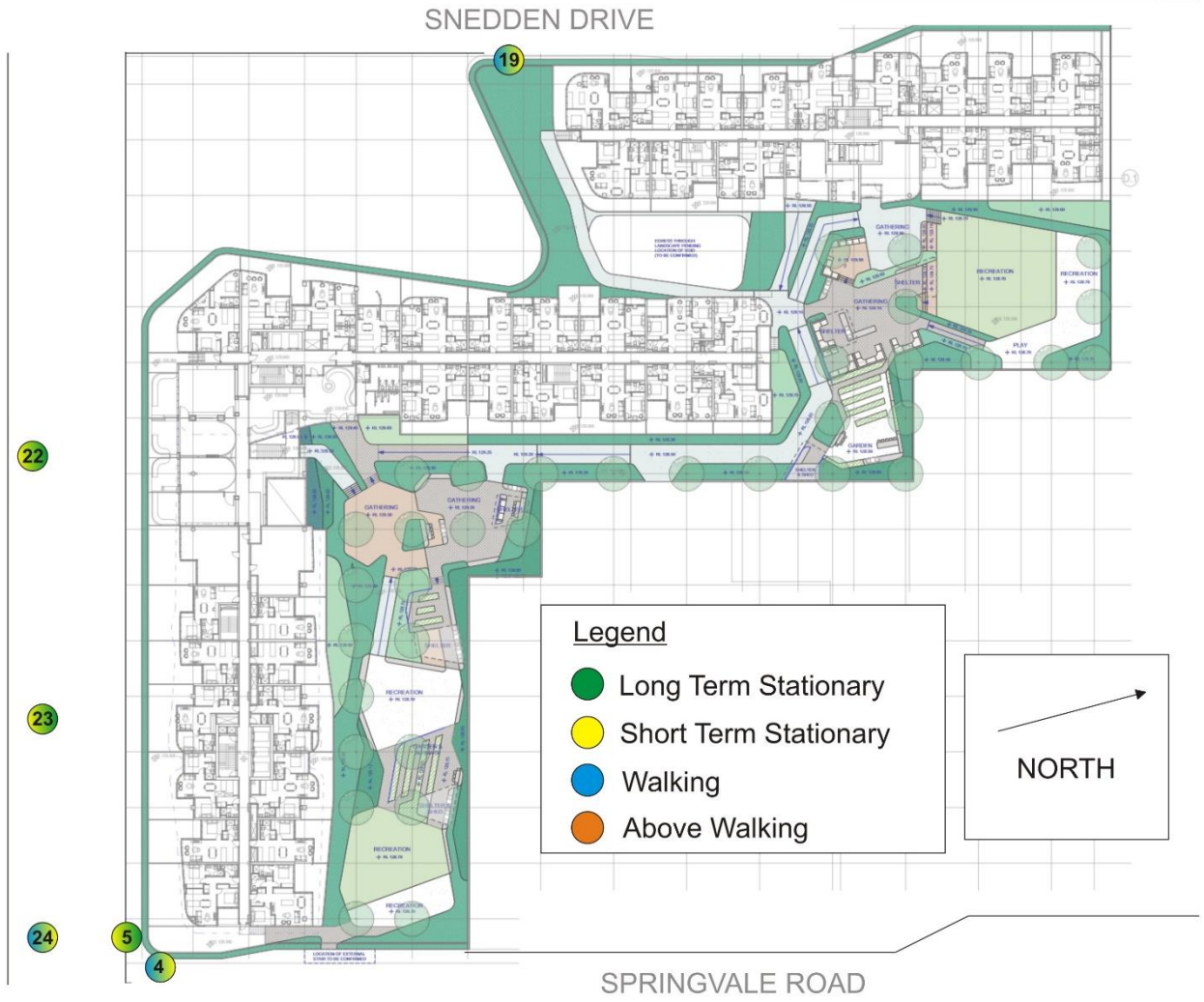


Figure 7c – Summary of Wind Conditions on Ground Level for the Basic Configuration with wind mitigation strategies

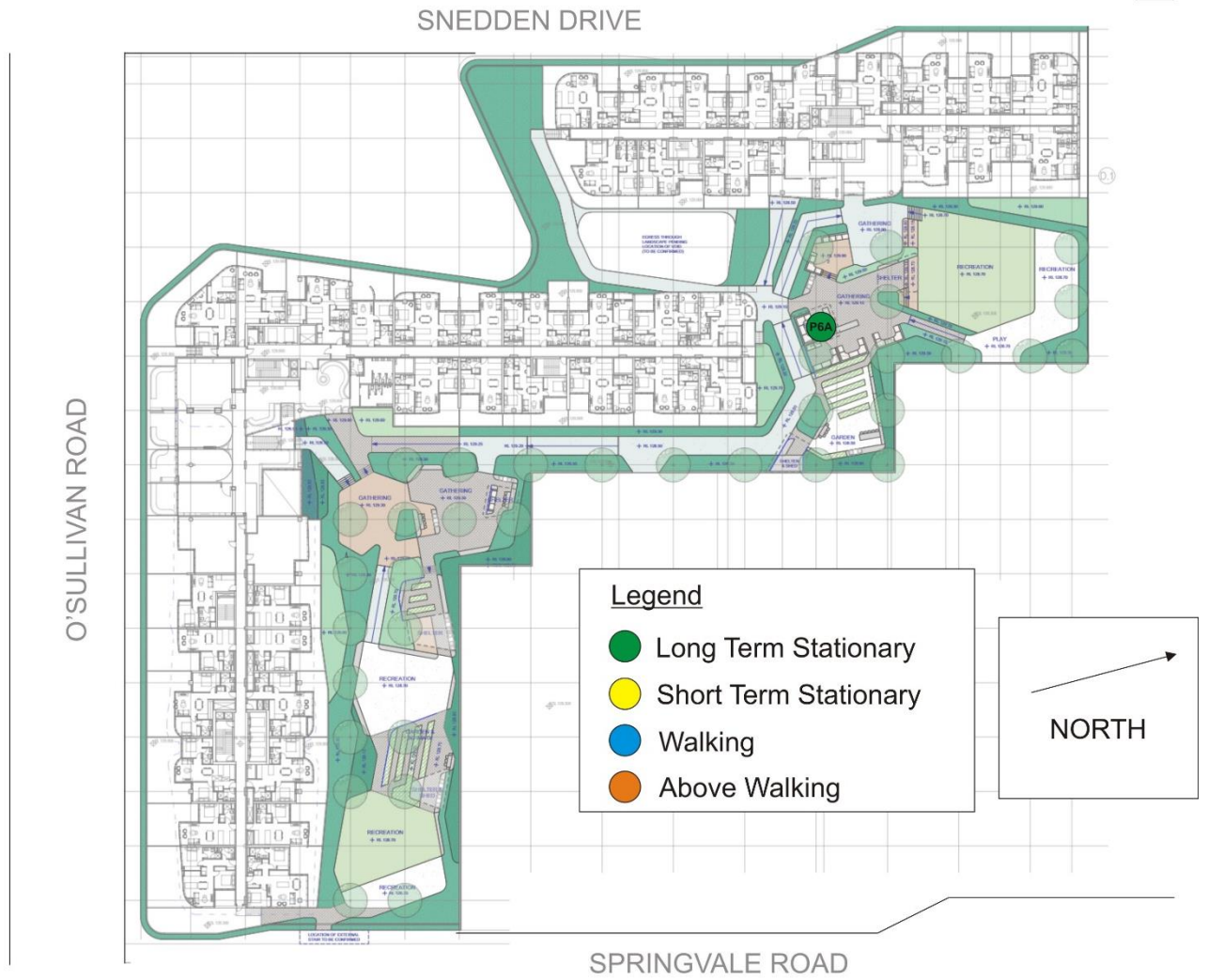


Figure 7d – Summary of Wind Conditions on Podium Level for the Basic Configuration with wind mitigation strategies

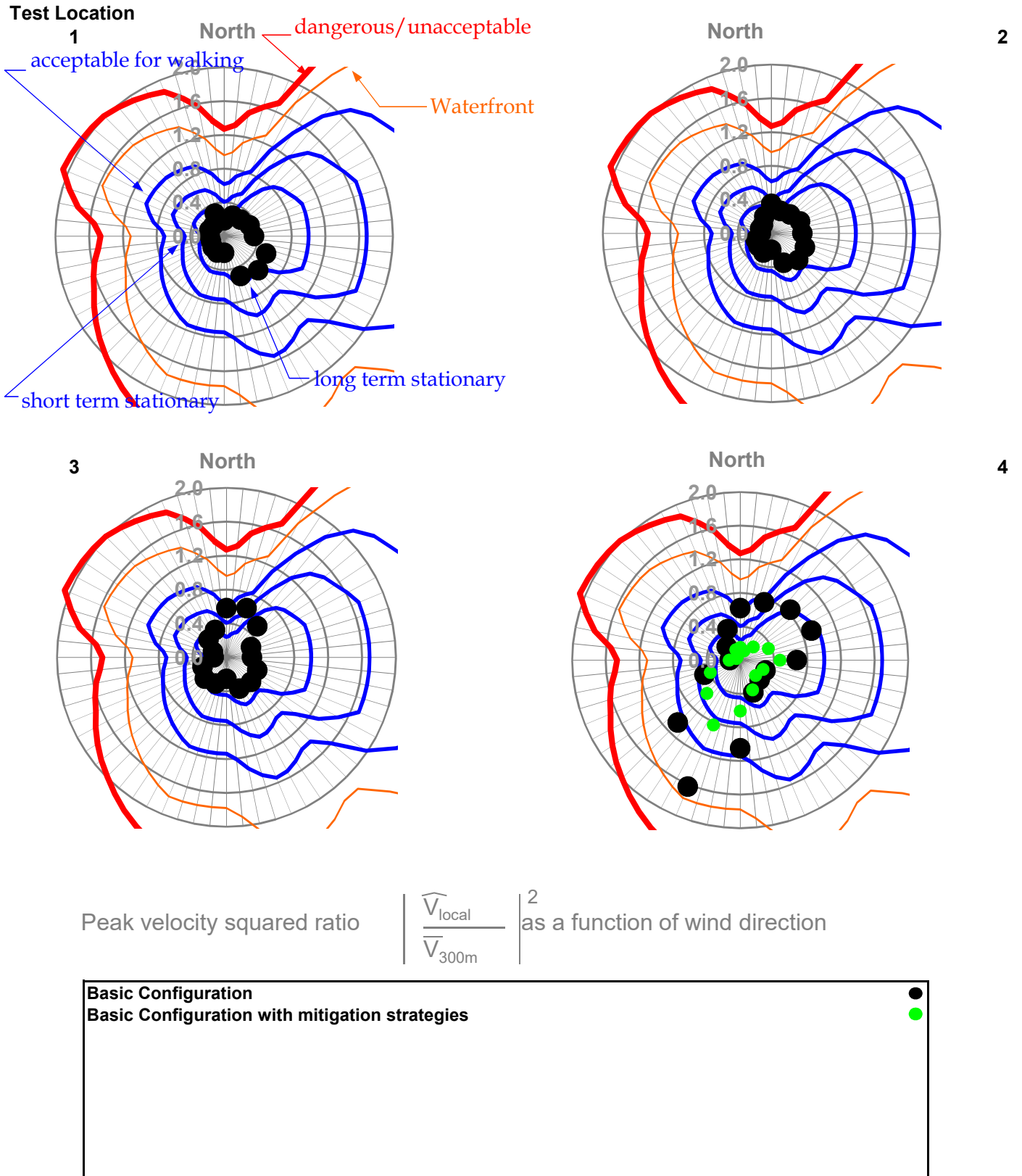
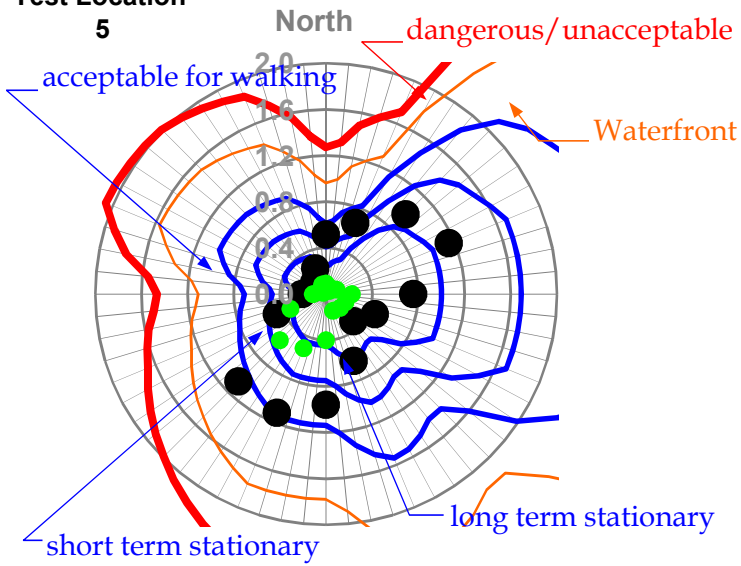
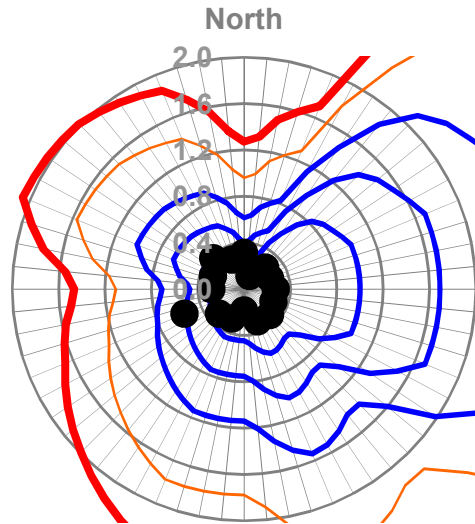


Figure 8 - Springvale Road

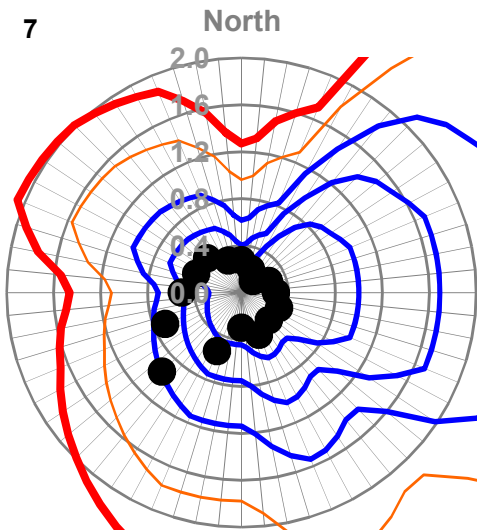
Test Location
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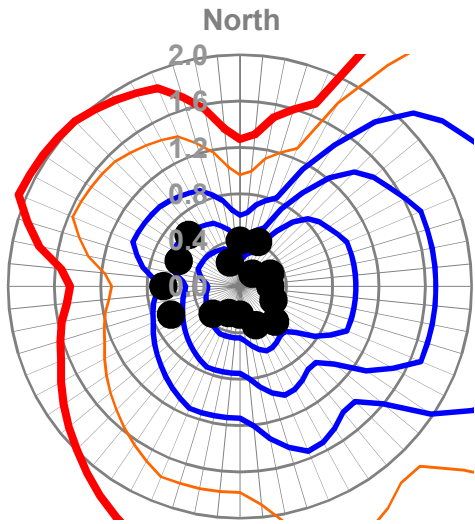
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Peak velocity squared ratio $\left| \frac{\widehat{V}_{local}}{\widehat{V}_{300m}} \right|^2$ as a function of wind direction

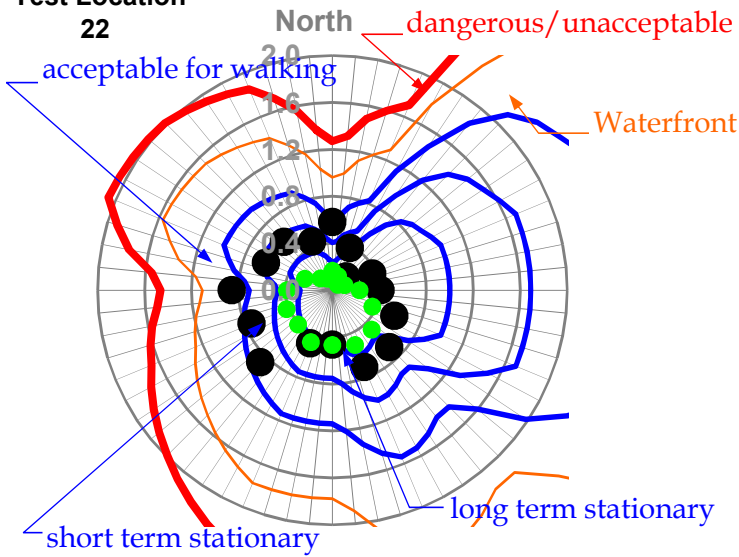
Basic Configuration

Basic Configuration with mitigation strategies

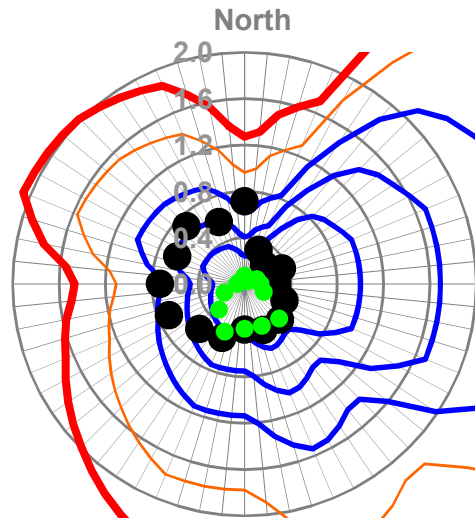


Figure 9 - O'Sullivan Road

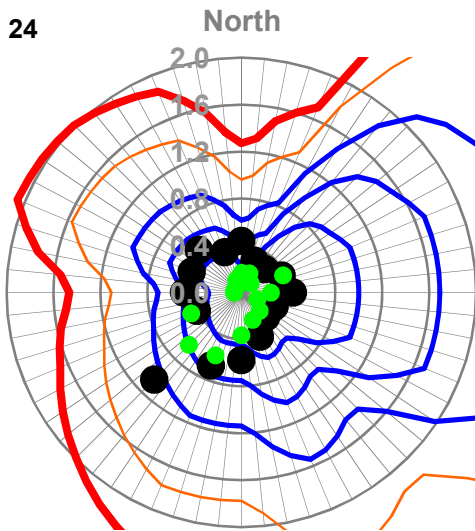
Test Location
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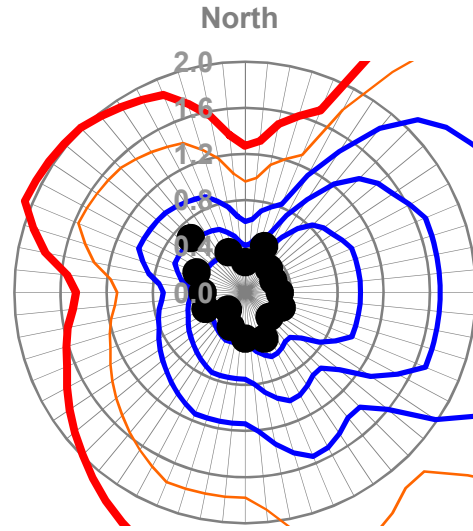
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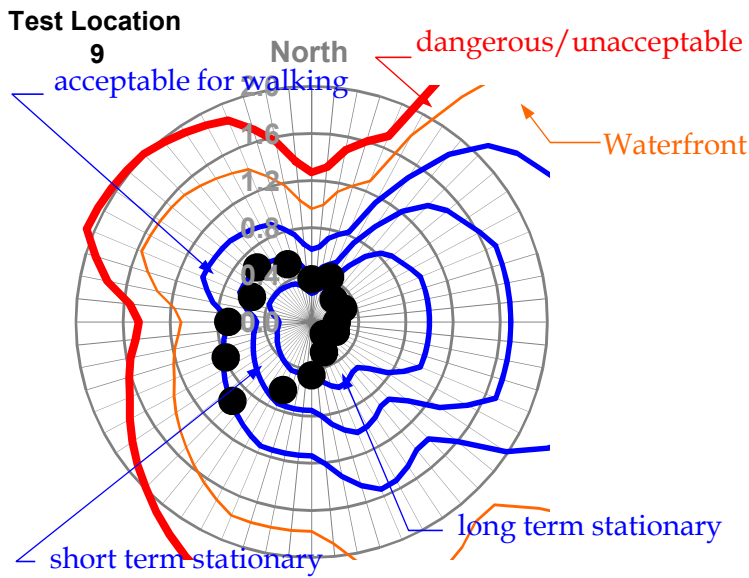
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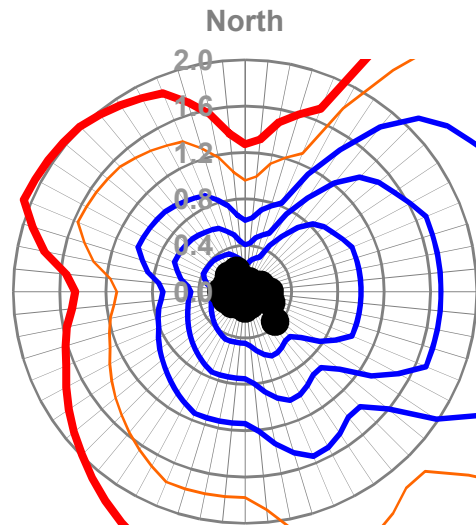
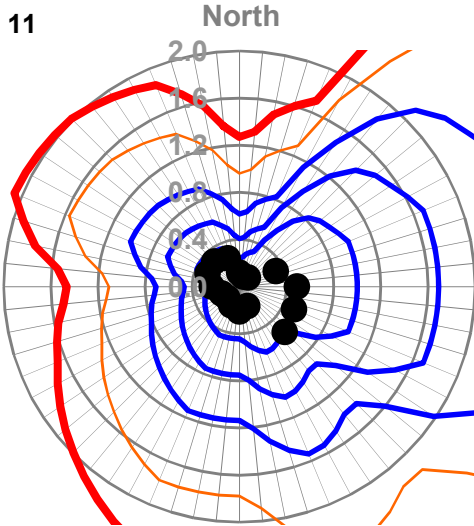
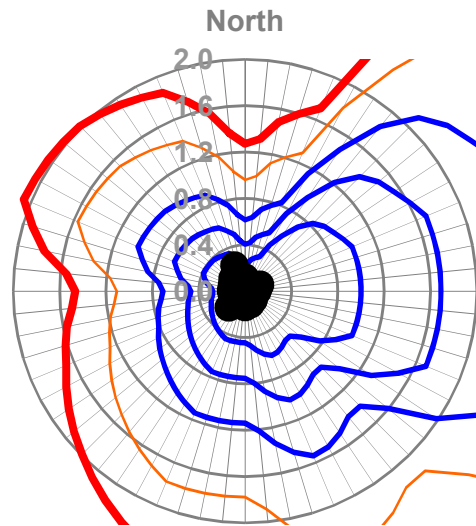
Peak velocity squared ratio $\left| \frac{\widehat{V}_{local}}{\widehat{V}_{300m}} \right|^2$ as a function of wind direction



Figure 10 - O'Sullivan Road - continued



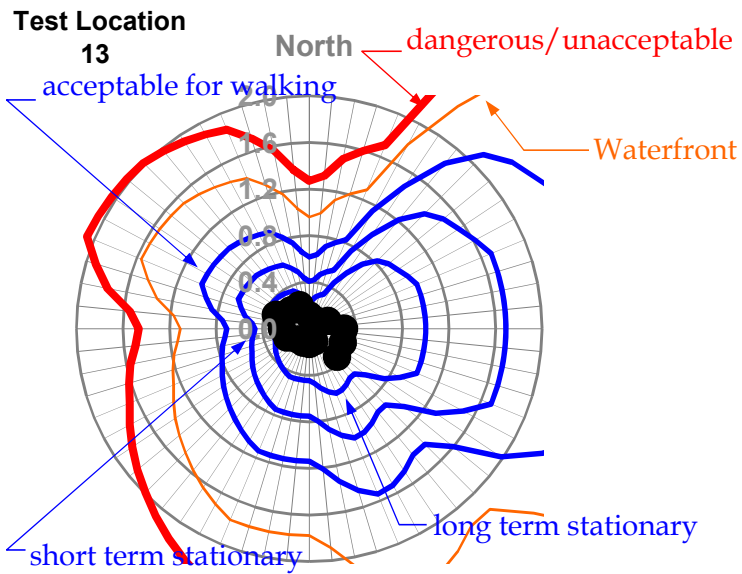
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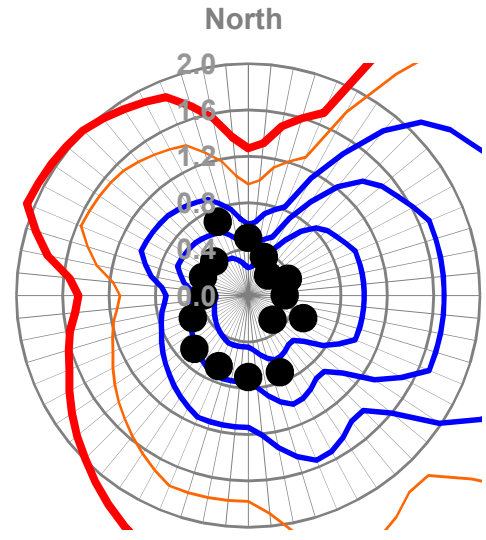
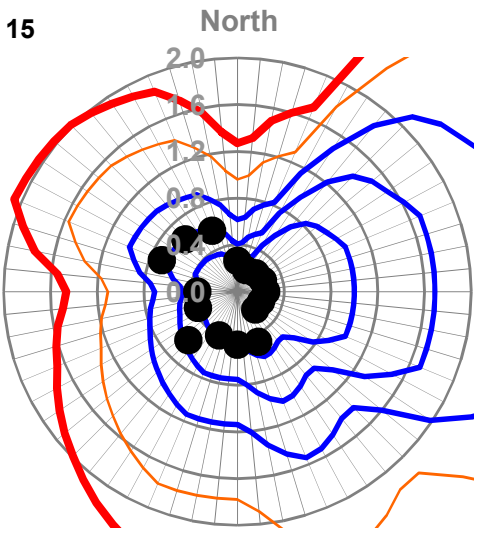
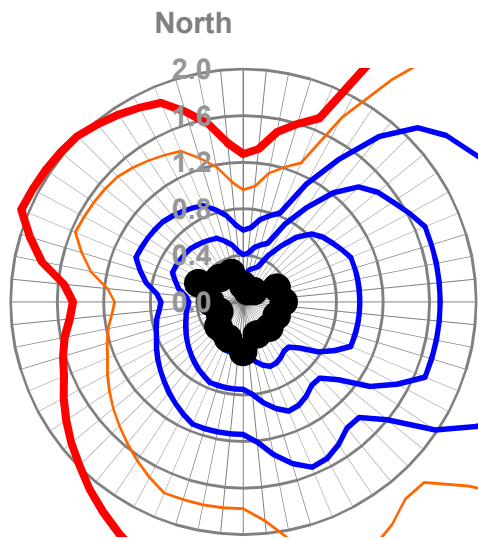
Peak velocity squared ratio $\left| \frac{\overline{V}_{local}}{\overline{V}_{300m}} \right|^2$ as a function of wind direction

Basic Configuration

Figure 11 - Public Square



14



Peak velocity squared ratio $\left| \frac{\widehat{V}_{local}}{\widehat{V}_{300m}} \right|^2$ as a function of wind direction

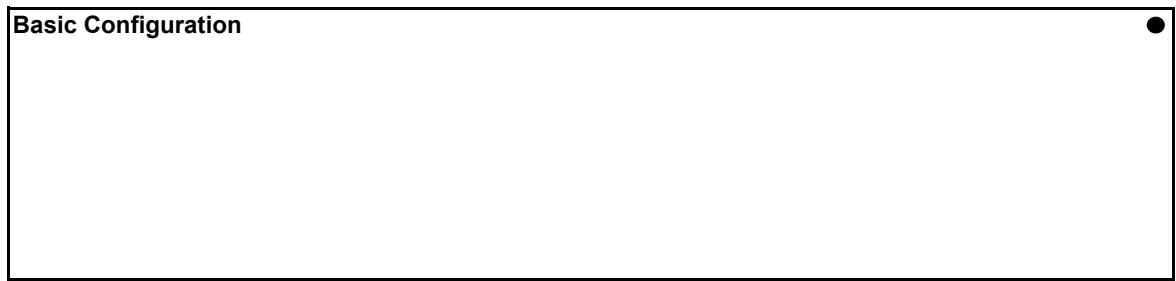
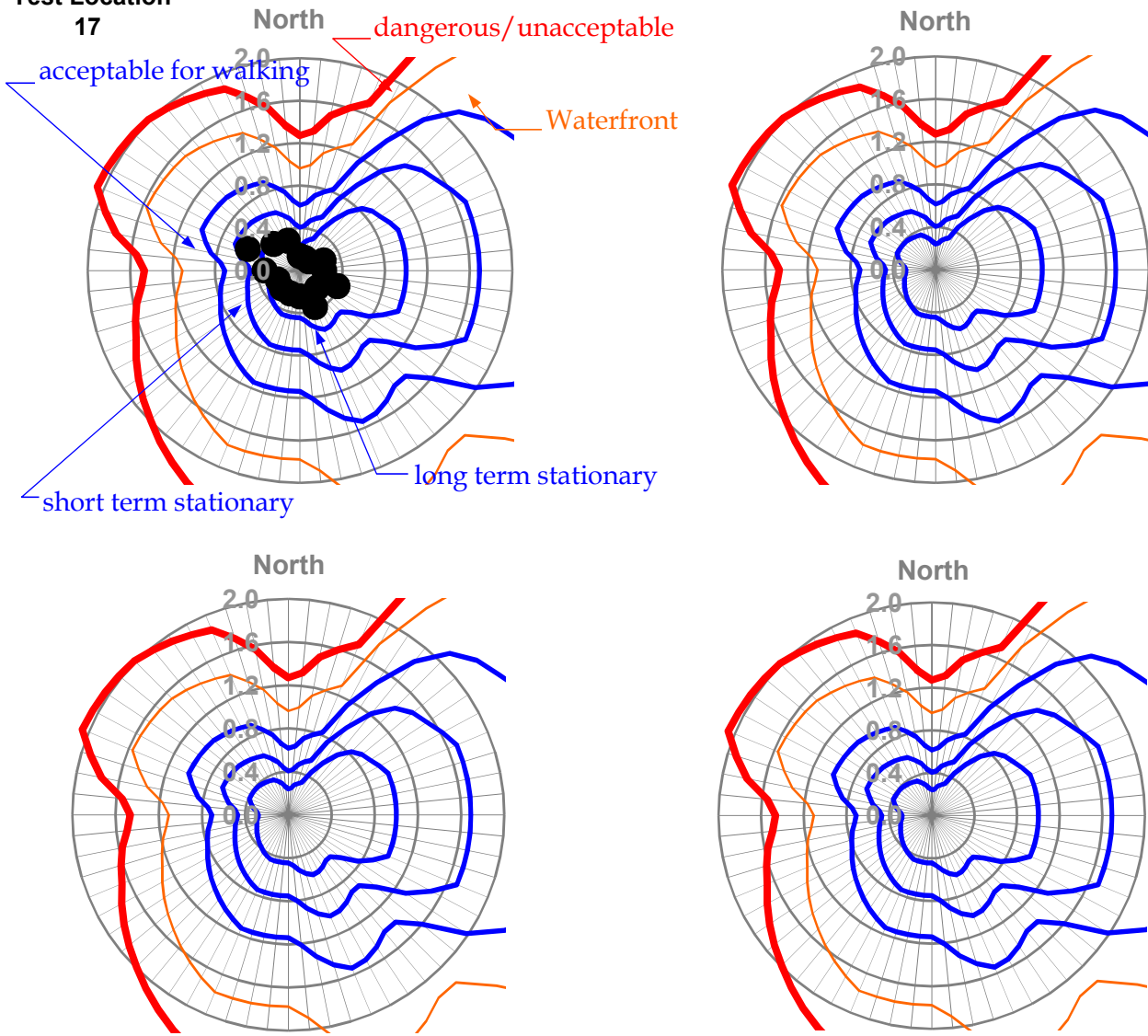


Figure 12 - Public Square - continued

Test Location
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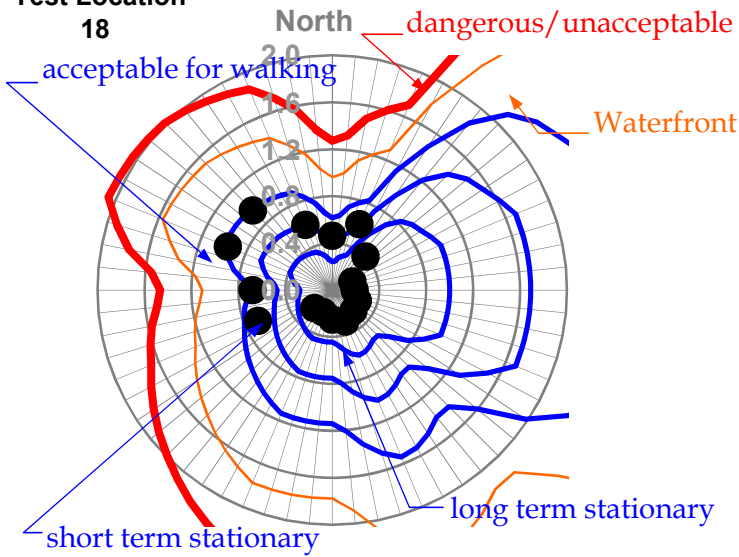


Peak velocity squared ratio $\left| \frac{\widehat{V}_{local}}{\widehat{V}_{300m}} \right|^2$ as a function of wind direction

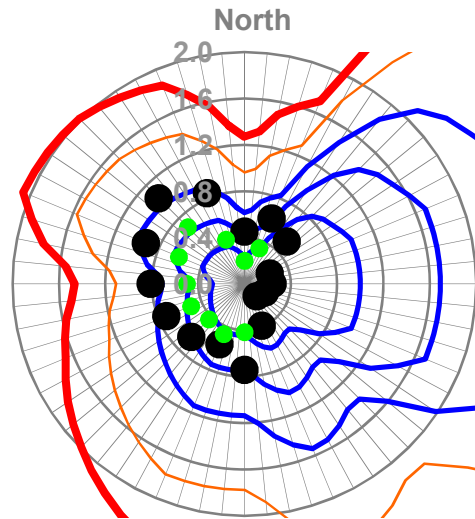
Basic Configuration

Figure 13 - Public Square - continued

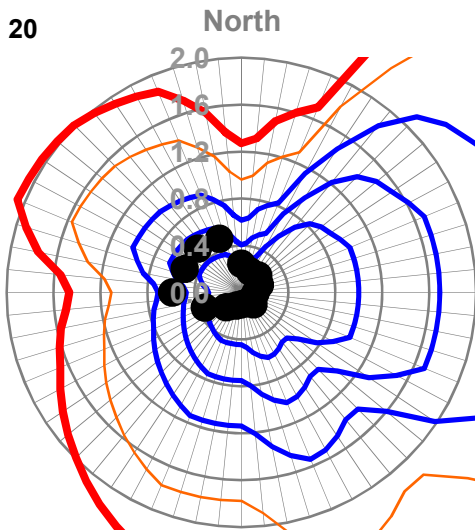
Test Location
18



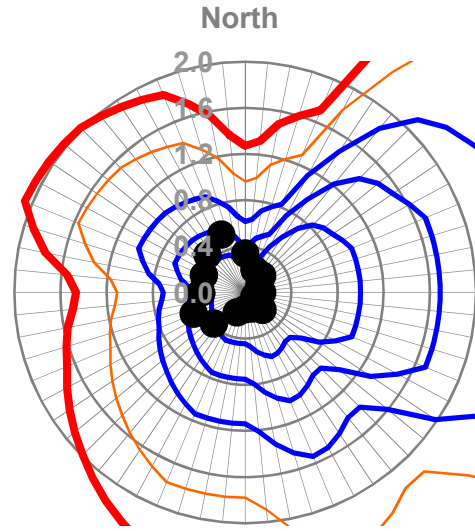
19



20



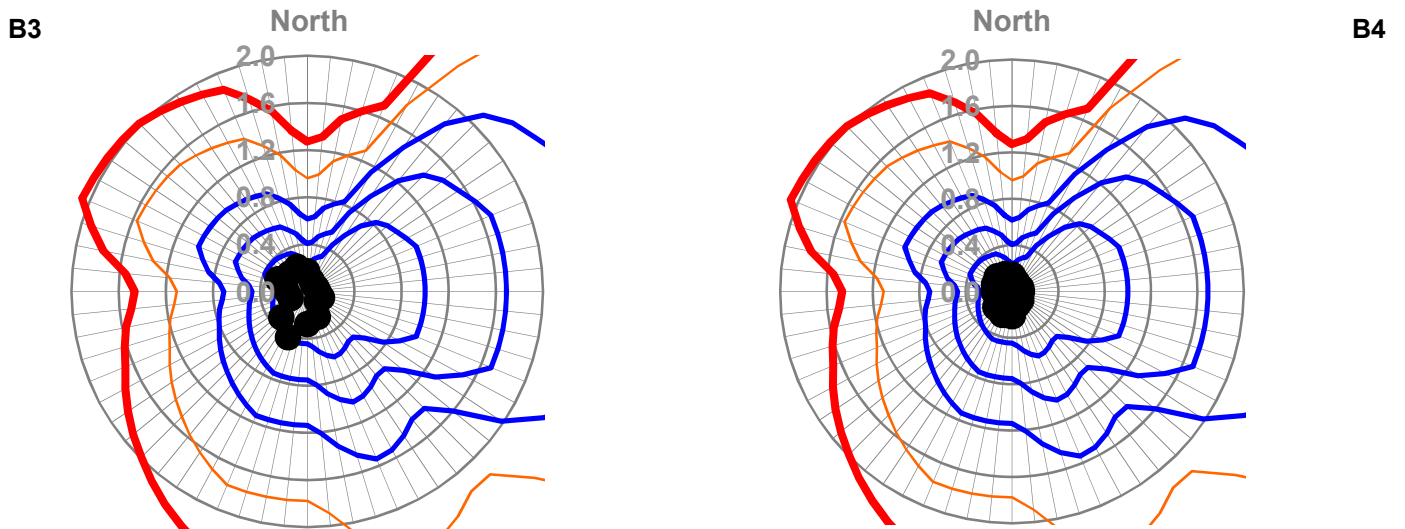
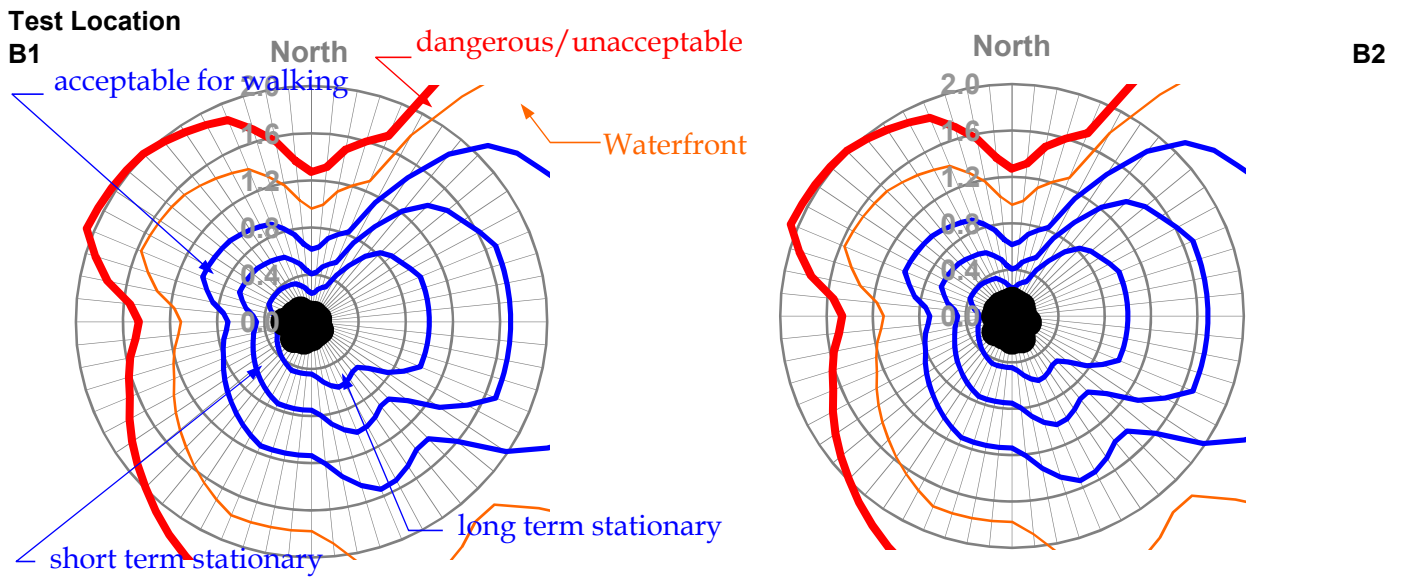
21



Peak velocity squared ratio $\left| \frac{\overline{V}_{local}}{\overline{V}_{300m}} \right|^2$ as a function of wind direction

Basic Configuration	●
Basic Configuration with mitigation strategies	●

Figure 14 - Snedden Drive



Peak velocity squared ratio $\left| \frac{\widehat{V}_{\text{local}}}{\widehat{V}_{300\text{m}}} \right|^2$ as a function of wind direction

Basic Configuration

Figure 15 - Level 1

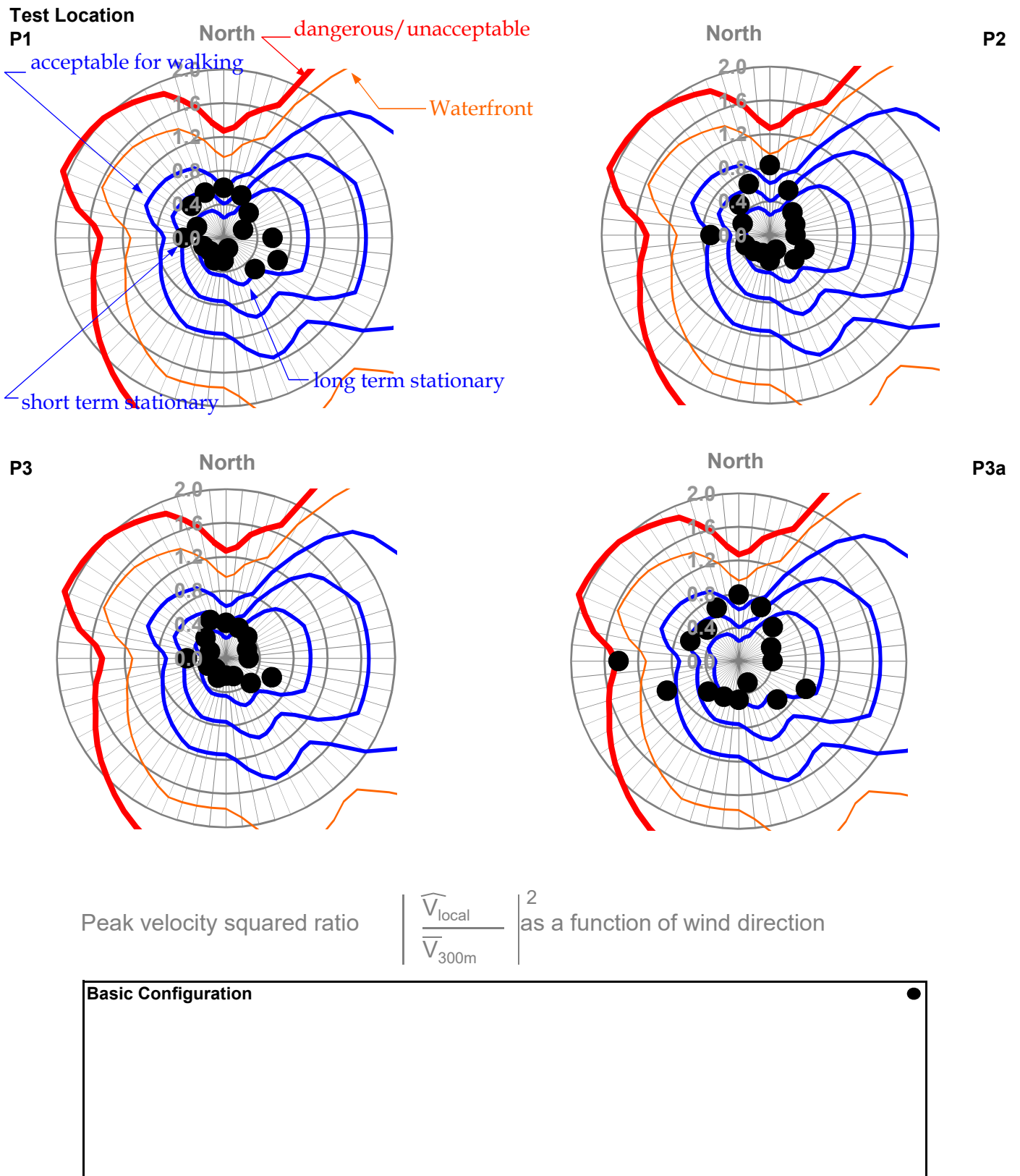
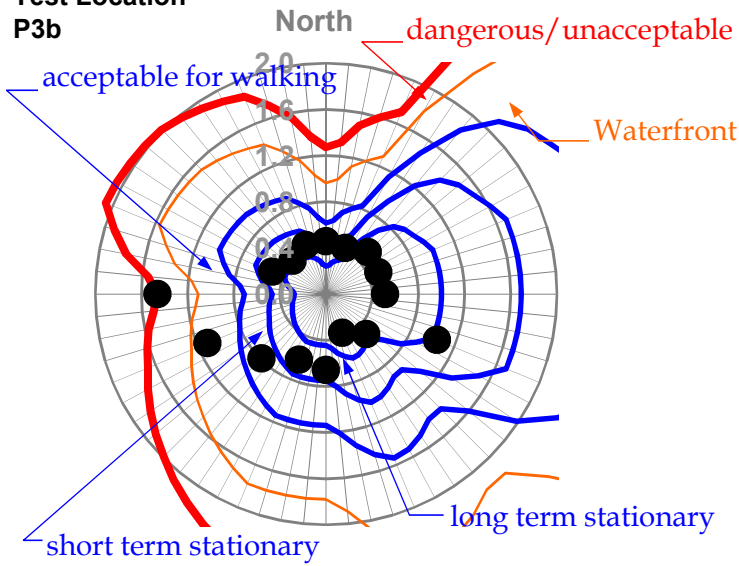
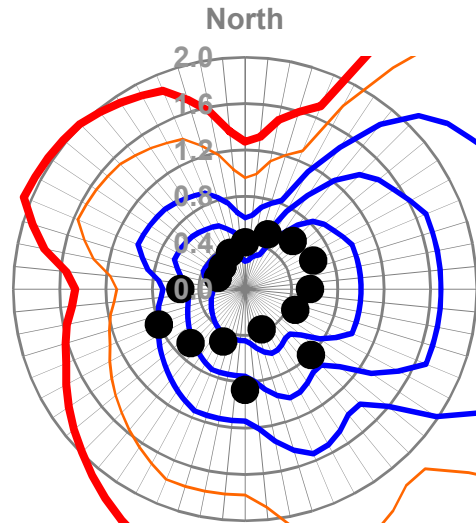


Figure 16 - Podium Level

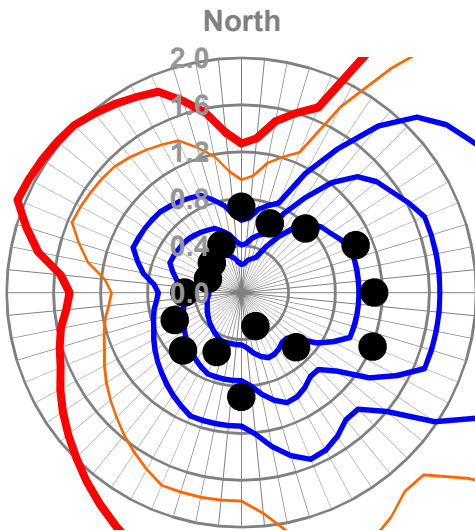
Test Location
P3b



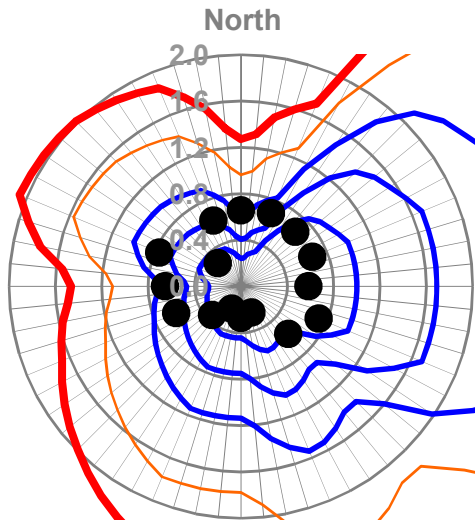
P4



P5



P6



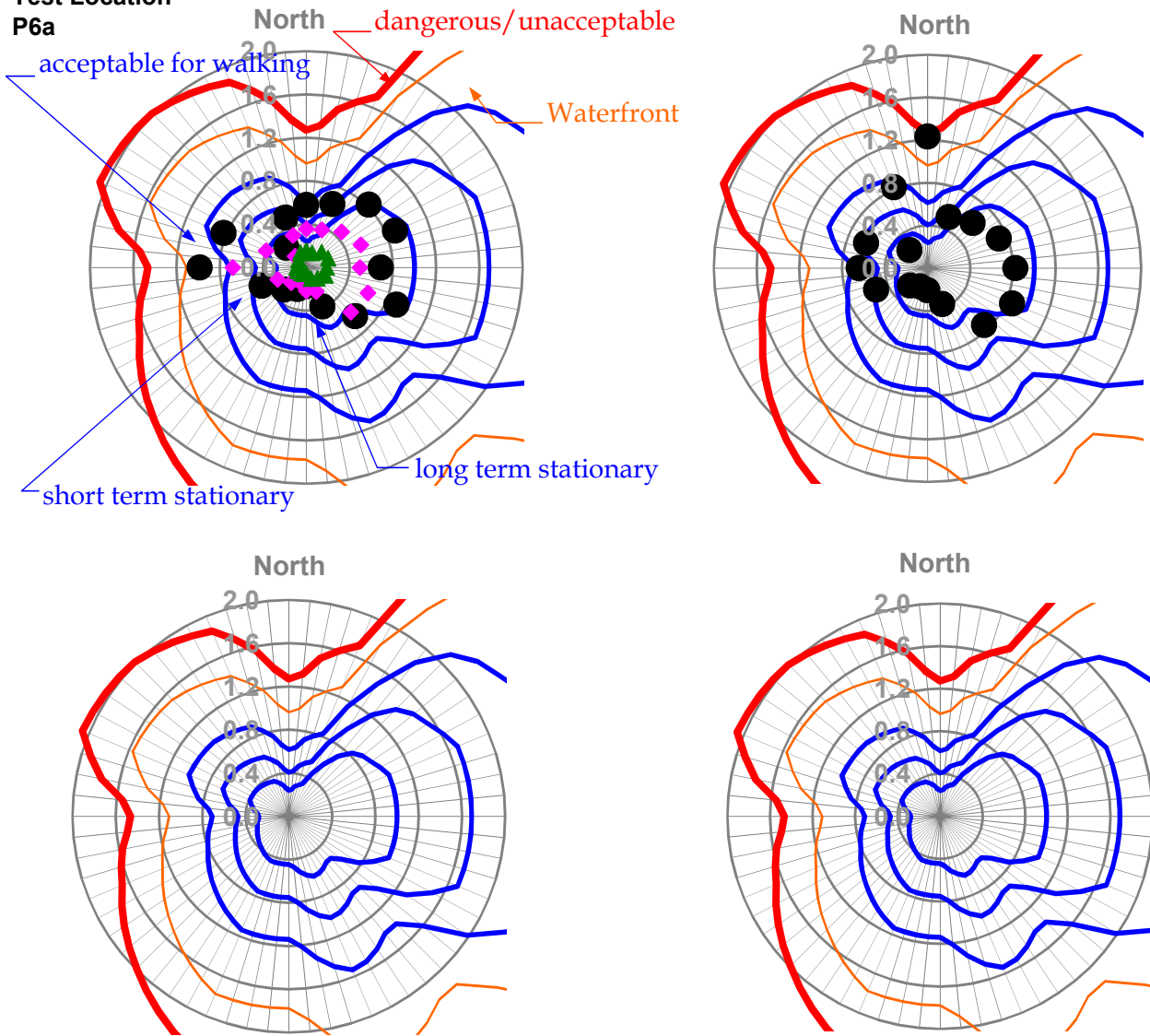
Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\hat{V}_{300m}} \right|^2$ as a function of wind direction

Basic Configuration

Figure 17 - Podium Level - continued

Test Location
P6a

P7



Peak velocity squared ratio $\left| \frac{\widehat{V}_{local}}{\widehat{V}_{300m}} \right|^2$ as a function of wind direction

Basic Configuration	●
Basic Configuration + Shelter (Canopy only)	●
Basic Configuration + Shelter (Canopy + Covered 3 sides)	◆
	▲

Figure 18 - Podium Level - continued