WINDTECH

PEDESTRIAN WIND ENVIRONMENT STUDY

900 LAKESHORE ROAD WEST, MISSISSAUGA ONTARIO

WI002-02F03(REV2)- WE REPORT

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DOCUMENT CONTROL

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EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the 900 Lakeshore Road West development, located in Mississauga. Testing was performed at Windtech's boundary layer wind tunnel facility. The wind tunnel has a 3.0m wide working section and a fetch length of 14m, and measurements were taken from 36 wind directions at 10-degree increments. Testing was carried out using a 1:300 detailed scale model of the development, which was fabricated based on the architectural drawings received on July 9, 2024. The effects of nearby buildings and land topography have been accounted for through the use of a proximity model which represents an area with a radius of 400m.

Peak gust and mean wind speeds were determined at selected critical outdoor trafficable locations within and around the subject development. Wind velocity coefficients representing the local wind speeds are derived from the wind tunnel and are combined with a statistical model of the regional wind climate (which accounts for the directional strength and frequency of occurrence of the prevailing regional winds) to provide the equivalent full-scale wind speeds at the site. The wind speed measurements are compared with criteria for pedestrian comfort and safety, based on Gust-Equivalent Mean (GEM) and annual maximum gust winds, respectively.

The model was tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, etc., which are not already shown in the architectural drawings. The effect of vegetation was also excluded from the testing. The existing site conditions were also tested, for comparison. In-principle treatments have been recommended for any area exposed to strong winds.

The results of the study indicate that wind conditions for some of the trafficable outdoor locations within and around the development will be suitable for their intended uses. However, there are areas that will experience strong winds which will exceed the relevant criteria for comfort and/or safety. Suggested treatments are described as follows:

Ground Floor:

- Retention of 3.0m high porous screening (30-35% porosity) at specified locations spanning to the designated footpath along the eastern frontage
- Retention of 1.0m high porous screening (30-35% porosity) along the eastern boundary
- Retention of 2.0m high porous screening (30-35% porosity) along the selected boundary perimeter of designated landscaping at the northern corner and southern section of the development
- Retention of proposed densely foliating tree planting at the specified landscaping areas on the northern and south to south-eastern corners of the development.

Roof:

- Retention of 1.5m high impermeable balustrade along the perimeter of the northern, eastern and southern aspects
- Retention of 2.5m high porous screening / gate (30-35% porosity) at the northern, eastern and southern segments of the mechanical penthouse

- Retention of 1.0m high planter box with 0.8-1.0m high densely foliating evergreen planting or hedging at the designated landscaping zones and the region centred between the south-western stairwell and mechanical penthouse.

With the inclusion of these treatments to the final design, it is expected that wind conditions for all outdoor trafficable areas within and around the development will be suitable for their intended uses.

CONTENTS

1 INTRODUCTION

A wind tunnel study has been undertaken to determine wind speeds at selected critical outdoor trafficable areas within and around the subject development. The test procedures followed for this wind tunnel study were based on the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2019), ASCE 7-16 (Chapter C31), and CTBUH (2013).

A scale model of the development was prepared, including the surrounding buildings and land topography. Testing was performed at Windtech's boundary layer wind tunnel facility. The wind tunnel has a 3.0m wide working section and a fetch length of 14m, and measurements were taken from 36 wind directions at 10-degree increments. The wind tunnel was configured to the appropriate boundary layer wind profile for each wind direction. Wind speeds were measured using either Dantec hot-wire probe anemometers or pressure-based wind speed sensors, positioned to monitor wind conditions at critical outdoor trafficable areas of the development.

The model was tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, etc., which are not already shown in the architectural drawings. The effect of vegetation was also excluded from the testing. The wind speeds measured during testing were combined with a statistical model of the regional wind climate to provide the equivalent full-scale wind speeds at the site. The measured wind speeds were compared against appropriate criteria for pedestrian comfort and safety, and in-principle treatments have been recommended for any area which was exposed to strong winds. These treatments could be in the form of retaining vegetation that is already proposed for the site, or including additional vegetation, screens, awnings, etc. Note however that, in accordance with the AWES Guidelines (2014), only architectural elements or modifications are used to treat winds which represent an exceedance of the existing wind conditions and exceed the safety limit.

A list of the architectural drawings reference for this assessment is provided in the table below.

Table 1: List of Architectural Drawings Referenced

Drawing/file name (Drawing No.)	Revision number	Date
A002 – SITE PLAN	1	09/01/2024
A003 – SITE PLAN (GF)	1	09/01/2024
A004 – 3D VIEWS	1	09/01/2024
A102 – P3 PLAN	1	09/01/2024
A103 – P2 PLAN	1	09/01/2024
A104 – P1 PLAN	1	09/01/2024
A105 – GROUND FLOOR PLAN	1	09/01/2024
A106 - 2ND FLOOR PLAN	1	09/01/2024
A107 – 3RD FLOOR PLAN	1	09/01/2024
A108 – 4TH FLOOR PLAN	1	09/01/2024
A109 – 5TH FLOOR PLAN	1	09/01/2024
A110 – 6TH FLOOR PLAN	1	09/01/2024
A111 – 7TH FLOOR PLAN	1	09/01/2024
A112 – 8TH TO 10TH FLOOR PLAN	1	09/01/2024
A113 – MECHANICAL PENTHOUSE PLAN	1	09/01/2024
A114 - ROOF PLAN	1	09/01/2024
A201 – NORTH ELEVATION	1	09/01/2024
A202 – SOUTH ELEVATION	1	09/01/2024
A203 – EAST ELEVATION	1	09/01/2024
A204 – WEST ELEVATION	1	09/01/2024
A301 – SECTION AA	1	09/01/2024
A302 – SECTION BB	1	09/01/2024
A303 – SITE AND ROAD SECTION	1	09/01/2024
A002 – SITE PLAN	8	03.10.2024
A003 – SITE PLAN (GF)	8	03.10.2024

2 WIND TUNNEL MODEL

Wind tunnel testing was carried out using a 1:300 scale model of the development and surroundings. The study model incorporates all necessary architectural features on the façade of the development to ensure an accurate wind flow is achieved around the model, and was constructed using a Computer Aided Manufacturing (CAM) process to ensure that a high level of detail and accuracy is achieved. The study model was fabricated based on the architectural drawings received on July 9, 2024. The effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents a radius of 400m from the development site. Photographs of the wind tunnel model are presented in Figures 1. A plan of the proximity model is provided in Figure 2.

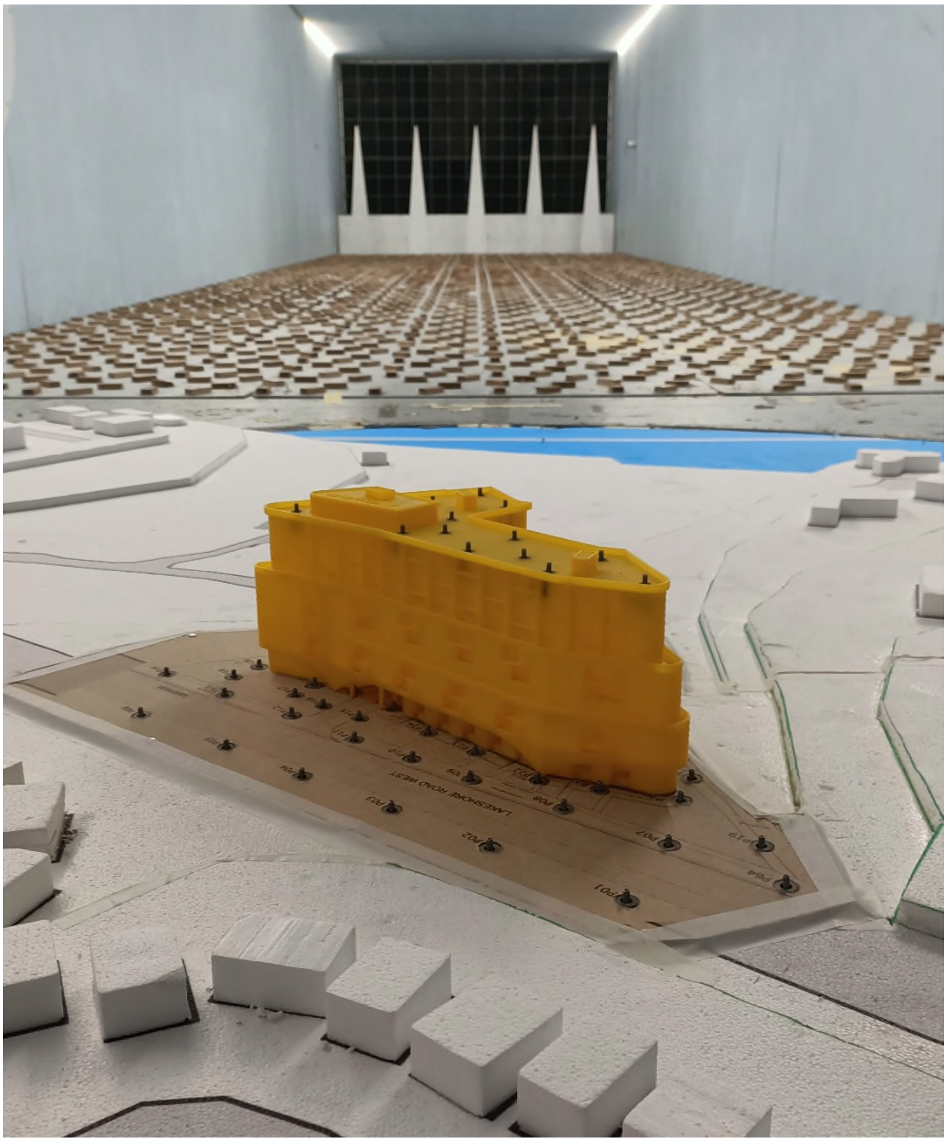

Figure 1a: Photograph of the Wind Tunnel Model (view from the west)

Figure 1b: Photograph of the Wind Tunnel Model (view from the north)

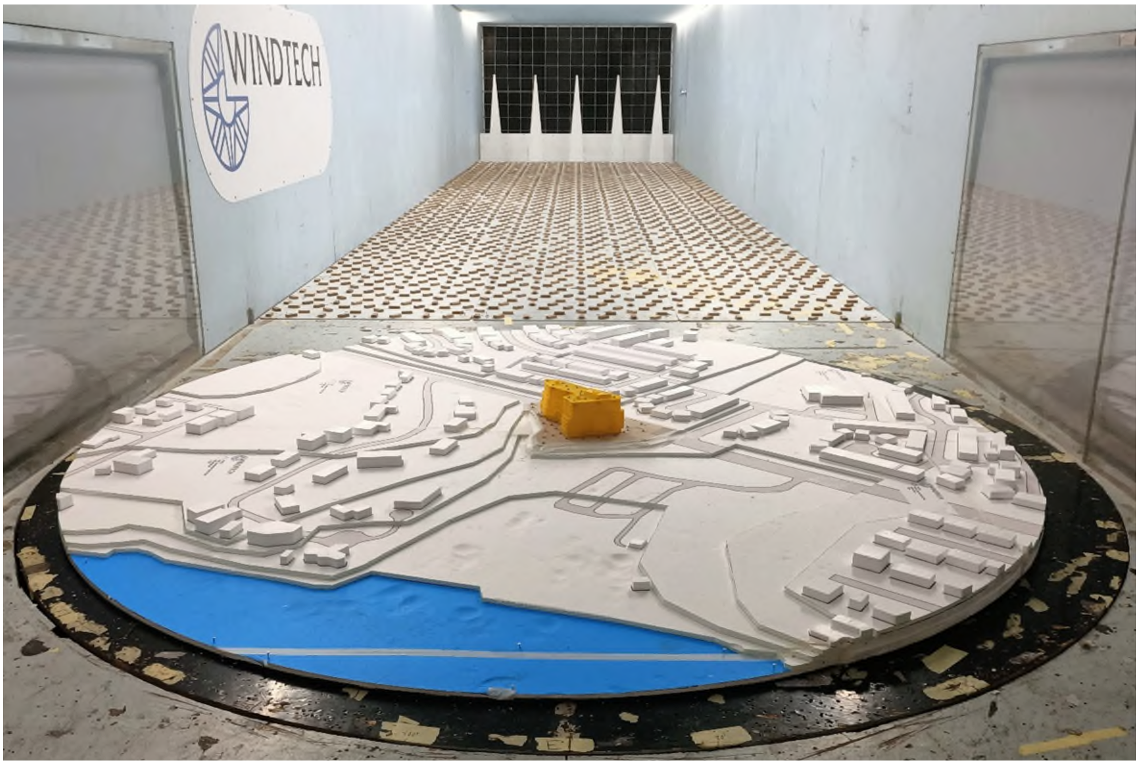

Figure 1c: Photograph of the Wind Tunnel Model (view from the east)

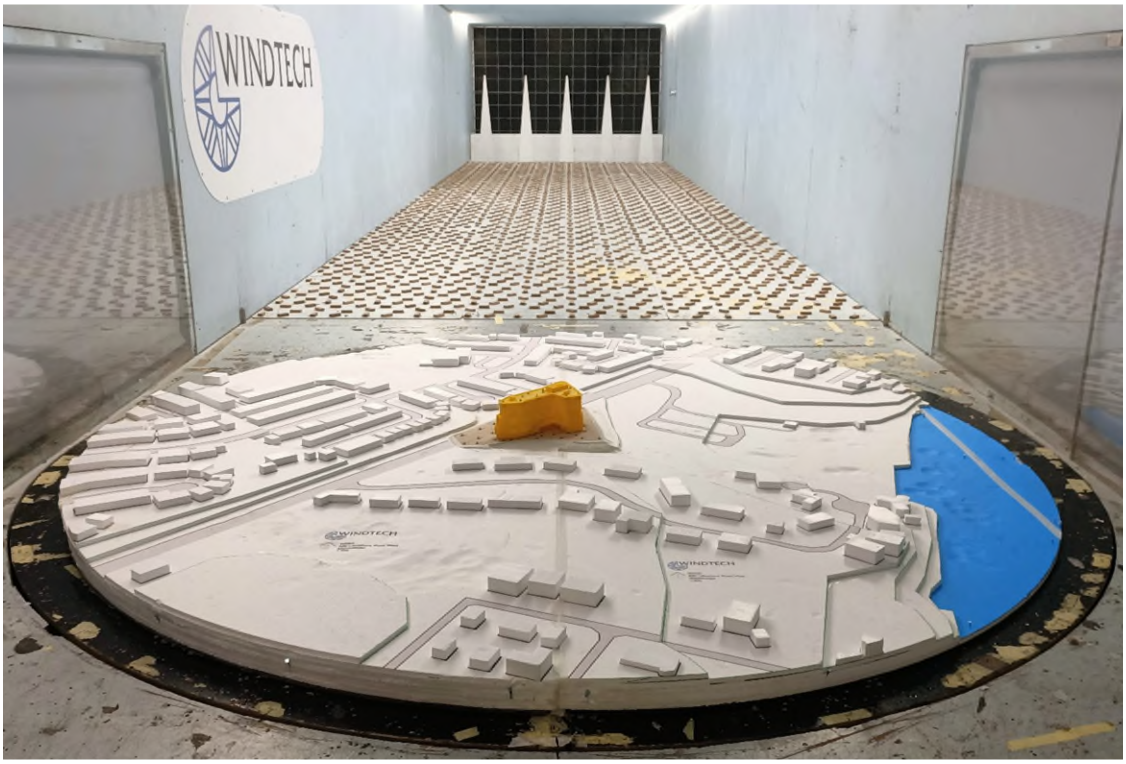

Figure 1d: Photograph of the Wind Tunnel Model (view from the south)

Figure 1e: Photograph of the Wind Tunnel Model (view from the west)

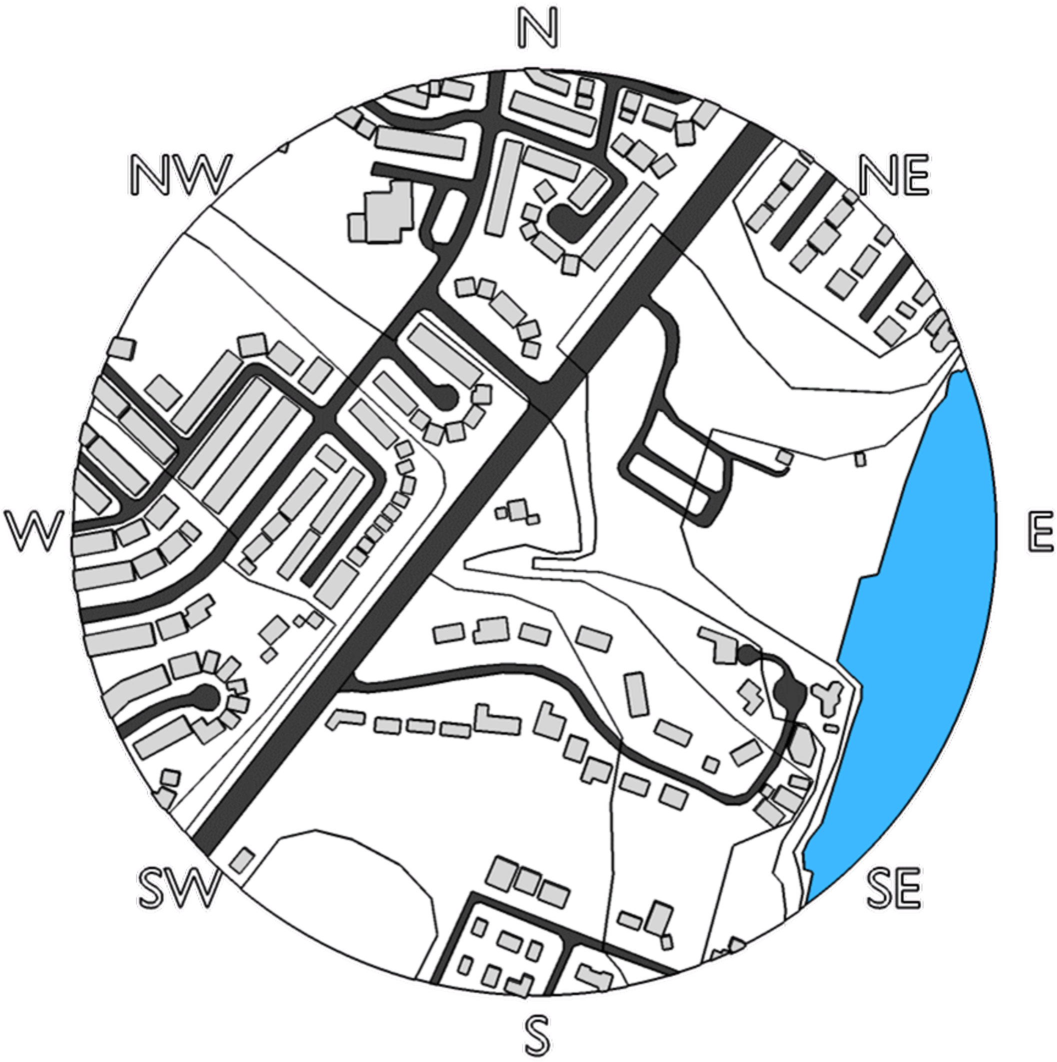

Figure 2a: Existing Model Plan

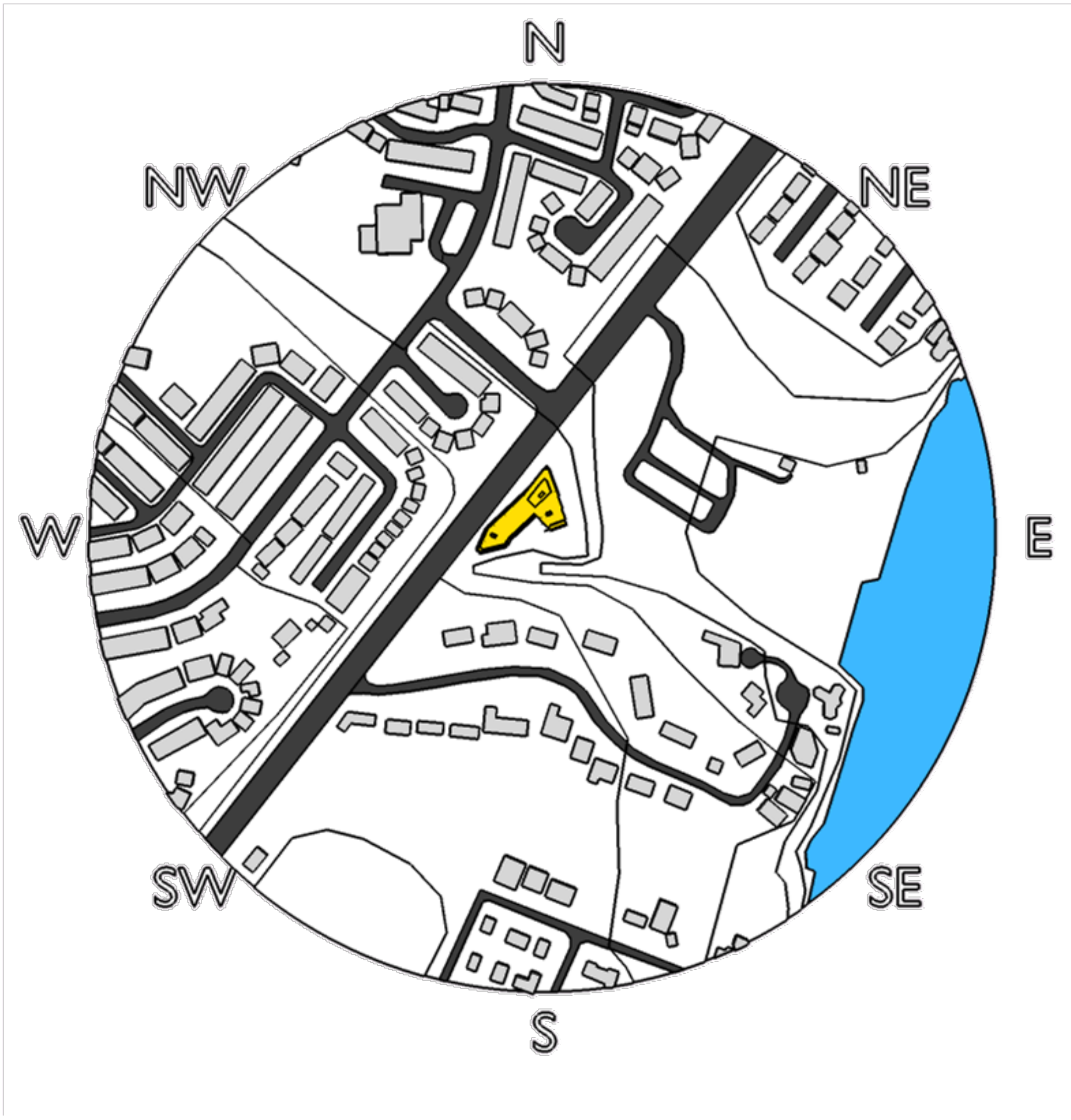

Figure 2b: Proposed Model Plan

3 BOUNDARY LAYER WIND PROFILES AT THE SITE

The roughness of the surface of the earth has the effect of slowing down the wind near the ground. This effect is observed up to the boundary layer height, which can range between 500m to 3km above the earth's surface depending on the roughness of the surface (ie: oceans, open farmland, etc). Within this range the prevailing wind forms a boundary layer wind profile.

Various wind codes and standards and other publications classify various types of boundary layer wind flows depending on the surface roughness z_0. Descriptions of typical boundary layer wind profiles, based on D.M. Deaves and R.I. Harris (1978), are summarised as follows:

- Flat terrain (0.002m < z_0 < 0.003m). Examples include inland water bodies such as lakes, dams, rivers, etc, and the open ocean.
- Semi-open terrain (0.006m < z_0 < 0.01m). Examples include flat deserts and plains.
- Open terrain (0.02m < z_0 < 0.03m). Examples include grassy fields, semi-flat plains, and open farmland (without buildings or trees).
- Semi-suburban/semi-forest terrain (0.06m < z_0 < 0.1m). Examples include farmland with scattered trees and buildings and very low-density suburban areas.
- Suburban/forest terrain (0.2m < z_0 < 0.3m). Examples include suburban areas of towns and areas with dense vegetation such as forests, bushland, etc.
- Semi-urban terrain (0.6m < z_0 < 1.0m). Examples include centres of small cities, industrial parks, etc.
- Urban terrain (2.0m < z_0 < 3.0m). Examples include centres of large cities with many high-rise towers, and also areas with many closely-spaced mid-rise buildings.

The boundary layer wind profile does not change instantly due to changes in the terrain roughness. It can take many kilometres (at least 100km) of a constant surface roughness for the boundary layer wind profile to achieve a state of equilibrium. Hence an analysis of the effect of changes in the upwind terrain roughness is necessary to determine an accurate boundary layer wind profile at the development site location.

The proximity model accounts for the effect of the near field topographic effects as well as the influence of the local built forms. To account for further afield effects, an assessment of the upwind terrain roughness has been undertaken based on the method given in ESDU-82026:2002. Aerial images showing the surrounding terrain are presented in Figure 3 for ranges of 5km and 50km from the edge of the proximity model used for the wind tunnel study. The resulting mean and gust terrain and height multipliers at the site location are presented in Table 2, referenced to the study reference height (which is approximately half the height of the subject development since typically we are most interested in the wind effects at the ground plane). Details of the boundary layer wind profiles at the site are combined with the regional wind model (see Section 4) to determine the site wind speeds.

Table 2: Approaching Boundary Layer Wind Profile Analysis Summary (at the study reference height)

Wind Sector (degrees)	Terrain and Height Multiplier $k_{tr,T=1hr}$ (hourly)	$k_{tr,T=10min}$ (10min)	$k_{tr,T=3s}$ (3sec)	Turbulence Intensity I_v	Equivalent Terrain Category (AS/NZS1170.2.2021 naming convention)
360	0.56	0.60	0.96	0.237	2.9
10	0.56	0.60	0.96	0.237	2.9
20	0.56	0.59	0.95	0.238	3.0
30	0.56	0.59	0.95	0.238	3.0
40	0.64	0.67	1.02	0.199	2.5
50	0.72	0.75	1.08	0.169	2.0
60	0.80	0.83	1.14	0.143	1.4
70	0.82	0.85	1.15	0.138	1.3
80	0.83	0.87	1.17	0.133	1.1
90	0.85	0.88	1.18	0.128	1.0
100	0.85	0.88	1.18	0.128	1.0
110	0.85	0.88	1.18	0.128	1.0
120	0.85	0.88	1.18	0.128	1.0
130	0.83	0.86	1.16	0.133	1.2
140	0.81	0.84	1.15	0.139	1.3
150	0.79	0.82	1.14	0.145	1.5
160	0.79	0.82	1.14	0.145	1.5
170	0.79	0.82	1.13	0.145	1.5
180	0.79	0.82	1.13	0.146	1.5
190	0.72	0.75	1.08	0.168	2.0
200	0.65	0.69	1.03	0.194	2.4
210	0.58	0.62	0.97	0.227	2.8
220	0.58	0.61	0.97	0.229	2.8
230	0.57	0.61	0.97	0.231	2.9
240	0.57	0.60	0.96	0.233	2.9
250	0.57	0.60	0.96	0.233	2.9
260	0.57	0.60	0.96	0.233	2.9
270	0.57	0.60	0.96	0.233	2.9
280	0.57	0.60	0.96	0.234	2.9
290	0.57	0.60	0.96	0.234	2.9
300	0.56	0.60	0.96	0.235	2.9
310	0.56	0.60	0.96	0.235	2.9

Wind Sector (degrees)	Terrain and Height Multiplier $k_{tr,T=1hr}$ (hourly)	$k_{tr,T=10min}$ (10min)	$k_{tr,T=3s}$ (3sec)	Turbulence Intensity I_v	Equivalent Terrain Category (AS/NZS1170.2.2021 naming convention)
320	0.56	0.60	0.96	0.236	2.9
330	0.56	0.60	0.96	0.237	2.9
340	0.56	0.60	0.96	0.237	2.9
350	0.56	0.60	0.96	0.237	2.9

NOTE: These terrain and height multipliers are to be applied to a basic regional wind speed averaged over 3-seconds. Divide these values by 1.10 for a basic wind speed averaged over 0.2-seconds, 0.69 for a basic wind speed averaged over 10-minutes, or 0.66 for a basic wind speed averaged over 1-hour.

For each of the 36 wind directions tested in this study, the approaching boundary layer wind profiles modelled in the wind tunnel closely matched the profiles listed in Table 2. Plots of the boundary layer wind profiles used for the wind tunnel testing are presented in Appendix E of this report.

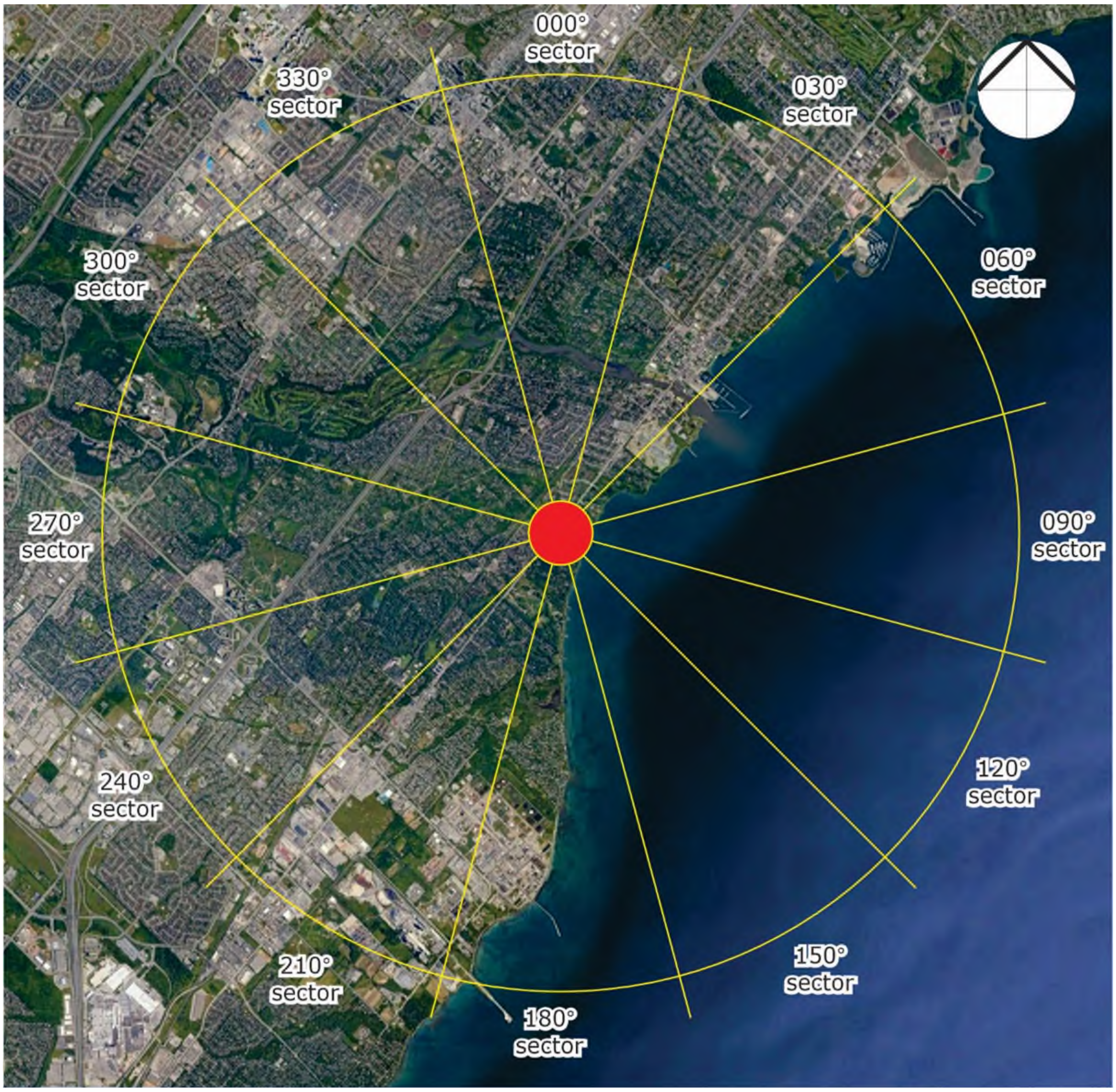

Figure 3a: Aerial Image of the Surrounding Terrain (radius of 5km from the edge of the proximity model)

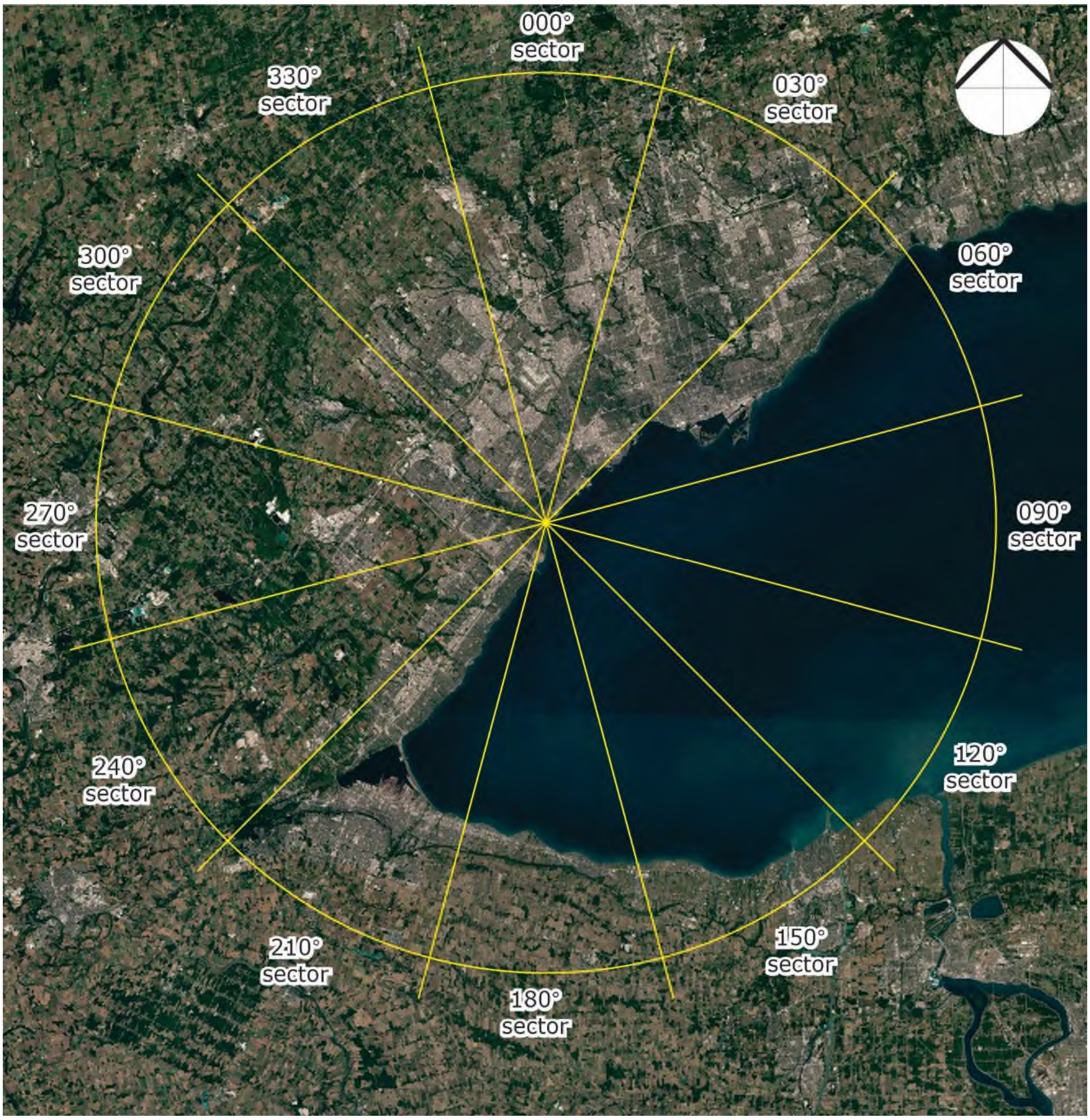

Figure 3b: Aerial Image of the Surrounding Terrain (radius of 50km)

4 REGIONAL WIND MODEL

The regional wind model used in this study was determined from an analysis of measured directional mean wind speeds obtained at the meteorological recording station located at Billy Bishop Toronto City Airport. A combined total of 29 years of wind climate data has been collected from this station, and the data from the station has been corrected so that it represents winds over standard open terrain at a height of 10m above ground. From this analysis, directional probabilities of exceedance and directional wind speeds for the region are determined. The directional wind speeds are summarised in Table 3. The directional wind speeds and corresponding directional frequencies of occurrence are presented in Figures 4.

The analysis indicates that the strongest winds of the region are mainly governed by the north-westerly to south-westerly winds, which are also the most frequently occurring winds for the region. The east-north-easterly winds are the next strongest and frequent.

The recurrence intervals examined in this study are for exceedances of 20% of the pedestrian comfort criteria using Gust-Equivalent Mean (GEM) wind speeds (for wind records between 6am to 11pm), and annual maximum wind speeds for the pedestrian safety criterion (24 hours of wind records). Note that the 20% probability wind speeds presented in Table 3 are only used for the directional plot presented in Figures 4 and are not used for the integration of the probabilities (these have been calculated per 90 degree sector).

Table 3: Regional Directional Wind Speeds (hourly means, at 10m height in standard open terrain) (km/h)

Wind Direction	All Year	Summer	Winter
360	12.7	11.0	14.4
10	11.0	7.5	12.2
20	12.0	0.0	12.4
30	13.0	7.6	12.7
40	15.3	11.3	17.3
50	23.8	21.8	26.8
60	26.0	24.7	28.9
70	25.0	24.0	29.1
80	21.4	21.3	24.6
90	14.5	15.0	16.0
100	8.6	9.6	9.9
110	6.1	6.9	6.7
120	6.1	7.9	6.4
130	5.7	7.2	5.2
140	4.8	6.8	3.6
150	5.1	6.3	4.6
160	9.2	11.2	7.2
	11.2	13.2	8.8

Wind Direction	All Year	Summer	Winter
170	13.4	14.6	11.3
180	13.3	15.3	12.4
190	14.0	15.8	15.0
200	14.6	15.1	17.6
210	18.6	15.6	22.0
220	21.1	12.7	29.2
230	23.4	12.5	30.9
240	26.3	12.6	32.1
250	23.7	18.6	31.6
260	24.8	19.0	31.3
270	24.8	19.5	28.5
280	24.1	19.4	27.7
290	24.5	22.0	27.2
300	22.3	21.1	24.5
310	21.6	20.9	23.4
320	20.4	19.4	22.1
330	17.8	16.7	19.2
340	14.9	13.9	18.8
350	12.7	11.0	14.4

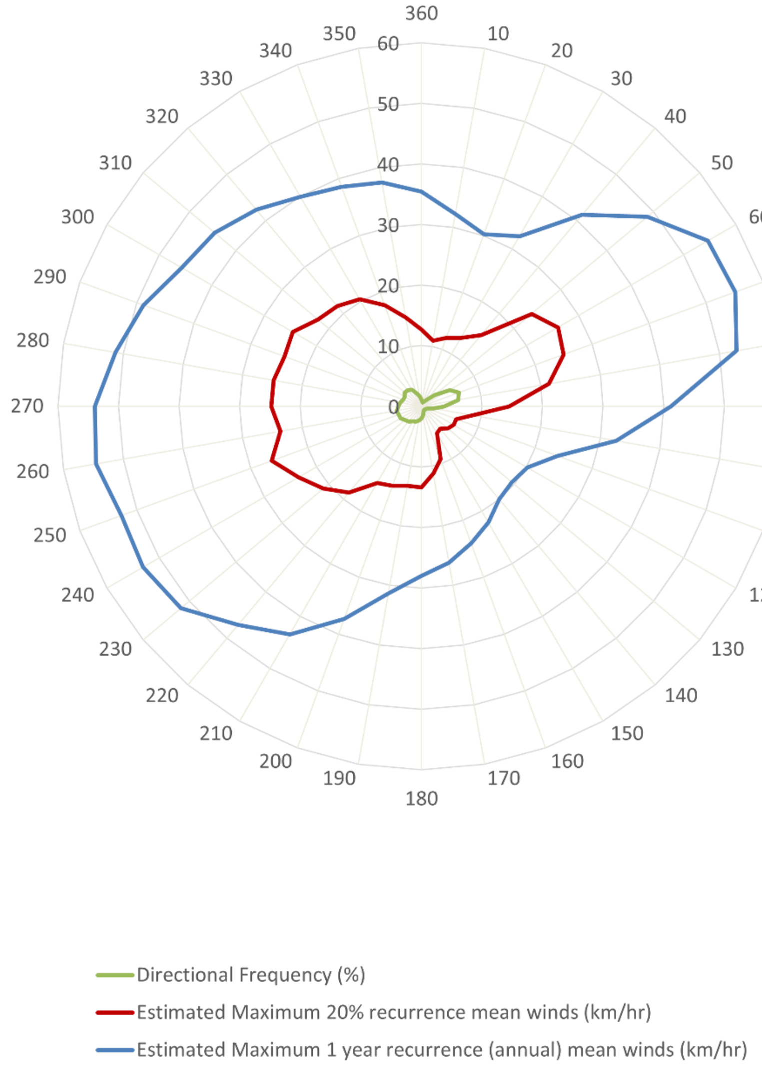

Figure 4a: Annual, 20% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Toronto Region (at 10m height in standard open terrain, all year). Based on wind climate data from Billy Bishop Toronto City Airport from 1995 to 2023

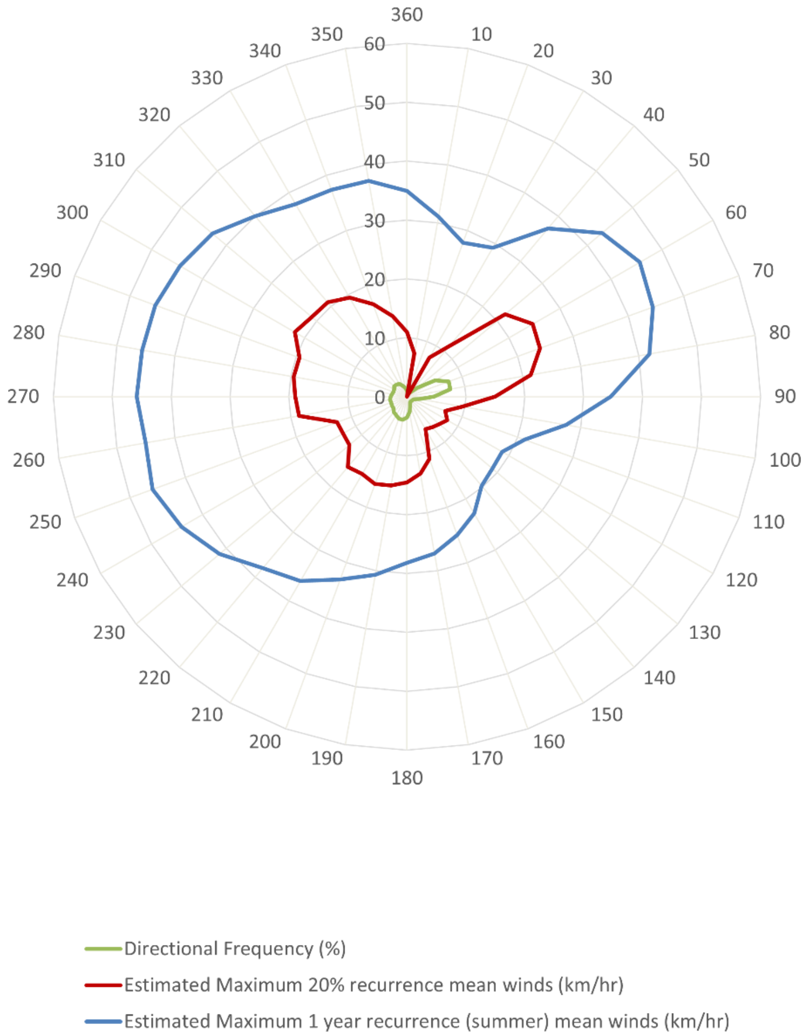

Figure 4b: Annual, 20% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Toronto Region (at 10m height in standard open terrain, Summer). Based on wind climate data from Billy Bishop Toronto City Airport from 1995 to 2023

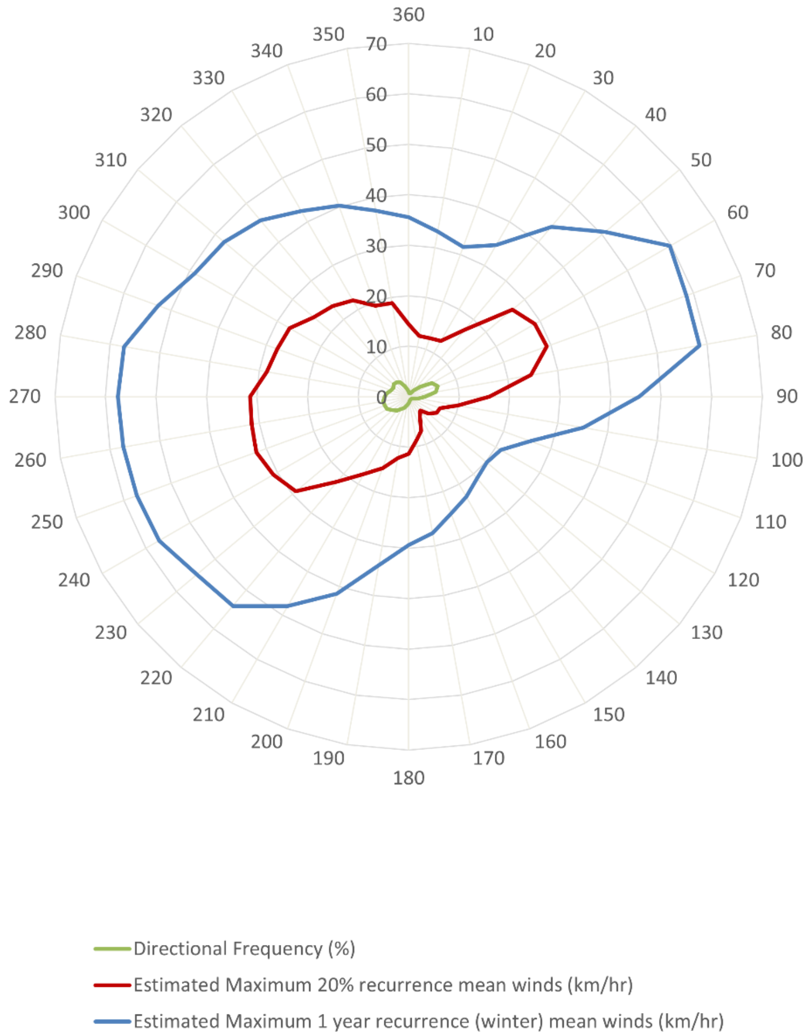

Figure 4c: Annual, 20% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Toronto Region (at 10m height in standard open terrain, Winter). Based on wind climate data from Billy Bishop Toronto City Airport from 1995 to 2023

5 PEDESTRIAN WIND COMFORT AND SAFETY

The acceptability of wind conditions for an area is determined by comparing the measured wind speeds against an appropriate criteria. This section outlines how the measured wind speeds were obtained, the criteria considered for the development, as well as the critical trafficable areas that were assessed and their corresponding criteria designation.

5.1 Measured Wind Speeds

Wind speeds were measured using either Dantec hot-wire probe anemometers or pressure-based wind speed sensors, positioned to monitor wind conditions at critical outdoor trafficable areas of the development. The reference mean free-stream wind speed measured in the wind tunnel, which is at a full-scale height of 200m and measured 3m upstream of the study model.

Measurements were acquired for 36 wind directions at 10 degree increments using a sample rate of 1,024Hz. The full methodology of determining the wind speed measurements at the site from either the Dantec Hot-wire probe anemometers or pressure-based wind speed sensors is provided in Appendix B. Based on the results of the analysis of the boundary layer wind profiles at the site (see Section 3), and incorporating the regional wind model (see Section 4), the data sampling length of the wind tunnel test for each wind direction corresponds to a full-scale sample length ranging between 30 minutes and 1 hour. Research by A.W. Rofail and K.C.S. Kwok (1991) has shown that, in addition to the mean and standard deviation of the wind being stable for sample lengths of 15 minutes or more (full-scale), the peak value determined using the upcrossing method is stable for sample lengths of 30 minutes or more.

5.2 Wind Speed Criteria Used for This Study

For this study the measured wind conditions of the selected critical outdoor trafficable areas are compared against two sets of criteria; one for pedestrian safety, and one for pedestrian comfort. The safety criterion is applied to the annual maximum gust winds, and the comfort criteria is applied to Gust Equivalent Mean (GEM) winds. In accordance with ASCE (2003) and City of Torontos Urban Design Terms of Reference: Pedestrian wind comfort and safety studies, 2024, the GEM wind speed is defined as follows:

$$GEM = max\left(\bar{V}, \frac{\hat{V}}{1.85}\right) \qquad (5.1)$$

where:

$\bar{V}$ is the mean wind speed.

$\hat{V}$ is the 3-second gust wind speed.

The measured wind conditions for the various critical outdoor trafficable areas within and around the subject development are compared against the City of Torontos Urban Design Terms of Reference: Pedestrian Wind Comfort and Safety Studies, 2024. This requires an acceptance of both a safety limit criteria and wind comfort to be achieved for the various outdoor public areas (for hours between 0600 and 2300). The safety criteria states that the gust wind speed must not exceed 90km/h for more than 0.1% of the time from any given wind direction. Furthermore, the criteria for wind comfort are used in conjunction with a minimum GEM wind speed (defined above) which must not be exceeded for at least 80% of the time from all directions combined, measured between 6am and 11pm over the year. Note that the Gust-Equivalent Mean (GEM) criteria, has been proven over time, and through field observations, to be the most reliable indicator of pedestrian comfort (Rofail, 2007). A more detailed comparison of published criteria has been provided in Appendix A.

The criteria considered in this study are summarised in Tables 4 and 5 for pedestrian comfort and safety, respectively. The results of the wind tunnel study are presented in the form of directional plots attached in Appendix C of this report. For each study point there is a plot of the GEM wind speeds using the comfort criteria, and a plot for the annual maximum gust wind speeds using the safety criterion.

Table 4: Comfort Criteria (City of Torontos Urban Design Terms of Reference: Pedestrian Wind Comfort and Safety Studies, 2023)

Comfort Category	Description	GEM Speed (km/h)	Minimum Occurrence (% of time)
Sitting	Calm or light breezes desired for outdoor restaurants and seating areas where one can read a paper without having it blown away	≤10	80
Standing	Gentle breezes suitable for main building entrances and bus stops	≤15	80
Walking	Relatively high speeds that can be tolerated if one's objective to walk, run or cycle without lingering	≤20	80
Uncomfortable	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended	>20	20

Table 5: Safety Criterion (City of Torontos Urban Design Terms of Reference: Pedestrian Wind Comfort and Safety Studies, 2023)

Safety Criterion	Description	Gust Speed (km/h)	Minimum Occurrence (% of time) Annual
Exceeded	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required	>90	0.1 (9 hours in a day)

5.3 Layout of Study Points

For this study a total of 64 study point locations were selected for analysis in the wind tunnel. This includes the following:

- 50 study points on Ground Floor, along the pedestrian footpaths and trafficable areas around the development site.

- 14 study points at various location situated within the trafficable rooftop area

The locations of the various study points tested for this study, as well as the target wind speed criteria for the various outdoor trafficable areas of the development, are presented in Figure 5 in the form of marked-up plans. It should be noted that only the most critical outdoor locations of the development have been selected for analysis.

Figure 5a: Study Point Locations and Target Wind Speed Criteria – Ground Floor Plan

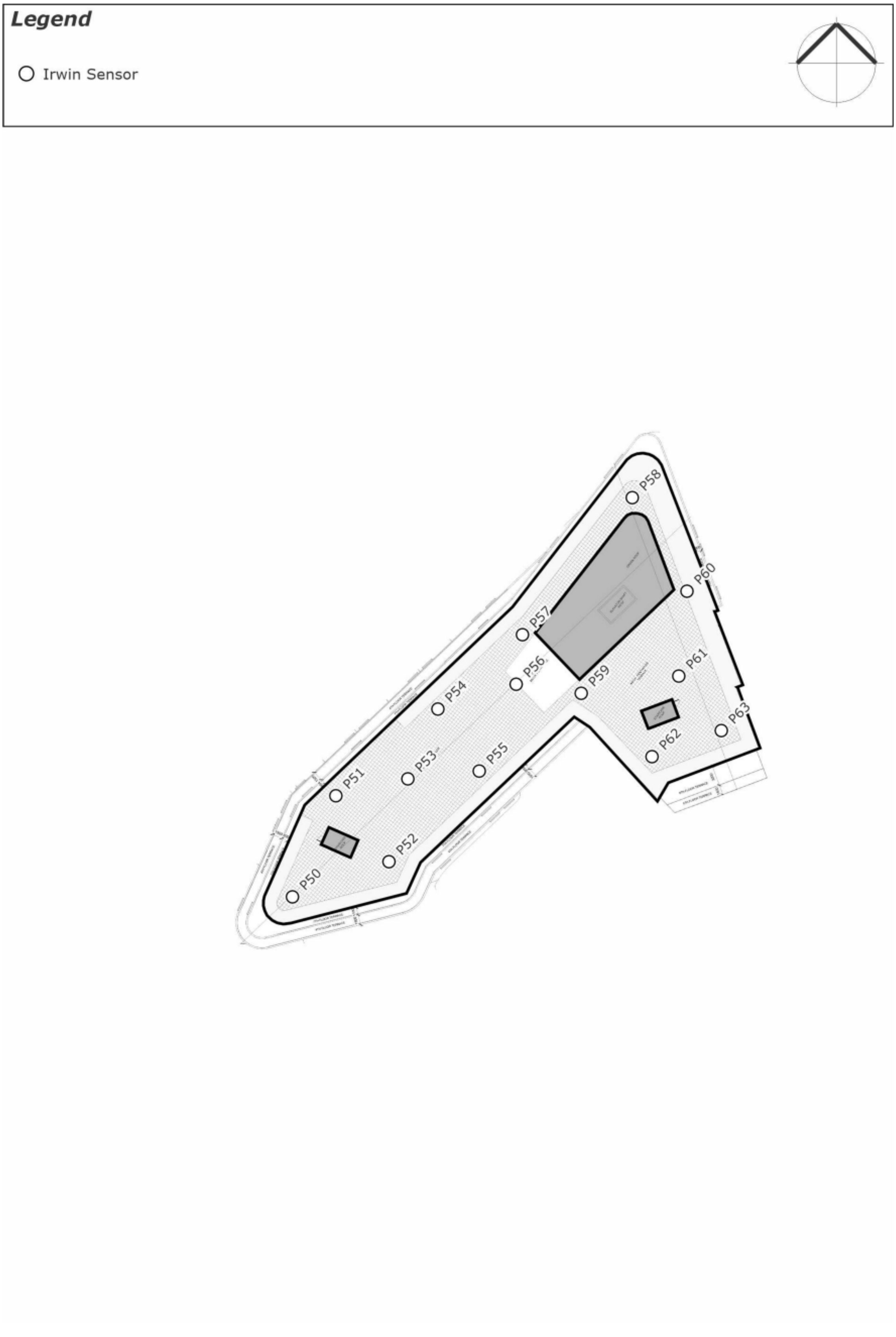

Figure 5b: Study Point Locations and Target Wind Speed Criteria – Roof Plan

6 RESULTS AND DISCUSSION

The results of the wind tunnel study are presented in the form of directional plots in Appendix C for all study points locations, summarised in Tables 6-8, and shown on marked-up plans in Figure 6 . The velocity coefficients are also presented in the form of directional plots in Appendix D. The wind speed criteria that the wind conditions should achieve are also listed in Tables 6-8 for each study point location, as well as in Figure 6.

The results of the study indicate that wind conditions for some of the trafficable outdoor locations within and around the development will be suitable for their intended uses. However, there are areas that will experience strong winds which will exceed the relevant criteria for comfort and/or safety. Suggested treatments are described as follows:

Ground Floor:

- Retention of 3.0m high porous screening (30-35% porosity) at specified locations spanning to the designated footpath along the eastern frontage
- Retention of 1.0m high porous screening (30-35% porosity) along the eastern boundary
- Retention of 2.0m high porous screening (30-35% porosity) along the selected boundary perimeter of designated landscaping at the northern corner and southern section of the development
- Retention of proposed densely foliating tree planting at the specified landscaping areas on the northern and south to south-eastern corners of the development.

Roof:

- Retention of 1.5m high impermeable balustrade along the perimeter of the northern, eastern and southern aspects
- Retention of 2.5m high porous screening / gate (30-35% porosity) at the northern, eastern and southern segments of the mechanical penthouse
- Retention of 1.0m high planter box with 0.8-1.0m high densely foliating evergreen planting or hedging at the designated landscaping zones and the region centred between the south-western stairwell and mechanical penthouse.

As a general note, the use of loose glass-tops and light-weight sheets or covers (including loose BBQ lids) is not appropriate on high-rise outdoor terraces and balconies. Furthermore, lightweight furniture is not recommended unless it is securely attached to the balcony or terrace floor slab.

With the inclusion of these treatments to the final design, it is expected that wind conditions for all outdoor trafficable areas within and around the development will be suitable for their intended uses.

6.1 Comfort Criterion

Criteria Legend

- Wind Comfort Standard for Sitting Criterion (10km/h)
- Wind Comfort Standard for Standing Criterion (15km/h)
- Wind Comfort Standard for Walking Criterion (20km/h)
- Uncomfortable (> 20km/h)

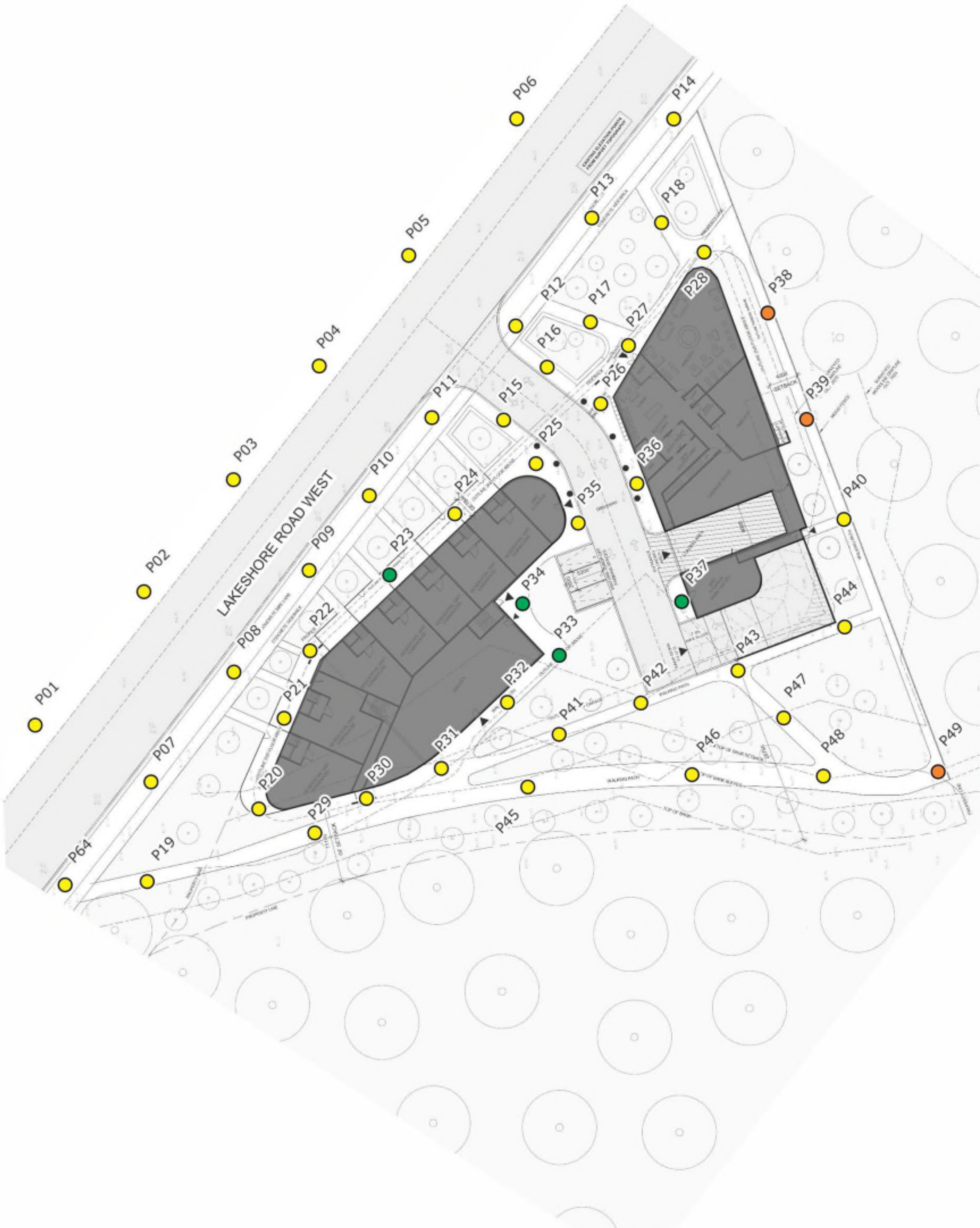

Figure 6. 1a: Wind Tunnel Results – Existing Scenario – Annual – Ground Level Plan
(results shown without treatments applied)

Criteria Legend

- 🔵 Wind Comfort Standard for Sitting Criterion (10km/h)
- 🟢 Wind Comfort Standard for Standing Criterion (15km/h)
- 🟡 Wind Comfort Standard for Walking Criterion (20km/h)
- 🟠 Uncomfortable (> 20km/h)

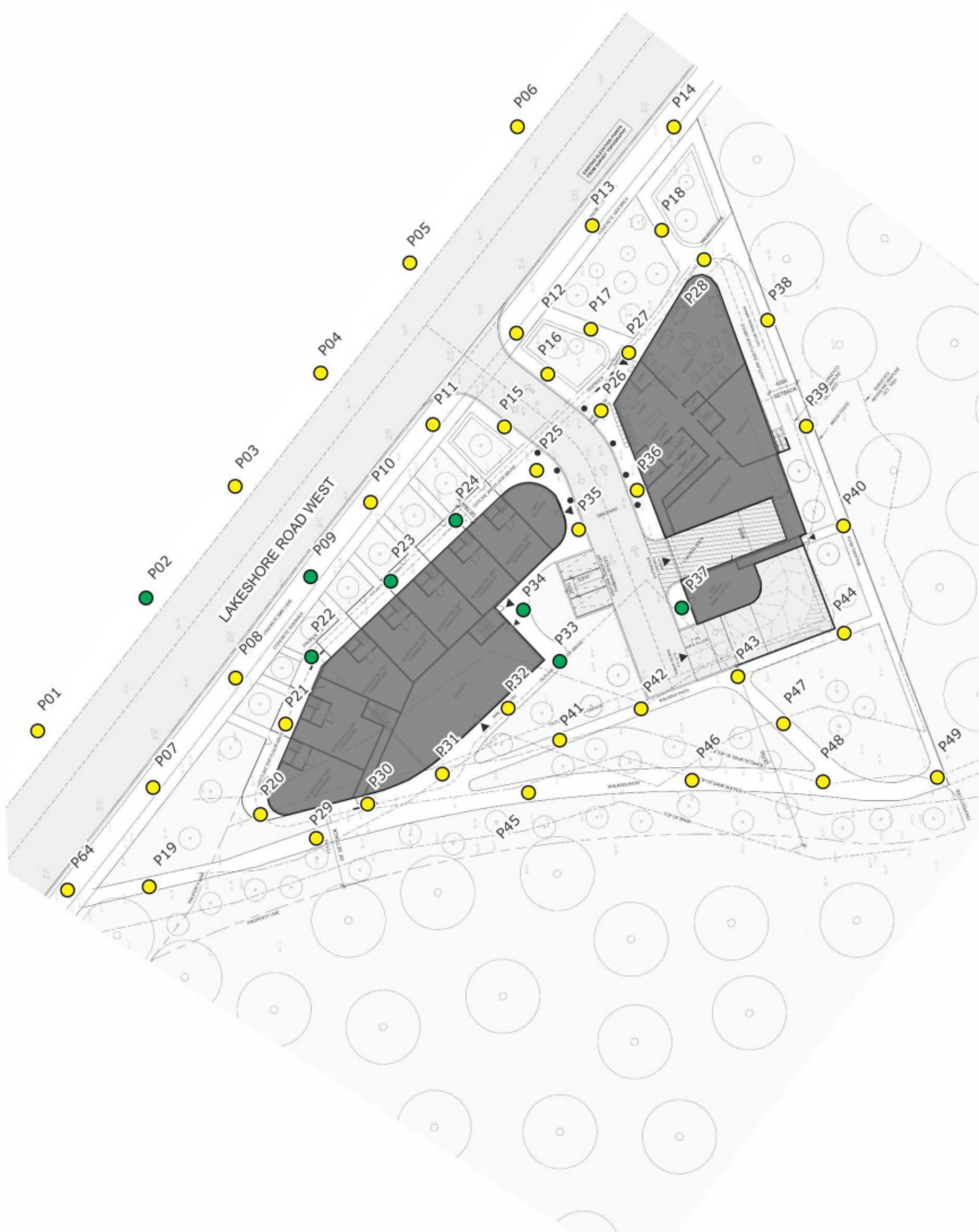

Figure 6. 1b: Wind Tunnel Results – Existing Scenario – Summer – Ground Level Plan
(results shown without treatments applied)

Criteria Legend

- Wind Comfort Standard for Sitting Criterion (10km/h)
- Wind Comfort Standard for Standing Criterion (15km/h)
- Wind Comfort Standard for Walking Criterion (20km/h)
- Uncomfortable (> 20km/h)

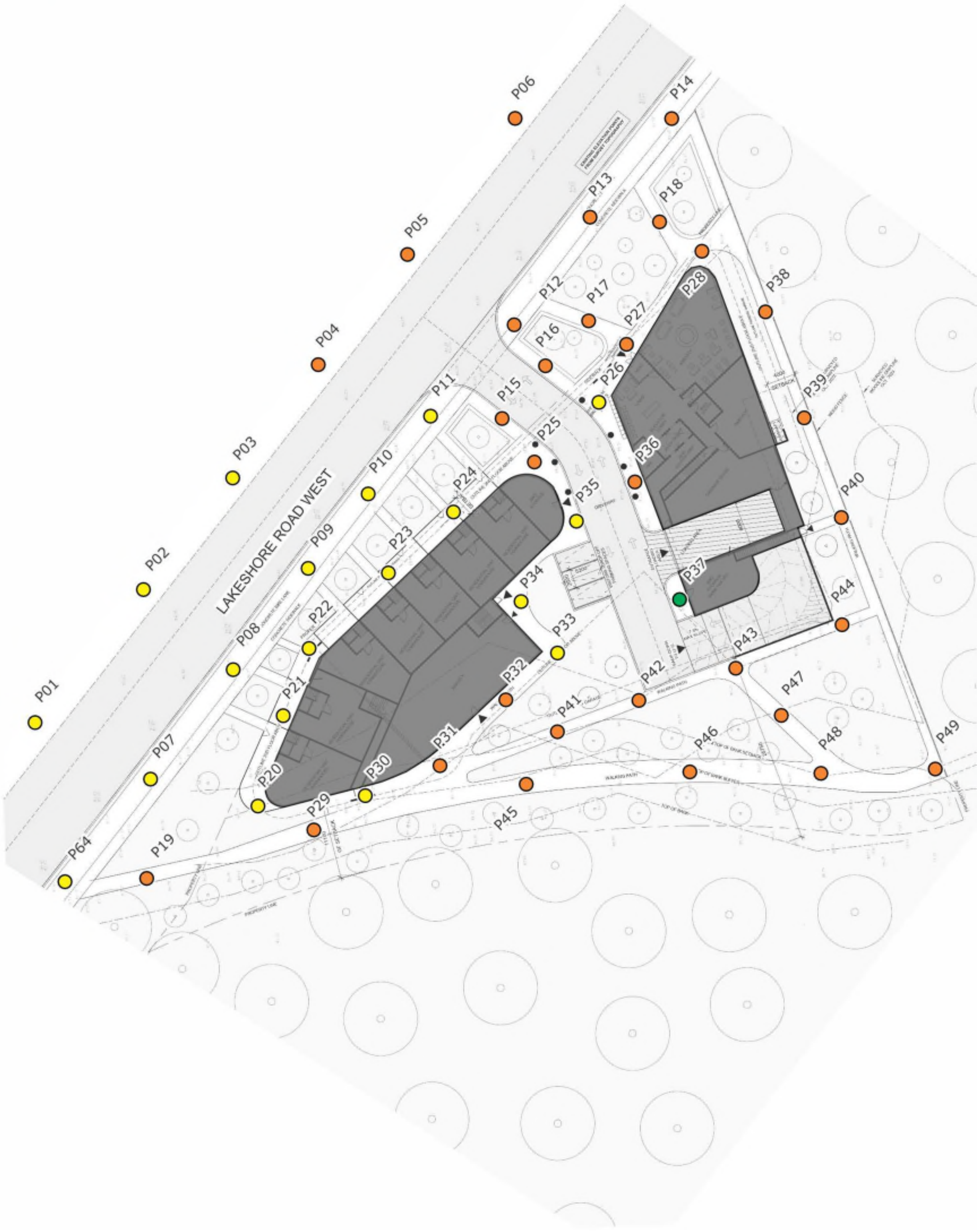

Figure 6. 1c: Wind Tunnel Results – Existing Scenario – Winter – Ground Level Plan
(results shown without treatments applied)

Criteria Legend

- Wind Comfort Standard for Sitting Criterion (10km/h)
- Wind Comfort Standard for Standing Criterion (15km/h)
- Wind Comfort Standard for Walking Criterion (20km/h)
- Uncomfortable (> 20km/h)

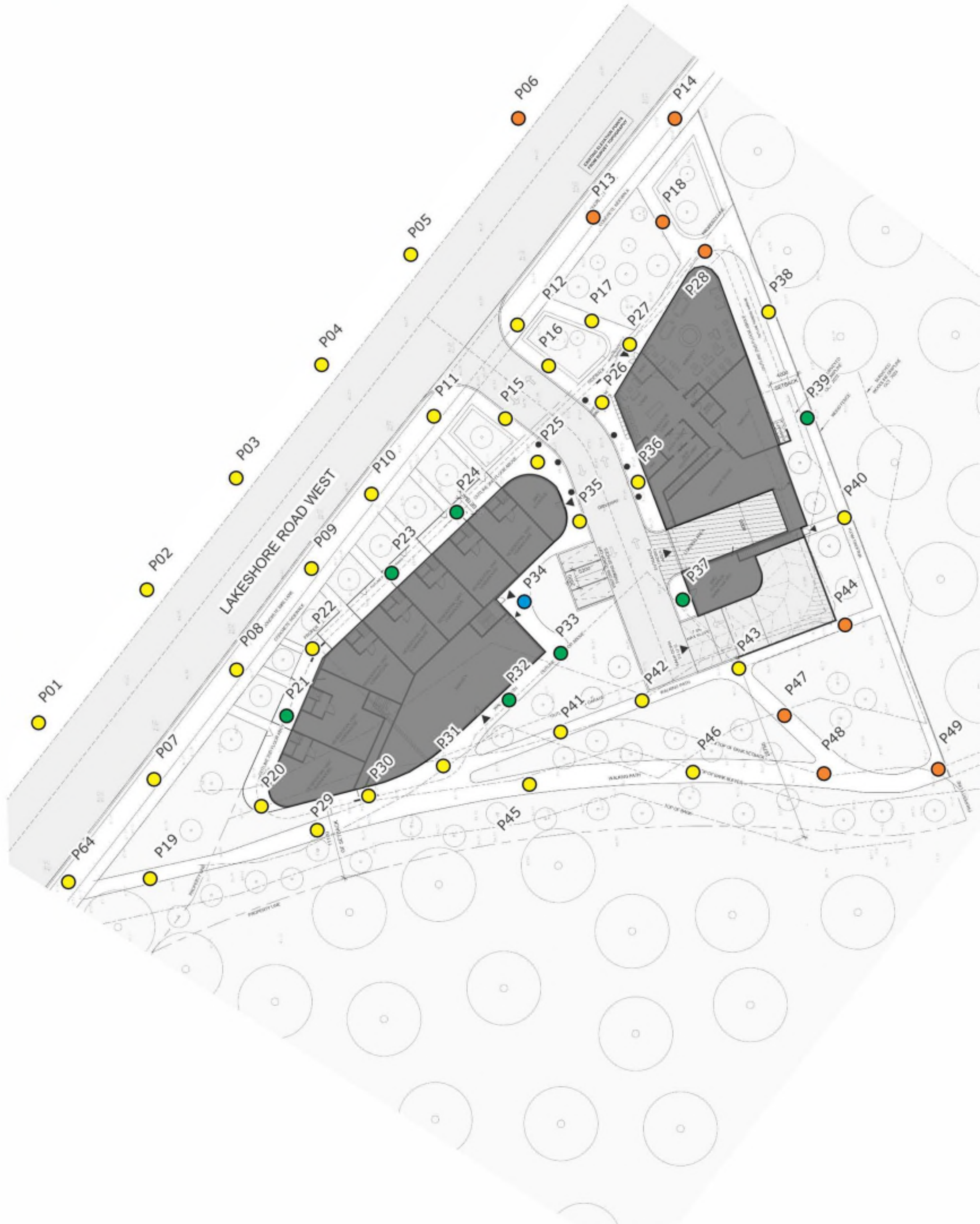

Figure 6. 1d: Wind Tunnel Results – Proposed Scenario – Annual – Ground Level Plan
(results shown without treatments applied)

Criteria Legend

- Wind Comfort Standard for Sitting Criterion (10km/h)
- Wind Comfort Standard for Standing Criterion (15km/h)
- Wind Comfort Standard for Walking Criterion (20km/h)
- Uncomfortable (> 20km/h)

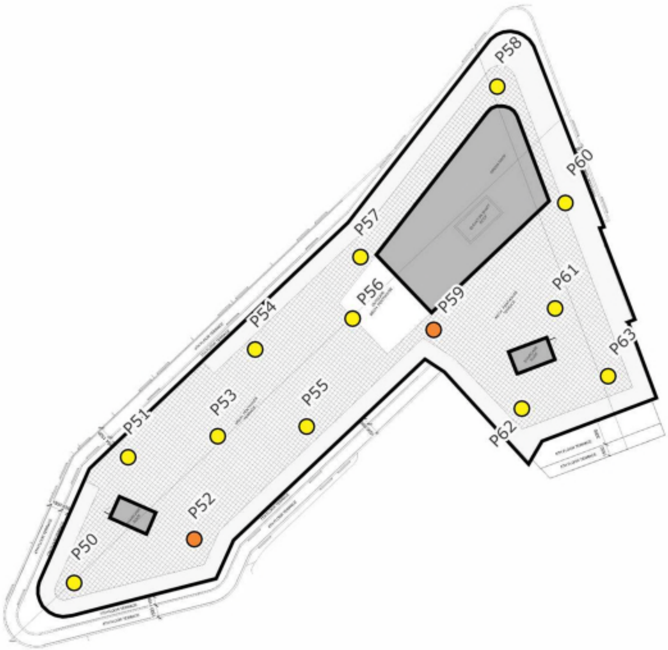

Figure 6. 1e: Wind Tunnel Results – Proposed Scenario – Annual – Roof Level Plan
(results shown without treatments applied)

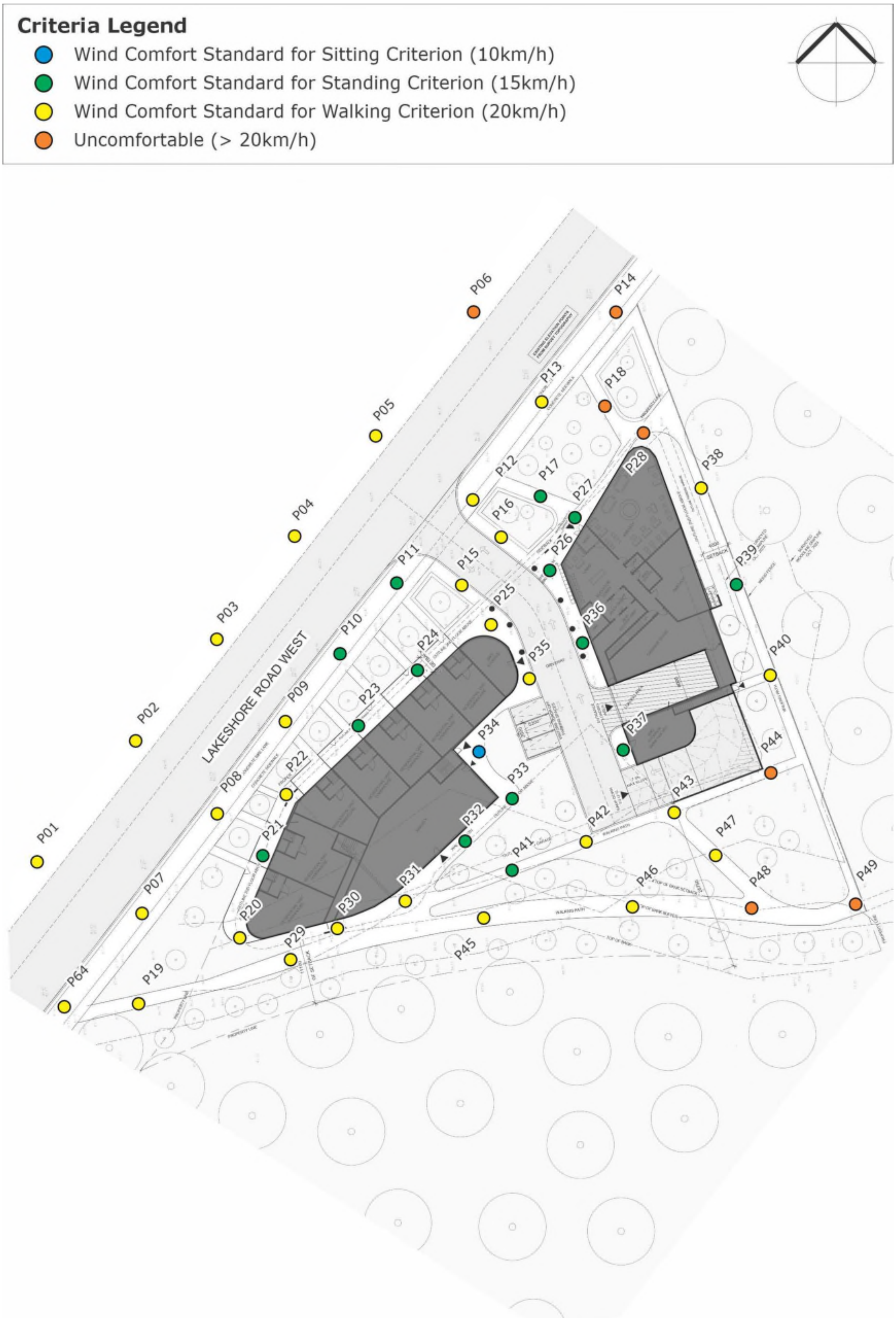

Figure 6. 1f: Wind Tunnel Results – Proposed Scenario – Summer – Ground Level Plan
(results shown without treatments applied)

Figure 6. 1g: Wind Tunnel Results – Proposed Scenario – Summer – Roof Level Plan
(results shown without treatments applied)

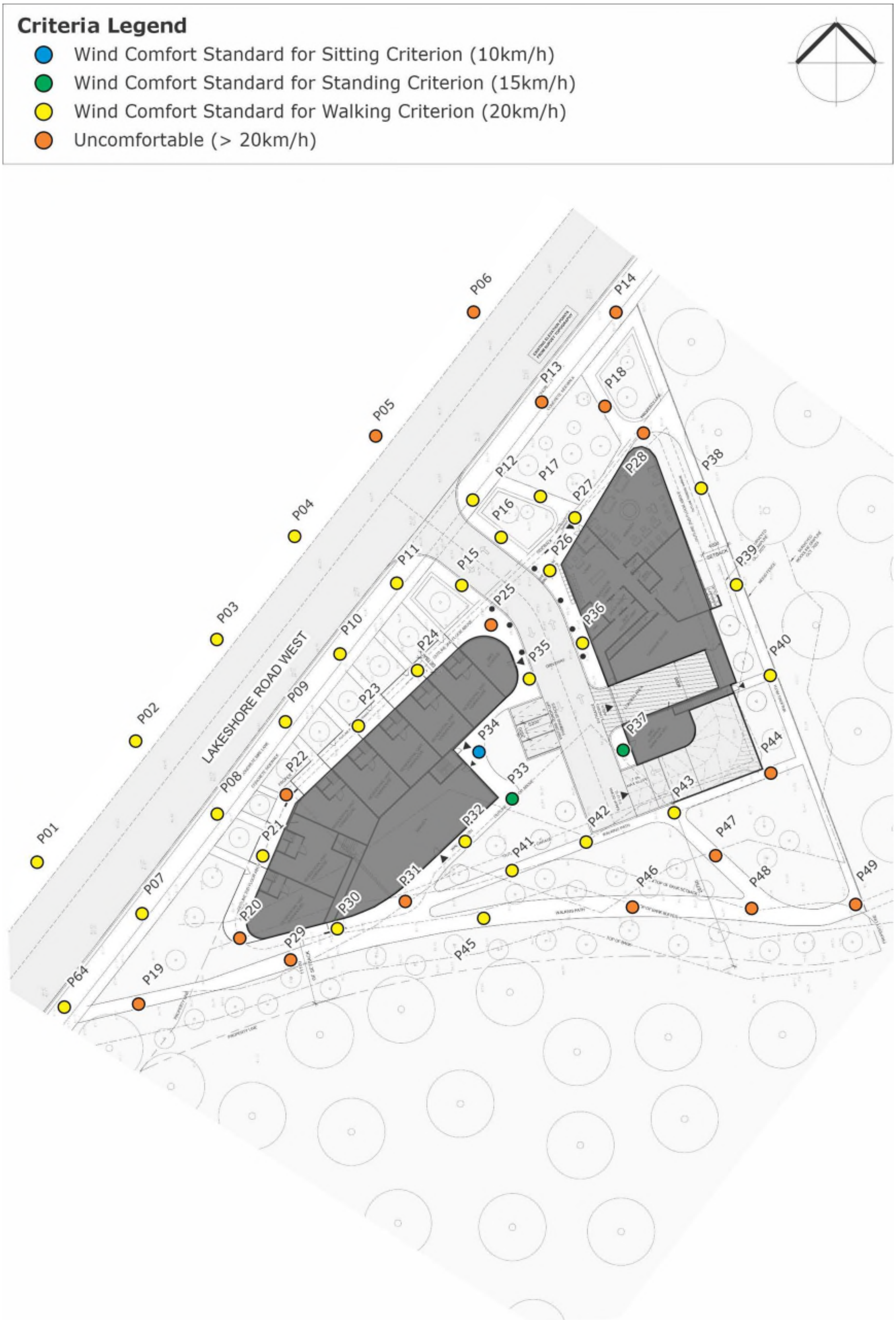

Figure 6. 1h: Wind Tunnel Results – Proposed Scenario – Winter – Ground Level Plan
(results shown without treatments applied)

Figure 6. 1i: Wind Tunnel Results – Proposed Scenario – Winter – Roof Level Plan
(results shown without treatments applied)

6.2 Safety Criterion

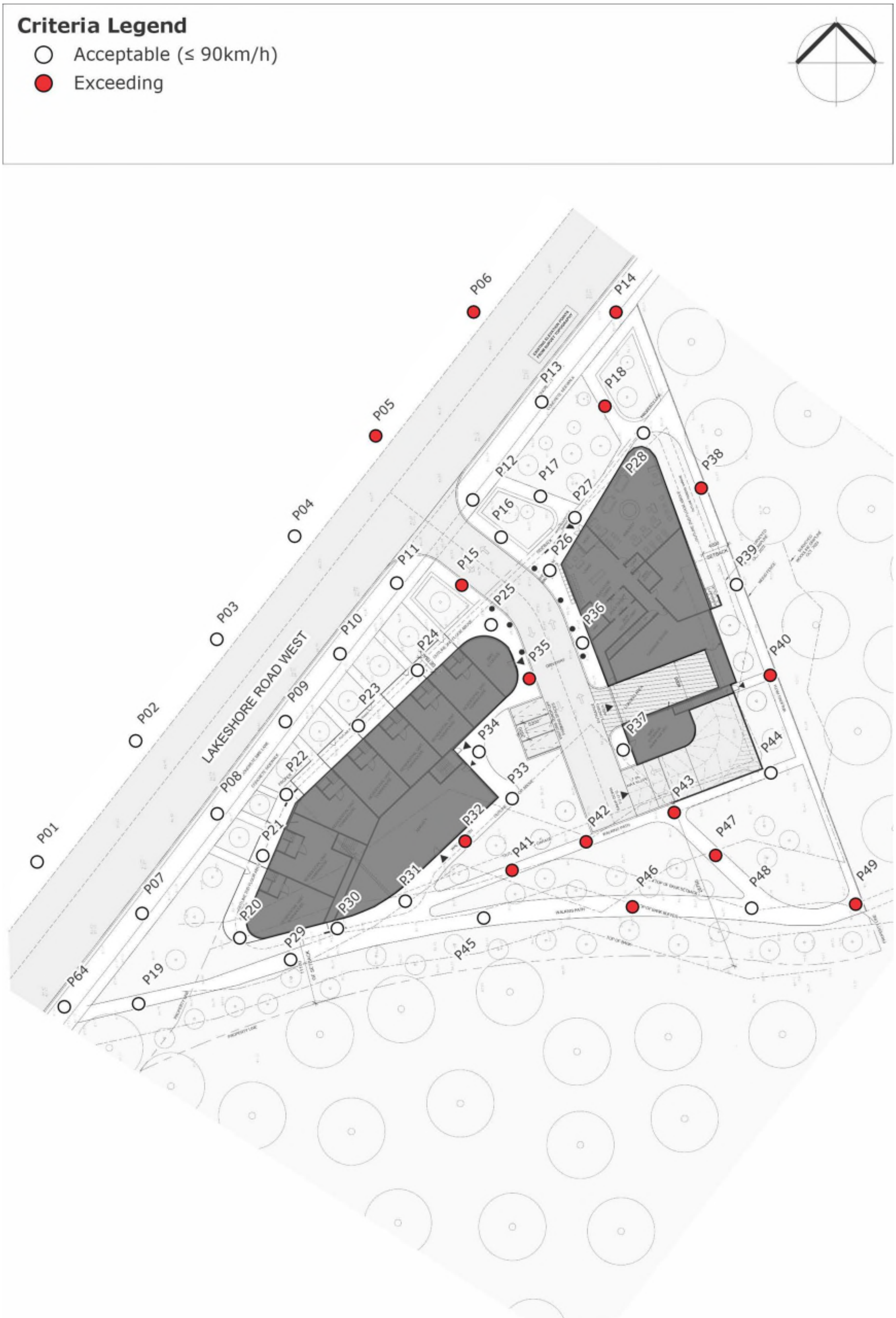

Figure 6. 2a: Wind Tunnel Results – Existing Scenario – Annual – Ground Level Plan
(results shown without treatments applied)

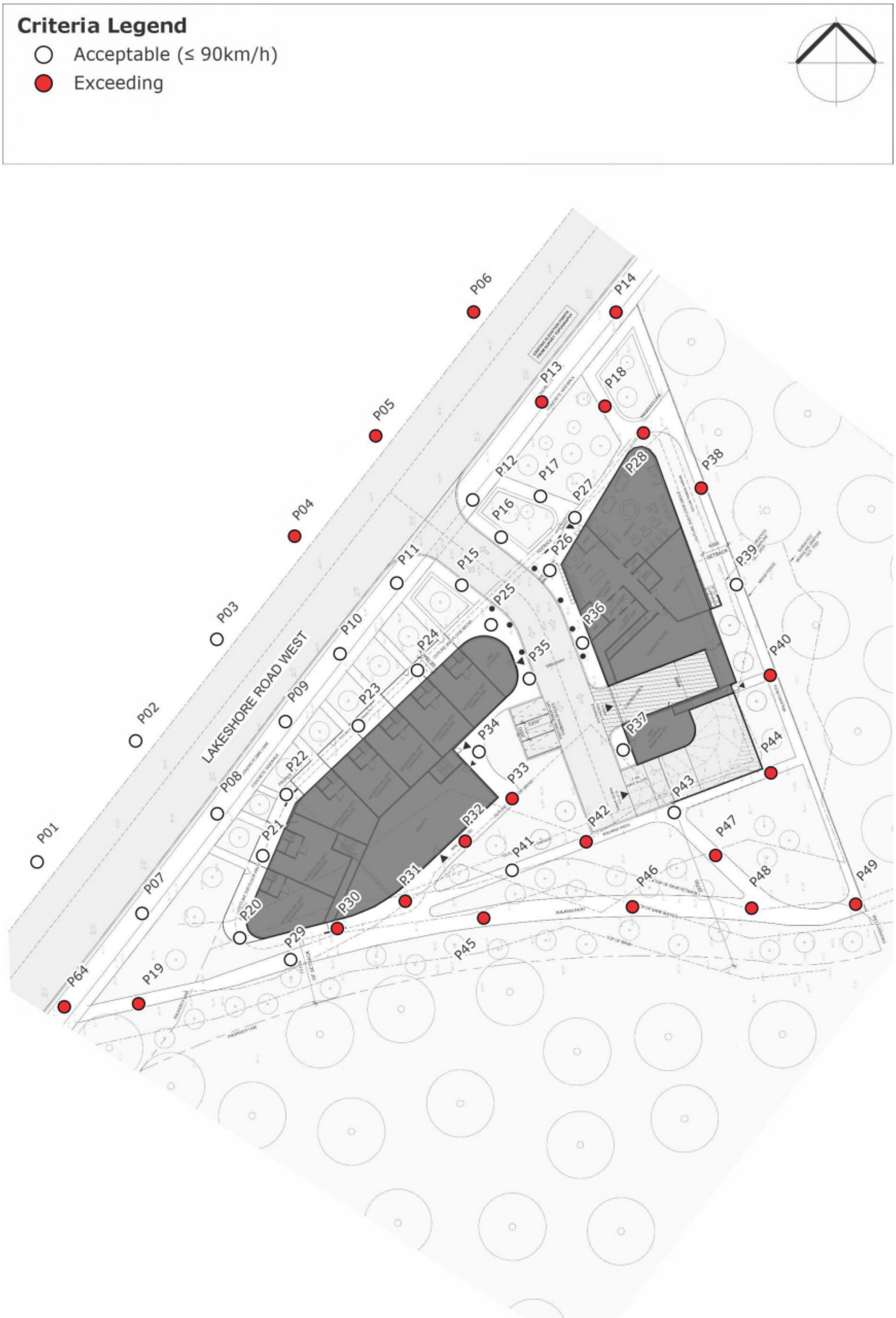

Figure 6. 2b: Wind Tunnel Results – Proposed Scenario – Annual – Ground Level Plan
(results shown without treatments applied)

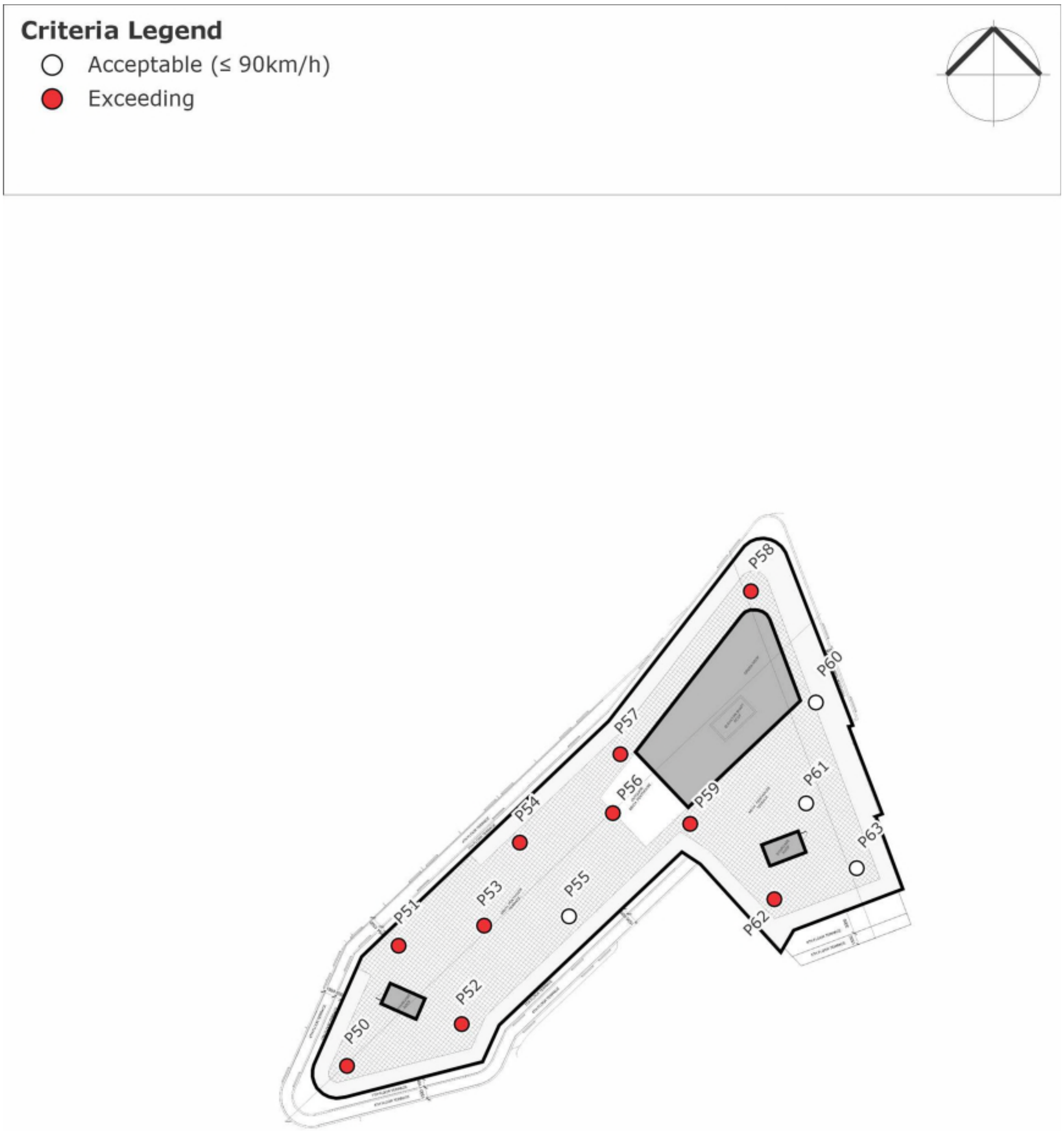

Figure 6. 2c: Wind Tunnel Results – Proposed Scenario – Annual – Roof Level Plan
(results shown without treatments applied)

6.3 Wind Roses

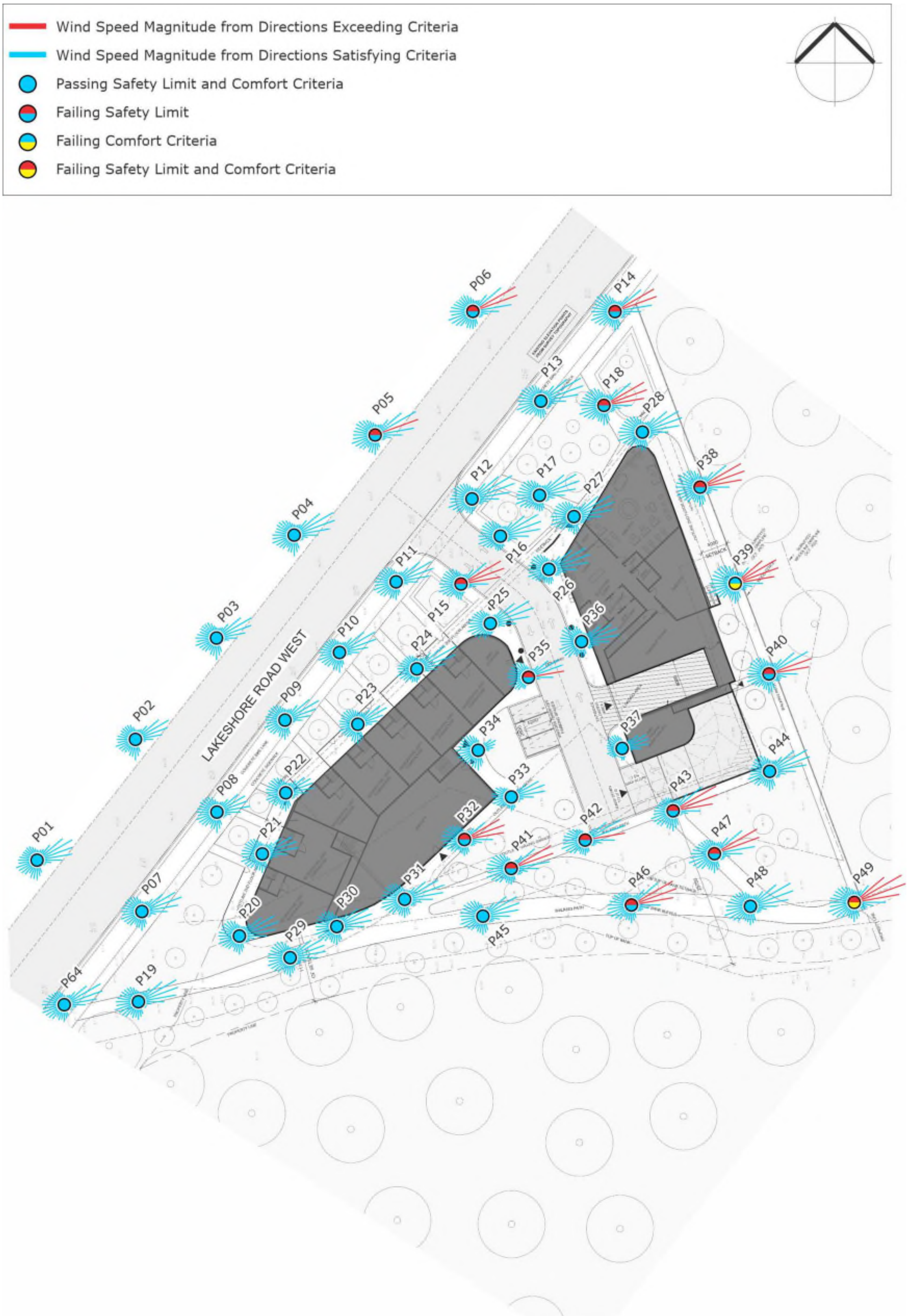

Figure 6. 3a: Wind Tunnel Results – Existing Scenario – Annual – Ground Level Plan
(results shown without treatments applied)

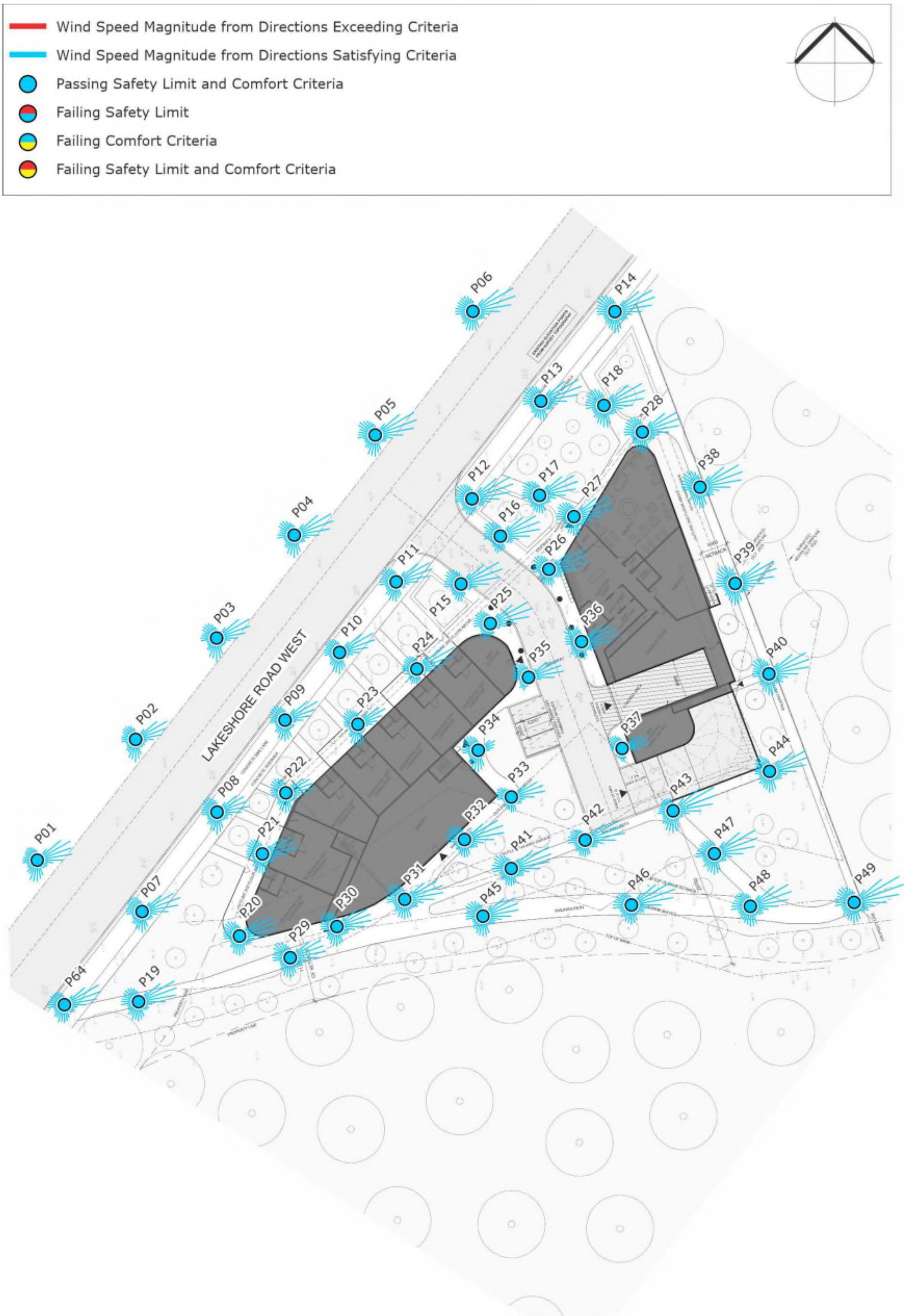

Figure 6. 3b: Wind Tunnel Results – Existing Scenario – Summer – Ground Level Plan
(results shown without treatments applied)

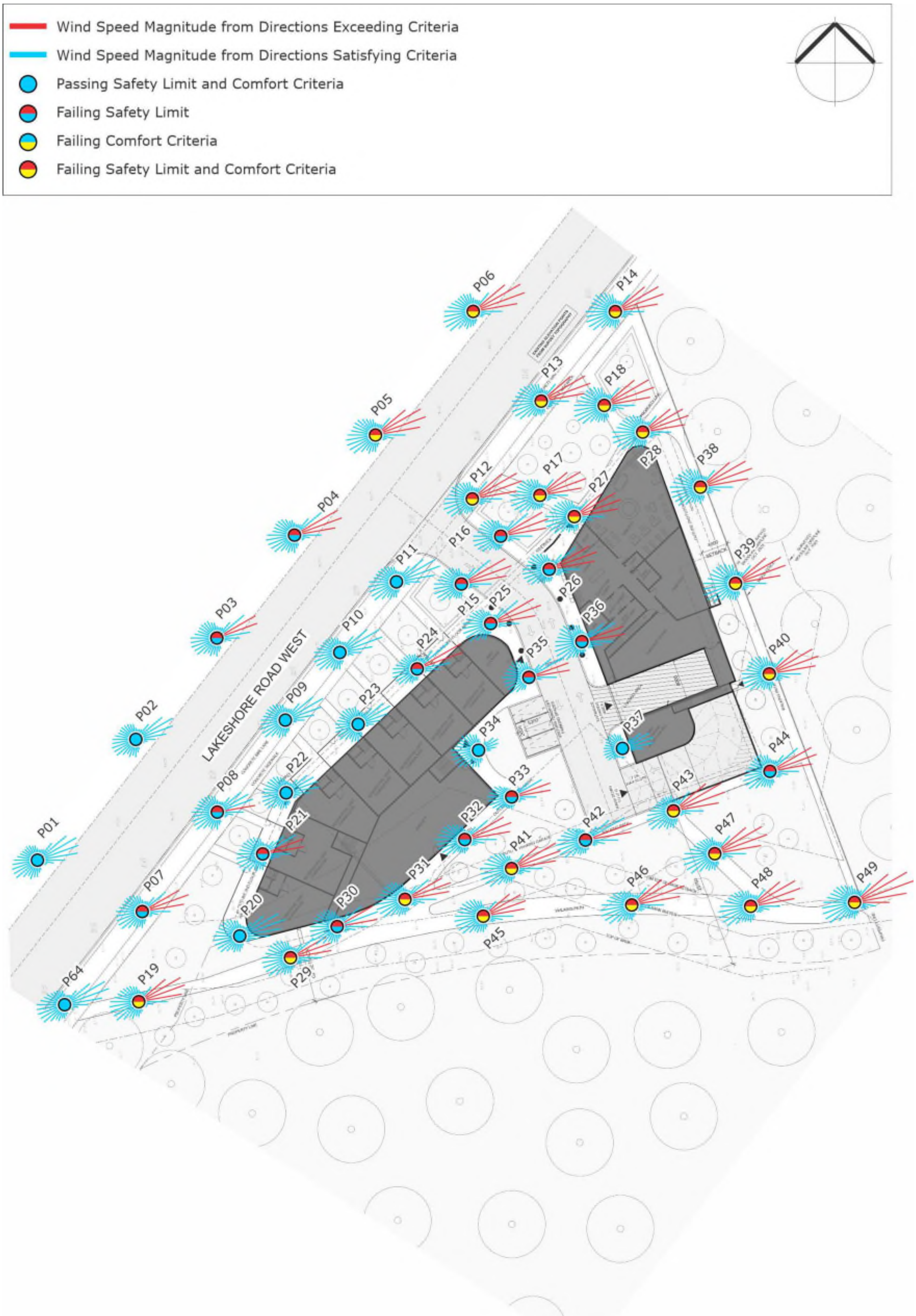

Figure 6. 3c: Wind Tunnel Results – Existing Scenario – Winter – Ground Level Plan
(results shown without treatments applied)

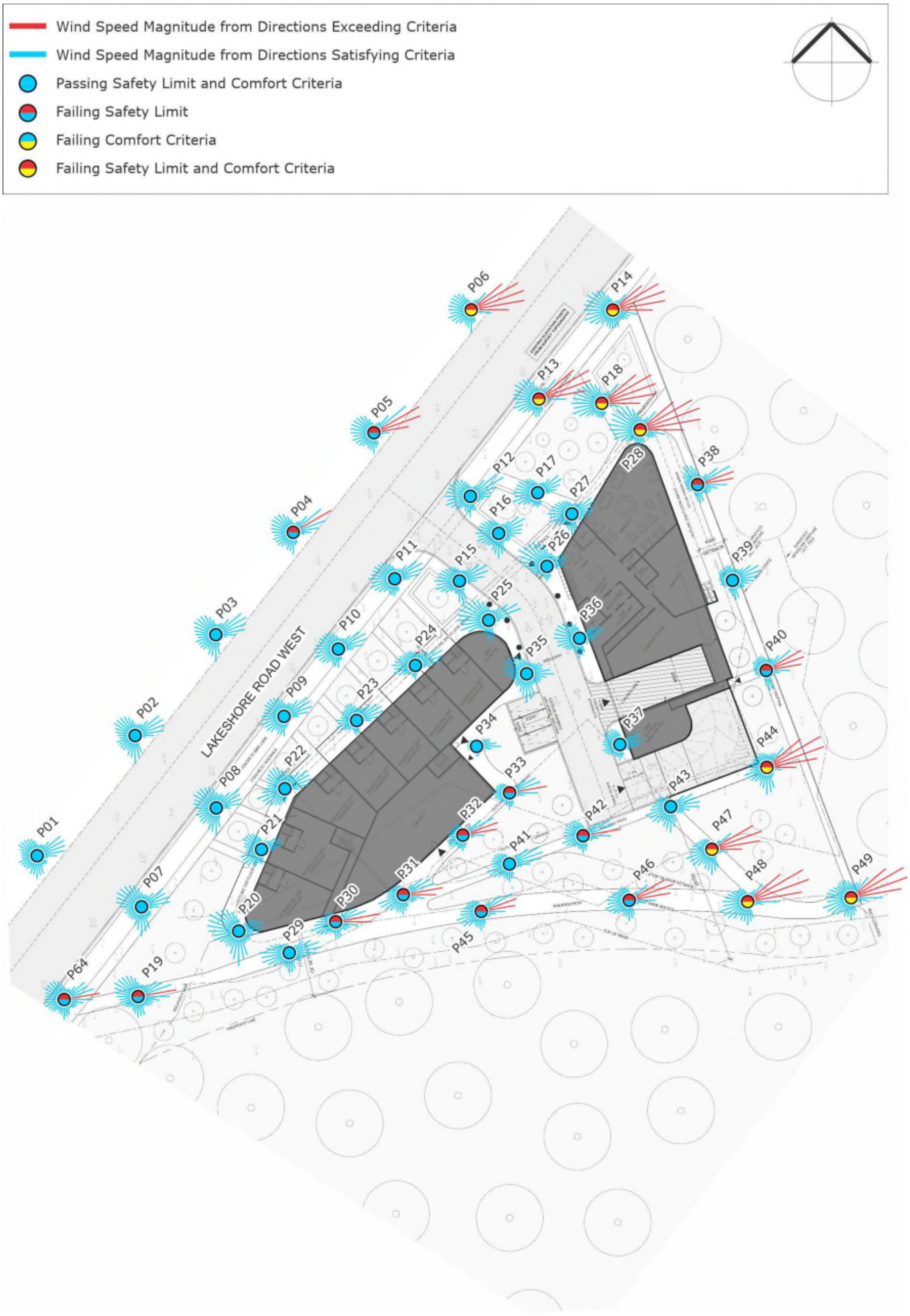

Figure 6. 3d: Wind Tunnel Results – Proposed Scenario – Annual – Ground Level Plan
(results shown without treatments applied)

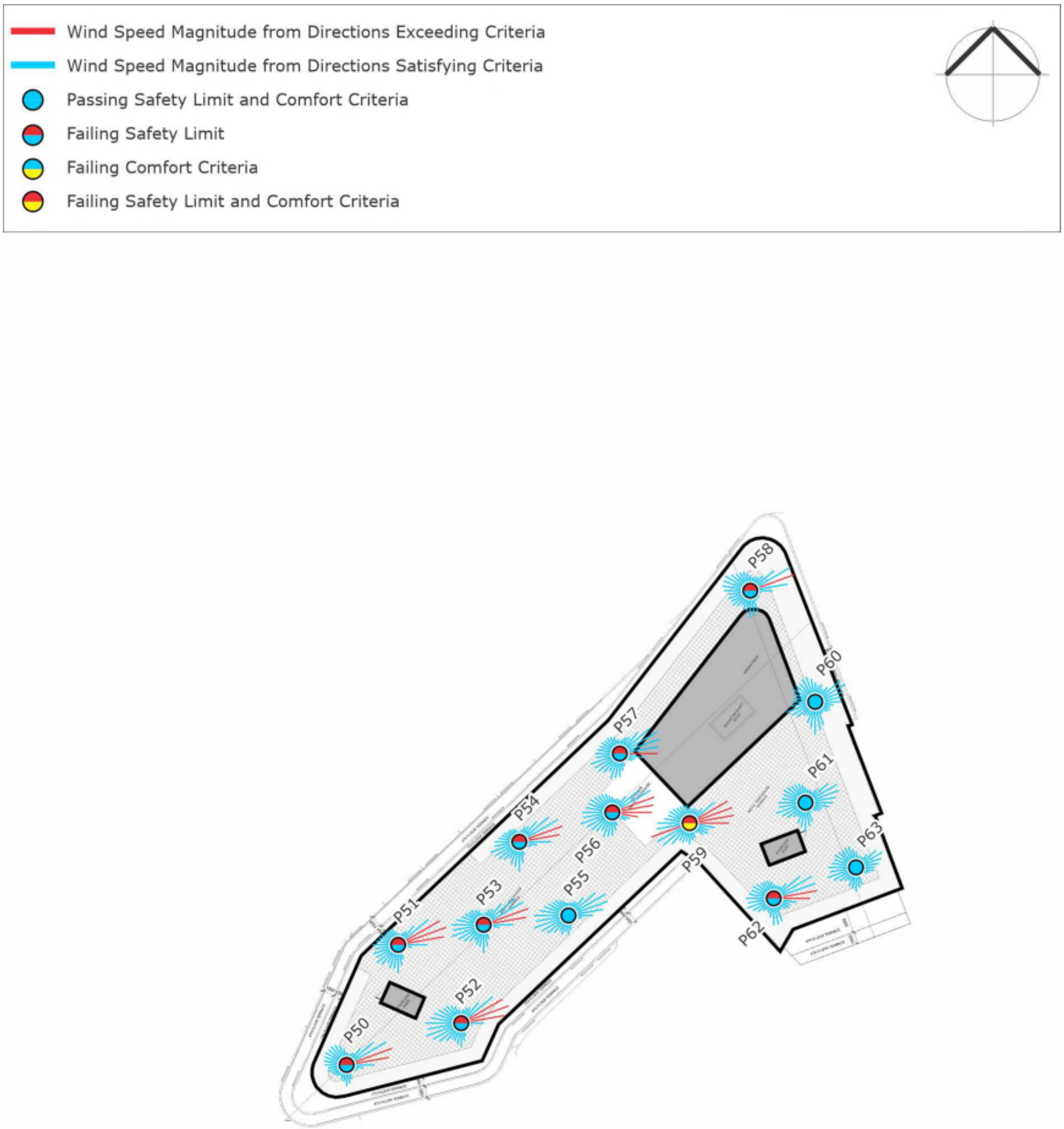

Figure 6. 3e: Wind Tunnel Results – Proposed Scenario – Annual – Roof Level Plan
(results shown without treatments applied)

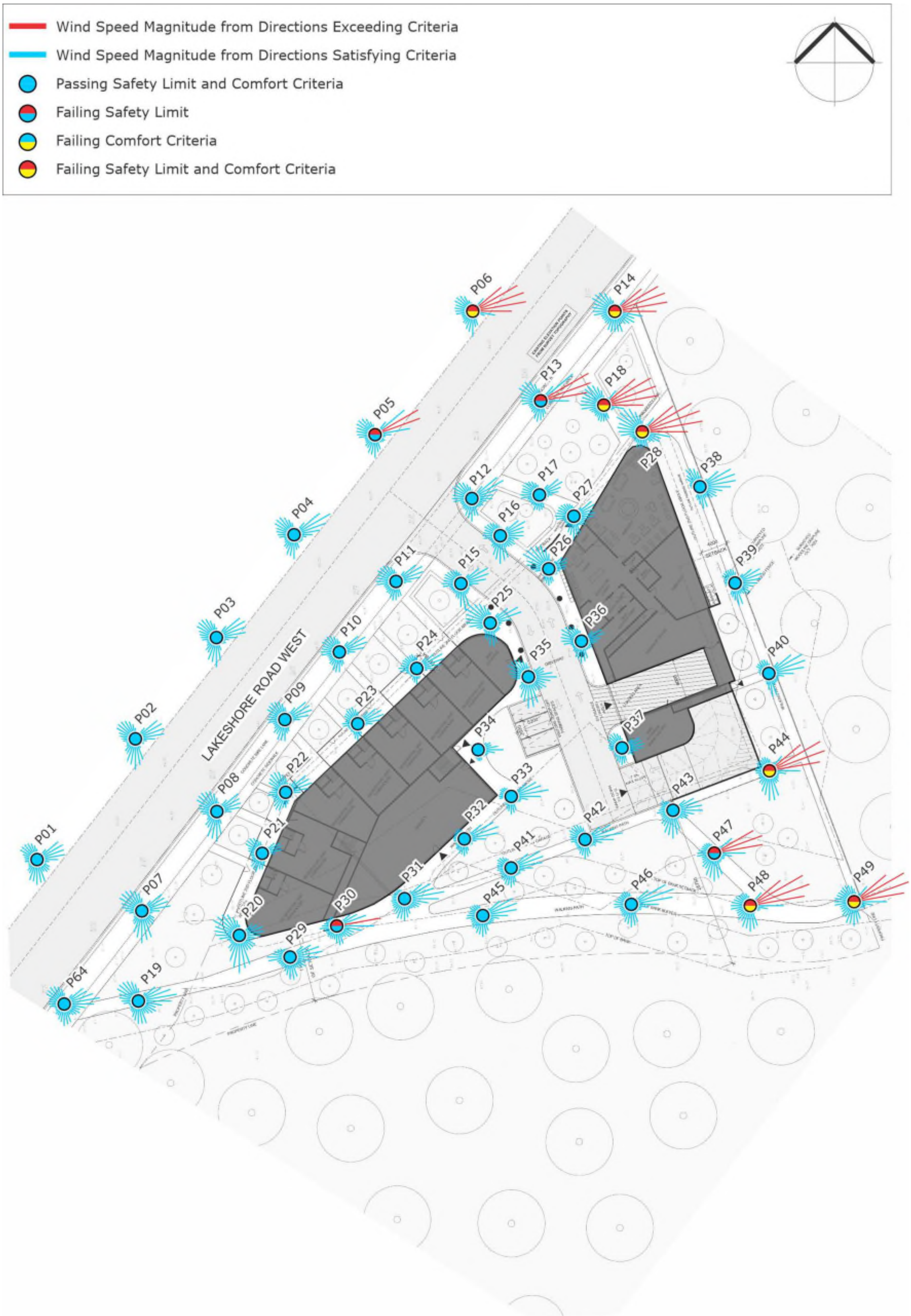

Figure 6. 3f: Wind Tunnel Results – Proposed Scenario – Summer – Ground Level Plan
(results shown without treatments applied)

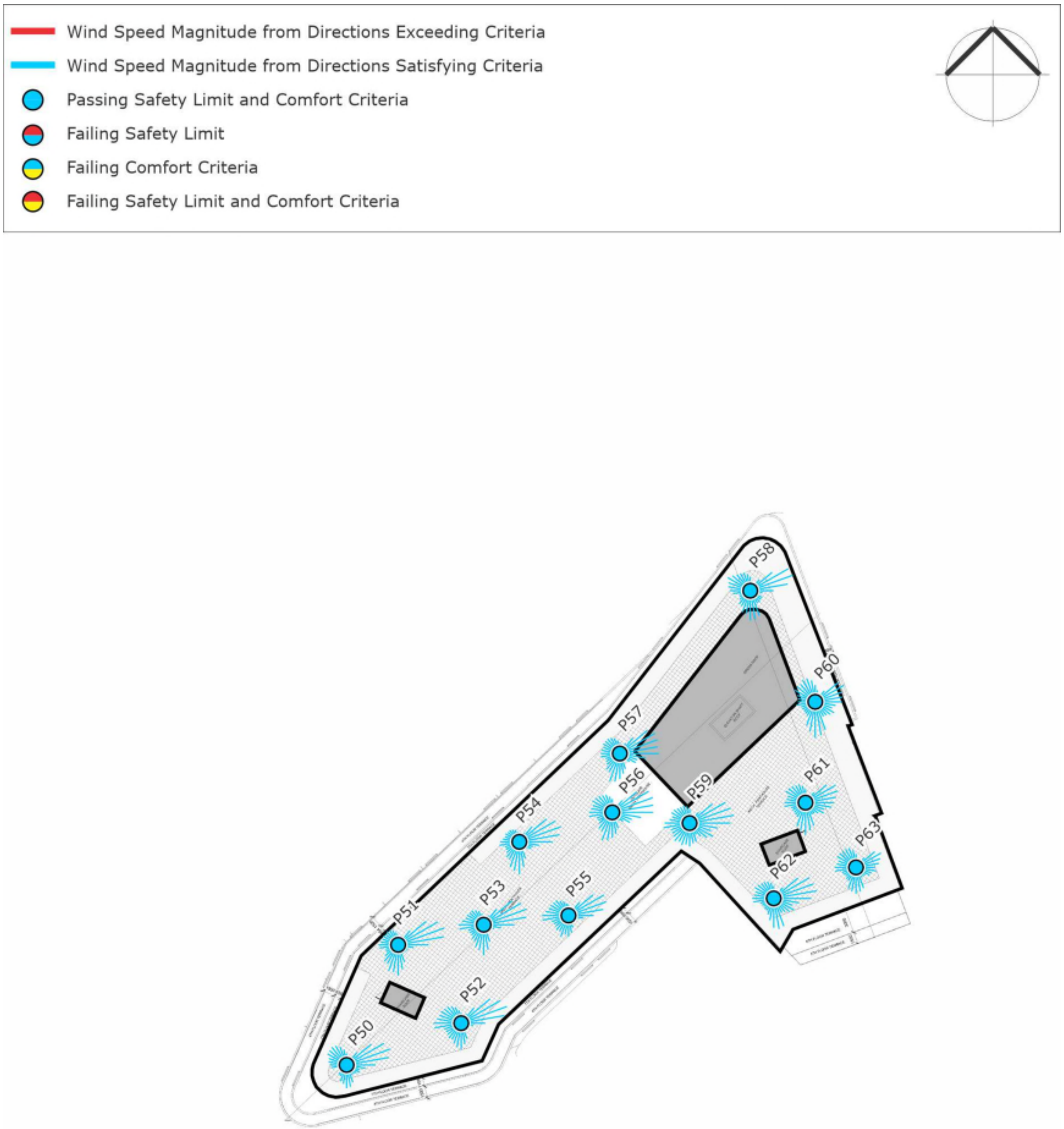

Figure 6. 3g: Wind Tunnel Results – Proposed Scenario – Summer – Roof Level Plan
(results shown without treatments applied)

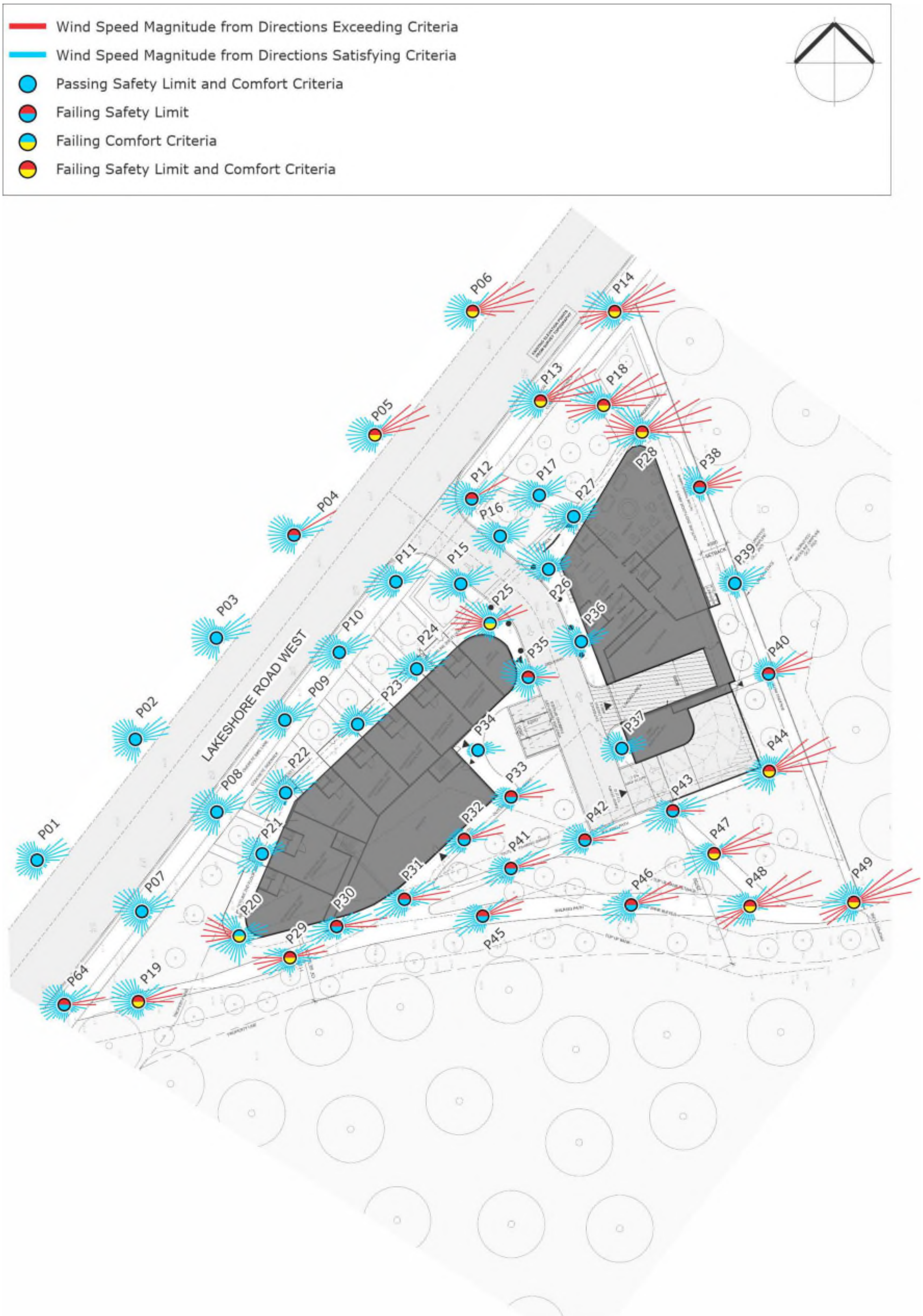

Figure 6. 3h: Wind Tunnel Results – Proposed Scenario – Winter – Ground Level Plan
(results shown without treatments applied)

Figure 6. 3i: Wind Tunnel Results – Proposed Scenario – Winter – Roof Level Plan
(results shown without treatments applied)

Table 6: Wind Tunnel Results Summary – Annual

Study Point	GEM (20% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
P01	20	16.2	Pass	90	75.6	Pass	Pass	
Existing		17.28	Pass		82.8	Pass	Pass	
P02	20	17.28	Pass	90	79.2	Pass	Pass	
Existing		15.48	Pass		82.8	Pass	Pass	
P03	20	18	Pass	90	79.2	Pass	Pass	
Existing		16.92	Pass		86.4	Pass	Pass	
P04	20	17.28	Pass	90	100.8	Fail	Fail	Refer to Figure 7a.
Existing		18	Pass		90	Pass	Pass	
P05	20	18.36	Pass	90	118.8	Fail	Fail	Refer to Figure 7a.
Existing		19.08	Pass		93.6	Fail	Fail	
P06	20	21.6	Fail	90	122.4	Fail	Fail	Refer to Figure 7a.
Existing		19.08	Pass		93.6	Fail	Fail	
P07	20	18.36	Pass	90	79.2	Pass	Pass	
Existing		17.64	Pass		90	Pass	Pass	
P08	20	17.64	Pass	90	68.4	Pass	Pass	
Existing		16.56	Pass		86.4	Pass	Pass	
P09	20	16.92	Pass	90	72	Pass	Pass	
Existing		15.84	Pass		82.8	Pass	Pass	
P10	20	16.56	Pass	90	72	Pass	Pass	
Existing		16.56	Pass		82.8	Pass	Pass	
P11	20	16.92	Pass	90	72	Pass	Pass	
Existing		17.28	Pass		86.4	Pass	Pass	
P12	20	17.28	Pass	90	86.4	Pass	Pass	
Existing		18.72	Pass		90	Pass	Pass	
P13	20	21.6	Fail	90	126	Fail	Fail	Refer to Figure 7a.
Existing		18.72	Pass		90	Pass	Pass	
P14	20	24.48	Fail	90	118.8	Fail	Fail	Refer to Figure 7a.
Existing		19.08	Pass		93.6	Fail	Fail	
P15	20	16.56	Pass	90	72	Pass	Pass	
Existing		18	Pass		97.2	Fail	Fail	
P16	20	16.56	Pass	90	68.4	Pass	Pass	
Existing		18	Pass		90	Pass	Pass	
P17	20	15.12	Pass	90	64.8	Pass	Pass	
Existing		18.36	Pass		90	Pass	Pass	
P18	20	24.12	Fail	90	136.8	Fail	Fail	Refer to Figure 7a.
Existing		19.8	Pass		93.6	Fail	Fail	
P19	20	18.72	Pass	90	104.4	Fail	Fail	Refer to Figure 7a.
Existing		18.36	Pass		82.8	Pass	Pass	

Study Point	GEM (20% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
P20	20	19.8	Pass	90	72	Pass	Pass	
Existing		17.64	Pass		86.4	Pass	Pass	
P21	20	13.68	Pass	90	61.2	Pass	Pass	
Existing		17.28	Pass		86.4	Pass	Pass	
P22	20	17.28	Pass	90	68.4	Pass	Pass	
Existing		15.48	Pass		79.2	Pass	Pass	
P23	20	14.4	Pass	90	68.4	Pass	Pass	
Existing		14.76	Pass		75.6	Pass	Pass	
P24	20	14.76	Pass	90	72	Pass	Pass	
Existing		15.84	Pass		90	Pass	Pass	
P25	20	18.72	Pass	90	82.8	Pass	Pass	
Existing		18	Pass		90	Pass	Pass	
P26	20	15.84	Pass	90	68.4	Pass	Pass	
Existing		18	Pass		90	Pass	Pass	
P27	20	15.12	Pass	90	57.6	Pass	Pass	
Existing		18.72	Pass		90	Pass	Pass	
P28	20	26.28	Fail	90	140.4	Fail	Fail	Refer to Figure 7a.
Existing		18.72	Pass		90	Pass	Pass	
P29	20	17.28	Pass	90	90	Pass	Pass	Refer to Figure 7a.
Existing		18	Pass		82.8	Pass	Pass	
P30	20	16.56	Pass	90	122.4	Fail	Fail	Refer to Figure 7a.
Existing		17.64	Pass		86.4	Pass	Pass	
P31	20	17.64	Pass	90	108	Fail	Fail	Refer to Figure 7a.
Existing		18.72	Pass		90	Pass	Pass	
P32	20	14.04	Pass	90	93.6	Fail	Fail	Better than or equivalent to Existing Conditions.
Existing		18.36	Pass		100.8	Fail	Fail	
P33	20	14.4	Pass	90	104.4	Fail	Fail	Refer to Figure 7a.
Existing		14.76	Pass		90	Pass	Pass	
P34	20	8.28	Pass	90	75.6	Pass	Pass	
Existing		13.68	Pass		50.4	Pass	Pass	
P35	20	16.56	Pass	90	86.4	Pass	Pass	
Existing		16.56	Pass		97.2	Fail	Fail	
P36	20	15.48	Pass	90	61.2	Pass	Pass	
Existing		18	Pass		90	Pass	Pass	
P37	20	12.96	Pass	90	61.2	Pass	Pass	
Existing		12.96	Pass		72	Pass	Pass	
P38	20	17.28	Pass	90	97.2	Fail	Fail	Refer to Figure 7a.
Existing		20.16	Pass		97.2	Fail	Fail	
P39	20	14.4	Pass	90	72	Pass	Pass	

Study Point	GEM (20% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
Existing		20.52	Fail		86.4	Pass	Fail	
P40	20	15.84	Pass	90	97.2	Fail	Fail	
Existing		19.08	Pass		93.6	Fail	Fail	
P41	20	15.84	Pass	90	86.4	Pass	Pass	
Existing		19.08	Pass		93.6	Fail	Fail	
P42	20	16.2	Pass	90	104.4	Fail	Fail	
Existing		18	Pass		93.6	Fail	Fail	
P43	20	16.56	Pass	90	90	Pass	Pass	
Existing		18.72	Pass		93.6	Fail	Fail	
P44	20	21.6	Fail	90	147.6	Fail	Fail	
Existing		18	Pass		90	Pass	Pass	
P45	20	17.28	Pass	90	93.6	Fail	Fail	
Existing		18.36	Pass		90	Pass	Pass	
P46	20	18.36	Pass	90	115.2	Fail	Fail	
Existing		19.44	Pass		93.6	Fail	Fail	
P47	20	20.52	Fail	90	133.2	Fail	Fail	
Existing		19.8	Pass		93.6	Fail	Fail	
P48	20	23.04	Fail	90	136.8	Fail	Fail	
Existing		19.44	Pass		90	Pass	Pass	
P49	20	22.68	Fail	90	115.2	Fail	Fail	
Existing		21.24	Fail		108	Fail	Fail	
P50	20	16.56	Pass	90	97.2	Fail	Fail	
P51	20	18.72	Pass	90	104.4	Fail	Fail	
P52	20	20.16	Pass	90	104.4	Fail	Fail	
P53	20	19.08	Pass	90	97.2	Fail	Fail	
P54	20	18.36	Pass	90	93.6	Fail	Fail	
P55	20	18.36	Pass	90	82.8	Pass	Pass	
P56	20	19.44	Pass	90	104.4	Fail	Fail	
P57	20	18.72	Pass	90	97.2	Fail	Fail	
P58	20	17.64	Pass	90	97.2	Fail	Fail	
P59	20	20.52	Fail	90	104.4	Fail	Fail	
P60	20	17.28	Pass	90	68.4	Pass	Pass	
P61	20	17.28	Pass	90	82.8	Pass	Pass	
P62	20	18.72	Pass	90	100.8	Fail	Fail	
P63	20	15.12	Pass	90	64.8	Pass	Pass	
P64	20	17.28	Pass	90	97.2	Fail	Fail	
Existing		16.92	Pass		86.4	Pass	Pass	

Table 7: Wind Tunnel Results Summary – Summer

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
P01	20	15.84	Pass	90	61.2	Pass	Pass	
Existing		16.56	Pass		68.4	Pass	Pass	
P02	20	16.92	Pass	90	61.2	Pass	Pass	
Existing		14.76	Pass		68.4	Pass	Pass	
P03	20	16.92	Pass	90	68.4	Pass	Pass	
Existing		15.84	Pass		72	Pass	Pass	
P04	20	16.2	Pass	90	86.4	Pass	Pass	
Existing		16.92	Pass		75.6	Pass	Pass	
P05	20	16.92	Pass	90	100.8	Fail	Fail	
Existing		18	Pass		75.6	Pass	Pass	
P06	20	20.52	Fail	90	97.2	Fail	Fail	
Existing		17.64	Pass		79.2	Pass	Pass	
P07	20	17.64	Pass	90	61.2	Pass	Pass	
Existing		16.56	Pass		72	Pass	Pass	
P08	20	16.56	Pass	90	64.8	Pass	Pass	
Existing		15.84	Pass		68.4	Pass	Pass	
P09	20	15.12	Pass	90	57.6	Pass	Pass	
Existing		14.76	Pass		68.4	Pass	Pass	
P10	20	14.76	Pass	90	61.2	Pass	Pass	
Existing		15.12	Pass		68.4	Pass	Pass	
P11	20	14.76	Pass	90	61.2	Pass	Pass	
Existing		15.84	Pass		68.4	Pass	Pass	
P12	20	15.48	Pass	90	72	Pass	Pass	
Existing		17.28	Pass		75.6	Pass	Pass	
P13	20	19.8	Pass	90	100.8	Fail	Fail	
Existing		17.64	Pass		75.6	Pass	Pass	
P14	20	23.04	Fail	90	93.6	Fail	Fail	
Existing		18	Pass		75.6	Pass	Pass	
P15	20	15.12	Pass	90	61.2	Pass	Pass	
Existing		16.92	Pass		75.6	Pass	Pass	
P16	20	15.84	Pass	90	57.6	Pass	Pass	
Existing		16.92	Pass		72	Pass	Pass	
P17	20	12.96	Pass	90	54	Pass	Pass	
Existing		16.92	Pass		72	Pass	Pass	
P18	20	21.96	Fail	90	108	Fail	Fail	
Existing		18.72	Pass		75.6	Pass	Pass	
P19	20	18.36	Pass	90	82.8	Pass	Pass	
Existing		16.92	Pass		68.4	Pass	Pass	

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
P20	20	18.72	Pass	90	68.4	Pass	Pass	
Existing		16.92	Pass		68.4	Pass	Pass	
P21	20	12.24	Pass	90	50.4	Pass	Pass	
Existing		16.2	Pass		68.4	Pass	Pass	
P22	20	15.12	Pass	90	57.6	Pass	Pass	
Existing		14.76	Pass		61.2	Pass	Pass	
P23	20	12.96	Pass	90	54	Pass	Pass	
Existing		14.04	Pass		64.8	Pass	Pass	
P24	20	13.32	Pass	90	57.6	Pass	Pass	
Existing		14.4	Pass		75.6	Pass	Pass	
P25	20	16.92	Pass	90	64.8	Pass	Pass	
Existing		16.2	Pass		72	Pass	Pass	
P26	20	13.32	Pass	90	64.8	Pass	Pass	
Existing		16.92	Pass		72	Pass	Pass	
P27	20	13.68	Pass	90	50.4	Pass	Pass	
Existing		17.64	Pass		72	Pass	Pass	
P28	20	24.84	Fail	90	111.6	Fail	Fail	
Existing		17.64	Pass		72	Pass	Pass	
P29	20	16.2	Pass	90	72	Pass	Pass	
Existing		17.28	Pass		68.4	Pass	Pass	
P30	20	15.84	Pass	90	97.2	Fail	Fail	
Existing		16.92	Pass		68.4	Pass	Pass	
P31	20	16.92	Pass	90	86.4	Pass	Pass	
Existing		17.64	Pass		72	Pass	Pass	
P32	20	13.32	Pass	90	72	Pass	Pass	
Existing		16.92	Pass		82.8	Pass	Pass	
P33	20	14.04	Pass	90	82.8	Pass	Pass	
Existing		13.32	Pass		72	Pass	Pass	
P34	20	8.28	Pass	90	64.8	Pass	Pass	
Existing		12.6	Pass		46.8	Pass	Pass	
P35	20	16.56	Pass	90	72	Pass	Pass	
Existing		15.12	Pass		75.6	Pass	Pass	
P36	20	13.68	Pass	90	54	Pass	Pass	
Existing		16.92	Pass		72	Pass	Pass	
P37	20	12.24	Pass	90	54	Pass	Pass	
Existing		12.24	Pass		57.6	Pass	Pass	
P38	20	17.28	Pass	90	79.2	Pass	Pass	
Existing		18.72	Pass		75.6	Pass	Pass	
P39	20	14.4	Pass	90	57.6	Pass	Pass	

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
Existing		19.08	Pass		72	Pass	Pass	
P40	20	15.84	Pass	90	79.2	Pass	Pass	
Existing		18.36	Pass		75.6	Pass	Pass	
P41	20	14.76	Pass	90	68.4	Pass	Pass	
Existing		17.64	Pass		75.6	Pass	Pass	
P42	20	15.48	Pass	90	82.8	Pass	Pass	
Existing		16.92	Pass		75.6	Pass	Pass	
P43	20	15.84	Pass	90	75.6	Pass	Pass	
Existing		17.64	Pass		75.6	Pass	Pass	
P44	20	21.24	Fail	90	118.8	Fail	Fail	
Existing		17.28	Pass		75.6	Pass	Pass	
P45	20	15.84	Pass	90	72	Pass	Pass	
Existing		17.28	Pass		75.6	Pass	Pass	
P46	20	16.92	Pass	90	90	Pass	Pass	
Existing		18	Pass		75.6	Pass	Pass	
P47	20	19.44	Pass	90	104.4	Fail	Fail	
Existing		18.36	Pass		75.6	Pass	Pass	
P48	20	20.88	Fail	90	111.6	Fail	Fail	
Existing		18	Pass		75.6	Pass	Pass	
P49	20	20.88	Fail	90	93.6	Fail	Fail	
Existing		19.8	Pass		86.4	Pass	Pass	
P50	20	15.84	Pass	90	79.2	Pass	Pass	
P51	20	17.64	Pass	90	82.8	Pass	Pass	
P52	20	17.64	Pass	90	82.8	Pass	Pass	
P53	20	17.64	Pass	90	79.2	Pass	Pass	
P54	20	17.28	Pass	90	75.6	Pass	Pass	
P55	20	15.84	Pass	90	68.4	Pass	Pass	
P56	20	18.36	Pass	90	86.4	Pass	Pass	
P57	20	17.64	Pass	90	82.8	Pass	Pass	
P58	20	16.56	Pass	90	75.6	Pass	Pass	
P59	20	19.08	Pass	90	86.4	Pass	Pass	
P60	20	16.56	Pass	90	64.8	Pass	Pass	
P61	20	16.2	Pass	90	68.4	Pass	Pass	
P62	20	18.36	Pass	90	79.2	Pass	Pass	
P63	20	14.04	Pass	90	54	Pass	Pass	
P64	20	16.56	Pass	90	79.2	Pass	Pass	
Existing		15.48	Pass		68.4	Pass	Pass	

Table 8: Wind Tunnel Results Summary – Winter

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
P01	20	18	Pass	90	82.8	Pass	Pass	
Existing		19.44	Pass		90	Pass	Pass	
P02	20	19.08	Pass	90	86.4	Pass	Pass	
Existing		17.28	Pass		86.4	Pass	Pass	
P03	20	19.8	Pass	90	90	Pass	Pass	
Existing		18.72	Pass		93.6	Fail	Fail	
P04	20	19.44	Pass	90	111.6	Fail	Fail	
Existing		20.16	Pass		97.2	Fail	Fail	
P05	20	20.52	Fail	90	133.2	Fail	Fail	
Existing		21.24	Fail		97.2	Fail	Fail	
P06	20	23.04	Fail	90	136.8	Fail	Fail	
Existing		21.6	Fail		100.8	Fail	Fail	
P07	20	19.8	Pass	90	86.4	Pass	Pass	
Existing		19.44	Pass		97.2	Fail	Fail	
P08	20	19.44	Pass	90	68.4	Pass	Pass	
Existing		18.72	Pass		97.2	Fail	Fail	
P09	20	19.08	Pass	90	75.6	Pass	Pass	
Existing		18	Pass		90	Pass	Pass	
P10	20	19.08	Pass	90	79.2	Pass	Pass	
Existing		18.36	Pass		90	Pass	Pass	
P11	20	19.44	Pass	90	79.2	Pass	Pass	
Existing		19.44	Pass		90	Pass	Pass	
P12	20	19.8	Pass	90	97.2	Fail	Fail	
Existing		20.88	Fail		97.2	Fail	Fail	
P13	20	23.76	Fail	90	140.4	Fail	Fail	
Existing		21.24	Fail		97.2	Fail	Fail	
P14	20	26.64	Fail	90	133.2	Fail	Fail	
Existing		21.6	Fail		100.8	Fail	Fail	
P15	20	18.72	Pass	90	79.2	Pass	Pass	
Existing		20.16	Pass		104.4	Fail	Fail	
P16	20	18.36	Pass	90	75.6	Pass	Pass	
Existing		20.16	Pass		100.8	Fail	Fail	
P17	20	18	Pass	90	68.4	Pass	Pass	
Existing		20.52	Fail		97.2	Fail	Fail	
P18	20	26.64	Fail	90	151.2	Fail	Fail	
Existing		21.96	Fail		100.8	Fail	Fail	
P19	20	20.52	Fail	90	118.8	Fail	Fail	
Existing		20.52	Fail		93.6	Fail	Fail	

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
P20	20	22.32	Fail	90	79.2	Pass	Fail	
Existing		19.44	Pass		90	Pass	Pass	
P21	20	15.84	Pass	90	64.8	Pass	Pass	
Existing		19.08	Pass		97.2	Fail	Fail	
P22	20	20.16	Pass	90	72	Pass	Pass	
Existing		17.28	Pass		86.4	Pass	Pass	
P23	20	16.2	Pass	90	72	Pass	Pass	
Existing		16.56	Pass		82.8	Pass	Pass	
P24	20	17.28	Pass	90	79.2	Pass	Pass	
Existing		17.64	Pass		97.2	Fail	Fail	
P25	20	21.96	Fail	90	86.4	Pass	Fail	
Existing		20.16	Pass		100.8	Fail	Fail	
P26	20	18.36	Pass	90	72	Pass	Pass	
Existing		19.44	Pass		97.2	Fail	Fail	
P27	20	17.28	Pass	90	64.8	Pass	Pass	
Existing		20.88	Fail		100.8	Fail	Fail	
P28	20	28.08	Fail	90	154.8	Fail	Fail	
Existing		21.24	Fail		97.2	Fail	Fail	
P29	20	20.52	Fail	90	97.2	Fail	Fail	
Existing		20.52	Fail		93.6	Fail	Fail	
P30	20	19.08	Pass	90	133.2	Fail	Fail	
Existing		19.8	Pass		93.6	Fail	Fail	
P31	20	20.16	Pass	90	122.4	Fail	Fail	
Existing		20.88	Fail		97.2	Fail	Fail	
P32	20	15.48	Pass	90	100.8	Fail	Fail	
Existing		20.16	Pass		108	Fail	Fail	
P33	20	14.76	Pass	90	115.2	Fail	Fail	
Existing		16.2	Pass		100.8	Fail	Fail	
P34	20	9	Pass	90	82.8	Pass	Pass	
Existing		15.84	Pass		57.6	Pass	Pass	
P35	20	18	Pass	90	93.6	Fail	Fail	
Existing		18	Pass		108	Fail	Fail	
P36	20	17.64	Pass	90	64.8	Pass	Pass	
Existing		20.16	Pass		100.8	Fail	Fail	
P37	20	14.4	Pass	90	68.4	Pass	Pass	
Existing		14.04	Pass		79.2	Pass	Pass	
P38	20	18.36	Pass	90	108	Fail	Fail	
Existing		21.96	Fail		104.4	Fail	Fail	
P39	20	15.48	Pass	90	79.2	Pass	Pass	

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (km/h)	Results (km/h)	Grade	Criterion (km/h)	Results (km/h)	Grade		
Existing		22.68	Fail		97.2	Fail	Fail	
P40	20	16.2	Pass	90	108	Fail	Fail	
Existing		20.88	Fail		100.8	Fail	Fail	
P41	20	18	Pass	90	93.6	Fail	Fail	
Existing		21.6	Fail		100.8	Fail	Fail	
P42	20	17.64	Pass	90	115.2	Fail	Fail	
Existing		20.16	Pass		104.4	Fail	Fail	
P43	20	19.08	Pass	90	100.8	Fail	Fail	
Existing		20.52	Fail		100.8	Fail	Fail	
P44	20	22.32	Fail	90	158.4	Fail	Fail	
Existing		20.16	Pass		97.2	Fail	Fail	
P45	20	19.8	Pass	90	104.4	Fail	Fail	
Existing		20.52	Fail		97.2	Fail	Fail	
P46	20	20.16	Pass	90	126	Fail	Fail	
Existing		21.96	Fail		104.4	Fail	Fail	
P47	20	22.32	Fail	90	147.6	Fail	Fail	
Existing		22.32	Fail		100.8	Fail	Fail	
P48	20	25.2	Fail	90	144	Fail	Fail	
Existing		21.96	Fail		97.2	Fail	Fail	
P49	20	25.2	Fail	90	122.4	Fail	Fail	
Existing		23.76	Fail		115.2	Fail	Fail	
P50	20	17.64	Pass	90	108	Fail	Fail	
P51	20	20.52	Fail	90	115.2	Fail	Fail	
P52	20	23.4	Fail	90	111.6	Fail	Fail	
P53	20	21.96	Fail	90	108	Fail	Fail	
P54	20	20.88	Fail	90	100.8	Fail	Fail	
P55	20	21.6	Fail	90	90	Pass	Fail	
P56	20	22.32	Fail	90	115.2	Fail	Fail	
P57	20	21.24	Fail	90	108	Fail	Fail	
P58	20	19.08	Pass	90	100.8	Fail	Fail	
P59	20	24.12	Fail	90	115.2	Fail	Fail	
P60	20	19.08	Pass	90	72	Pass	Pass	
P61	20	19.44	Pass	90	90	Pass	Pass	
P62	20	20.52	Fail	90	111.6	Fail	Fail	
P63	20	17.28	Pass	90	68.4	Pass	Pass	
P64	20	19.08	Pass	90	108	Fail	Fail	
Existing		19.08	Pass		90	Pass	Pass	

Note that, for any study points listed in Tables 6-8 with two rows of results data, the second row is for the existing site conditions. The test results shown in Tables 6-8 are without any treatments applied. If treatment is required, the treatment is described in Tables 6-8.

Treatments Legend

- Retention of 3.0m high porous screening (30-35% porosity)
- Retention of 2.0m high porous screening (30-35% porosity)
- Retention of 1.0m high porous screening (30-35% porosity)
- Retention of proposed densely foliating tree planting

Figure 7a: Suggested Treatments – Ground Level Plan as per drawing A003 – SITE PLAN (GF), 03/10/2024
(Based on annual results)

Treatments Legend

- Retention of 1.5m high impermeable balustrade
- Retention of 2.5m high porous screening / gate (30-35% porosity)
- Retention of 1.0m high planter box with 0.8-1.0m high densely foliating evergreen planting or hedging

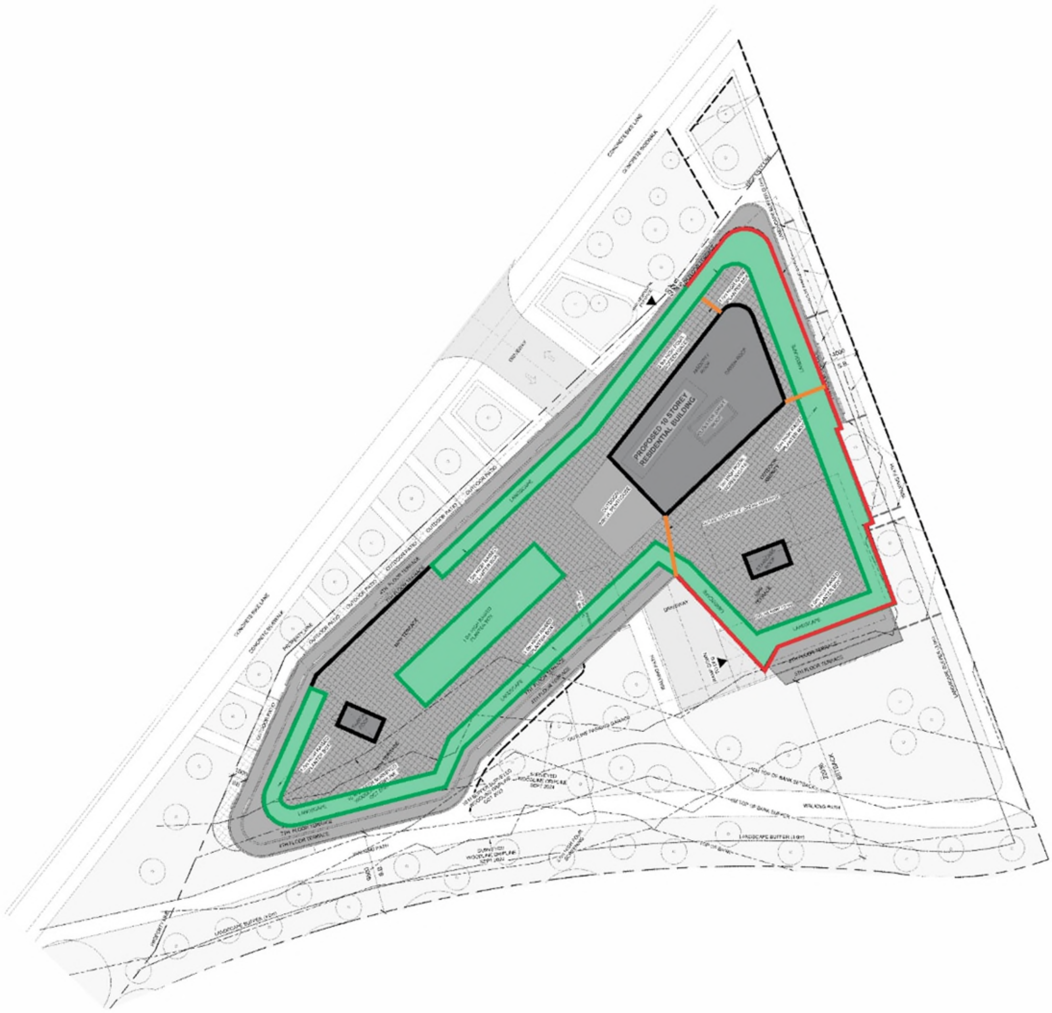

Figure 7b: Suggested Treatments – Roof Plan as per drawing A002 – SITE PLAN, 03/10/2024
(Based on annual results)

7 REFERENCES

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APPENDIX A PUBLISHED ENVIRONMENTAL CRITERIA

A.1 Wind Effects on People

The acceptability of wind in an area is dependent upon the use of the area. For example, people walking or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. Quantifying wind comfort has been the subject of much research and many researchers, such as A.G. Davenport, T.V. Lawson, W.H. Melbourne, and A.D. Penwarden, have published criteria for pedestrian comfort for pedestrians in outdoor spaces for various types of activities. This section discusses and compares the various published criteria.

A.2 A.D. Penwarden (1973) Criteria for Mean Wind Speeds

A.D. Penwarden (1973) developed a modified version of the Beaufort scale which describes the effects of various wind intensities on people. Table A.1 presents the modified Beaufort scale. Note that the effects listed in this table refers to wind conditions occurring frequently over the averaging time (a probability of occurrence exceeding 5%). Higher ranges of wind speeds can be tolerated for rarer events.

Table A.1: Summary of Wind Effects on People (A.D. Penwarden, 1973)

Type of Winds	Beaufort Number	Hourly Mean Wind Speed (m/s)	Effects
Calm	0	0 - 0.3	
Calm, light air	1	0.3 - 1.6	No noticeable wind
Light breeze	2	1.6 - 3.4	Wind felt on face
Gentle breeze	3	3.4 - 5.5	Hair is disturbed, clothing flaps, newspapers difficult to read
Moderate breeze	4	5.5 – 8.0	Raises dust, dry soil and loose paper, hair disarranged
Fresh breeze	5	8.0 – 10.8	Force of wind felt on body, danger of stumbling
Strong breeze	6	10.8 – 13.9	Umbrellas used with difficulty, hair blown straight, difficult to walk steadily, wind noise on ears unpleasant
Near gale	7	13.9 – 17.2	Inconvenience felt when walking
Gale	8	17.2 - 20.8	Generally impedes progress, difficulty balancing in gusts
Strong gale	9	20.8 – 24.5	People blown over

A.3 A.G. Davenport (1972) Criteria for Mean Wind Speeds

A.G. Davenport (1972) also determined a set of criteria in terms of the Beaufort scale and for various return periods. Table A.2 presents a summary of the criteria based on a probability of exceedance of 5%.

Table A.2: Criteria by A.G. Davenport (1972)

Classification	Activities	5% exceedance Mean Wind Speed (m/s)
Walking Fast	Acceptable for walking, main public accessways.	7.5 - 10.0
Strolling, Skating	Slow walking, etc.	5.5 - 7.5
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	3.5 - 5.5
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	0 - 3.5

A.4 T.V. Lawson (1975) Criteria for Mean Wind Speeds

In 1973, T.V. Lawson, while referring to the Beaufort wind speeds of A.D. Penwarden (1973) (as listed in Table A.1), quoted that a Beaufort 4 wind speed would be acceptable if it is not exceeded for more than 4% of the time, and that a Beaufort 6 wind speed would be unacceptable if it is exceeded more than 2% of the time. Later, in 1975, T.V. Lawson presented a set of criteria very similar to those presented in A.G. Davenport (1972) (as listed in Table A.2). These criteria are presented in Table A.3 and Table A.4 for safety and comfort respectively.

Table A.3: Safety Criteria by T.V. Lawson (1975)

Classification	Activities	Annual Mean Wind Speed (m/s)
Safety (all weather areas)	Accessible by the general public.	0 – 15
Safety (fair weather areas)	Private areas, balconies/terraces, etc.	0 – 20

Table A.4: Comfort Criteria by T.V. Lawson (1975)

Classification	Activities	5% exceedance Mean Wind Speed (m/s)
Business Walking	Objective Walking from A to B.	8 - 10
Pedestrian Walking	Slow walking, etc.	6 - 8
Short Exposure Activities	Pedestrian standing or sitting for short times.	4 – 6
Long Exposure Activities	Pedestrian sitting for a long duration.	0 - 4

A.5 W.H. Melbourne (1978) Criteria for Gust Wind Speeds

W.H. Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions that were developed for a temperature range of 10°C to 30°C and for people suitably dressed for outdoor conditions. These criteria are presented in Table A.5, and are based on maximum gust wind speeds with a probability of exceedance of once per year.

Table A.5: Criteria by W.H. Melbourne (1978)

Classification	Activities	Annual Gust Wind Speed (m/s)
Limit for Safety	Completely unacceptable: people likely to get blown over.	23
Marginal	Unacceptable as main public accessways.	16 - 23
Comfortable Walking	Acceptable for walking, main public accessways	13 - 16
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	10 - 13
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	0 - 10

A.6 Comparison of the Published Wind Speed Criteria

W.H. Melbourne (1978) presented a comparison of the criteria of various researchers on a probabilistic basis. Figure A.1 presents the results of this comparison, and indicates that the criteria of W.H. Melbourne (1978) are comparatively quite conservative. This conclusion was also observed by A.W. Rofail (2007) when undertaking on-site remedial studies. The results of A.W. Rofail (2007) concluded that the criteria by W.H. Melbourne (1978) generally overstates the wind effects in a typical urban setting due to the assumption of a fixed 15% turbulence intensity for all areas. It was observed in A.W. Rofail (2007) that the 15% turbulence intensity assumption is not real and that the turbulence intensities at 1.5m above ground is at least 20% and in a suburban or urban setting is generally in the range of 30% to 60%.

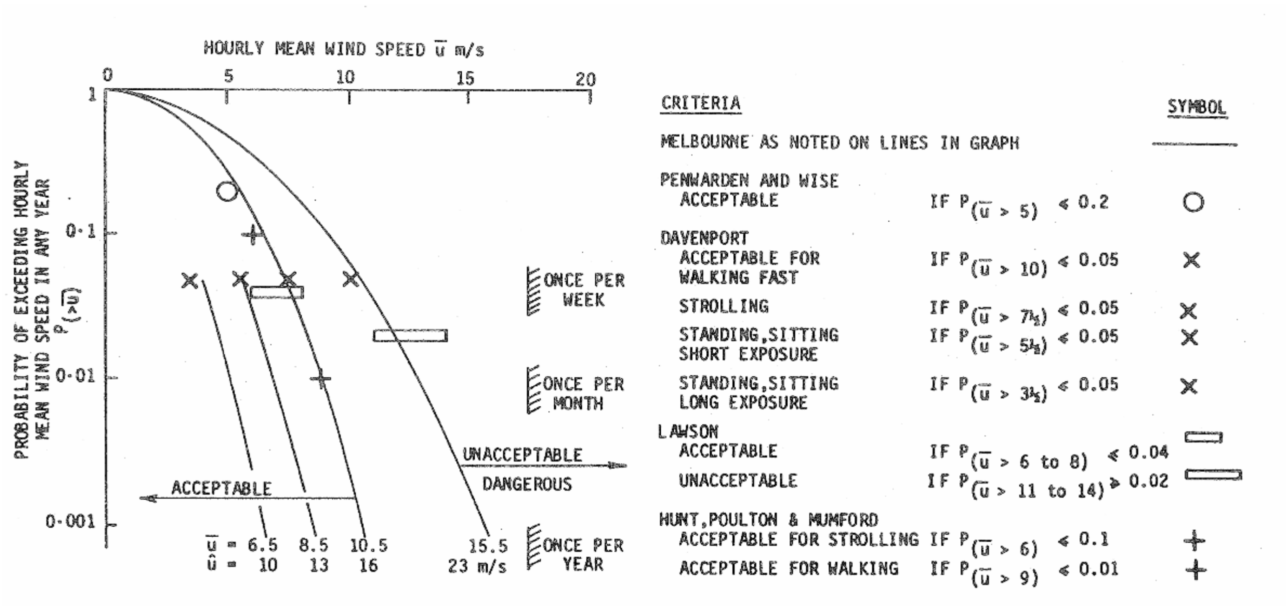

Figure A.1: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (W.H. Melbourne, 1978)

A.7 References relating to Pedestrian Comfort Criteria

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APPENDIX B DATA ACQUISITION

The wind tunnel testing procedures utilised for this study were based on the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2019), ASCE 7-16 (Chapter C31), and CTBUH (2013). The wind speed measurements for the wind tunnel study were determined as coefficients using data acquired by either Dantec hot-wire probe anemometers or pressure-based wind speed sensors and converted to full-scale wind speeds using details of the regional wind climate obtained from an analysis of directional wind speed recordings from the local meteorological recording station(s).

B.1 Measurement of the Velocity Coefficients

The study model and proximity model were setup within the wind tunnel which was configured to the appropriate boundary layer profile, and the wind velocity measurements were monitored using either Dantec hot-wire probe anemometers or pressure-based wind speed sensors at selected critical outdoor locations. The wind velocity results presented in this study for each study point are representative of wind at a full-scale height of approximately 1.5m above ground/slab level. In the case of the Dantec hot-wire probe anemometers, the support of the probe is mounted such that the probe wire is vertical as much as possible to ensure that the measured wind speeds are independent of wind direction along the horizontal plane. In addition, care was taken in the alignment of the hot-wire probe wire and in avoiding wall-heating effects.

Wind speed measurements were made in the wind tunnel for the wind directions described within this report. Data was acquired for each wind direction using a sample rate of 1024Hz. The sample length was determined to produce a full-scale sample time that is sufficient for this type of study. In the case of the pressure-based wind speed sensors, the phase lag between the various channels where data is acquired simultaneously is within 10% of a typical pressure cycle, and the signal is low-pass filtered at 500Hz and then digital filtering is applied over this range to provide an unbiased response from the pressure measurement system (A.W. Rofail, 2004).

The mean, gust and standard deviation velocity coefficients were determined from the data acquired in the wind tunnel. The gust velocity coefficients were also derived for each wind direction from by the following relation:

$$\hat{C}_V = \bar{C}_V + g \cdot \sigma_{C_V} \qquad \text{B.1}$$

where:

$\hat{C}_V$ is the gust velocity coefficient.

$\bar{C}_V$ is the mean velocity coefficient.

g is the peak factor, taken as 3.0 for a 3-sec gust and 3.4 for a 0.5-sec gust.

σ_{C_V} is the standard deviation of the velocity coefficient measurement.

In the case of a Dantec hot-wire probe anemometer, the velocity coefficient is obtained as follows:

$$C_V = \frac{C_{V,study}}{C_{V,200m}} \tag{B.2}$$

where:

$C_{V,study}$ is the velocity coefficient measurement obtained from the Dantec hot-wire probe anemometer at the study point location.

$C_{V,200m}$ is the velocity coefficient measurement obtained from the Dantec hot-wire probe anemometer at the free-stream reference location at 200m height upwind of the model in the wind tunnel.

However, in the case of the pressure-based wind speed sensors, these are determined from the measured differential mean, standard deviation and maximum pressure coefficients obtained from the wind speed sensor. For this analysis all calculations are performed on the square root of the differential pressure measurements. The velocity coefficient at the pressure-based wind speed sensor location is then calculated as follows:

$$C_V = \frac{\alpha + \beta\sqrt{\Delta p}}{V_{200m}} \tag{B.3}$$

where:

C_V is the velocity coefficient measurement at the study point location.

α is a calibration coefficient for the pressure-based wind speed sensor.

β is a calibration coefficient for the pressure-based wind speed sensor.

Δp is the differential pressure obtained from the pressure-based wind speed sensor at the study point location.

V_{200m} is the wind speed at the free-stream reference location of 200m height (full-scale) in the wind tunnel, which is determined directly in the wind tunnel using a pitot static probe.

B.2 Calculation of the Full-Scale Results

The full-scale results determine if the wind conditions at a study location satisfy the designated criteria of that location. More specifically, the full-scale results need to determine the probability of exceedance of a given wind speed at a study location. To determine the probability of exceedance, the measured velocity coefficients were combined with a statistical model of the local wind climate that relates wind speed to a probability of exceedance. Details of the wind climate model are outlined in Section 4 of the main report.

The statistical model of the wind climate includes the impact of wind directionality as any local variations in wind speed or frequency with wind direction. This is important as the wind directions that produce the highest wind speed events for a region may not coincide with the most wind exposed direction at the site.

The methodology adopted for the derivation of the full-scale results for the maximum gust and the GEM wind speeds are outlined in the following sub-sections.

B.3 Maximum Gust Wind Speeds

The full-scale maximum gust wind speed at each study point location is derived from the velocity coefficient using the following relationship:

$$V_{study} = V_{ref,RH}\left(\frac{k_{200m,tr,T=1hr}}{k_{RH,tr,T=1hr}}\right)C_V \qquad \text{B.4}$$

where:

V_{study} is the full-scale wind speed at the study point location.

$V_{ref,RH}$ is the full-scale reference wind speed at the study reference height. This value is determined by combining the directional wind speed data for the region (detailed in Section 4) and the upwind terrain and height multipliers for the site (detailed in Section 3).

$k_{200m,tr,T=1hr}$ is the hourly mean terrain and height multiplier at the free-stream reference location of 200m height.

$k_{RH,tr,T=1hr}$ is the hourly mean terrain and height multiplier at the study reference height (Section 3).

C_V is the velocity coefficient, obtained from either Equation B.2 (in the case of Dantec hot-wire probe anemometers) or Equation B.3 (in the case of pressure-based wind speed sensors).

The value of $V_{ref,RH}$ varies with each prevailing wind direction. Wind directions where there is a high probability that a strong wind will occur have a higher directional wind speed than other directions. To determine the directional wind speeds, a probability level must be assigned for each wind direction. These probability levels are set following the approach used in AS/NZS1170.2:2011, which assumes that the major contributions to the combined probability of exceedance of a typical load effect comes from only two 45 degree sectors.

B.4 Maximum Gust-Equivalent Mean Wind Speeds

The contribution to the probability of exceedance of a specified wind speed (ie: the desired wind speed for pedestrian comfort, as per the criteria) was calculated for each wind direction. These contributions are then combined over all wind directions to calculate the total probability of exceedance of the specified wind speed. To calculate the probability of exceedance for a specified wind speed a statistical wind climate model was used to describe the relationship between directional wind speeds and the probability of exceedance. A detailed description of the methodology is given by T.V. Lawson (1980).

The criteria used in this study is referenced to a probability of exceedance of 5% of a specified wind speed.

B.5 References relating to Data Acquisition

American Society of Civil Engineers (ASCE), ASCE-7-16, 2016, “Minimum Design Loads for Buildings and Other Structures”.

Australasian Wind Engineering Society, QAM-1, 2019, “Quality Assurance Manual: Wind Engineering Studies of Buildings”, edited by Rofail A.W., et al.

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APPENDIX C DIRECTIONAL PLOTS OF WIND TUNNEL RESULTS

C.1 Annual

C.2 Summer

C.3 Winter

APPENDIX D DIRECTIONAL VELOCITY COEFFICIENT PLOTS

APPENDIX E VELOCITY AND TURBULENCE INTENSITY PROFILES